TUMESCENT TECHNIQUE

Tumescent Anesthesia
& Microcannular Liposuction

Safety Warning

7 mg/kg of lidocaine continues to be the maximum safe dosage of commercial out-of-the-bottle lidocaine with epinephrine.
35 mg/kg of tumescent lidocaine (very dilute: less than 1.5 g/L = 0.15%) with epinephrine is the maximum safe dosage for local anesthesia without liposuction.
50 mg/kg of tumescent lidocaine (very dilute: less than 1.5 g/L = 0.15%) with epinephrine is the maximum safe dosage for liposuction.

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& Microcannular Liposuction

JEFFREY A. KLEIN, MD
Associate Clinical Professor
Department of Dermatology
University of California, Irvine
College of Medicine
Irvine, California

Foreword by
Rudolph de Jong, MD
Columbia, South Carolina

Cover Illustration by
Earl D. Klein
(1915-1994)

With 575 illustrations,
Including 130 line drawings by Elizabeth Massari

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To Earl and Maria

FOREWORD

All too rarely, a medical text arrives that truly does justice to the term *seminal,* in the sense of being original and creative and laying the foundation for the development of new therapeutic approaches. Dr. Klein's *Tumescent Technique* is all that and more, since it challenges traditional long-cherished pharmacologic tenets to open up new cross-specialty practice horizons. As a single-authored text, it offers the uniformity of style, the coherence of thought, the consistency of description, the breadth of detail, and the depth of experience so often lacking in multiauthored volumes.

In 40 chapters, grouped into physiology, pharmacology, techniques, complications, and applications, the essentials of tumescent liposuction are presented with clarity, common sense, and case vignettes. Dr. Klein is uniquely qualified to author this comprehensive yet readable text, having pioneered the technique of high-volume, dilute-medication field block. He coined the term *tumescent anesthesia,* which has made Klein and his technique synonymous around the world. The author comes with a rich and diverse scientific base, drawing on mathematics, statistics, and clinical pharmacology. Dual-boarded in internal medicine and dermatology, he has maintained academic standing despite a thriving private practice and has published substantially, culminating in this landmark text.

Tumescent Technique is a tribute to a pioneering, internationally renowned medical vision, since tumescent anesthesia, involving subcutaneous infiltration of highly dilute lidocaine with epinephrine, has been controversial. I was one of the doubters. To the author's credit, his clinical research left little alternative other than to accept that conventional pharmacology was inadequate to the task. New concepts apply to the pharmacokinetics of highly dilute drugs. The science of pharmacokinetics had to be expanded and revitalized to meet the challenges of unexplained observations by Dr. Klein.

The author presents his facts and findings and allows physicians to decide when, where, and why to apply the information to their practice. As stressed throughout, tumescent anesthesia is not foolproof; the massive doses of lidocaine used in the tumescent technique are *safe only if and when* the author's unique technique of infiltrating highly dilute local anesthetic (with added epinephrine) is followed precisely. A dichotomy in empirical pharmacology is exposed here, since lidocaine is a two-headed local anesthetic dragon: docile and compliant when diluted extensively, but fiery and vicious when injected at full strength, directly out of the bottle.

Here, at last, is the long-awaited definitive text of tumescent liposuction from the technique's originator. Thorough, complete, level headed, pace setting, and objective, *Tumescent Technique* is a must-have practice guideline for physicians worldwide.

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Rudolph H. de Jong, MD
Professor of Surgery/Anesthesia
University of South Carolina School of Medicine
Columbia, SC

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PREFACE

Tumescent liposuction totally by local anesthesia is about safety, finesse, gentleness, and optimal cosmetic results. Liposuction is a medium of artistic expression that displays itself in (1) the practical application of scientific knowledge, (2) the production of what is beautiful, (3) the perfection of workmanship, (4) the continuing improvement in technique, and (5) the skill attained through intellectual inquiry and clinical experience.

The *art* in liposuction requires an open mind. Many ways are available to do liposuction, and there is always a better way. Maximum speed and maximum volume of aspirate are not criteria for excellence. An attitude that regards liposuction as a crude and brutal procedure is self-fulfilling. Ultimately, excellence is measured in terms of patient satisfaction, which is a function of safety, patient comfort, and quality of results.

Artistry and ethical behavior are not independent. The artist competes in the market by providing better results and using the safest technique. For example, even if a patient wants to have a large volume of liposuction accomplished in one session, the artist convinces the patient that serial liposuction, with several weeks between sequential procedures, is safer and ultimately yields better results. Taking risks and pushing the technique to the limits of safety are not artistic.

Invented and developed in 1985, first presented at a scientific meeting in 1986, and first published in 1987, tumescent liposuction totally by local anesthesia significantly improves the safety of large-volume liposuction by eliminating significant surgical blood loss and the risks of systemic anesthesia, including general anesthesia, intravenous (IV) sedation, and narcotic analgesia. In contrast, traditional forms of liposuction relied on systemic anesthesia and were associated with so much surgical blood loss that autologous blood transfusions were often routine.

Liposuction was developed by multiple specialties. Fundamental prerequisites for competent liposuction include surgical training in an accredited residency training program (e.g., dermatology, general surgery, gynecology, ophthalmology, otolaryngology, plastic surgery) and expertise in aseptic surgical technique and emergency management of surgical and medical complications. Didactic instruction in liposuction and clinical experience with hands-on liposuction training through an accredited continuing medical education (CME) course are essential. Advanced cardiac life support training and certification should also be part of every liposuction surgeon's qualification.

The tumescent technique is a method for drug delivery of local anesthesia that maximizes safety by using pharmacokinetic principles to achieve extensive regional anesthesia of skin and subcutaneous tissue. The subcutaneous infiltration of a large volume of very dilute lidocaine and epinephrine causes the targeted tissue to become swollen and firm, or tumescent, and permits large-volume liposuction totally by local anesthesia.

Microcannular tumescent liposuction incorporates the tumescent technique for local anesthesia with the use of liposuction microcannulas and multiple adits (1-mm, 1.5-mm, and 2-mm punch biopsy excisions) for microcannula access that are not closed with sutures. Adits promote copious postoperative drainage, which in turn reduces bruising, tenderness, swelling, and systemic lidocaine absorption.

Maximum recommended dosage of tumescent lidocaine is much greater than the standard dosage limitations recommended for out-of-the-bottle commercial preparations of lidocaine with epinephrine. The tumescent technique permits safe lidocaine dosage of 35 to 50 mg/kg and typically provides effective surgical anesthesia for more than 8 to 10 hours. With thorough infiltration technique, tumescent anesthesia provides 24 to 36 hours of significant postoperative analgesia. This book explores the pharmacokinetics of subcutaneous local anesthesia, as well as the inaccurate and unsubstantiated but widely accepted "FDA-approved" dosage limitation of 7 mg/kg for lidocaine with epinephrine when injected into subcutaneous tissue.

The concepts that justify the tumescent technique are often contrary to surgeons' intuition and understanding of traditional pharmacologic and surgical dogma. For example, a 10:1 or 20:1 dilution of commercial lidocaine with epinephrine provides more profound and more extensive local anesthesia than out-of-the-bottle preparations. Also, microcannulas facilitate more complete fat removal than larger cannulas, and incisions heal better when not closed with sutures. Finally, tumescent liposuction totally by local anesthesia is less painful with more rapid healing than liposuction using systemic anesthesia.

Many thought that the infiltration of a large volume of tumescent fluid would distort subcutaneous fat and make accurate liposuction more difficult. Such misconceptions, based on intuition rather than experience, were widely prevalent. Many surgeons preferred to treat surgical hemorrhage by using autologous blood transfusions rather than prevent hemorrhage by using the tumescent technique to produce intense vasoconstriction.

The absorption of tumescent anesthesia from a subcutaneous deposit is analogous to the absorption of a slow-release tablet taken by mouth. Although the drug is inside the body, most of the drug is isolated from the circulation. Only the drug on the outer surface of the subcutaneous tumescent reservoir is available for systemic absorption. The capillary bed within the central portion of the tumescent adipose tissue is so completely vasoconstricted that no significant absorption can occur from these tissues. Thus the tumescent technique results in extremely slow and safe lidocaine absorption.

The greatest danger of liposuction is the use of systemic anesthesia and the associated tendency for surgeons to do too much liposuction and infuse unnecessary IV fluids. Liposuction under general anesthesia can be accomplished safely and

with excellent results, but tumescent liposuction plus systemic anesthesia has proved to be an unnecessarily dangerous combination.

Tumescent liposuction has long been the standard of care for liposuction among dermatologic surgeons. The concept of tumescent liposuction, however, has diffused slowly across the boundaries between surgical specialties. As of early 2000, I am unaware of any mention in the anesthesiology literature that the tumescent technique is available for regional anesthesia by direct infiltration or that tumescent delivery permits safe lidocaine dosage of 35 to 50 mg/kg. Through this book I hope to promote the interchange of knowledge among all surgical specialists and anesthesiologists.

Clinical isolation has prevented surgeons from becoming aware of the degree of safety provided by the tumescent technique. The vast majority of surgeons who do liposuction by general anesthesia have never witnessed liposuction totally by local anesthesia. Even the "teachers" in some specialties have not witnessed liposuction of two or more areas in a patient who is awake, fully conversant, and comfortable. Also through this book, I hope to enlighten all specialties about the full capabilities of the tumescent technique, which has numerous advantages.

Even when general anesthesia is combined with the tumescent treatment, liposuction is quite safe provided the volume of fat removed and the number of areas treated during a single surgery are not excessive and unrelated surgical procedures are avoided. The profound hemostasis provided by tumescent infiltration is now widely recognized as indispensable for safe liposuction with or without general anesthesia.

Some surgeons are unaware of tumescent liposuction's other benefits. The ability to perform superficial liposuction, syringe liposuction, and even ultrasonic liposuction is the direct result of the tumescent technique. Open drainage and bimodal compression, when used with the tumescent liposuction, decrease the systemic absorption of lidocaine and accelerate postoperative healing, with reduced pain, swelling, and bruising.

New applications of the tumescent technique permit surgical procedures of the skin that can be accomplished totally by local anesthesia, including breast reduction by microcannular liposuction, dermabrasion, CO_2 laser resurfacing, chemical peels, ambulatory phlebectomy, facelift, hair transplantation, abdominoplasty, burn resuscitation, anesthesia for zoster dermatitis, endoscopic breast biopsy, skin grafts, and virtually any dermatologic surgical procedure. In addition to surgical analgesia, tumescent anesthesia provides postoperative analgesia and assists in accelerated wound healing.

Future applications of the tumescent technique for drug delivery might include prophylaxis against surgical wound infections; targeted delivery of therapeutic, chemotherapeutic, and diagnostic agents to lymphatic vessels; therapy for snakebite envenomation; and delayed systemic absorption of parenteral medications. New therapeutic applications will depend on the imagination of specialists in other clinical disciplines and the nature of the clinical problems they must solve. For example, the tumescent delivery of chemotherapeutic agents to lymphatic vessels might be applicable to the treatment of lymphatic metastases associated with breast cancer.

Every aspect of the tumescent technique can be expected to evolve and be improved. Liposuction surgeons can assist in this development by publishing descriptions of liposuction complications. Further information will be available at **www.liposuction.com.** The reader may send comments and suggestions regarding this book or information about unusual or severe liposuction-related complications to me by e-mail at **jeffklein@liposuction.com.**

Jeffrey A. Klein

ACKNOWLEDGMENTS

ABOUT THE AUTHOR

Jeffrey Alan Klein, MD, studied mathematics and physics as an undergraduate at the University of California (UC) Riverside (BA in mathematics). As a graduate student, he studied mathematics at the Université de Paris and UC San Diego (MA in mathematics, 1971). He graduated from the School of Medicine, UC San Francisco in 1976 and spent 8 additional years in advanced postgraduate training, with a master's degree in public health (biostatistics and epidemiology) from UC Berkeley; 3 years at UC Los Angeles as a resident in internal medicine (certification by the American Board of Internal Medicine, 1980); 2 years as a National Institute of Health research fellow in clinical pharmacology; and 3 years at UC Irvine as a resident in Dermatology (certification by the American Board of Dermatology, 1984). Dr. Klein is currently Associate Clinical Professor of Dermatology at UC Irvine College of Medicine and in private practice in San Juan Capistrano, California. He lives in Newport Beach, California, with his wife, Kathleen, and children, Elan, Luke, Dora, and Paytra.

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PART I

FOUNDATIONS AND ISSUES

History of Tumescent Liposuction

The tumescent technique for local anesthesia has revolutionized liposuction by eliminating both the risks of general anesthesia and the bleeding once associated with liposuction. The associated vasoconstriction has permitted the extensive use of microcannulas and superficial liposuction, thus dramatically improving aesthetic results. Also, patients experience less pain with tumescent liposuction than with liposuction by general anesthesia.

The words *tumescent, tumescence,* and *tumesce* are derived from the Latin verb *tumere,* meaning "to swell, become tumid." In clinical medicine, *tumescent* describes an anatomic feature that is swollen and firm; for example, an inflamed lesion may become red and tumescent. The tumescent technique permits liposuction totally by local anesthesia.

The reality of clinical experience with tumescent liposuction is often the opposite of what one might predict based on "common-sense" assumptions and traditional tenets of surgery. For example, the dilution of a local anesthetic solution of lidocaine and epinephrine does not weaken its effect; rather, it *enhances* the degree of anesthesia and vasoconstriction. Although microcannulas remove less fat per unit of time, they actually permit the removal of greater volumes of fat than traditional liposuction cannulas.

As these concepts become better accepted and understood, the tumescent technique will find increasing application in liposuction.

EARLY LIPOSUCTION

The first written description of liposuction was published by Fischer of Italy in 1977. Soon afterward the French surgeons Illouz and Fournier popularized liposuction using blunt-tipped cannulas. The common adverse sequelae of liposuction were excessive bleeding, prolonged recovery time, and disfiguring irregularities of the skin. Preoperative infiltration of a small volume of a vasoconstrictive solution of epineph-

rine into the targeted fat was termed the *wet technique.* Using no preoperative infiltration was known as the *dry technique.*

By 1982 several American dermatologists had been to France to observe Illouz do liposuction using general anesthesia together with a subcutaneous injection of a small volume of a hypotonic solution of epinephrine and hyaluronidase. For many years, general anesthesia was a prerequisite for liposuction. The standard cannulas of the 1980s were huge, with diameters of 6 to 10 mm and cross-sectional areas 9 to 25 times greater than today's 2-mm microcannulas. Dolsky et al[1] reviewed the development of early liposuction techniques and the associated complications.

By 1983 dermatologists were doing liposuction of lipomas, the submental chin, and limited areas of the body using general anesthesia, epidural regional anesthesia, or heavy intravenous (IV) sedation supplemented by small volumes of local anesthesia. The IV sedation usually consisted of diazepam (Valium) and a narcotic analgesic and the local anesthesia 0.25% to 0.5% lidocaine (Xylocaine) with epinephrine 1:200,000.[2]

With increasing experience, dermatologic surgeons gradually began to use larger and larger doses of lidocaine without signs of toxicity. Eventually they were routinely giving lidocaine doses two to three times the 7 mg/kg maximum dosage specified by the FDA. The common, but erroneous, explanation for this lack of toxicity was that liposuction removed the lidocaine before it could be absorbed into the patient's blood.

In late 1984, having recently achieved board certification in dermatology, I focused on starting a private practice and learning more dermatologic surgery. At that point, my years of advanced training and study of other areas of medicine seemed to have little practical relevance. In retrospect, two master degrees (mathematics as well as public health biostatistics), 2 years as a National Institutes of Health research fellow in clinical pharmacology, and board certification in internal medicine provided the concinnity of experience and knowledge that produced the concept of the tumescent technique.

Ironically, I had mixed reactions on first hearing about liposuction. Larry Field, a pioneer of modern dermatologic surgery, convinced me that liposuction was destined to become an important dermatologic surgical procedure. In February 1985 I attended a liposuction course given by Gary Fenno and sponsored by the American Society for Liposuction Surgery. None of the faculty had done liposuction by local anesthesia, which was thought to be impractical, if not impossible. The plastic surgery literature stated, without discussion, that liposuction required general anesthesia.

In April 1985, using local anesthesia, I performed my first liposuction procedure. By the end of that year, an elementary form of the tumescent liposuction with intramuscular (IM) diazepam sedation and meperidine (Demerol) analgesia had evolved. I first described the tumescent technique at the Second World Congress of Liposuction Surgery sponsored by the American Academy of Cosmetic Surgery held in Philadelphia in June 1986. The first article describing the tumescent technique was published in the *American Journal of Cosmetic Surgery* in January 1987.[3]

Subsequent years have seen continual improvement. With the tumescent technique, liposuction is now a procedure of exceptional finesse and gentleness that is accomplished totally by local anesthesia.

DERMATOLOGIC ORIGINS

A preference for local anesthesia, an aversion to the high costs of hospital operating rooms, and skepticism about established surgical dogma explain why a dermatologist invented the tumescent technique.

The tumescent technique has a natural appeal to dermatologists and is uniquely compatible with traditional dermatologic surgical training. Dermatologists prefer local anesthesia for skin surgery and abhor the complications associated with general anesthesia. They have the training, the patience, and the experience to deal with patients who are awake and alert. Without such qualifications, it is nearly impossible to do liposuction without general anesthesia, IV sedation, or narcotic analgesia.

The perceived value of the tumescent technique depends on the surgeon's education. Training that inculcates a preference for general anesthesia usually does not emphasize the benefit of having an awake patient. The distinction between necessary and convenient forms of anesthesia is often disregarded. Extensive training with general anesthesia does not afford much opportunity to acquire the experience and temperament needed to manage an alert patient during surgery. On the other hand, most dermatologic surgeons are exclusively trained to use local anesthesia. Using general anesthesia is rarely necessary or desirable.

MISCONCEPTIONS ABOUT LIDOCAINE

The U.S. Food and Drug Administration (FDA) must approve any drug before it can be sold in the United States. As a part of this process, the FDA must also approve the exact wording of the drug information and dosage recommendations published annually in the *Physicians' Desk Reference* (PDR). For lidocaine (Xylocaine) as a local anesthetic, the PDR states that "in all cases the lowest concentration and smallest dose that will produce the desired result should be given." The tumescent technique was developed in direct response to this FDA imperative.

Lidocaine is the most common local anesthetic used in cutaneous surgery, but the FDA has no data to support its officially approved recommended maximum safe dosage of 7 mg/kg body weight of lidocaine with epinephrine. The official dose limits for lidocaine were established in 1948 in a brief letter to the FDA from Astra Pharmaceutical, the drug's manufacturer, which simply stated that "the maximum safe dose of lidocaine is probably the same as that for procainamide." The FDA has no further data on which to support its current recommendations. The "common wisdom" about maximum safe doses of lidocaine has resulted in underestimating the maximum safe dosage of lidocaine and sometimes encouraging the unnecessary use of general anesthesia.

In the early 1980s the pharmacology and absorption kinetics of local anesthesia in skin and subcutaneous tissue were considered trivial, uninteresting, and unworthy of systematic investigation. Years of well-published pharmacokinetics orthodoxy had convinced most surgeons and anesthesiologists that it was impossible to do moderate or large-volume liposuction using only local anesthesia. Several fallacious assumptions, many of which persist today, have obscured the potential benefits of local anesthesia (Box 1-1).

Clinical experience and clinical studies have convinced me that these assumptions are wrong. First, no scientific publication exists to support 7 mg/kg as the maximum safe dose of lidocaine with epinephrine when infiltrated into subcutaneous tissue.[10]

BOX 1-1 FALLACIOUS ASSUMPTIONS ABOUT LOCAL ANESTHESIA

Fallacy 1: The effect of local anesthesia rarely persists for more than 2 hours; and the higher the concentration of local anesthesia, the longer its duration.[4]

Fallacy 2: Peak plasma lidocaine levels occur within 60 to 90 minutes after subcutaneous infiltration.[5,6]

Fallacy 3: Most of the lidocaine infiltrated for tumescent liposuction is removed along with the aspirated fat.[7,8]

Fallacy 4: Bupivacaine (Marcaine) is as safe as lidocaine, and the combination of lidocaine and bupivacaine for liposuction by local anesthesia is appropriate and safe.

Fallacy 5: Lidocaine dosage restrictions (7 mg/kg with epinephrine) should be the same for all forms of local anesthesia, including epidural, axillary, or intercostal nerve block and subcutaneous and intradermal infiltration.[4,9]

Fallacy 6: The rate of absorption is independent of the concentration of the infiltrated lidocaine.[4]

Second, an experimental study of lidocaine published in 1948 reported that the median lethal dose (LD_{50}) of subcutaneous lidocaine in mice was inversely proportional to drug concentration; in other words, the greater the dilution, the greater the dose of subcutaneous lidocaine necessary to kill a mouse. This supported the conjecture that extremely dilute solutions of lidocaine might permit safe doses significantly greater than 7 mg/kg.

Third, many surgeons, including myself, wrongly assumed that liposuction removed a significant amount of lidocaine along with fat. Because it seemed logical to remove the tumescent lidocaine as soon as possible, surgeons would do infiltration and liposuction one area at a time. In other words, after infiltration of a targeted area had been completed, liposuction would commence as soon as vasoconstriction had been achieved. This one-area-at-a-time approach would be repeated until a reasonable number of areas had been completed. As described in Chapter 19, liposuction removes only 20% of the infiltrated dose of tumescent lidocaine. Once this fact had been recognized, surgeons could reasonably complete tumescent infiltration of all areas before commencing liposuction.

Finally, when blood was sampled 1 hour after a lidocaine dose of 10 to 20 mg/kg by the tumescent technique, the plasma concentrations were less than 0.3 μg/ml, well below the 5 μg/ml threshold for early lidocaine toxicity. This finding provided the naive confidence that lidocaine toxicity was a remote risk. This erroneous assumption was based on the belief, supported by virtually all previously published reports, that peak plasma lidocaine concentrations occur within 2 hours after infiltration. The perfunctory explanation for the remarkably low plasma lidocaine levels was that the liver was rapidly metabolizing the lidocaine. Only later did researchers realize that the peak lidocaine plasma levels were higher and occurred up to 12 hours after completion of tumescent liposuction.

In 1987 many surgeons believed that a dose of lidocaine in excess of 7 mg/kg was considered more dangerous than the combination of general anesthesia and the high surgical blood loss that routinely required autologous blood transfusions. At a medical meeting, my report of using 15 mg/kg of lidocaine for tumescent liposuction provoked a public accusation of medical malpractice.

Even today, despite the results of several well-documented studies validating the estimate of 35 mg/kg as a safe upper limit for a lidocaine dose with the tumescent technique for liposuction, many surgeons and anesthesiologists persist in using techniques that risk excessive IV fluid infusions, IV fluid overload, coagulopathy, massive bleeding, and potentially fatal complications connected with general anesthesia.

THE FIRST CASE

The volunteer patient for my first liposuction surgery had a localized accumulation of fat on the lower abdomen above a transverse hysterectomy scar.

Using only 50 ml of a commercially available local anesthetic formulation containing 500 mg of lidocaine [1%] and 0.5 mg of epinephrine [1:100,000], the result of the procedure was encouraging but less than satisfactory. Approximately 45 ml of fat was removed. The degree of hemostasis was profound, with the aspirated fat containing almost no blood. However, the volume of fat that could be anesthetized using only 50 ml of local anesthetic was too small. The 0.5 mg of epinephrine at a concentration of 1:100,000 caused tachycardia. The most painful part of the procedure was the burning-stinging sensation caused by the infiltration of the local anesthetic. The actual liposuction, although not painless, was more easily tolerated than the infiltration.

The patient returned for a more extensive liposuction of the lower abdomen and lateral thighs 1 month later. On this occasion the anesthetic solution was more dilute, and the results were better with fewer side effects. The anesthetic solution consisted of lidocaine [2000 mg/L] with epinephrine [2 mg/L] in 1000 ml of physiologic saline, yielding a formulation of approximately 0.2% lidocaine and epinephrine 1:250,000.

This concentration of epinephrine still produced tachycardia (approximately 120 beats/min), but hemostasis was excellent. The aspirate contained 450 ml of bloodless fat and 100 ml of mildly blood-tinged infranatant anesthetic solution. Pain caused by infiltration was eased with IM meperidine and diazepam. Lidocaine at a 0.2% concentration was clearly effective and well below the 0.4% [4 g/L] concentration, which at that time was the published minimal effective concentration (MEC) for cutaneous local anesthesia.

Liposuction totally by local anesthesia was clearly feasible. The unanswered question was how much fat could be removed using local anesthesia.

Clearly, the formulation of the anesthetic solution needed to be perfected. Two significant parameters required scientific estimation: (1) the MEC of lidocaine and epinephrine and (2) the maximum safe total dose of lidocaine.

ANESTHETIC FORMULATIONS

In this book, for reasons of safety and convenience, the concentrations of lidocaine and epinephrine in a tumescent solution of local anesthesia are usually specified in terms of milligrams per liter (mg/L). This convention is motivated by the fact that when specifying a concentration of lidocaine in terms of mg/L, the calculation of "total dosage (mg/kg) of lidocaine" is more easily calculated, and dosage errors are more easily avoided.

Pharmaceutical manufacturers have traditionally specified the concentrations of commercially available lidocaine in terms of grams per 100 milliliters of solution (grams percent, or g%). However, a 0.1% lidocaine solution (0.1 g of lidocaine per 100 ml of solution), when intended for tumescent local anesthesia, is more appropriately specified as 1000 mg/L, that is, 1000 mg of lidocaine per liter of solvent, such as physiologic (0.9%) saline or lactated Ringer's solution. Thus the total *mg dose* of lidocaine and the total *mg/kg dosage* of lidocaine are easily determined.

LIDOCAINE: MINIMUM EFFECTIVE CONCENTRATION

In 1985 a careful review of the literature on lidocaine found no studies specifically concerned with local anesthesia of subcutaneous fat. The MECs of lidocaine and epinephrine for cutaneous and subcutaneous local anesthesia were not well defined.

Any estimate of the lidocaine MEC for liposuction depends on both surgical and patient factors. Surgical factors include the completeness and the uniformity of anesthetic infiltration, the surgeon's finesse and skill, the cannula diameter, and personality traits of the surgeon and nursing staff. Patient variables include age, gender, anxiety level, and anatomic location of the fat. Any use of anodyne drugs such as narcotic analgesics or IV sedatives also affects the *limen*, or threshold of pain.

More clinical experience showed that a formulation consisting of 0.1% lidocaine [1 g/L] and epinephrine 1:1 million [1 mg/L] was effective. Because the burning and stinging pain persisted, however, the process of infiltration was not easily tolerated.

The range of lidocaine concentrations currently recommended for tumescent liposuction totally by local anesthesia is 500 to 1500 mg/L. This range was derived with the cooperation of several patients by comparing the subjective effect of a given lidocaine concentration in one thigh with that of a slightly lower concentration in the opposite thigh. More patients can distinguish between 400 mg/L [0.04%] and 500 mg/L [0.05%] lidocaine than between 500 mg/L [0.5%] and 750 mg/L [0.75%].

Clinical experience now clearly demonstrates that 0.075% to 0.1% lidocaine [750 to 1000 mg/L] is sufficient for tumescent liposuction, totally by local anesthesia, of the hips, thighs, knees, arms, and neck/facial areas, provided the surgeon uses microcannulas and careful infiltration. Lidocaine at 0.1% to 0.125% [1000 to 1250 mg/L] provides more consistent anesthesia for the more fibrous or more sensitive areas, such as the periumbilical area, the upper abdomen, the fat of the lower abdomen deep to Scarpa's fascia, the female infrascapular and posterior axillary areas, and the male flanks and male breasts. For liposuction of female breasts totally by local anesthesia, the lidocaine concentration is 1500 mg/L.

EPINEPHRINE: MINIMUM EFFECTIVE CONCENTRATION

The vasoconstriction associated with epinephrine has the following three consequences for tumescent liposuction:
1. It prolongs the local anesthetic effect.
2. It slows the rate of absorption of lidocaine, permitting greater doses of lidocaine.
3. It produces such dramatic hemostasis that clinically significant surgical blood loss is eliminated.

The epinephrine MEC was derived by careful clinical observation of cutaneous blanching and pulse rate. Experience has shown that epinephrine at 0.65 to 1.0 mg/L provides consistently excellent vasoconstriction for many hours, with a very low incidence of tachycardia. By comparison, commercially available lidocaine with epinephrine typically has an epinephrine concentration of 10 mg/L, which is equivalent to 1:100,000, or 1 g/100,000 ml.

LIDOCAINE: MAXIMUM SAFE DOSE

The search for a better estimate of the maximum safe dose of lidocaine has been controversial. Some aesthetic surgeons publicly stated that dermatologists were incapable of doing liposuction safely.

Prudence and good documentation were necessary to prove that 7 mg/kg grossly underestimated the maximum safe dose for tumescent lidocaine. After 1000 mg/L [0.1%] lidocaine was established as effective, this concentration was maintained as a constant, while a total volume of solution, and thus the total dose of lidocaine, was cautiously increased. Clinical observation revealed no evidence of early lidocaine toxicity as doses were incrementally augmented during succeeding surgeries.

In April 1988, after liposuction on her husband, I asked a nurse to obtain extra venous blood samples at home for determination of additional lidocaine blood levels. The sequential blood samples obtained over 7 hours produced unexpected results. The blood levels increased linearly with time over the entire 7-hour interval, indicating that the maximum concentration occurred well after 7 hours. In another patient, lidocaine blood levels taken over 24 hours showed a maximum concentration at approximately 12 hours. This finding was unprecedented. The prevailing belief was that peak lidocaine blood levels occur less than 2 hours after infiltration.

No formal investigational review board (IRB) or human studies research committee gave approval before the procedures for obtaining these blood samples to determine plasma lidocaine concentration. Before being asked to participate in the pharmacologic evaluation of lidocaine levels, however, all patients had requested liposuction and had agreed to pay the usual surgical fees. Furthermore, all patients gave informed consent before participating in the sequential measurement of lidocaine blood levels.

Measurements in other patients led to the determination that peak lidocaine blood levels for tumescent liposuction occur at 12 ± 3 hours. Most likely the time of this peak level varies somewhat as a function of the method of infiltration, total dosage of lidocaine, and concentrations of lidocaine and epinephrine. The pharmacologic information obtained for each patient included the peak lidocaine plasma concentration [mg/L] and total dosage of lidocaine (mg/kg) given by tumescent infiltration.

By graphing the magnitude of the peak concentrations [mg/L] as a function of dosage (mg/kg), a safe dosage for tumescent lidocaine was shown to be at least 35 mg/kg. This result was published in 1990 and provided scientific justification for lidocaine doses five times greater than the 7 mg/kg limits approved by the FDA.[11] The first published description of the tumescent technique had already shown that it eliminates significant blood loss.[9]

Thus it was established that liposuction could be done safely with minimal risks of blood loss and minimal risks of anesthetic toxicity with the use of the tumescent technique. Together, these two findings were revolutionary and established dermatologic surgery as the authority on safe liposuction surgery.

In 1993, when the *Journal of Plastic and Reconstructive Surgery* published its first article on tumescent liposuction, the plastic surgery community began to adopt the technique. Currently, most plastic surgeons prefer to use a modified version of the tumescent technique, or a semitumescent technique, that relies heavily on general anesthesia or IV sedation, while using tumescent infiltration for its profound vasoconstriction and surgical hemostasis.

IMPROVED FORMULATION AND DELIVERY

In 1988 I read that the addition of sodium bicarbonate ($NaHCO_3$) at a concentration of 10 mEq/L significantly reduced the pain associated with the infiltration of local anesthesia. Others confirmed that adding sodium bicarbonate to the anesthetic solution eliminated the burning and stinging pain associated with the acidic pH of commercially available lidocaine preparations.[5,12,13]

This simple modification greatly improved patient comfort and safety. It eliminated the need for parenteral sedation with benzodiazepines, for narcotic analgesia, and for pulse oximetry and its attendant difficulties. Sodium bicarbonate was the key to large-volume liposuction *totally* by local anesthesia.

The use of a peristaltic infiltrating pump has made it possible to use 25-gauge and 20-gauge spinal needles for the initial stages of infiltration. Previously, tumescent infiltration required much larger, 12-gauge cannulas with a 2.5-mm outside diameter. The use of spinal needles has dramatically increased the effectiveness tumescent infiltration and reduced the discomfort associated with infiltration into the most fibrous areas of fat, such as the knees, upper abdomen, the back and flanks, and male breasts. Furthermore, the pump has eliminated the "brute strength" needed to infiltrate using a syringe, allowing properly trained female registered nurses to perform the infiltration with accuracy and finesse.

Triamcinolone. At one time, I had recommended the addition of 10 mg of triamcinolone per liter bag of tumescent solution. It is now apparent that triamcinolone is not necessary. Furthermore, as with other antiinflammatory drugs, triamcinolone may decrease the patient's immune response and increase the risk of postoperative infection. Although the tumescent technique dramatically reduced surgical bleeding, my surgical technique was similar to that of most other surgeons. I used larger cannulas and the minimum number of incisions and closed every incision with sutures. My patients thus experienced postoperative swelling and ecchymoses.

In the early days of tumescent liposuction, approximately 1 in 50 patients experienced a peculiar type of postoperative inflammation. Typically, this presented 5 to 8 days after surgery with focal areas of increased warmth, tenderness, and swelling. I referred to this clinical condition as "postliposuction panniculitis." Every attempt to culture an affected area gave negative bacteriologic results. Furthermore, the empiric use of antibiotics produced no improvement.

When 10 mg/day of the antiinflammatory corticosteroid prednisone by mouth was added to the antibiotic regimen, however, the focal inflammation subsided within 24 to 48 hours. Corticosteroids induce the synthesis of an antiphospholipase protein that inhibits the enzyme phospholipase A_2, which converts arachidonic acid to prostaglandin PGG_2.

It seemed reasonable to add an injectable analog of prednisone, such as triamcinolone, to the anesthetic solution and thereby preempt the focal inflammation. Triamcinolone, with its low aqueous solubility, tends to persist locally and reduce symptomatic inflammation for up to 6 days. Triamcinolone became a standard part of the formulation of the anesthetic solution for tumescent liposuction.

Subsequently I noticed that every patient had less postoperative soreness and swelling and that the incidence of postliposuction panniculitis had decreased significantly. I was mistakenly convinced that adding triamcinolone [10 mg/L] to the anesthetic solution did decrease postoperative inflammation and soreness.

Elimination of Sutures. Eventually I learned that the relation between triamcinolone and the reduction of postoperative pain and edema was merely a spurious correlation. At the same time that I started using triamcinolone, I also ceased closing the incisions with sutures. It is now apparent that decreased postoperative inflammation is simply the result of the elimination of sutures. Omitting sutures encourages copious postoperative drainage of the inflammatory blood-tinged anesthetic solution.

Any liposuction surgeon can easily test this hypothesis in the following manner. When doing liposuction of the outer thighs, place a small incision at the most distal and dependent portion of both thighs. Some amount of liposuction must be done through this incision to ensure an adequate path for drainage. Suture one distal incision, and allow the contralateral distal incision to remain nonsutured. The nonsutured incision will require an absorbent pad to contain the drainage. The relative absence of swelling, bruising, and tenderness on the side with open drainage versus the side with sutured incision will become apparent within a few days.

Careful Documentation Versus Experimentation. Tumescent liposuction is radically different from other liposuction techniques. It is the only technique that permits liposuction totally by local anesthesia. The early development of tumescent liposuction, however, did not involve the use of lidocaine dosages above the amounts already being used by many surgeons who were doing liposuction at that time with relatively concentrated lidocaine, in combination with IV narcotics and sedation. The unprecedented aspects of the

tumescent technique were the demonstration that a 10- to 20-fold dilution of commercially available 1% lidocaine with epinephrine resulted in the following:

1. Significantly lower peak plasma lidocaine concentrations
2. Virtual elimination of liposuction blood loss
3. Dramatically more extensive and profound local anesthesia

Most importantly, for any given mg/kg dosage of subcutaneous lidocaine with epinephrine, dilution dramatically reduced peak plasma lidocaine concentrations. The advent of the tumescent technique provided the rationale for beginning careful clinical observations that, for the first time, provided a scientific estimate for the maximum safe dose of subcutaneous lidocaine.

The development of the tumescent technique was the result of using commonly accepted doses of lidocaine and epinephrine and showing that dilution improved clinical local anesthesia. Long after tumescent liposuction was widely practiced, plasma lidocaine levels were documented in a manner analogous to the routine documentation of lidocaine plasma levels in cardiac care units. This documentation of plasma levels is regarded as sound clinical practice among cardiologists whenever significant doses of lidocaine are given. The documentation of plasma lidocaine concentrations associated with tumescent liposuction should not be regarded as clinical experimentation. Careful clinical documentation of drug levels associated with a well-established, safe clinical procedure is good clinical practice. It is not clinical experimentation.

CONTINUING DEVELOPMENTS

Recent advances in the tumescent technique continue in the areas discussed earlier.

Sutures are being avoided to maximize postoperative drainage and thus minimize postoperative swelling, bruising, and tenderness.

Microcannulas are now employed to permit liposuction in the most fibrous areas of fat. Surgeons are realizing that microcannulas permit the removal of more fat and provide smoother results than larger cannulas.

A more comprehensive pharmacokinetic study of tumescent lidocaine is in progress. It involves both formal IRB approval and submission of an Investigational New Drug (IND) application to the FDA. The IND application includes a formal request for a change in the official FDA-recommended maximum dose of subcutaneous lidocaine.

SUMMARY

The development of the tumescent technique was the result of dermatologists' preference for local anesthesia. Dermatologic surgeons achieved this by pursuing an uncharted path to an unanticipated destination, guided only by clinical observation and cautious, incremental optimization.

With time the pharmacologic principles of the tumescent technique will result in applications far beyond dermatologic surgery. The range of these applications will depend on the imagination of specialists in other clinical disciplines, the nature of the clinical problems that confront them, and the needs and satisfaction of the patients they serve.

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Two Standards of Care for Liposuction

Because of its superior safety, the tumescent technique is now regarded as the worldwide standard of care for liposuction. The tumescent technique for liposuction has evolved into two distinct but similar procedures, with two distinct standards of care: tumescent liposuction *totally by local anesthesia* and tumescent liposuction *with systemic anesthesia.*

A *systemic anesthetic* is any parenteral drug that can be expected to impair the patient's respiration, protective airway reflexes, and ability to communicate verbally when given in a sufficiently large dose. Systemic anesthetics include inhalational agents such as halothane or isoflurane, intravenous (IV) drugs such as propofol (Diprivan), benzodiazepines such as midazolam (Versed), narcotic analgesics such as meperidine (Demerol) or fentanyl (Sublimaze), and similar drugs used for conscious sedation, including ketamine (Ketalar). For the purposes of this book, *general anesthesia, conscious sedation, monitored anesthesia care* (MAC), and *heavy IV sedation* are considered synonymous with systemic anesthesia.

Most surgeons who do liposuction with systemic anesthesia have not had the experience of doing liposuction totally by local anesthesia. Without specific training, a surgeon would be incapable of doing routine tumescent liposuction totally by local anesthesia without systemic anesthesia.

SAFETY ISSUES

When one considers the safety record and the risks of serious complications, tumescent liposuction by local anesthesia and tumescent liposuction with systemic anesthesia are clearly two distinct procedures with two distinct levels of safety.

Liposuction-related malpractice litigation has shown that more problems occur when liposuction is done with systemic anesthesia versus liposuction totally by local anesthesia. The pooled data from an organization of malpractice insurance companies from 1996 through 1998 found that 257 lawsuits were attributed to surgeons who used systemic anesthesia, with total losses of more than $9 million. Only two lawsuits involved surgeons who performed tumescent liposuction totally by local anesthesia.[1]

COMPETITION

The competition between the two standards of care for tumescent liposuction is a natural and a desirable part of the "darwinian" evolution of competing surgical techniques. In the context of *therapeutic surgical techniques,* a competition between two standards of care is decided by means of clinical trials, and the winner is the technique that offers the greatest degree of patient safety. In the context of *cosmetic surgical techniques,* however, safety issues can be subordinated by the economics of "turf battles" between competing specialties. This is a reality of liposuction surgery and cannot be ignored.

State legislatures are correctly concerned about safety issues that involve liposuction and cosmetic surgery. Two strategies exist for a legislative remedy that would minimize the risks of liposuction. Legislatures can pass laws that either (1) restrict liposuction to surgeons who are trained in only the use of systemic anesthesia or (2) encourage surgeons to perform liposuction more safely by using local anesthesia. Current legislative strategies seem to be more concerned about turf battles between competing specialties than about optimizing patient safety (Box 2-1).

The superior safety record of liposuction by local anesthesia should not be obscured by the political lobbying of those whose financial well-being depends on the use of systemic anesthesia.

CONVENIENCE

Whereas local anesthesia is safer, systemic anesthesia is more convenient. Safety is the preeminent value for the standard of

Suppose one group of dental surgeons has no training in doing dentistry totally by local anesthesia and instead performs all dentistry using systemic anesthesia. Another group of dentists does all dental procedures totally by local anesthesia. Which of the following two legislative strategies would be preferred in resolving the conflict between these two groups?

1. Pass laws that restrict dentistry exclusively to dentists who have years of training using systemic anesthesia.

2. Pass laws that encourage safety by requiring all dentists to learn the use of local anesthesia.

Prohibiting dentists from doing dentistry merely because they do not have years of training using systemic anesthesia is irrational and is not in patients' best interest. Legislators should not be misled by a small group of dentists who, under the guise of having more training using systemic anesthesia, want to eliminate competition from dentists who use local anesthesia.

care that favors local anesthesia. Convenience is more valued by those who favor the standard of care that permits the use of systemic anesthesia.

When a surgeon is planning to remove a large volume of fat, it is safer to do serial liposuction procedures on separate days, but it is more convenient to do all the liposuction during a single procedure. With local anesthesia it is safer to limit the surgery done in one day to only liposuction and to do other cosmetic surgeries on a separate day. In contrast, with systemic anesthesia, it is more convenient and cost-effective to do all anticipated cosmetic surgical procedures together with liposuction on the same day. Because of the expense and danger of multiple exposures to general anesthesia, many surgeons who prefer systemic anesthesia consider it safer to do one megasession of cosmetic procedures.

Surgeons who do liposuction using systemic anesthesia presume that patient safety risks associated with systemic anesthesia are only slightly greater compared with local anesthesia. They believe that the risks of liposuction using systemic anesthesia are outweighed by the convenience. Many believe it is safe to remove more than 4 to 5 L of supranatant fat during a single surgery and to perform marathon surgeries that include liposuction, facial surgery, and breast surgery.

AGGRESSIVE APPROACH

Systemic anesthesia has a permissive effect that allows (1) multiple concomitant cosmetic procedures on the same day, (2) excessively prolonged and extensive cosmetic procedures exposing patients to many hours of general anesthesia, and (3) more voluminous liposuction. Regardless of surgical specialty, a more aggressive approach to cosmetic surgery is often more dangerous. In this sense, systemic anesthesia has been responsible for virtually all liposuction deaths.

Systemic anesthesia removes the self-limiting safety net imposed by local anesthesia. With systemic anesthesia, no well-defined boundary line exists between "conservatively safe" and "excessively dangerous." Restrictions on the total dose of lidocaine limit the amount of fat removed and the number of areas treated by liposuction on a single day. Most surgeons who do liposuction by systemic anesthesia are reasonable and conservative. Nevertheless, systemic anesthesia facilitates a trend toward excessive, and unsafe, cosmetic surgical practices.

Every death reported in association with liposuction has been *associated* with systemic anesthesia or heavy IV sedation or with bupivacaine. To my knowledge, no deaths have been associated with tumescent liposuction totally by local anesthesia.

SPECIAL KNOWLEDGE AND SKILLS

Effective tumescent infiltration without systemic anesthesia requires special technical training and empathetic interpersonal skills. Special knowledge of lidocaine pharmacology and pharmacokinetics is required to perform tumescent liposuction totally by local anesthesia. Sophisticated "people skills" are required when doing liposuction in a fully conscious and conversant patient.

LIDOCAINE'S ROLE

Liposuction by local anesthesia requires lidocaine. The liposuction by systemic anesthesia uses subcutaneous infiltrate only to achieve surgical hemostasis by the vasoconstriction induced by dilute epinephrine; lidocaine is often eliminated from the subcutaneous infiltrate.

EXCESSIVE VERSUS LIMITED LIPOSUCTION

It is impossible to know the exact point at which too much of a safe procedure becomes dangerous. The ability to survive a toxic dose of a traumatic surgical procedure is a probabilistic phenomenon without a distinct border that delineates the zone of danger.

When liposuction crosses beyond the boundary of common sense and into the domain of excessive surgical trauma, it metamorphoses from a benign cosmetic procedure into a potentially malignant process. An imperious surgical attitude, a naive sense of security, and a foolish desire to satisfy a patient's request to "do it all in one surgery" are dangerous ingredients; add systemic anesthesia to the recipe and the result is a prescription for disaster. No antidote exists for this toxic combination.

The only safe approach is *prevention*, which requires common sense, a knowledge of modern pharmacology and physiology, a careful surgical technique, and prudent limits to the amount of surgery.

With tumescent liposuction totally by local anesthesia, surgeons typically remove no more than 2 to 3 L of suprana-

tant fat in one session. In obese patients, even the removal of up to 4 L of supranatant fat by liposuction totally by local anesthesia has never been associated with serious complications. For liposuction of more than 4 L of fat, it is progressively safer to divide the liposuction into smaller procedures, doing serial surgeries separated by weeks or months.

When using systemic anesthesia, some surgeons remove more than 5 to 8 L of supranatant fat during a prolonged liposuction procedure.

Before the tumescent technique, the safe maximum volume of liposuction was limited by surgical blood loss. With the advent of *tumescent hemostasis,* surgical blood loss is almost invisible, and the safety limits for liposuction are much less obvious. Tumescent hemostasis seduces surgeons into a false sense of security. With liposuction totally by local anesthesia, a conscious patient can communicate and warn the surgeon about symptoms of excessive surgery, such as hypervolemia, hypovolemia, hypotension, hypothermia, and pulmonary congestion.

Excessive liposuction is most frequently associated with systemic anesthesia because excessive volumes of fat can be liposuctioned without complaint from the patient. Consequently, the risk of an iatrogenic death is significantly greater with liposuction by systemic anesthesia than with liposuction totally by local anesthesia. Based on data published in the dental surgery literature, I would estimate that the risk of death associated with liposuction is at least 100 to 1000 times greater with general anesthesia compared with pure tumescent local anesthesia.[2]

SUMMARY

Liposuction by either local or systemic anesthesia is regularly accomplished without serious morbidity. With liposuction by systemic anesthesia, however, a surgeon unwittingly tends to exceed the limits of safety. In this sense, much greater risks are associated with liposuction using systemic anesthesia.

Differences in surgical training are not an important predictor of liposuction safety. The most significant factor in determining the safety of liposuction is the *type of anesthesia* used. The tumescent technique for liposuction totally by local anesthesia is safer than the liposuction by systemic anesthesia.

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CHAPTER 3

Ethical Considerations

*The right to search for truth implies also a duty,
one must not conceal any part of what one
has recognized to be true.*

Albert Einstein

Cosmetic surgery is judged on its aesthetic merits and the patient's ultimate satisfaction, not on the speed by which it is accomplished. Cosmetic procedures must also be judged by ethical criteria. Because of the elective and purely cosmetic nature of liposuction, significant surgical risks are unreasonable, and it is unethical to subject a patient to unknown or unnecessary surgical risks. Convenience or financial considerations should not compromise patient safety.

Ethics is an important aspect of cosmetic surgery. Physicians are confronted daily with ethical issues. Cultivating moral behavior within professional groups requires that decisions involving ethics be identified and candidly discussed. The ethical ramifications of everyday decisions are often subtle or obscured by a lack of awareness. Financial conflicts of interest and inappropriate professional behavior in "turf warfare" are two obvious examples of ethical issues that directly affect patients' welfare. Whether to inform an anxious patient about the risk of death from anesthesia and whether to offer local anesthesia or the "speedier general anesthesia" are more subtle examples.[1]

DO NO HARM: SPECIFIC ISSUES

Tumescent liposuction has become the most popular, and possibly the most lucrative, cosmetic surgical procedure in the world. Whenever physicians' personal financial concerns are intertwined with patients' health care decisions, the potential for an ethical conflict of interest cannot be ignored. Ethics and professional decorum must be central to every liposuction surgeon's commitment to maintain the highest standard of care.

Ethics is a complex subject with many facets and profound dilemmas.[2,3] In its simplest terms, ethics is about vulnerability and potential harm. We are all vulnerable, and therefore ethics is a concern for everyone. Causing harm to someone is unethical when the harm is unnecessary. Thus the motivation behind an action that harms someone is an important determinant in judging the ethics of the action. Was the action unnecessary, preventable, or intentional? Was it the result of negligence, ignorance, or wrong beliefs (blind obeisance to dogma)?

No mystery or subtlety surrounds the main tenet of medical ethics: *benevolence*, or *do no harm.*

Criteria for assessing the relative merits of an action have evolved over the centuries. In the 1700s, Emanuel Kant held that *intention* is most important in appraising the ethical merits of an action. In the 1800s, Jeremy Bentham and John Stuart Mill were utilitarians who shared the view that human action should be assessed in terms of its production of maximum value; in other words, the greatest good for the greatest number. They believed that *consequences* of a person's actions are more important than the person's intentions. In the 1900s, multiculturalism recognized that good is defined relative to a cultural perspective. Respecting differences of *perspective* is important. For example, different surgical specialties have different cultures and different perspectives.

CHOICE OF ANESTHESIA

A *sibi-placebo* ("to please oneself") is a treatment that a physician prescribes because it is convenient, not because it is best for the patient. General anesthesia is a sibi-placebo when it is used merely for the surgeon's convenience, not because it is necessary.

When given a choice between local and heavy IV sedation or general anesthesia, most patients choose local anesthesia. Most surgeons also prefer local anesthesia for themselves when having cosmetic surgery. In a survey of plastic surgeons who previously had cosmetic surgery, 90% had chosen to have local anesthesia.[4] In contrast, among the patients of these same surgeons, only 40% received local anesthesia for their cosmetic procedures.

This raises the following two questions:

1. How often is general anesthesia used as a sibi-placebo?
2. To what extent do surgeons provide fully informed consent to their patients with regard to choice of anesthesia?

On the other hand, local anesthesia is not appropriate for all patients. A small percentage are unable to tolerate any surgery under local anesthesia. Such patients should be offered general anesthesia together with information about its risks and benefits.

CONFLICTS OF INTEREST

Fraud and cheating of insurance companies are obvious forms of unethical behavior. It is unethical to bill insurers for an elective procedure that is principally motivated by cosmetic concerns.

Conflict of interest is a particular type of ethical dilemma and occurs when an individual or a group is motivated by conflicting goals, such as service to the public and a self-serving hidden agenda that is not in the public's best interest. Physicians, both individually and as a group, are subject to the principles of medical ethics.[5] In medicine the utilitarian view of ethics maintains that an action should be judged in terms of what is best for the patient.

Financial conflict of interest is well recognized as being unethical. For example, if a procedure with local anesthesia is safer and more comfortable for patients, but a surgeon believes that general anesthesia is more time efficient, or an anesthesiologist recognizes that general anesthesia is more remunerative, a possible financial conflict of interest exists.

Editorial conflict of interest in peer review and publication in medical journals occurs when a reviewer or editor is associated with activities that could inappropriately influence judgment, regardless of whether that judgment is directly affected. Promoting high ethical standards and avoiding conflict of interest currently are major topics of discussion among medical journal editors.[6-9]

Intellectual conflict of interest is more elusive and occurs when one's ethical judgment is influenced by the possibility of personal recognition, career advancement, increased power, or enhanced prestige for oneself or one's group. Real and potential intellectual conflicts of interest are pervasive in science and medicine.[10]

Compromising one's academic honesty in favor of satisfying intense peer pressure to conform to political dogma is an intellectual conflict of interest.

MISINTERPRETATION OF TECHNIQUE

In 1995 the ABC television program "20/20" presented the tumescent technique as it was intended to be used: totally by local anesthesia. Hugh Downs declared it to be safe. It became so popular that patients simply would not consider liposuction by any other technique.

After viewing "20/20," prospective patients naturally asked surgeons if they performed tumescent liposuction. If surgeons did not know how to do tumescent liposuction to-

tally by local anesthesia, they might compensate by saying they did "a modified version of tumescent liposuction" using systemic anesthesia together with the elimination of blood loss provided by the tumescent technique. Patients often misinterpret such an answer and assume that liposuction with systemic anesthesia is as safe as liposuction totally by local anesthesia. Encouraging such a misconception is disingenuous and an unethical conflict of interest.

Surgeons may exploit the combination of tumescent hemostasis plus systemic anesthesia to remove excessive volumes of fat during a single liposuction surgery. The danger of such excessive surgical trauma is rarely explained to prospective patients. In this sense, patients are deceived when led to believe that liposuction under systemic anesthesia with tumescent infiltration for hemostasis is as safe as liposuction totally by local anesthesia.

The safety of tumescent liposuction is based on (1) avoidance of the risks of general anesthesia, (2) elimination of bleeding, and (3) elimination of intravenous fluids. Surgeons who claim to do tumescent liposuction but use general anesthesia are misleading patients.

Patients and the media have failed to recognize the distinction between *tumescent liposuction totally by local anesthesia* and *tumescent liposuction with systemic anesthesia*. In essence, two definitions and two standards of care have evolved (see Chapter 2).

WITHHOLDING OF KNOWLEDGE

Inhibiting the exchange of ideas between specialties is the antithesis of academic freedom. Anything that impedes communication or fosters enmity between specialties is not in patients' best interests. It is an intellectual conflict of interest. Patients are harmed to the extent that some surgeons are unaware of higher standards of care that might exist outside their particular professional group.

The rationalization that any specialty is justified in hoarding knowledge because other specialties are not trained to use such knowledge safely is a potential conflict of interest. To the extent that the particular specialty believes that it stands to gain financially by not sharing knowledge with competitors, to the potential detriment to patients, a financial conflict of interest exists.

Dermatologists have debated the ethics of restricting the participation of another specialty in dermatologic education. The main focus has been on whether or not dermatologists should teach dermatologic therapy to primary care physicians. In a symposium on *ethics* with audience participation during the 1994 annual meeting of the American Academy of Dermatology, more than 90% of the voters thought that withholding knowledge was unethical.[11] Where patients' health is concerned, a more knowledgeable physician or surgeon clearly is in patients' best interest. A self-serving financial motive for withholding knowledge would be unethical.

Dermatologists should teach other specialties how to do liposuction more safely and with better aesthetic results using the true tumescent technique.

COMPETITION

The American Medical Association (AMA) encourages competition among physicians based on quality of service, skill, experience, and safety. Ethical medical practice thrives best under free-market conditions, when prospective patients have adequate unbiased information and opportunity to choose freely between and among competing physicians.[5]

Competing medical specialties, as with nations, can interact with comity or enmity. Publicly maligning the competition is not ethical. It is considered unethical to denigrate the reputation of a colleague or the credentials of a competing medical specialty.[12] The Council of Medical Specialty Societies has passed a resolution condemning such behavior.

Surgeons have not made a "good faith" effort to obtain sound epidemiologic data that would support any particular specialty's claims of greater safety or superior surgical skills. Deceptive and misleading claims of superiority are unethical. When surgeons make public statements claiming that patients should choose *only* a surgeon certified by their specialty, they imply "a prediction of future success or guarantees that satisfaction or a cure will result from the performance of the member's services."[13] To the extent that such public proclamations "appeal primarily to a lay person's fears, anxieties or emotional vulnerabilities," it is unethical.

It is reasonable to ask, "Which specialty has had the greatest incidence of deaths associated with liposuction and greatest incidence of unplanned hospitalizations after liposuction?" Without a sincere effort to study the epidemiology of liposuction-associated deaths, any surgical specialty's claim that it has superior training is hypocrisy. To ignore surgeons' affirmative responsibility to pursue actively such an epidemiologic study is an ethical conflict of interest.

UNETHICAL ADVERTISING

Advertising that is misleading is unethical. For example, it is deceptive to show a "before photograph" with an "after photograph" that encompasses multiple cosmetic procedures, while stating or implying that only one procedure was done. Other aspects of ethics and advertising are more subtle. For example, it would be unethical to accuse a competitor of false advertising irresponsibly. One must be sure of the facts. A statement that is actually true might appear to be false to a naive surgeon from one specialty who has not kept up with state of the art or the literature of another specialty.

A public relations campaign implying that certain cosmetic surgical procedures should be performed only by surgeons certified by a particular board is viewed by other specialties as undignified, offensive, and unethical. The claim that any group of surgeons is better trained to do cosmetic surgery is a meretricious argument; it is plausible but specious. Self-serving claims of clinical superiority, unsubstantiated by objective data, transform "medical ethics" into an oxymoron. The intensity of belief in the superiority of one's own training is not a measure of the validity of such beliefs.

Liposuction advertising is particularly prone to exaggerated and misleading claims of experience and expertise. For example, an advertisement that claims that the surgeon has done "more than 3000 procedures" implies that the surgeon has treated more than 3000 patients. If the surgeon has merely done liposuction on multiple areas of only 400 patients, the advertisement is deceptive and unethical.

HEALTHY COMPETITION

Unethical behavior between competing specialties cannot be dismissed as simply a manifestation of "turf warfare." Calling attention to unethical conduct and conflict of interest is the essence of professional behavior and editorial responsibility.

Competition between individual or groups of surgeons in the arena of cosmetic surgery is in patients' best interests. Surgeons should strive to provide patients with the best cosmetic results, the safest anesthetic technique, the most comprehensive information, and the most respectful and dignified care. In the interest of optimal patient care, surgeons should share their knowledge with one another. As professionals, they should strive to win through positivity. Journal editors, leaders of professional societies, and individual surgeons should actively promote ethical competition and eschew negativity and denigration of competitors.

SUMMARY

Each medical specialty has its own unique cultural view of the world. Surgical training is analogous to religious education. It inculcates belief in clinical dogma and nurtures a deep faith in the fundamental truthfulness of instruction. Understandably, therefore, a group of specialists might disregard an intellectual conflict of interest in a debate with a competing specialty. The multicultural concepts of twenty-first-century ethics, however, demand great tolerance among different surgical and medical specialties.

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Educational and Clinical Qualifications

What type of training and experience are necessary for doing safe and artistically refined liposuction surgery? What are the minimal qualifications? What are the optimal qualifications? These questions have been contemplated by surgical specialty societies, state medical boards, malpractice insurance carriers, and hospital credentialing committees. The only certainties about liposuction qualifications are that no consensus exists and professional politics dominates.

From a patient's perspective, issues that concern medical politics and economic "turf battles" between specialties are unprofessional and puerile. Patients simply want to know what qualifications are most likely to predict the safest surgical technique and the most satisfying cosmetic results.

Cosmetic surgery's safety standards and priorities are different from those of therapeutic and restorative surgery. Safety standards for cosmetic surgery are higher than for therapeutic surgery. In cosmetic surgery, significant risks must always be avoided; in therapeutic surgery, significant risks are often unavoidable. In cosmetic surgery, only healthy patients are acceptable candidates for surgery; in therapeutic surgery, unhealthy patients are the rule. Cosmetic surgery is prudent, and serial procedures are preferred to avoid the risks of excessive trauma; therapeutic surgery often necessitates one major, potentially life-threatening procedure. Thus the philosophy and training for cosmetic surgery are qualitatively different.

PREREQUISITE TRAINING

Surgical training in liposuction must teach a philosophy that places patient safety above all other priorities. Safety must have primacy over convenience and efficiency. Without an absolute commitment to optimizing safety, surgical training in liposuction will beget misconception and tragedy. The first priority of liposuction training is teaching safety and prevention; the second is teaching operating room (OR) skills.

Surgical training that places the highest priority on operative techniques and surgical dexterity is destined to produce an unnecessarily high incidence of complications. Any aspiring liposuction surgeon must have training and experience in basic aseptic surgical technique and the artistic use of liposuction cannulas. Instruction in such skills is not as important, however, as instruction that covers judicious patient selection and the pathophysiology and prevention of liposuction complications. Thorough instruction of the relevant clinical pharmacology, clinical psychology, and pathophysiology is prerequisite to minimizing complications. Such instruction should precede the OR experience and hands-on liposuction training.

Board certification in any surgical specialty is desirable but not sufficient to guarantee optimal patient safety. The absolute number of years of formal surgical training is not correlated with increased liposuction safety. If longer surgical training tends to engender an overconfident attitude, it may ultimately be responsible for excessively aggressive and dangerous liposuction. In fact, the incidence of liposuction-associated malpractice litigation increases with increasing years of surgical training in systemic anesthesia.[1]

Every liposuction surgeon should have an expert's knowledge of the following:

1. Pharmacology, drug interactions, and fluid kinetics of the tumescent technique
2. Prevention of perioperative infections
3. Diagnosis and initial management of infectious, cardiopulmonary, and surgical emergencies
4. Appropriate consultation when needed

RESIDENCY TRAINING

Residency training in internal medicine may be more appropriate and more effective than general surgery training in the prevention and management of common liposuction-related

emergencies. All available data suggest that the danger of liposuction is the result of complications associated with anesthesia, inappropriate patient selection, or overaggressive surgery. Knowing how to select appropriate surgical candidates and how to make an early diagnosis of the most dangerous liposuction complications (cardiopulmonary insufficiency, thromboembolism, infection, drug toxicity) is more important than extensive experience in treating surgical complications. The surgeon who has avoided intravascular fluid imbalances by not doing excessive liposuction is better qualified to do cosmetic surgery than the surgeon who regularly does too much surgery and must treat iatrogenic hypovolemia or hypervolemia.

Considering the relative rarity and wide range of possible liposuction complications, no surgeon can be expected to manage every serious complication. Knowing when to seek a consultation from an appropriate specialist is the mark of good clinical judgment. A surgeon who pretends to have expertise in the management of all possible liposuction complications lacks good judgment.

Residency training in general surgery or board certification in anesthesia does not protect liposuction patients from complications that follow a decision to do too much surgery. On the other hand, outmoded residency training and antiquated board certification are dangerous if surgeons are unaware of limitations and inadequacies.

Surgeons with more than 5 years of surgical training and experience in treating massive trauma must guard against overconfidence. A cavalier attitude about the consequences of extensive surgical trauma in elective cosmetic surgery is probably the greatest risk for death in liposuction surgery. Extra years of surgical training do not automatically guarantee a superior safety record in liposuction surgery.

ACLS Certification

Every liposuction surgeon should have training that is equivalent to the American Heart Association's certification in Advanced Cardiac Life Support (ACLS). In addition to the surgeon, at least one other member of the OR staff should have ACLS certification.

When tumescent liposuction is done in an office setting, the following equipment should be immediately available: supplemental oxygen supply, Ambu bag for assisted respiration, cardiac monitor, defibrillator, pulse oximeter, and automatic blood pressure machine with various sizes of cuffs. Three sizes of blood pressure cuffs are recommended: regular-size arm cuff, thigh cuff for an obese patient's arm, and pediatric cuff for a patient's wrist during arm liposuction. The surgeon and staff must be well trained in the use of this equipment.

All patients assume that surgeons are well trained and capable of managing the most common acute cardiopulmonary emergencies. If the surgeon and staff do not have up-to-date training that is equivalent to ACLS certification, preoperative informed consent should indicate that the surgeon and staff are not capable of managing a cardiac arrest.

SURGICAL TRAINING

As mentioned, the first priority when teaching a surgeon to do liposuction is to inculcate a philosophy of "safety first." Hands-on OR training is of secondary importance. The specialty that regards learning surgical technique as sufficient for doing liposuction will have the highest malpractice and mortality rates.

The novice liposuction surgeon should take one or more courses accredited by an organization qualified to grant continuing medical education (CME) credits. The surgeon should attend comprehensive didactic lectures, live OR demonstrations, and scientific conferences. All liposuction surgeons, but especially the novice, should attend scientific meetings that focus on recent advances in liposuction safety and technique. Interdisciplinary meetings are invaluable for their free and open exchange of ideas and unabashed discussions about complications and safety. Discussions about the ethics of cosmetic surgery are also an essential part of liposuction training (see Chapter 3).

Instructional material should provide in-depth coverage of patient selection and education, liposuction complications and pathophysiology, relevant clinical pharmacology, surgical anatomy of subcutaneous fat, tumescent infiltration technique, microcannular surgical technique, and postoperative care. A knowledge of the risks of excessive liposuction and excessive intravenous fluids is an essential factor in truly safe liposuction.

With this fundamental knowledge and experience observing live OR surgeries and postoperative care, a fledgling liposuction surgeon can begin hands-on experience with tumescent liposuction. Initial attempts at liposuction should be limited to a small procedure treating a limited area. After acquiring some experience with limited procedures, such as on the female hip, the novice surgeon can then gradually increase the scope and duration of procedures.

With liposuction totally by local anesthesia, the patient can safely return for sequential procedures, spaced sufficiently apart, without the risks of multiple exposures to systemic anesthesia. This gradual, step-by-step approach is safer than merely assuming that several years of training in general surgery automatically guarantees the surgical skills, common sense, and good judgment necessary for safe liposuction.

The definition of "adequate training" for a multidisciplinary procedure such as tumescent liposuction should not be based on the narrow criteria of one specialty. Again, traditional training in general surgery does not guarantee safe liposuction. More than 90% of all liposuction-related malpractice lawsuits have involved surgeons with several years of training in treating major trauma but virtually no training in tumescent local anesthesia.[1]

All liposuction surgeons should have training in doing liposuction totally by local anesthesia. Whereas virtually all liposuction surgical deaths have been associated with systemic anesthesia, no death has been associated with the true tumescent liposuction totally by local anesthesia. Liposuction surgeons who lack training in this technique automatically relegate their patients to systemic anesthesia.

Surgeons who do tumescent liposuction should have clinical expertise in the pharmacology of all anesthetic and perioperative drugs that are being used for their patients. The number of drugs used and the individual dosages should be minimized. In particular, the surgeon should know (1) appropriate doses; (2) rates of systemic absorption, metabolism, and elimination; (3) principal cytochrome P450 isoenzymes responsible for metabolism; (4) common and potentially serious drug interactions; (5) contraindications; and (6) nature and clinical presentations of adverse effects.

The surgeon should be prepared to manage all potential adverse drug effects.

The office-based liposuction surgeon should have a surgical OR that is dedicated to sterile surgical procedures. If any drugs are used at dosages that could impair a patient's protective airway reflexes, the surgery must be performed in a facility with competent licensed personnel in attendance and adequate monitoring and resuscitation equipment available.

PEER REVIEW

Regular peer review is an essential component of continuing quality assurance. All liposuction surgeons should participate in ongoing peer review and quality assurance programs. At present, no organized peer review programs exist for office-based liposuction. Because of the restrictive criteria often used for granting hospital surgical privileges for liposuction, hospital-based peer review for liposuction does not guarantee the highest standard of care. A disproportionate majority of liposuction-associated malpractice cases have involved surgeons who have hospital surgical privileges and who are subject to hospital peer review.[1]

All surgeons, including dermatologic, obstetric-gynecologic, and cosmetic surgeons who do safe tumescent liposuction surgery totally by local anesthesia, should be encouraged and welcomed to participate in hospital credentialing, peer review, and ongoing quality assurance programs. Peer review is meant to enhance patient safety. Peer review for liposuction should involve all the major specialties that perform liposuction. In particular, hospitals should encourage the peer review participation by specialties with the best liposuction safety record. This is the most efficient means of eliminating dangerous "substandard standards of care."

State or local medical associations or specialty societies should cooperate with cosmetic surgeons in establishing voluntary peer review programs for monitoring out-of-hospital cosmetic surgery. Such a program might require a participating surgeon to keep complete lists of all liposuction procedures and complications. Surgical records would be subject to review, serious complications would be reportable, and disciplinary action would result from any action or inaction that suggests a deliberate effort to conceal the facts about a complication.

COMMITMENT TO SHARE KNOWLEDGE

Liposuction is a multidisciplinary procedure, not the exclusive domain of any one specialty. For optimal patient care, liposuction surgeons should seek interdisciplinary educational experiences, and specialty organizations should participate in interdisciplinary meetings. At present, a North American liposuction society excludes all other specialists from its meetings. Such intellectual isolation tends to exclude fresh ideas, institutionalize outmoded procedures, and promote antiquated and unsafe techniques.

Regulatory agencies must avoid being influenced by any group of specialists who claim hegemony in liposuction. State regulatory agencies should seek to identify surgical specialties with the most liposuction-related deaths and malpractice cases, then help those specialties improve their training.

The intellectual isolation of a surgical specialty limits awareness of current advances and the current scope of training in other specialties. Unaware of newer and safer techniques, a group of isolated surgical specialists may be truly convinced of the superiority of their own training. They may not appreciate the skill and advanced training of other specialists.

HOSPITAL SURGICAL PRIVILEGES

Any surgeon who claims proficiency in tumescent liposuction should seek to participate in peer review for liposuction procedures. Unfortunately, the opportunity to participate in peer review typically requires hospital privileges for liposuction. In many enlightened medical communities, dermatologists, obstetricians-gynecologists, and other specialists have obtained hospital surgical privileges for liposuction. In other communities, well-qualified liposuction surgeons are routinely denied hospital privileges for liposuction under the pretext that these specialists have inadequate surgical training. In the world of hospital politics the definition of "inadequate surgical training" is based more on economic self-interest than on objective data.

An application for hospital surgical privileges for liposuction is evaluated by a hospital credentialing committee whose policies are influenced by surgeons who only do liposuction by systemic anesthesia. These surgeons may or may not have a realistic perspective on the important safety factors of liposuction. For example, pooled data from 1996 to 1998 from physician-owned malpractice insurance companies showed that 70% of all liposuction-related malpractice cases were performed in hospital.[1] Surgeons who currently have hospital surgical privileges for liposuction might learn more about liposuction safety from specialists who are routinely denied such privileges.

The bizarre logic that is cited when qualified surgeons are denied hospital privileges for liposuction surgery totally by local anesthesia is an example of political sophism. A *sophism*, or sophistic logic, is an argument that is deceptively plausible but knowingly fallacious. A political sophism is used to deliberately deceive or mislead. The classic example of political sophistry in the realm of hospital privileges is the following "reasoning":

1. "Liposuction surgery under general anesthesia is so dangerous that only surgeons who have had extensive training using general anesthesia should have hospital surgical privileges for liposuction."

2. "Dermatologic surgeons have not had extensive training in the use of general anesthesia." (Instead, they do liposuction totally by local anesthesia.)
3. "Therefore dermatologic surgeons should not have hospital surgical privileges for liposuction."

This self-serving sophistry ignores that liposuction surgery totally by local anesthesia is much safer than liposuction surgery by systemic or general anesthesia (inhalational or intravenous anesthesia). It ignores that two distinct surgical procedures have been labeled as "liposuction" and that one is safe and one is less safe (see Chapter 2).

A more realistic *syllogism* (deductive reasoning in which a conclusion is derived from two premises) is the following:

1. To improve the safety of liposuction for patients, surgeons should participate in quality assurance programs such as hospital peer review, which usually requires hospital surgical privileges.
2. True tumescent liposuction totally by local anesthesia is so safe that it does not require years of training in general surgery.
3. Therefore, in the best interest of patients, general surgery training should not be required for hospital privileges and participation in peer review.

A cynical observer might suspect the true reason that surgeons who do liposuction by systemic anesthesia oppose liposuction hospital privileges for surgeons who do liposuction totally by local anesthesia is to discourage competition and to avoid being criticized for using a more dangerous technique.

SUMMARY: LIPOSUCTION PRIVILEGES

Many well-qualified and prudent liposuction surgeons find it difficult to obtain hospital surgical privileges. Surgeons are usually required to meet the following criteria:

1. Board certification in a surgical specialty
2. Board certification in a specialty that recognizes liposuction as a surgical technique germane to that specialty

Many gynecologists and otolaryngologists are also well-qualified liposuction surgeons. Hospital credentialing committees may be reluctant to grant them liposuction privileges, however, until these surgeons' specialty boards explicitly state that liposuction is within their purview.

The nature of dermatologic training and clinical dermatology as practiced in the United States has changed from a medical specialty to an increasingly surgical specialty. Surgical procedures account for approximately 70% of the fees earned by the average U.S. dermatologist. Many dermatologists have attained an outstanding degree of surgical training and expertise. Tumescent liposuction is a dermatologic surgical procedure that was invented and popularized by dermatologists and is recognized by the American Board of Dermatology (ABD). All physicians who take the examination for ABD certification must answer questions pertaining to tumescent liposuction.

I believe that hospital surgical credentialing committees are increasingly likely to grant surgical privileges for liposuction to dermatologists and other specialists with appropriate documentation of training and experience.

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Problems in Reporting Liposuction Deaths

*F*irst, do no harm. Second, learn from mistakes.
Third, teach what you have learned.

Deaths as the result of cosmetic surgery, and liposuction in particular, are probably underreported. Without accurate epidemiologic data, the common causes of liposuction deaths cannot be identified. Without accurate information about the causes of such deaths, it is difficult for surgeons to learn from the mistakes of others. Ultimately, patients will suffer needlessly as a result of surgeons' collective ignorance about preventable liposuction deaths. The cause may be an *iatrogenic complication,* or an unfavorable response to a medical or surgical treatment that is induced by the therapeutic effort itself.[1]

What are the risks of general anesthesia in ambulatory surgery? What are the most risky aspects of cosmetic surgery? Which surgical specialty has had the most deaths among its liposuction patients? My answers here are merely based on anecdotal cases and enlightened speculation. No unbiased statistical studies exist on which to base reasonable answers, and no comprehensive, systematic data have been collected on mortality risks of outpatient surgery. In other words, surgeons simply do not have accurate answers. More surprisingly, the perpetuation of this ignorance seems to be institutionalized throughout U.S. society.

LACK OF EPIDEMIOLOGIC DATA

Suppose an unrecognized drug interaction causes the deaths of five ambulatory surgery patients each month throughout the United States. Because these cases are isolated and not reported to any centralized registry, the pattern of these deaths might never be recognized. Therefore, every year, 60 preventable deaths might occur.

SURGEONS AND QUALITY CONTROL

Surgeons participate in quality control audit programs through hospital-based morbidity and mortality conferences. No mechanism exists, however, to provide a centralized collection and analysis of important sentinel events. A *sentinel event* is an unusual occurrence that, if recognized and appropriately investigated, can reveal important flaws in accepted clinical practice and standards of care. The surgical specialties have been recalcitrant in accepting responsibility for specialty-wide quality control programs that focus on problems at the surgery-anesthesiology interface.[2]

Surgeons and anesthetists must know the potential pitfalls, dangers, and potential iatrogenic complications of surgery. Learning about serious complications from the other physicians' experiences is preferable to self-instruction. Ethical surgeons, however, have no system to report their own adverse outcomes without fear of public embarrassment or professional retribution. Concealing unanticipated disasters and inexplicable complications exposes future patients to needless dangers, and physicians must relearn the same lesson again and again.

In the setting of medical school or residency surgical training, errors in judgment and technique are viewed as morally neutral, whereas failure to report or to correct them is viewed as more serious.[3] The same moral imperatives should apply to out-of-hospital surgeries in private practice, which now account for more than half of all surgeries.

An ethical conflict of interest exists when a physician is motivated by self-interest at the cost of patients' well-being. Potential surgical disasters must be identified and prevented to serve the best interest of patients. When medicine does not make a concerted effort to report and study iatrogenic surgical complications systematically, this suggests an unethical conflict of interest.

DISINCENTIVES TO REPORT

A surgeon would be reluctant to report voluntarily a significant cosmetic surgical complication and thereby harm his own reputation. For less obvious reasons, a medical equipment manufacturer might be motivated to discourage surgeons from reporting surgical complications involving the manufacturer's medical equipment.

The U.S. Food and Drug Administration (FDA) regulates the manufacturers of medical devices and equipment. If a manufacturer receives an *official written* notification of a surgical complication associated with one of the manufacturer's devices, the manufacturer is required by law to notify the FDA about the mishap. If the manufacturer hears about such a surgical complication unofficially, such as during a casual conversation, the manufacturer need not report the event. An official report of a serious complication to the FDA may result in a time-consuming investigation, a reassessment of the device's safety, and a restriction in sales. This is an incentive for manufacturers to remain ignorant about complications involving their equipment.

In California, county coroners and medical examiners are not required to cross-reference deaths resulting from a medical misadventure. Such cases are merely recorded by the name of the deceased. It is virtually impossible to obtain information from a coroner's office about unknown patients who might have died from a specific category of causes. This subtle form of concealing data, which otherwise would be readily available, discourages researchers from studying the causes of death.

Deaths or severe complications of cosmetic surgery are usually not reported or discussed at open sessions of professional scientific surgical meetings. Fear of both embarrassment and loss of income may preclude some voluntary reporting. A central registry is needed for reporting deaths associated with recent ambulatory surgery and for collating information on possible iatrogenic complications.

NO CENTRAL REGISTRY

Research into the causes of airline accidents has shown that 70% of airline accidents involved some degree of human error. Most of these errors have stemmed from failures in communication, teamwork, and decision making rather than from technical shortcomings.[4] Similarly, most surgical accidents involve some degree of preventable human errors resulting from incomplete knowledge, inadequate communication, and faulty decision making.

Professional airline pilots, without stigma or fear of personal consequences, are required to report confidential information about their mistakes and near-misses to a centralized agency. This agency routinely notifies other pilots about newly recognized problems and methods of prevention. No similar central registry exists for catastrophic surgical complications, and no effective mechanism encourages surgeons to report complications.

Almost all ambulatory surgery is performed on healthy patients, and the procedures are expected to be safe and un-

eventful. When a death does occur, it is likely to be associated with a preventable iatrogenic injury, such as drug interactions, genetic defects in drug metabolism, or preventable errors in surgical or anesthetic technique. Concerned physicians need a central registry that uses epidemiologic techniques to detect isolated events.

Every unexpected death of a healthy cosmetic surgery patient is presumably preventable. Preventable ambulatory surgical deaths should be subject to the same epidemiologic scrutiny as any other public health problem, as follows:

1. Identify the existence of similar unexplained deaths.
2. Methodically determine the probable causes.
3. Institute preventive measures.

For ambulatory surgery the most formidable problem is identifying the existence of unexplained but similar deaths.

GOVERNMENT REPORTING

The obfuscation of medical mistakes and surgical catastrophes seems to be institutionalized. Virtually every institution in U.S. society seems to ignore the problem or actively impede the distribution of knowledge about factors associated with unexpected surgical fatalities.

More than half of all surgeries are performed in out-of-hospital facilities, but according to the Medical Board of California (MBC), no statistics are kept about the safety of these surgeries. The MBC does not maintain databases that permit the identification of all the deaths associated with ambulatory surgery. For example, the MBC denies being able to retrieve information on reported deaths associated with liposuction in a way that would allow epidemiologic analysis. The MBC apparently has made no effort to categorize, analyze, and report its extensive data on medical and surgical catastrophes.

County coroners also do not categorize their data on unexpected deaths in an epidemiologically useful manner. Autopsy reports from county medical examiners and coroners on deaths associated with "medical misadventures" are already part of the public record and should be available. The coroner's office of Orange County, California, records deaths by the address where the death occurred. Deaths are not cross-referenced by cause or by attending physician. Furthermore, budgetary constraints may not allow a county coroner's office to investigate all suspicious cases.

HOSPITAL AND INSURANCE PRACTICES

When a patient dies in a hospital after ambulatory surgery, the death is reviewed by a committee of physicians on the hospital staff, but the relevant findings are usually not shared with interested outside physicians. The hospital peer review process is specifically designed to deny oversight or scrutiny from the public or from interested professionals who are not members of the review committee.

Malpractice insurance carriers deny being able to retrieve information about deaths associated with liposuction or ambulatory surgical deaths. These institutions possess comprehensive databases listing almost all fatal therapeutic

misadventures. Because of statutory law, lack of insight, or simple indifference, these insurance companies publish no scientific data on ambulatory surgical deaths. These huge databases most likely possess valuable information that could be published as anonymous statistical summaries to help prevent surgical complications.

Physicians and institutions are not required to report deaths in ambulatory surgery to any state or national epidemiologic registry or database. Thus, in the United States, no scientific mechanism is available to collect and scrutinize data so that subsets of deaths with a common pattern of predisposing factors can be identified. Although California law appropriately requires the reporting of rare infectious zoonotic diseases and certain cancers such as cutaneous melanoma, preventable ambulatory surgical deaths are not reportable.

DEATH CERTIFICATE DATA

California has death certificate regulations that are intended to provide epidemiologic data on preventable causes of death. At present, however, death certificate data on mortality associated with either outpatient surgery or outpatient anesthesia are not recorded. California death certificates do not require the attending physician to specify that death was associated with an injury sustained during an ambulatory surgical procedure. Typically, such deaths are simply listed as the result of a "cardiac arrest." In 1995 the California Medical Association defeated a proposal that state death certificates must identify any death occurring within 30 days of an ambulatory surgery.

The National Center for Injury Prevention and Control (NCIPC) of the Centers for Disease Control and Prevention (CDC) has a surveillance program to identify head injuries related to bicycle riding, but it does not collect data on preventable injury associated with anesthesia or ambulatory surgery. When asked if the CDC/NCIPC could act as a registry for reporting fatal and potentially fatal events that occur during or soon after (within 30 days) ambulatory surgery, the director suggested that another, unspecified agency was responsible for the analysis and prevention of surgical injury.[5]

POSSIBLE SOLUTIONS

NONPUNITIVE POLICY

Better incentives are needed to encourage surgeons and anesthesiologists to report their outcomes, mistakes, and problems.[6] The present system of voluntary reporting is inadequate; physicians responding to questionnaire surveys most likely underreport the incidence of serious injury and death associated with surgery.[7-10] Surgeons must be required to report all such deaths. Government legislatures, state medical boards, malpractice insurance companies, and the medical profession must cooperate in formulating a nonpunitive policy toward reporting surgical complications.

Surgeons must be guaranteed anonymity to encourage them to share their experiences. Surgeons must be compelled to report cases without fear of committing professional suicide. Government agencies responsible for public health issues must provide epidemiologic analyses that present data in the form of statistical summaries, without revealing the names of individuals or organizations.

To protect the anonymity of individuals and institutions, access to initial case reports and raw data should be restricted. Research protocols using such data and publication of all research reports must be approved by an appropriate human subjects research committee.

THE IDEAL SOLUTION

Ideally, to identify unrecognized causes of death resulting from surgery or anesthesia, each specialty would take full responsibility for reporting and analyzing each unanticipated death. This would require compulsory reporting, absolute confidentiality, and significant penalties for noncompliance. Ultimately, the systematic epidemiologic investigation and the reporting of statistical analyses would be required to ensure the anonymity of all participants.

Unfortunately, little evidence is available to suggest that any surgical specialty will soon institute a useful surveillance-quality assurance program.

A REALISTIC SOLUTION

To identify the sources of preventable injury to patients and to evaluate the efficacy of government regulations for ambulatory surgical facilities, I would propose the following solution:

1. To facilitate epidemiologic analyses of preventable deaths associated with outpatient surgery or outpatient anesthesia, state medical boards and state medical associations should propose and support legislation requiring state death certificates to answer the following questions:
   a. Was the death related to an outpatient surgery or an outpatient anesthetic misadventure?
   b. Did the deceased patient have surgery at an ambulatory facility within 30 days before death?
2. Any death associated with outpatient surgery or outpatient anesthesia and any death within 30 days after ambulatory surgery must be reported to the local county coroner's office. The surgical facility's medical director, the surgeon, the anesthetist-anesthesiologist, and the director of nursing each must complete an *epidemiologic death certificate questionnaire,* designed jointly by the state medical board and the state department of public health.
3. The raw data from these questionnaires should be made available to state agencies and scientific investigators whose research projects have been approved by an institutional review committee on human research. These data must only be published or made available to the public in a summary or statistical form that does not reveal the identities of patients, physicians, or surgical facilities.

SUMMARY

At present, minimal reliable epidemiologic data exist on deaths and serious complications associated with outpatient surgery. Until such data are available, surgeons and anesthesiologists will remain uninformed about measures and techniques that might prevent iatrogenic complications among ambulatory surgery patients.

Death certificates should require mandatory reporting of all deaths and serious complications that are either (1) related to an outpatient surgery or anesthetic misadventure or (2) associated with a death within 30 days of an outpatient surgery.

Surgeons and anesthesiologists should be allowed to report a death associated with outpatient surgery in confidentiality, without stigma or fear of personal consequences. They should encourage government legislatures, licensing agencies, state and national medical associations, and their own speciality societies to implement efficient and nonthreatening epidemiologic data collection systems.

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PATHOPHYSIOLOGY AND COMPLICATIONS

CHAPTER 6

Clinical Biostatistics of Safety

Cosmetic surgical procedures must be judged in three dimensions: (1) *patient safety* (does the procedure expose the patient to any unnecessary risks?), (2) *ethical propriety* (is the procedure truly in the patient's best interest, or would the patient be better served without the procedure?), and (3) *aesthetic results* (are surgical outcomes beneficial to the patient?). Patient safety has precedence over the other two and all other considerations.

How can a surgeon objectively decide when a cosmetic surgical procedure is safe and when it is not? Risk-benefit analysis is one of the surgeon's most basic and recurring activities. A comparison between two methods to prevent perioperative deep venous thromboses is a straightforward example of comparing the risks and benefits of alternative procedures. When considering drug safety, however, the analysis and decisions are not the simple "yes" or "no" results of comparing two alternatives. Drug safety is a more subtle assessment and involves a toxicologic dose-response analysis.

What is safety? Dictionary definitions of *safety*, such as "the state of being safe" or "freedom from injury," have little clinical usefulness. The clinical distinction between safe and unsafe is cloudy, with no definite boundary line. In medicine and surgery the concept of safety is most appropriately defined in terms of *probability* and *statistics*.

DOSE-RESPONSE PHENOMENON

Tumescent liposuction has two potential sources of danger: too much lidocaine and excessive liposuction. The more lidocaine or the more liposuction, the greater is the danger. Either situation can be represented mathematically by dose-response function (see later discussion).

What is a safe amount of lidocaine? A surgeon's administration of more than 85 mg/kg body weight of lidocaine on numerous occasions without "serious complications" does not prove this is a safe practice. Which of the following local lido-

caine doses is ethically preferable: 90 mg/kg for a single surgery, at a risk of one death in 1000 surgeries, or 45 mg/kg for each of two liposuction procedures, each performed 1 month apart, at a risk of one death in 100,000 surgeries for each procedure?

What is a safe amount of liposuction? Although a single anecdotal report can easily disprove the safety of a procedure, it requires a much greater sample size to prove safety. A surgeon's removal of more than 5 L of supranatant fat by liposuction on numerous occasions does not prove the safety of this procedure. Which of the following is safer: a single megaliposuction of 9 L of fat, at a risk of one death in 1000 surgeries, or three liposuction procedures, each removing 3 L of fat and performed at 1-month intervals, at a risk of one death in 100,000 surgeries for each procedure?

In cosmetic surgery, especially liposuction surgery, questions about safety often are not determined by scientific method. The philosophic and conceptual aspects of safety are a challenging part of biostatistics. For example, when determining the maximum safe dose of lidocaine with tumescent liposuction, the surgeon might simply treat a few patients whose mg/kg doses of tumescent lidocaine were not predetermined, then do linear regression on *mg/kg lidocaine dose versus serum lidocaine concentration*. Such an approach gives the illusion of science, but it is no more helpful than a "clinical guess."

EXPERIMENTAL TOXICOLOGY

The experimental design of a scientific study of toxicity using experimental animals is distinctly different from a clinical study of toxicity in human subjects. It is instructive to have a conceptual understanding of experimental toxicology using animals before discussing clinical toxicology in humans.

Observational linear regression merely provides an estimate of safe tumescent lidocaine dose. Any estimate with a large but unknown standard deviation (or variance) is of minimal clinical utility when it involves potentially lethal doses of a

drug used for cosmetic surgery. The smaller the standard deviation of the estimate of a parameter's numeric value, the greater is the accuracy of the estimate. Predictions based on observational linear regression are much less accurate than experimental linear regression.

Experimental linear regression provides more accurate results by giving the same mg/kg dose of lidocaine to a large number of experimental animals (e.g., mice) and provides good estimates with small variance. For example, a specified dose, d_i (mg/kg), results in a fatality with a probability, p_i. Thus, if 10 mice are given a subcutaneous dose (d_i) of lidocaine and observe n_i lethal outcomes, $n_i/10$ is an estimate of the true p_i that d_i will cause a death. The more mice that are given the same d_i, the more accurate (smaller standard deviation) will be the estimate of p_i. If 1000 mice are given the same d_i, the frequency of death as $N_i/1000$ is a more accurate estimate of p_i than the first estimate, $n_i/10$.

The conceptual framework of animal toxicology is important for an appreciation of clinical situations involving patients. A typical toxicologic study might use mice to determine the probability that any chosen dose will produce a toxic reaction. Suppose $P(d)$ is the probability of toxic reaction T occurring at dose d (mg/kg) of lidocaine, where $0 \leq P(d) \leq 1$ by definition. Although we cannot ever know the true probability that d will cause a toxic reaction, we can obtain an estimate of $P(d)$ by counting the frequency $p(d) = n/100$, where n is the number of toxic reactions that occur when 100 mice are given dose d.

If we select 10 different doses $(d_1, d_2, d_3 \ldots, d_{10})$ of lidocaine and estimate the probability of a toxic reaction $p(d_i)$ at each dose, a plot of the graph of $p(d_i)$ will be a sigmoid, S-shaped curve (Figure 6-1).

For example, if we define T as a peak serum lidocaine level of 6 µg/ml or greater, the graph of $p(d)$ will help us estimate the chance that any given dose will result in a serum lidocaine concentration greater than 6 µg/ml. This graph allows us to derive a quantitative definition of *safety* in terms of potentially toxic serum levels. Thus we might define *safe* to mean that less than one mouse in 100 will have a serum lidocaine concentration greater than 6 µg/ml.

Similarly, if we want to study the probability that any given dose of lidocaine will kill a mouse, we can repeat the previous study by defining T as death. In this case we might define *safe dose* as the dose expected to yield less than one death per 100 mice. The graph of $p(d)$ is also used to estimate the median lethal dose (LD_{50}) for lidocaine in mice, which is the minimum dose that has a 50% probability ($p = 0.5$) of killing a mouse.

HUMAN TOXICOLOGY

When researching lidocaine toxicity among humans, any study design using experimental linear regression is unlikely to find many volunteers. Because toxicity experiments using humans are unacceptable, we must glean as much information as possible by simply observing the real world.

When studying human toxicology, epidemiologic methods provide an ethical way of obtaining reasonably accurate
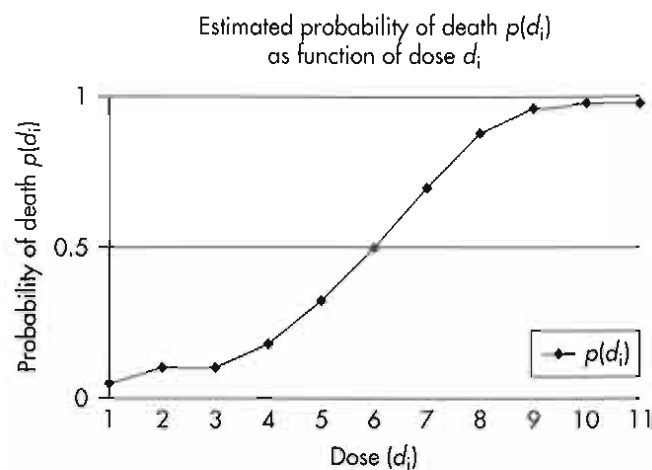

Estimated probability of death $p(d_i)$ as function of dose d_i

Figure 6-1

Estimating median lethal dose (LD_{50}), the minimal dose that can be expected to kill approximately 50% of treated individuals. In other words, LD_{50} is minimum dose that has a 50% chance, or a probability $p = 0.5$, of killing a mouse. In this graph, half the mice can be expected to have a fatal reaction to a dose equivalent to d_6. Thus $LD_{50} = d_6$. Analogously, minimal dose that can be expected to kill 10% of mice is d_2.

data on dose-response phenomena. When studying a drug that might cure a fatal disease, we can ethically consider a drug dose with a 1 in 10 chance of lethal toxicity. In this setting a clinical study involving a relatively small number of patients is reasonable. In cosmetic surgical procedures, however, ethical tolerance for lethal toxicity is much lower. This is where moral philosophy interfaces with cosmetic surgery. How much of a risk of fatal toxicity are we willing to accept? Which of the following thresholds represent an acceptable probability that a given total dose of lidocaine will result in a patient's death?

    1 in 10 patients
    1 in 100 patients
    1 in 1000 patients
    1 in 10,000 patients
    1 in 100,000 patients
    1 in 1 million patients

After agreeing on the level of acceptable risk, we can then discuss whether or not a given surgical procedure is "safe."

Toxicity Estimates. Without human experiments, we cannot generate enough experimental data to construct a sigmoid dose-response curve. Nevertheless, by understanding the principles behind the curve, we can better understand how safety is defined *quantitatively*. The clinical approach to lidocaine toxicity in humans is based more on pragmatism and art than on precise science.

In the experimental animal study the likelihood of toxicity was estimated by calculating the frequency $n/100$. In this case, the experimenter specified the denominator as 100 mice, then determined the number n by giving dose d to each of 100 mice.

TABLE 6-1 ESTIMATES OF LIPOSUCTION-RELATED MORTALITY RATES	
Technique*	Mortality Estimate
True tumescent	1:500,000
Superwet	1:5000
Extreme superwet	1:1000
Megaliposuction	1:100

*See text for descriptions.

BOX 6-1 FACTORS IN DETERMINING SAFETY OF LIPOSUCTION

Number of areas treated
Volume of supranatant fat removed
Percent of body fat removed
Ratio of body weight to the weight of fat removed
Dosage (mg/kg) of lidocaine
Volume of intravascular fluid infused
Duration of surgical procedure

In humans, typically the numerator is specified as $n = 1$, and the denominator is determined by epidemiologic observation. For example, suppose I have never observed a patient with a potentially toxic serum lidocaine concentration of 6 μg/ml. Then, after giving a patient 60 mg/kg, I find that the patient's serum lidocaine concentration is 6 μg/ml. In my experience with tumescent lidocaine, I have given 60 mg/kg or more to about 300 patients. The 1 in 300 is a rough estimate of the incidence of lidocaine toxicity at a dose of 60 mg/kg.

At present in the United States, it is virtually impossible to conduct epidemiologic studies of iatrogenic disasters (see Chapter 5). Not revealing such data is systematically built into the U.S. legal system, and peer review often makes it illegal to comment publicly about another surgeon's complications. The only clinical solution is an expert's best estimate.

The following estimates of liposuction-related surgical mortality are based on my *subjective* experiences as a physician with training in epidemiology and biostatistics (Table 6-1). *Objective* epidemiologic data would show that the true risk of death is less for the tumescent technique totally by local anesthesia but greater for the superwet technique (see Chapter 9).

The *true tumescent technique* for liposuction uses no intravenous (IV) fluids, with supranatant volumes of fat less than 4 L and less than 4% of the patient's weight. Let us make the hypothetic supposition that one unreported death has been associated with tumescent liposuction (as a result of a pulmonary embolism). Considering the number of patients worldwide who have had true tumescent liposuction, 1:500,000 is probably a conservative estimate of mortality.

The *superwet technique* for liposuction uses systemic anesthesia, significant IV fluid infusions, and a 50% smaller volume of subcutaneous infiltration. The mere exposure to prolonged use of general anesthesia or IV sedation/analgesia has an estimated mortality rate of 1:10,000 to 1:20,000 in healthy ASA (American Society of Anesthesiologists) class 1 patients. A recent survey of surgeons who use the superwet technique reported that the risk of death associated with liposuction under systemic anesthesia is 1:5000.[1] Among surgeons who limit volumes of supranatant fat to less than 4 L and do not use IV infusions, the mortality should be significantly less than 1:10,000.

The *extreme superwet technique* for liposuction is significantly more dangerous than the true tumescent technique totally by local anesthesia. It exposes the patient to excessive volumes of liposuction (supranatant fat exceeding 4 L), excessive number of areas liposuctioned in a single day, routine infusion of multiple liters of IV fluids, use of bupivacaine instead of lidocaine, surgery of excessive duration, excessive number of ancillary surgical procedures, and excessive amounts of anesthetic agents. I estimate that approximately 100 deaths have been associated with the extreme superwet technique or with ultrasonic liposuction.

Megaliposuction combines all the high-risk factors for liposuction and inflicts them on a single, usually naive and unsuspecting patient. Its value and safety have never been established. It is an experimental procedure without ethical oversight by a human studies research committee or an institutional review board. Megaliposuction exposes patients to the greatest risks of liposuction syndromes, which involve pulmonary embolism and pulmonary edema.

LIPOSUCTION VOLUME LIMITS

What is the LD_{50} for liposuction? The volume limits of safe liposuction must be defined, but it is simplistic to measure the degree of surgical risk based solely on the volume of aspirated supranatant fat. Which is more dangerous: removing 3 L of fat from a 50-kg woman or 6 L from a 100-kg woman, where each patient has the same lean body mass?

Several factors help to determine the amount of liposuction that can be safely performed in a single day of surgery (Box 6-1). Despite the lack of a well-defined threshold for safety, *subjective* criteria can be defined for liposuction safety. I feel more secure about safety when my patient is alert and conversing during surgery. When the patient is alert and smiling and can walk out of the surgicenter 30 minutes after liposuction, I have some confidence that the surgery has not been too aggressive. When a patient can return to work within 1 or 2 days after surgery, I am confident that I have not treated too many areas or removed too much fat.

The total volume of supranatant fat is not the only determinant of safety, but it does correlate with the length of postoperative recovery and the risk of complications. The following definitions of liposuction volumes of supranatant fat facilitate communication among surgeons:

1. *Small-volume liposuction:* less than 100 ml. Small-volume liposuction with tumescent local anesthesia is probably

as safe as any minor dermatologic surgery. The risk from small-volume liposuction is comparable to removing an equivalent volume of fat by the excision of multiple lipomas.

2. *Medium-volume liposuction:* 100 to 1500 ml. With traditional liposuction, aspiration of more than 1500 ml of "stuff" was widely regarded as an indication for an autologous blood transfusion. With current tumescent liposuction, blood loss with medium-volume liposuction should be insignificant. Surgeons with limited experience should not remove more than 1500 ml of fat in a single day.

3. *Large-volume liposuction:* 1500 to 4000 ml. Large-volume liposuction was revolutionized with the widespread recognition of the profound hemostasis provided by tumescent vasoconstriction. A patient's case of recovery is inversely related to the volume of aspirated fat. In my practice, liposuction of more than 3000 ml in a single day is uncommon; liposuction of more than 4000 ml is extremely rare. The belief that "do-it-all-at-once" surgery will minimize recovery time is a fallacy. Patients who have had liposuction of 2000 ml of supranatant fat require approximately 25% of the recovery time needed by patients with liposuction of 4000 ml.

4. *Extremely large-volume liposuction:* 4000 to 7000 ml. Removing more than 4 L of supranatant fat in 1 day is relatively unsafe; it is safer to divide the procedure and perform it on 2 different days separated by several weeks or months. Extremely large-volume liposuction has been appropriately described as "beyond the pale"; it is "beyond bounds" and beyond the pale of safety. Surgeons who assert that extremely large-volume liposuction is safe because many other surgeons boast of doing it are instruments of the *consensus gentium fallacy* (see Chapter 7).

5. *Megaliposuction:* (more than 7000 ml). Megaliposuction is "licentious" in the sense of disregarding commonly accepted rules, deviating freely from correctness, and overstepping customary limits.

LIDOCAINE DOSE LIMITS

To verify that 55 mg/kg yields safe peak serum lidocaine concentrations, a researcher would have to repeat the study in a large number of volunteers. This requirement makes such an achievement unrealistic even if the effort is shared by multiple researchers. If we accept a conservative estimate for a maximum safe tumescent lidocaine dose, however, a large study is probably unnecessary. Again, we can obtain considerable information from simple clinical observations.

Two fatalities have occurred in patients who inadvertently received 105 mg/kg of lidocaine, as well as excessive IV fluids. In each case the coroner diagnosed pulmonary edema and lidocaine toxicity. Therefore any estimate of the maximum safe dose of tumescent lidocaine will be significantly less than 100 mg/kg.

One surgeon (who shall remain anonymous) gave lidocaine doses of 70 to 90 mg/kg to more than 10 patients and reported that 30% experienced nausea or vomiting. Clearly this range of tumescent lidocaine is associated with an unacceptably high incidence of clinical toxicity.

I now recommend lidocaine doses of *50 mg/kg or less, with a strict maximum of 55 mg/kg.* I have measured the peak serum lidocaine concentration in approximately 20 patients after tumescent lidocaine doses in the range of 55 to 65 mg/kg. All patients had peak serum concentrations of less than 3.5 μg/ml. In addition, we have treated more than 400 patients with doses of approximately 55 mg/kg without clinical toxicity.

In one patient, 60 mg/kg of tumescent lidocaine with liposuction was associated with an episode of clinical toxicity (nausea and disorientation). Serum lidocaine concentration approximately 12 hours after infiltration was 6.1 μg/ml. In this case a probable lidocaine drug interaction with sertraline (Zoloft) may have been mediated by competitive inhibition of the hepatic microsomal enzyme cytochrome P450 3A4 (CYP3A4). Because serum lidocaine levels greater than 6.0 μg/ml are considered potentially toxic, we must assume that a safe maximum lidocaine dosage is less than 60 mg/kg.

Another patient had three serial tumescent liposuction procedures over 1 year. At the first and second surgery the patient received 58.3 and 49.7 mg/kg of lidocaine, respectively, without incident. At the third surgery, however, the lidocaine dose of 55.3 mg/kg produced a 3-hour episode of disorientation, confusion, short term memory loss, and ataxia. The patient was taken to an emergency room, and the serum lidocaine concentration was 5.0 μg/ml. Interestingly, the day before surgery, the patient had completed a 10-day course of the antibiotic clarithromycin (Biaxin), which inhibits CYP3A4.

Based on these experiences, I would recommend that lidocaine doses be minimized and, again, should never intentionally exceed 50 mg/kg. Furthermore, drugs that interfere with CYP3A4 should be discontinued 1 or 2 weeks before surgery (see Chapter 18).

Finally, the maximum safe dose of tumescent lidocaine should be determined with serial measurements of blood concentration when there is no concurrent liposuction. Sequential serum lidocaine concentrations measured in the same patient after equal tumescent lidocaine doses are approximately 20% lower with liposuction than without liposuction. Because some disruption might prevent completion of liposuction after infiltration of lidocaine, the surgeon would not want to give a relatively high dose of tumescent lidocaine and then be obligated to do liposuction in order to avoid lidocaine toxicity.

To reiterate, my current estimate for a safe maximum tumescent lidocaine concentration is 50 mg/kg. Greater dosages, as high as 55 mg/kg, should be avoided.

SUMMARY

One case report is often sufficient to prove a procedure is unsafe. An anecdotal report of 100 cases without complications, however, is insufficient to prove a procedure is *safe*. A huge sample size is necessary to prove safety.

When is it reasonable to be enthusiastic about a new procedure? If a new procedure has advantages in terms of increased safety and improved clinical results, a cautious test of the new technique is warranted. When tumescent liposuction was first introduced, the advantages in safety were the elimination of significant surgical bleeding and the elimination of risks of general anesthesia. Surgeons were correct to withhold judgment, however, until the tumescent doses of lidocaine were shown to be safe based on extensive clinical experience.

When is it reasonable to be skeptical about a new procedure? Clearly, if a procedure offers no cosmetic advantages over an existing technique and is potentially more dangerous, skepticism is in order. The mere absence of unfavorable reports does not prove safety. For example, internal ultrasonic liposuction has yet to be proved safe. The dismal European experience with ultrasonic-assisted liposuction (UAL) should be a warning not to jump on the U.S. media bandwagon that has promoted UAL (see Chapter 29).

REFERENCE

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CHAPTER 7

Risks of Systemic Anesthesia

This chapter supports the assertion that liposuction totally by local anesthesia is safer than liposuction by general anesthesia. Although local anesthesia is not completely safe, it is considerably safer than other forms of anesthesia used for liposuction.

This chapter compares surgical techniques, not surgical specialties. Any surgical specialist, given the proper training and experience with local anesthesia and microcannular liposuction, can become an expert at doing tumescent liposuction. Death associated with liposuction is not correlated with surgical training, but a correlation does exist with the use of general anesthesia.

Modern systemic anesthesia represents an outstanding advance in medical science. The routine application of systemic anesthesia to liposuction surgery, however, leaves much to be desired.[1] The anesthesiology literature seems to contain no comparisons between the safety of systemic anesthesia for liposuction and the safety of local anesthesia by subcutaneous infiltration (Box 7-1).

As a review of the current literature, this chapter objectively weighs the relative merits of systemic anesthesia and tumescent local anesthesia for liposuction. It is not an editorial in favor of one form of anesthesia over another. This chapter is intended as a dialectic examination of the relative safety of systemic anesthesia and local anesthesia for liposuction.

Liposuction surgery, which can be accomplished either by subcutaneous infiltration of local anesthesia or by systemic anesthesia, presents a unique opportunity to compare the relative safety of local and systemic anesthesia. Later chapters discuss the risks of tumescent local anesthesia in detail.

The greatest danger of systemic anesthesia is not any of its intrinsic pharmacologic properties, but rather human error and poor clinical judgment by those who use systemic anesthesia.[2-4] The most dangerous aspect of systemic anesthesia for liposuction may be a permissiveness that facilitates excessive amounts of liposuction surgical trauma on a single day.

Since human error and poor clinical judgment present the greatest risk of using systemic anesthesia for liposuction, this chapter discusses some of the most serious pitfalls in this regard. All surgeons and anesthesiologists who use systemic anesthesia for liposuction should be aware of the literature discussed here and must strive to identify and eliminate every possible risk factor and potential complication.

SYSTEMIC ANESTHESIA AND LIPOSUCTION DEATHS

Virtually all reported liposuction deaths have been associated with systemic anesthesia. This includes all five deaths recorded by the New York Medical Examiner from 1993 to 1998.[5] These five deaths were associated with liposuction under systemic anesthesia plus dilute subcutaneous lidocaine. The article did not mention the risks of systemic anesthesia or excessive liposuction surgery. Although they concluded that lidocaine might have contributed to the five deaths, the authors presented no objective evidence of lidocaine toxicity. Tumescent liposuction routinely uses lidocaine doses greater than those reported, but no deaths have been reported in association with tumescent liposuction totally by local anesthesia.

Inculcated biases may prevent surgeons from being objective about the relative benefits of local anesthesia versus systemic anesthesia. During residency training, surgeons and anesthesiologists receive indoctrination that systemic anesthesia is safe and becoming safer all the time. They see no incongruity in the argument that the convenience of general anesthesia outweighs its risks.

Systemic anesthesia may be more dangerous than most physicians believe. Aspiration remains an important anesthetic-related morbidity, but few good estimates of its incidence are available. Aspiration has recently been reported twice as often in elective as in emergency surgery. Passive

midazolam are infrequently required. The degree of neurologic effects of IV sedation is a continuum that varies as a function of dosage, with apnea and total loss of consciousness at one end and subtle sedation, anxiolysis, and mild analgesia at the other.

The greatest risks of systemic anesthesia are the dose-dependent impairment of protective laryngeal reflexes and respiratory depression.[8] Respiratory impairment can occur when least expected. Unusually susceptible individual patients, excessive doses, undetected airway disconnections or airway blockage, and human error can lead to disaster.

Liposuction using the combination of tumescent infiltration and systemic anesthesia is termed the *superwet technique, modified tumescent technique,* or *semitumescent technique for liposuction.* All these names refer to the same liposuction technique, which consists of the following:

1. Relatively small volume of tumescent infiltration
2. Some form of systemic anesthesia
3. Significant volume of IV fluid supplementation

True tumescent liposuction totally by local anesthesia does not use parenteral (IV, IM, inhalational) analgesia.

All liposuction-related deaths have been associated with systemic anesthesia, excessive IV fluids, or bupivacaine. To my knowledge, no deaths have been associated with tumescent liposuction totally by local anesthesia. The greatest risk factors for liposuction-related deaths follow:

1. Using systemic anesthesia, with its associated risk of apnea and thromboembolism
2. Performing too much surgery in a single day
3. Lacking knowledge about the kinetics of tumescent fluids.

CONSENSUS GENTIUM FALLACY

One of the two classic arguments justifying systemic anesthesia for liposuction relies on the consensus gentium fallacy, which concludes that an idea is true because everyone agrees it is true or because it has always been accepted as true. The clinical application of this argument states, "Systemic anesthesia for liposuction is the standard of care and therefore any doubt about the safety of using systemic anesthesia may be disregarded." This argument is a *paralogism,* which is based on false or erroneous reasoning, an illogical argument, or a faulty syllogism in which the reasoner is unconscious of the fallacy.

The first contraindication to any drug is lack of indication.[9] It is unconscionable to use a technique that is convenient for the surgeon but less safe for the patient. Invoking the consensus gentium fallacy, however, achieves both the appearance of moral rectitude and an exemption from ethical responsibility.

IMPROBABILITY FALLACY

The second classic argument justifying systemic anesthesia for liposuction relies on the improbability fallacy, which concludes that a proposition is true because all alternatives are believed to be highly unlikely. The clinical application of this argument states, "None of my patients have died from sys-temic anesthesia, and therefore any doubt about the safety and ethics of using systemic anesthesia may be disregarded." The following quote, referring to anesthesia for liposuction, is an example of this fallacy, "Although we agree that avoiding any unnecessary procedure or medication is a benefit, we believe that general anesthesia, as it is delivered today, can be safe and effective without an undue patient risk."[10]

FALLACIES EXPOSED

Two basic truths clarify the fallacious nature of the previous arguments. First, standards of care transform and vary over time, and even liposuction now has two standards of care.[11] With new clinical insight and new epidemiologic data, any standard of care can change.

Second, clinical safety is not absolute; it is relative. Any statement about clinical safety is best expressed as a probability based on accurate epidemiologic data.

Hypothetically, suppose a particular type of systemic anesthesia causes the death of a healthy liposuction patient once in every 2000 patients. Among 100 liposuction surgeons who use this technique, 10 have had a patient die during or after liposuction from a specific preventable but unrecognized complication of anesthesia. Because of "confidentiality" issues, the deaths are never reported in the literature or at meetings. The death certificates list the cause of death as "unknown," "cardiac arrest," or some other nonspecific diagnosis. Therefore the common factor among the deaths is never discovered, and the 10 surgeons never know the causes of death. The 90 other surgeons, totally unaware of any deaths, remain genuinely convinced that their systemic anesthetic technique is safe.

INHERENT RISKS

Murphy's Law states, "If something can go wrong, it will." When Murphy's Law is applied to the use of systemic anesthesia for liposuction, it is known as the *surgeons' lemma:* "If something can go wrong with systemic anesthesia, it will; and the consequences can be catastrophic." The logical corollaries to this lemma are the following:

Corollary 1: If systemic anesthesia is not necessary, it is inappropriate to use systemic anesthesia merely for the surgeon's convenience.

Corollary 2: If a liposuction surgeon has not been trained to do liposuction totally by local anesthesia, the surgeon's training needs improvement.

HUMAN ERROR

Any type of human error with anesthesia is worrisome, but is especially dangerous when the patient cannot breathe spontaneously. Data from the 1970s and 1980s showed that, of all the serious errors and equipment failures that occur during systemic anesthesia, approximately 65% to 70% result from human error, 13% from disconnection, and 11% to 19% from equipment failure.[12,13] Although modern anesthesia

monitoring equipment has probably decreased many of these dangers, data from the 1990s show that a substantial number of preventable injuries and deaths result from disconnections.[14] An undetected accidental disconnection of artificial ventilatory support can be fatal in patients unable to breathe on their own.

Several studies have found that approximately 80% of serious complications associated with anesthesia are the result of human error.[15-18] Types of human error that lead to anesthesia-related catastrophes include improper interpretation of monitoring device data, failure to check equipment properly, inadequate experience with equipment, incorrect drug dose, and wrong drug given.

Human attributes, such as lack of attention, haste, fatigue, stress, information overload, pressure to cut costs, and failure to communicate, can lead to inattention and failure to recognize problems. Gas supply and flow errors, loss of airway, esophageal intubation, ventilator failure, breathing circuit disconnection, and monitor breakdown have all resulted in patient deaths. Human error is directly responsible for 76% of the complications resulting in death or permanent brain injury due to gas delivery equipment problems.[15] Only about 4% of serious complications are caused by equipment failure.

OVERRELIANCE ON MONITORING

No amount of monitoring can overcome poor clinical judgment, human error, or carelessness. Some assert that modern anesthesia is extremely safe, largely attributable to widespread use of modern anesthesia monitoring equipment. Unfortunately, little objective, statistically unbiased data support the assertion that modern anesthesia is much safer than that of the previous two decades. Overconfidence and overreliance on modern monitoring devices may be a major risk factor for human error in anesthesiology. Monitoring has not reduced mortality from modern anesthesia as dramatically as some had predicted.

The anticipated benefits of technology are often outweighed by the technology's unexpected consequences. Newly designed anesthesia monitoring equipment reacts with real people in real situations in ways that the designers do not foresee. Anesthesia monitoring has been disappointing for several reasons.

First, the dangers of monitoring are not always appreciated. In certain situations the dangers of patient monitoring may outweigh the benefits. The use of pulmonary artery catheterization in the first 24 hours of postoperative intensive care is associated with increased mortality.[19] Some situations may be less obvious and more insidious.

Second, messages conveyed by monitors and alarms may easily be misinterpreted. When a noninvasive blood pressure monitor indicates a trend that suggests hypotension, the most appropriate response might be a clinical reevaluation of the patient, taking into account the patient's position and physiologic situation. A serious misinterpretation would occur if the anesthesiologist incorrectly concluded that a measurement indicated an intravascular volume deficit, which prompted an increase in the rate of IV fluid infusion, which ultimately precipitated pulmonary edema.[20]

Third, when annoying alarms convey known information, or constantly "cry wolf," the alarm may simply be ignored. Such alarms may be switched off by the anesthesiologist or other staff. A disabled alarm can be more dangerous than no monitoring at all.

Fourth, anesthesiologists may lack knowledge of the basic statistical rules of measurement. Without such knowledge the ability to discriminate between significant and insignificant monitoring results is limited. Anesthesiologists must understand the clinical consequences of not knowing the difference between systematic error and random error in anesthesia monitors. Misunderstanding the validity, reproducibility, and reliability of measurements yields misinterpretations. Misinterpreting a monitor and responding inappropriately can be disastrous.

These points are mentioned only to give some perspective to the use of anesthesia monitors. Pulse oximeters certainly represent a great advance in patient safety in ambulatory office surgery, as well as in hospital anesthesia. Monitors do not replace careful clinical observation of the patient, however, or eliminate the risks of systemic anesthesia.

Potential Paradox. Hypothetically, suppose that modern anesthesia monitoring techniques succeed in reducing the risk of death from systemic anesthesia by one half. The resulting enthusiasm induces more than four times as many healthy people to choose cosmetic surgery by systemic anesthesia. The net result could be twice as many deaths from systemic anesthesia.

PERMISSIVENESS

When considering anesthesia for liposuction, the most troubling aspect of systemic anesthesia is not its intrinsic respiratory toxicity, but rather its tendency to release the surgeon from common-sense restraints and permit too much liposuction.

Surgery of up to 8 or more hours' duration, surgery involving multiple cosmetic procedures done concomitantly, and megaliposuction are examples of surgery far beyond reasonably safe limits. Succumbing to the urge to do too many separate procedures on one occasion is the greatest risk of systemic anesthesia.

By obscuring clinical evidence of excessive surgical trauma, systemic anesthesia permits liposuction beyond the patient's ability to compensate and survive. With local anesthesia the patient can inform the surgeon of lightheadedness, dizziness, difficulty breathing, or unusual pain, that is, when the degree of surgical trauma is becoming excessive. In contrast, with systemic anesthesia the surgeon can exceed the safe limits of surgical trauma without patient comment. Excessive surgery significantly increases the risk of thromboembolism, pulmonary edema, disseminated intravascular coagulation (DIC), and necrotizing fasciitis.

The true danger of systemic anesthesia is its permissive influence.

MULTIPLE PROCEDURES

Prospective patients who seek multiple cosmetic surgical procedures present the surgeon with a unique dilemma. Risks are associated with both repeated exposures to systemic anesthesia and too many surgical procedures done simultaneously. The surgeon who only uses systemic anesthesia must choose between two risky alternatives.

For example, exposing the body to multiple surgical traumas increases the risks of infection. Compounding the sources of postoperative pain augments the dosage and duration of narcotic analgesics, increasing the risks of adverse drug effects; increased pain also delays ambulation, increasing the risk of pulmonary thromboembolism. On the other hand, multiple exposures to systemic anesthesia multiply the risks of aesthetic procedures and anesthetic toxicity.

The obvious solution is simply to use local anesthesia. The surgeon can avoid an excessive number of concomitant procedures as well as the greater dangers of systemic anesthesia. Local anesthesia, however, does not automatically eliminate the dangers of excessive surgery. When financial considerations or personal conveniences are allowed to outweigh safety concerns, the final choice is often in favor of marathon surgery.

UNIQUE RISKS OF LIPOSUCTION

The specific dangers of systemic anesthesia are well known and presented whenever an anesthesiologist obtains a patient's informed consent for systemic anesthesia. Some unique hazards associated with combined systemic anesthesia and liposuction, however, are not as well known.

DELAYED DIAGNOSIS

Peritonitis. Penetration of the peritoneal cavity by a cannula is more likely to be missed with systemic anesthesia. Under local anesthesia the patient would inform the surgeon, and a consultation by a general surgeon would be obtained without delay.

With the patient under general anesthesia, the surgeon may be unaware that the liposuction cannula has penetrated the abdominal cavity. Even excessive postoperative pain is likely to be ignored, and the diagnosis may not be considered until there are clinical signs of peritonitis (Case Report 7-1).

Pneumothorax. Tension pneumothorax has been reported as a result of general anesthesia and infiltration of local anesthesia in a young woman undergoing breast augmentation.[21] General anesthesia with endotracheal intubation produces a positive intrathoracic pressure. In this setting, any inadvertent pleural injury by an infiltrating needle or a cannula is likely to produce a tension pneumothorax.

As with the diagnosis of a punctured abdominal viscus, general anesthesia will delay the diagnosis of a tension pneumothorax. A punctured lung is more quickly and easily diagnosed when the patient is alert and conversant.

CASE REPORT 7-1 Undiagnosed Peritonitis

A 34-year-old female had liposuction of her abdomen under general anesthesia. The evening on the day of surgery, on telephoning her surgeon to complain of horrible abdominal pain, she was told, "Abdominal pain is not unusual after abdominal liposuction." The next day, with the onset of fever, nausea, and vomiting, the correct diagnosis was made and the injury repaired by a general surgeon. The patient survived the peritonitis after more than 2 weeks in the hospital receiving IV antibiotics.

Delayed Fluid Overload. Both transurethral resection of the prostate (TURP) and operative hysteroscopy intravascular absorption (OHIA) syndrome carry the risk of fluid overload. Local anesthesia is safer than general anesthesia in both cases, because any symptoms of an impending fluid overload with central nervous system or cardiac toxicity are more easily diagnosed under local anesthesia than general anesthesia.[22] Patients subjected to general anesthesia or heavy IV sedation have an increased risk of a delayed diagnosis of fluid overload. The adult respiratory distress syndrome has been reported in association with general anesthesia and liposuction of 1.3 L of aspirate.[25]

THROMBOSIS AND EMBOLISM

General surgery is associated with an increased risk of deep venous thrombosis (DVT) and pulmonary embolism (PE). Even though the cause of DVT or PE is usually cited as the surgical procedure, systemic anesthesia may be an independent risk factor (see Chapter 10).

Hypothetically, suppose general anesthesia causes a hypercoagulable state and is a significant risk factor for postoperative DVT and PE. To test this hypothesis, one might compare the hypercoagulable effects of exposing volunteers to 3 hours of general anesthesia and then, on another occasion, to 3 hours of local anesthesia. Thromboelastograms could be used to measure hypercoagulability.

It would be unethical to expose patients or volunteers to a dangerous drug without fully informed consent. An ethical surgeon who routinely uses general anesthesia for liposuction instead of local anesthesia, however, must believe general anesthesia is safe. Even if surgeons believe general anesthesia is "quite safe," ultimately they admit that it is not as safe as local anesthesia.

DRUG INTERACTIONS

The combined use of general and local anesthesia increases the risk of serious complications resulting from drug interactions. For example, concomitant use of IV sedative-analgesics and local anesthetics increases the risk of an adverse drug reaction.[7] The combination of halothane and nitrous oxide el-

CASE REPORT 7-2 Risk of Drug Interactions

A healthy 38-year-old patient had an abdominoplasty in an outpatient surgical facility. Preoperative medications consisted of IM diazepam, meperidine, and phencyclidine; IV anesthesia consisted of midazolam, fentanyl, and ketamine. During the procedure the patient suffered cardiopulmonary arrest, and she died 4 days later of anoxic brain death. The death certificate listed the cause of death as unknown.[25]

Discussion. This case exemplifies the futility of using death certificate data to study the epidemiology of cosmetic surgical mortality. The designation "cause of death: unknown" represents a perfunctory analysis of the truly preventable cause of death. A more candid analysis would conclude that death resulted from the decision to have cosmetic surgery and more specifically from a probable adverse drug interaction or exposure to general anesthesia.

The surgeon must always consider that a patient may be taking a drug not reported in the medical history. Since patients often ignore, deny, or even lie about taking herbal remedies, nonprescription drugs, vitamins, and weight loss medications, the risk of unrecognized adverse drug reactions is increased. This patient, of Chinese ancestry, may have been taking traditional Chinese or Western herbal medications, which might have interacted with her anesthetic medications. One popular herbal medication sold as a dietary supplement is St. John's wort (Hypericum perforatum), a monoamine oxidase inhibitor that can have potentially dangerous interactions with many drugs, including meperidine.

evates lidocaine plasma concentrations and thus decreases the maximum safe dose of lidocaine.[24] This potentially dangerous drug interaction is likely to be the result of competition and inhibition of hepatic cytochrome P450 3A4, as well as decreased hepatic blood flow. It is not known to what extent other inhalational or IV systemic anesthetics might impair hepatic metabolism of lidocaine. In light of the ability to accomplish liposuction totally by local anesthesia, the risks of drug interactions with systemic anesthetic agents cannot be dismissed.

Both IV propofol and general anesthesia can be used to treat seizures induced by local anesthesia. The surgeon should not conclude, however, that propofol or other forms of systemic anesthesia allow higher doses of lidocaine. Lidocaine-induced seizures act as premonitory signs of impending cardiac toxicity, including fatal cardiovascular collapse. The routine use of propofol or other systemic anesthetics in conjunction with lidocaine may merely obscure an unanticipated episode of lidocaine toxicity. Having exceeded a safe dose of tumescent lidocaine because the symptoms were masked by general anesthesia, a surgeon may continue to infiltrate still more lidocaine, unaware of an impending lidocaine-induced iatrogenic cardiovascular arrest (Case Report 7-2).

IMMEDIATE AND PRECIPITANT CAUSES OF DEATH

Physicians with an interest in portraying general anesthesia as safe may classify surgical deaths in a way that minimizes the association of general anesthesia. With lifesaving surgery it is understandable when anesthesiologists categorize surgical deaths in a way that minimizes the apparent responsibility of anesthesia in perioperative mortality. It is deceptive and unethical, however, to apply the same statistical reasoning to elective cosmetic surgical procedures.

When a surgical procedure can be accomplished by either local or systemic anesthesia, the surgeon and anesthesiologist must offer the patient the choice. The surgeon is responsible for fully explaining the relative risks and thus for *knowing* the relative risks. Ignorance of the true risks of general anesthesia based on the consensus gentium fallacy is not an ethical defense of an unsafe practice. With cosmetic surgery the many risks of death traditionally accepted as necessary when using general anesthesia or heavy IV sedation-analgesia are no longer acceptable.

The two ways to classify the etiology of deaths related to anesthesia are (1) immediate cause and (2) precipitant cause. *Immediate cause* is the narrowest definition; it lessens an iatrogenic responsibility for the death. When a chain of causation exists, listing the immediate cause of death suggests an unfounded safety for general anesthesia. *Precipitant cause* is the proximate, fundamental, initiating cause of death and has the greatest importance in terms of prevention.

PULMONARY EMBOLISM

A potential conflict of interest exists when general anesthesia is used for a cosmetic surgical procedure that can easily be accomplished more safely and more comfortably for the patient totally by local anesthesia. The association of fatal PE with general anesthesia is a significant risk of general anesthesia usually ignored in epidemiologic studies of anesthesia-related mortality.

Traditionally, oncologic and orthopedic surgeons considered a perioperative fatal PE as an acceptable risk of a potentially lifesaving surgery. Fatal PE is usually not *attributed* to general anesthesia but is clearly *associated* with general anesthesia and extremely rare with local anesthesia. When a patient dies of a PE after liposuction by general anesthesia, the immediate cause on the death certificate is usually cardiopulmonary arrest. The precipitant cause of death, however, was the decision to use general anesthesia, when a safer method using local anesthesia was available.

PE has never been reported in association with tumescent liposuction totally by local anesthesia and probably does not typically result from liposuction. Fatal PE, however, is one of the leading causes of death associated with liposuction using general anesthesia. Systemic anesthesia appears to be both an immediate and a precipitant cause of PE. It is an immediate cause because of a dose-response relationship between general anesthesia and PE; prolonged exposure to general anesthesia

may increase the risk factor for PE. For example, a comparison between anesthetic techniques during the surgical repair of femoral neck fractures found that the incidence of DVT was 31% greater among patients receiving general anesthesia compared with those receiving regional anesthesia.[26]

General anesthesia is also a precipitant cause of PE because it permits (1) procedures with painful postoperative recovery (e.g., abdominoplasty) that discourage early ambulation, (2) extensive trauma with multiple areas and large-volume liposuction, and (3) multiple concomitant cosmetic procedures together with liposuction, requiring prolonged exposure to general anesthesia. In addition, general anesthesia can cause hypothermia, which in turn causes hypercoagulability and predisposes to DVT.

ANESTHESIA AS PRECIPITATING CAUSE

The decision to use general anesthesia is the greatest danger associated with liposuction. The general anesthesia, as well as the surgeon who decides to use it, assumes the responsibility as the material cause of subsequent injury.

When general anesthesia is the proximal or initiating cause of death, it is self-serving and disingenuous to attribute a death to such a trivial explanation as cardiac arrest. For a liposuction death associated with pulmonary thromboembolism,[27] undiagnosed intestinal peforation, or pulmonary edema from unnecessary IV fluids, the precipitant cause would most likely be the decision to use general anesthesia.

The greatest contraindication to using any drug is the lack of an indicated use.[9] When a drug is not necessary, it should not be used. In light of the superior safety of local anesthesia, any advocate of the routine use of general anesthesia for a procedure that can be done with local anesthesia is obligated to provide data supporting the safety of such a position. Not to provide such data might be an ethical conflict of interest.

ANESTHESIA-RELATED MORTALITY RISKS

UNDERREPORTING OF DEATHS

To determine the risk of death, both the number of deaths (the numerator) and the total number of patient exposures to systemic anesthesia (the denominator) are required. As mentioned, obtaining an accurate estimate of the numerator is almost impossible. First, little agreement exists on the definition of a death associated with systemic anesthesia. For example, with PE, undetected airway disconnection, tension pneumothorax, or pulmonary edema from anesthetic-induced dysrhythmia in a patient with mitral regurgitation, should a death be defined as "death caused by anesthesia"?

Second, a large proportion of anesthesia-related deaths are simply never reported. Deaths caused by anesthesia are often officially listed on the death certificate merely as death from cardiac arrest, not from hypoxemia or anesthetic mismanagement.

I estimate that at least 110 deaths per year in California result from systemic anesthesia. Among the estimated 3500 anesthesiologists in California, 2200 are active members of the California Society of Anesthesiologists (CSA). The CSA estimates that each of its members works an average 250 days per year and provides anesthesia for four patients per day, or 1000 cases per year. Thus approximately 2.2 million cases use general anesthesia per year in California. If the combined risk of death from systemic anesthesia and regional anesthesia is one death per 20,000 patients, 110 deaths per year from systemic anesthesia would be expected in California. During a recent 2-year interval, however, only two California death certificates mentioned any association between anesthesia and the cause of death.

Serious drug interactions can occur in the polypharmaceutical setting of modern anesthesia. The vast majority of fatal drug interactions are either misdiagnosed or unreported simply because no centralized reporting system exists.[28]

Even "closed-claims" studies based on information from malpractice insurance companies can be expected to represent the results of gross underreporting. It is unhelpful to assert that, based on closed-claims analyses from malpractice insurance carriers, the risk of death from general anesthesia is 1:250,000.

The underreporting of anesthesia-related deaths precludes reliable epidemiologic studies on the safety of systemic anesthesia.

Conflict of Interest. The method of deciding and reporting the cause of death on death certificates may be a source of conflicts of interest (see Chapter 5). Deaths from an anesthetic "therapeutic misadventure" are rarely reported correctly. A conflict of interest may exist when anesthesiologists and surgeons who rely on systemic anesthesia are in a position to influence the choice of diagnosis listed on a death certificate as the cause of death.

The lack of good epidemiologic information regarding the true incidence of death and serious disability caused by systemic anesthesia also may be a source of potential conflicts of interest. Without reliable epidemiologic data on the risk of anesthetics, anesthesiologists and surgeons should be cautious in their endorsement of these drugs' safety. At least the *perception* of potential conflict of interest arises when surgeons and anesthesiologists, who benefit financially from the use of general anesthesia, are also expected to provide patients with unbiased information in the process of informed consent.

Deaths in Healthy Patients. Informative epidemiologic studies of death resulting from systemic anesthesia do exist. One study of mortality associated with general anesthesia reviewed 41 cases of cardiac arrest during surgery.[29] More than half the patients were healthy (ASA class I), and the rest were of class II or class III. Sixteen surgeries were minor, and 32 were elective procedures. The causes of death were categorized as anesthetic mismanagement in nine pa-

tients, cardiovascular abnormality in nine, hypoxemia in 18, and miscellaneous in five.

DEATHS ATTRIBUTABLE TO GENERAL ANESTHESIA

Many anesthesiologists believe that 1:20,000 is a reasonable estimate of the risk of death associated with systemic anesthesia in the late 1990s. Unfortunately, the amount of published data to support this estimate is minimal. As stated earlier, the frequency of death and serious complications associated with anesthesia is difficult to determine because cases are often systematically concealed or merely listed as death from cardiac arrest.

If either local or systemic anesthesia can be used and death occurs after choosing the latter, the death must be associated with systemic anesthesia. The criteria for attributing a death to anesthesia should not be restricted to a narrow definition of pharmacologic toxicity, such as anesthetic overdose or anaphylactic shock.

Systemic anesthesia continues to be associated with unexpected fatality. The most common cause of death or serious injury is the human error of failing to ventilate the patient. Mistakes, lack of vigilance, inexperience, inadequate supervision, and failure of communication are recurring problems.[4] A death caused by human error in the setting of general anesthesia should be a death attributable to general anesthesia, especially when a safer alternative exists.

Substantial literature documents that the risk of death attributable to general anesthesia is 1:2000 to 1:10,000. In a prospective study of anesthesia-related morbidity and mortality among 17,201 patients who had surgery with general anesthesia, 19 deaths (1.1:1000) and 23 myocardial infarctions occurred.[30] In ambulatory surgical patients, general anesthesia continues to be associated with significant risk of complications.[31,32]

One study that reviewed complications associated with 160,000 anesthetics found that the incidence of cardiac arrest was 17:10,000 and death attributable to anesthesia 0.9:10,000.[33] Another study reviewed 250,000 cases of anesthesia and found the incidence of cardiac arrest was 4.6:10,000 and death attributable to anesthesia 0.3:10,000.[34] A study of 38,958 patients after ambulatory surgery found that the risk of dying within 30 days of surgery was 1:11,273.[35]

To my knowledge, cardiac arrest with tumescent local anesthesia has never occurred. With the decision to use systemic anesthesia for liposuction, the surgeon has also decided that one death in 10,000 to 20,000 cases is an acceptable risk for liposuction. One death in 10,000 to 20,000 is the approximate risk of death among healthy (ASA class I) surgical patients who are exposed to prolonged general anesthesia.

DECEPTIVE PROMISES OF LOCAL ANESTHESIA

It is deceptive to tell prospective patients that they can expect liposuction by local anesthesia when the anticipated anesthetic technique will rely heavily on significant doses of IV

sedation-analgesia. Although the routine use of IM benzodiazepines and narcotic analgesics is probably safer than IV delivery, IM sedation-analgesia is clearly less safe than liposuction totally by local anesthesia.

The safety profile of IV sedation-analgesia combined with local anesthesia is vastly different than that of local anesthesia alone. The State of California legislature recognizes the potential dangers of IV sedation-analgesia and has passed laws that limit its extensive use to accredited surgical facilities.

General anesthesia and IV sedation-analgesia are similar in terms of both risks and requirements for perioperative monitoring. The policy of the American Society of Anesthesiologists (ASA) explicitly states that the same standard of care and monitoring should be provided for both monitored anesthesia care (MAC) and general anesthesia.[36]

MAC is more dangerous than pure local anesthesia because of the hazardous nature of drugs that suppress respirations. One survey of ambulatory surgery facilities in the United States found a greater risk of complications with local anesthesia plus IV sedation-analgesia (1:106) than with local anesthesia alone (1:268).

The duration of a surgical procedure helps predict the morbidity risk in ambulatory surgery. The risk of perioperative morbidity in ambulatory surgery lasting less than 1 hour is 1:155, compared with 1:35 for procedures that last more than 3 hours.

The risk of adverse drug reactions increases when IV sedation is combined with local anesthesia.[37] With IV midazolam at 0.05 mg/kg, no significant respiratory depression occurred, and with IV fentanyl at 2 μg/kg, 50% of patients had hypoxia. The combination of midazolam and fentanyl, however, produced hypoxia in 11 of 12 and apnea in 6 of 12 patients.

More than 40% of oral surgery patients breathing room air develop clinically significant oxygen desaturation with IV sedation-analgesia.[38] Even with oxygen supplementation, the risk of hypoventilation is much greater with sedation-analgesia than with local anesthesia alone.

A significant number of anesthetic-related tragedies have occurred in the recovery room after the anesthesiologist has departed.[39] Propofol, fentanyl, and related opioids may be associated with unanticipated responses or even postoperative complications that have never been described in the clinical literature (Case Report 7-3).

RECURRENT RESPIRATORY DEPRESSION

Recurrent respiratory depression (RRD) is a puzzling and seemingly random phenomenon of sudden relapse into unconsciousness and respiratory failure after routine emergence and recovery from anesthesia. RRD was first described in 1976 for fentanyl as a biphasic, unpredictable delayed recurrent depression of the carbon dioxide response when a patient was left without stimulation in the postoperative period.[40]

RRD is an unusual but significant risk with total IV anesthesia using propofol and alfentanil.[41] The combination of propofol and fentanyl depresses protective airway reflex

CASE REPORT 7-3 Outpatient Death After Routine Surgery

A healthy 35-year-old female had routine outpatient bilateral breast augmentation in a surgeon's office. An anesthesiologist provided the anesthesia, which consisted of propofol and fentanyl plus local anesthesia. After an uneventful recovery, the patient was discharged to the waiting room, where she remained unattended while awaiting arrival of a family member. Later the patient was discovered to be apneic and unresponsive. Paramedics transported her to a local hospital, where she was in full cardiac arrest on arrival. Although she was resuscitated, she later died as a result of anoxic brain injury.

Discussion.   The coroner's report did not mention the specific anesthetic drugs used in this case. Without reliable epidemiologic reporting of adverse outcomes after ambulatory surgery in healthy patients, many physicians will be unaware of the dangers of anesthetic drugs. Anesthetic drugs that are widely considered to be *relatively* safe should never be regarded as *absolutely* safe. Many of the "fashionable" IV anesthetic drugs currently so widely used in outpatient surgery may be more dangerous than some choose to admit.

responses in a dose-related manner, except for apnea with laryngospasm.[42] The persistence of the apnea and laryngospasm reflexes after a combination of propofol and fentanyl may play a role in the pathophysiology of RRD.

Although propofol is promoted as a safe drug, few surgeons are aware of its adverse effects. For example, a recent systematic analysis has shown that propofol carries a significant risk for bradycardia, with potential for major harm despite prophylactic anticholinergics.[43] Sixty-five published and 187 spontaneous reports to drug-monitoring centers revealed that propofol had induced 1444 bradycardias, 86 asystoles, and 24 deaths. The risk of asystole is 1:660 propofol anesthetics. The risk of death from a propofol-induced bradycardia is estimated to be 1:112 asystoles. Thus the risk of death from bradycardia is 1.4:100,000 propofol anesthetics. Propofol might be relatively contraindicated in the presence of an increased risk for bradycardia, such as a history of vasovagal near-syncope, cardiac dysrhythmias, beta blockers, clonidine, laparoscopies, strabismus surgery, and very old or very young patients.

Safety of Local Versus Systemic Anesthesia

Local infiltration anesthesia is much safer than systemic anesthesia. The consequences of an adverse reaction to local anesthesia with the patient able to breathe without assistance differ greatly from the consequences of complications associated with systemic anesthesia, when apnea is always a risk. This fundamental difference between local and systemic anesthesia is obvious, but only a few published

large-scale epidemiologic surveys quantify the difference in safety and mortality between local anesthesia and systemic anesthesia.

Dental Data.   Any useful comparison between the safety of local versus general anesthesia must be limited to similar surgical procedures. The most enlightening comparisons between the risks of local and general anesthesia are found in the literature of dental surgery.

A study by Coplans and Curson[44] of the mortality rates for dental surgery between 1970 and 1979 in Great Britain provided some of the most reliable comparative mortality data. Of the 120 deaths associated with dental disease or treatment during this 10-year period, 100 fatalities were associated with general anesthesia and 10 with local anesthesia. Six deaths were not associated with any anesthesia, and insufficient information was available to determine a cause in four cases.

If general anesthesia is associated with death 10 times as often as local anesthesia, and if local anesthesia is used at least 100 to 1000 times as often as general anesthesia, I would conclude that the risk of death with general anesthesia is at least 1000 to 10,000 times greater than with local anesthesia.

A 1955 survey of dentists found only two deaths in an estimated 90 million procedures over 10 years.[45] It is enlightening to calculate the expected number of deaths associated with 90 million procedures performed with general anesthesia. Hypothetically, if one death occurs with every 10,000 administrations of general anesthesia, the expected number of deaths with 90 million procedures by general anesthesia would be 9000. Clearly, anesthetic complications are more serious when the patient's ability to breathe is impaired.

Morbidity Risks.   Small studies have compared general anesthesia to regional anesthesia in terms of risks for morbidity, but the numbers of patients involved are much too limited to give accurate data on mortality. General anesthesia, however, increases perioperative morbidity compared with epidural anesthesia.[46]

SUMMARY

I am a proponent of maximizing the safety of liposuction by every possible means. I want to identify and eliminate every possible risk factor and potential complication. If either local or systemic anesthesia can be used for liposuction, the surgeon should use the safest of the two. I support the view that systemic anesthesia is significantly more dangerous than local anesthesia.

Some might consider it unnecessary to have formal instruction in tumescent pharmacology and pathophysiology, assuming that 5 or more years of surgical training is sufficient to perform tumescent liposuction. No amount of surgical training, however, will alter the following: (1) systemic anesthesia is associated with the vast majority of liposuction

deaths, and (2) the number of years of surgical training is highly correlated with the preferential use of systemic anesthesia. It is difficult for surgeons to overcome years of indoctrination that systemic anesthesia is "safe."

Although liposuction by systemic anesthesia can be accomplished with an acceptable degree of safety, liposuction totally by local anesthesia is safer. Convenience and financial factors must be considered in the choice of anesthesia for liposuction, but these aspects should not be the overriding factor. Safety is the most important concern.

In dentistry, because of the well-known dangers of systemic anesthesia, it is an ethical imperative that routine dental procedures are preferably done under local anesthesia. The same ethical standards have yet to be applied to liposuction.

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CHAPTER 8

Miscellaneous Complications

Minor or miscellaneous complications are defined as those associated with minimal mortality risk. Most minor complications are the result of clinical inexperience, carelessness, dogmatic technique, or simple bad luck.

An *abecedarian* is someone who is just beginning to learn, a novice. Abecedarian liposuction complications are the result of mistakes typically associated with inexperience or inadequate training. Abecedarian-like complications can occur in the hands of an experienced liposuction surgeon who has failed to learn from previous mistakes. If a better technique will avoid a problem, the problem can no longer be considered an expected sequela, but rather below the current standard of care and therefore an unnecessary sequela.

EXCESSIVE LIPOSUCTION

Excessive liposuction probably accounts for the most complications associated with liposuction surgery. Too much fat may be removed from a single area, creating a cadaveric appearance. Irregular amounts removed from a single area may produce lipotrops and liponots.

Too much volume removed, too many areas treated during a single surgery, and too many hours of surgery can prove fatal and therefore are discussed in later chapters that focus on catastrophic complications.

CADAVERIC APPEARANCE

Excessive liposuction in a specific body area can produce a cadaveric or cachectic appearance in the affected area of subcutaneous fat. Removing too much fat does not yield a cosmetic result that appears natural and attractive. The goal of liposuction is not to remove the maximum amount of fat, but rather to produce an optimal cosmetic improvement and maximize patient satisfaction through careful conservative surgery, with minimal exposure to the risks of surgical complications.

In particular, the normal female body has subcutaneous fat. In general, complete lack of subcutaneous fat on a female body does not appear normal, cosmetically attractive, or sexually appealing. The lack of subcutaneous fat feels peculiar to the touch and does not produce a tactile sensation normally associated with femininity.

Attempting to remove the entire subcutaneous adipose deposit in any area of the female body is a mistake and a prime example of abecedarian surgical naivete. Pierre Fournier has said, "It is not the fat that is removed, but the fat that remains after liposuction that determines success."

EXCESSIVE SUPERFICIAL LIPOSUCTION

Excessive superficial liposuction is a special case of excessive liposuction that requires special attention. Superficial liposuction has become a common practice, without much attention to its associated complications. Several significant, well-defined cosmetic complications can result from too much superficial liposuction.

Before the advent of tumescent technique liposuction, surgeons only used large cannulas, which precluded the ability to perform liposuction in relatively superficial planes of subcutaneous fat. The intense tumescent vasoconstriction and its associated surgical hemostasis permitted the use of smaller cannulas (see Chapter 27). With smaller cannulas, liposuction can be performed more superficially with less risk of producing irregularities of the skin.[1]

Dermatologic liposuction surgeons have been doing superficial liposuction since the late 1980s,[1] and in the 1990s other surgeons became aware of the advantages of the tumescent technique in this regard.[2] Unfortunately, authors who have promoted superficial liposuction have not detailed the undesirable consequences of excessive superficial liposuction.

Dermatologists are well aware of the superficial vascular plexus that is intimately associated with the immediate undersurface of the dermis. Other specialties have not appreciated

Figure 8-1

Trauma-induced vesicles and ecchymosis on inner thigh and knee from excessive superficial liposuction. Such vesiculation is often an early clinical sign of inchoate, full-thickness dermal necrosis.

Figure 8-2

Erythema ab igne. This reticulated, hyperpigmented erythema results from excessive chronic thermal trauma to subdermal vascular plexus. This patient's source of chronic heat exposure was an area (space) heater under his desk.

the clinical and histopathologic consequences of injury (immunologic, thermal, or mechanical) to this delicate network of blood vessels and lymphatics.

Direct and intentional physical injury to the undersurface of the dermis is done by some surgeons in the mistaken belief that such an injury will induce dermal contraction. No histologic evidence supports the theory that subsurface dermal trauma produces an increase in dermal collagen or dermal elastin. Any apparent liposuction-induced contraction of the skin is the direct consequence of unweighting the skin (removing the gravitational effect of subcutaneous fat) as well as a consequent fibrotic contraction of the collagenous subcutaneous fascia. Every liposuction surgeon knows that when re-treating an area by liposuction, there is ample clinical evidence of subcutaneous fascial fibrosis resulting from previous liposuction in the fatty tissue.

A deliberate iatrogenic injury to the dermis with a liposuction cannula is reminiscent of "blood letting" as treatment for inflammation; there is no scientific support that either is beneficial. Dermal injury is not necessary for skin contracting after liposuction. The dermis does possess innate elastic properties that allow it to contract uniformly after liposuction in a way similar to the contraction of abdominal skin after pregnancy or breast skin after lactation.

Excessive superficial liposuction can produce a wide range of adverse clinical and aesthetic problems that range from annoyance to catastrophe, including erythema ab liporaspiration, lipotrops, liponots, postoperative seromas, and full-thickness dermal necrosis. Most of these iatrogenic problems have not been well described in the medical literature.[3,4] Surgeons who advocate superficial liposuction must be careful to understand the full range of these consequences. Some surgeons "do superficial liposuction" but are not aware of the distinction between *sufficient* and *excessive* superficial liposuction (Figure 8-1).

Erythema Ab Liporaspiration. Erythema ab liporaspiration is a common result of excessive superficial liposuction. Its clinical appearance is similar to erythema ab igne, which is a distinct reticulate erythema resulting from prolonged chronic exposure to radiant heat, for example, from chronic application of an electric heating pad (Figure 8-2). Erythema ab liporaspiration is a persistent, iatrogenic reticulated erythema resulting from trauma to the superficial subdermal vascular plexus by aggressive rasping of the dermal undersurface with a liposuction cannula. One surgeon openly advocates aggressive superficial liposuction and deliberately applies the apertures of liposuction cannulas directly against the undersurface of the dermis.[5]

Unfortunately, no treatment exists for this chronic reticulated erythema, and it does not seem to improve with time (Figure 8-3).

Postoperative Seromas. Postoperative seromas as a result of tumescent liposuction with microcannulas are rare. Causes of seromas include (1) liposuction done too superficially, with damage to subdermal lymphatic plexus, and (2) prolonged excessive liposuction in a local area with complete transection of all fibrous subcutaneous strands and sheets, creating a subcutaneous cavity. When liposuction ceases to yield additional fat, continued aspiration may merely damage the connective tissue, causing an exudative process and diminishing the septa's absorptive surfaces.

Using microcannulas in a crisscross pattern that radiates from several incisions and initiating liposuction as deeply as possible may minimize the risks of seromas. Factors that predispose to seromas include the use of large cannulas, excessive liposuction in a focal area, insufficient hemostasis as a result of insufficient tumescence, use of ultrasonic liposuction, and recent ingestion of drugs such as aspirin or ibuprofen, which predispose to hematoma and seroma (Figure 8-4).

Figure 8-3

Erythema ab liporaspiration. This reticulated, blanching erythema is typically seen after superficial liposuction trauma to subdermal vascular plexus. As with erythema ab igne, the erythema of these three patients will not improve with time.

Figure 8-4

Seroma on right lower abdomen of this male patient first became apparent after vigorous physical activity 5 days after liposuction.

Full-Thickness Dermal Necrosis. Full-thickness dermal necrosis can result from excessive superficial liposuction that directly injures the vascular supply of the overlying skin. Other causes of full-thickness dermal necrosis after liposuction include flap necrosis, infection, thrombosis, and vasculitis. Placing ice packs on a patient with cryoglobulinemia can precipitate cryoglobulins and produce dermal thrombosis with intense vascular insufficiency, leading to dermal necrosis. When excessive superficial liposuction precipitates patchy partial-thickness dermal necrosis, a secondary infection may precipitate a full-thickness necrosis.

At best, deliberate trauma to the undersurface of the skin will injure the dermal vascular supply and cause induration and delayed healing. At worst, it will result in full-thickness dermal necrosis and its sequelae (Figure 8-5).

Figure 8-5

Full-thickness dermal necrosis after excessive superficial liposuction. Four different patients, all treated by same surgeon, developed full-thickness necrosis. Surgeon might have believed that dermal trauma would produce dermal contraction. **A,** Left medial thigh. **B,** Right medial thigh. **C,** Left back and flank area. **D,** Necrosis resulted in necrotizing fasciitis requiring extensive surgical debridement, with consequent disfiguring scars (see Figure 12-3).

SURGICAL SITE COMPLICATIONS

ALLERGIC CONTACT DERMATITIS

Reston foam, when applied to the skin after liposuction, can produce an allergic contact dermatitis. Although some surgeons use Reston foam to reduce postoperative ecchymosis, this adhesive-backed, centimeter-thick foam does not reduce swelling, local tenderness, or soreness. Use of the foam prevents postoperative showering or bathing. The allergic response to the adhesive is aggravated by the effect of prolonged occlusion, which delays the diagnosis, produces bullae, and results in a prolonged postinflammatory hyperpigmentation.

Friction and shearing forces exerted on the skin by the edges of the foam sheets can also produce bullae and prolonged postinflammatory hyperpigmentation. The denuded skin resulting from open bullae predisposes to infection.

The brief cosmetic benefits of reduced ecchymosis do not justify the risks of prolonged postinflammatory hyperpigmentation, the inconvenience of not being able to shower daily, and the risk of infection. Postoperative management with open drainage and bimodal compression not only provides an equivalent reduction in ecchymosis, but also avoids the risks and inconvenience of Reston foam.

Polymyxin B, neomycin, and bacitracin topical antibiotic ointments (e.g., Neosporin) applied to liposuction incision

sites have been associated with allergic contact dermatitis. These preparations are not necessary and can be eliminated from routine postliposuction care. In a small clinical study of wound care after liposuction, we asked 10 consecutive patients to apply bacitracin to the incision sites on one side of their body and to apply nothing to the incisions on the opposite side. Asked to judge which side healed the best, three patients found no difference, and seven stated bacitracin delayed healing and was associated with incisional erythema.

RETRACTED AND INDENTED SCARS

Retracted scars at the sites of liposuction cannula access incisions are rarely encountered. The best treatment or repair is uncertain, although tincture of time would be a primary consideration. If the scars have persisted for more than a year, however, they probably will not resolve in the near future. Injections of triamcinolone (Kenalog) are unlikely to improve a retracted scar and would risk the additional disfigurement of subcutaneous fat atrophy. The potential benefits of an excision of such a scar would have to be balanced against the risk of an even more unsightly scar.

The most important consideration is how to avoid such scars. Preventive strategies include the following:

1. Make the incision sites large enough to obviate any puckering as the cannula moves in and out of the incision.
2. Use the smallest effective cannulas.
3. Do not bruise or injure the incision site by allowing the cannula hub to pound, rub, or abrade the incision site. Protecting the incision site by placing tip of the index finger over the cannula hub is helpful.
4. Use multiple incision sites so that the friction and trauma from the cannula are not concentrated on only a few sites.
5. Do not close incisions with sutures.

HYPERPIGMENTATION AND HYPOPIGMENTATION

Postinflammatory discoloration of incisions used for microcannula access can be avoided, except in darkly pigmented individuals. Preventing pigmentation requires careful surgical technique that minimizes epidermal trauma and friction caused by a liposuction cannula as it is advanced and retracted through a skin incision. In the vast majority of patients, postinflammatory dyschromia is not a problem.

Darkly pigmented patients are especially susceptible to prolonged postoperative hyperpigmentation of incision sites. Such patients must be informed about the risk of pigment changes. The liposuction surgeon can minimize hyperpigmentation and hypopigmentation of incision sites by (1) minimizing the number of incisions, especially in darkly pigmented patients; (2) avoiding incisions that are too small and that can result in excessive friction as the cannula passes through an incision; and (3) directing the cannula so that it enters the incision without rubbing and abrading the skin.

Hyperpigmentation at microincision sites on flank and hip. Making too many incisions, as in this patient, should be avoided. Using microcannulas 15 and 22.5 cm (6 and 9 inches) long can help reduce number of incisions. Gentle technique minimizes cannula-induced trauma to epidermal-dermal junction. These hyperpigmented areas were virtually invisible within 6 months.

Trauma to the dermal-epidermal junction and the dermis will lead to postinflammatory dyschromia and scarring. The interface between the epidermis and the dermis is where melanocytes are found. Injury and inflammation in this area cause rupture of melanocytes, releasing melanosomes into the interstitium of the papillary dermis. An ensuing phagocytosis of free melanosomes by local macrophage cells produces long-term hyperpigmentation of the involved dermis.

Postinflammatory hyperpigmentation also involves capillary vascular proliferation and ectasia. With eventual resolution of the inflammatory response, local capillaries return to normal, and the vascular component of the hyperpigmentation resolves (Figure 8-6).

In most patients with light pigmentation the microincision sites on the skin become invisible within a few months. Occasionally, hyperpigmentation of incisions can persist for more than a year. The degree of postoperative or postinflammatory hyperpigmentation depends on the patient's skin type and the degree of trauma to the incision site. Incisions on the lateral aspect of the torso, the outer thighs, the inner thighs, and the arms are less prone to hyperpigmentation. Hyperpigmentation of incisions on the back and abdomen resolves much more slowly. Avoiding trauma to an incision site requires an incision large enough to accommodate the cannula without undue friction. The surgeon should avoid injuring the epidermis by rubbing the cannula over the skin adjacent to the incision. Small 1.5-mm and 2-mm punch excisions can be used for cannula insertion sites and will also minimize microcannula trauma.

Most liposuction patients do not experience bothersome hyperpigmentation. Any person is susceptible to postinflammatory hyperpigmentation. As a general rule, the darker a per-

son's natural pigmentation, the darker and the more persistent will be any postinflammatory hyperpigmentation. Allergic contact dermatitis, such as from adhesive tape or Reston foam, can precipitate hyperpigmentation that can last for months to years. Similarly, a minor abrasion or friction burn that affects the epidermis can produce persistent hyperpigmentation.

Trauma and friction caused by the cannula rubbing the skin can cause injury. As a cannula is advanced into an incision, the skin adjacent to the incision is susceptible to a traumatic abrasion or friction burn whenever the cannula rubs the skin too vigorously. Clumsy or aggressive actions that allow the hub of the liposuction cannula to pound the epidermis repeatedly are guaranteed to produce epidermal injury and postinflammatory hyperpigmentation. If an incision is too small, the in-and-out cannula friction will injure both the dermis and the epidermis with each cannula stroke, producing a hypertrophic and hyperpigmented scar. An often unrecognized source of epidermal trauma is an incessant tangential cannula stroking that rubs across the epidermis at the skin surrounding an incision. The surgeon can avoid this frictional epidermal trauma by gripping and subtly elevating the skin surrounding an incision; this permits the cannula to enter an incision at a slight angle, thereby avoiding repeated rubbing on the skin.

Incisional hyperpigmentation occurs most often on the upper abdomen and the back and least often on the skin of the thighs, arms, and submental chin, cheeks, and jowls.

When no excessive incision site trauma has occurred, the vast majority of hyperpigmented incision sites return to "normal," eventually becoming invisible to the casual observer. In some patients with darkly pigmented skin, initial hyperpigmentation may eventually become mild hypopigmentation.

The risk of hyperpigmentation can be minimized with a gentle liposuction technique and judicious choice of incisions. In some patients the postinflammatory appearance at an incision site is caused by vascular prominence and capillary neogenesis, in addition to pigment deposition in macrophages after inflammation. On resolution of the hyperpigmentation and the capillary prominence, residual focal hypopigmentation is possible. Both hyperpigmentation and hypopigmentation usually improve with time (Figure 8-7).

Treatment. Incisional postinflammatory hyperpigmentation can be treated using topical agents, such as a hydroxyquinone or a kojic acid cream, that suppress pigment formation. This is a prudent approach, with minimal risks of exacerbating the clinical situation. Although significant postinflammatory hyperpigmentation is uncommon, all patients should be warned before their surgery about the potential for this type of dyschromia.

There have been anecdotal reports of using lasers to treat incision site hyperpigmentation. The effectiveness of lasers in the reduction of postinflammatory hyperpigmentation is somewhat debatable. Theoretically, a tunable pulsed-dye laser having a 585-angstrom wavelength might accelerate the disappearance of the capillary vascular component of postin-

Figure 8-7

Hypopigmentation of incision sites on abdomen. These scars were originally hyperpigmented because of trauma to incision site during vigorous liposuction of excessively fibrous subcutaneous fat in patient with previous abdominal liposuction. Hypopigmented scarring may eventually develop after initial postinflammatory hyperpigmentation.

flammatory hyperpigmentation. The Q-switched ruby laser has been mentioned as an effective treatment for certain pigmented lesions. Any laser, however, has the potential to exacerbate hyperpigmentation or precipitate hypopigmentation.

VASOVAGAL SYNCOPE

Vasovagal presyncope and syncope (also known as neurocardiogenic, neurogenic, reflexogenic, vasodepressor, and neurally mediated syncope) are characterized by transient failure of physiologic mechanisms responsible for maintaining both blood pressure and cerebral blood flow. Vasovagal syncope is one of the most frequent causes of recurrent syncope in patients with a structurally normal heart. Two circulatory phenomena, systemic arterial vasodilation and bradycardia, are typically present. Cerebrovascular constriction may also contribute to the fainting.[6] Neurocardiogenic syncope has been suggested as a cause of sudden infant death syndrome (SIDS).[7]

Vasovagal syncope is a sudden transient loss of consciousness that resolves spontaneously. It is caused by a reduction of blood flow to the brain. Abnormal autonomic nervous system control of cardiovascular homeostasis can impair blood supply to the brain and produce syncope in two different disorders: autonomic failure and vasovagal syncope. In *autonomic failure*, sympathetic regulation of vasoconstriction is chronically impaired, causing chronic orthostatic hypotension and syncope or presyncope. The head-up tilt table is a recent technique for evaluating autonomically mediated syncope.[8,9] In vasovagal syncope, some episodic triggering event precipitates a failure of sympathetically mediated vasoconstriction, producing hypotension and syncope. Between syncopal episodes, patients with vasovagal syncope have normal blood pressure and orthostatic tolerance.[10]

Head or neck trauma resulting from a fall is the greatest risk associated with syncope. Fainting or syncope can occur before, during, or after surgical procedures done under local anesthesia, including liposuction. From 1990 through 1995, the Vaccine Adverse Event Reporting System in the United States documented 697 cases of syncope (57.5% female) within 12 hours after vaccination. Tonic or clonic movements, which have been associated with the anoxia of vasovagal syncope, were reported in 30.4% of syncopal episodes occurring 15 minutes or less and in 12.8% of those occurring 15 minutes or longer after vaccination ($P < .001$). The hospitalization rate was 9.6%. Six patients suffered skull fracture, cerebral bleeding, or cerebral contusion after falls; three of these patients required neurosurgery.[11]

Any surgical procedure in an awake patient can trigger vasovagal syncope. Vasovagal reactions occur in a small but significant number of blood donors.[12] Among shoulder surgery patients in the sitting position under interscalene block anesthesia, at least 13% experience a vasovagal episode characterized by a sudden decrease in heart rate and blood pressure.[13] Vasovagal reactions are a common complication during diagnostic hysteroscopy with endometrial biopsy in postmenopausal women.[14]

Liposuction Syncope

Because tumescent liposuction patients have mild fluid overload and slight hemodilution, it is unlikely that intravascular fluid deficiency is the cause of syncope associated with tumescent liposuction. Twenty-four hours after tumescent liposuction, patients are generally in a state of mild fluid overload with 5% to 10% hemodilution.

In the operating room (OR), near-syncope with lightheadedness and vomiting or nausea typically occurs in predisposed individuals with a history of fainting or dizziness at the sight of a medical procedure. A vasovagal loss of consciousness is unusual when lying supine.

Postliposuction lightheadedness or syncope most often occurs the morning after liposuction. It can be caused by at least three different stimuli: (1) the sight of blood-tinged anesthetic drainage on absorptive pads, (2) orthostatic decompression of the lower extremities on removal of postoperative compression garments, and (3) micturition syncope.[15]

Liposuction surgery is not necessarily the cause of syncope. For example, a patient who had not been given preoperative medication fainted from a standing position while the surgeon was taking preoperative photographs. She sustained a laceration on her occipital scalp; fortunately, neurologic examination and skull radiographs were normal. A husband fainted while helping his wife remove her blood-soaked absorptive pads; immediately afterward the wife also fainted.

Operating Room Near-Syncope

In the OR setting during tumescent liposuction totally by local anesthesia, true syncope is unusual. The syndrome of vasovagal near-syncope may occur, however, and represents the premonitory phase of neurocardiogenic syncope, which stops just before complete loss of consciousness.

Vasovagal near-syncope in a supine OR patient is distinctly different from a vasovagal event in a sitting or standing patient. Because the patient is already supine, loss of consciousness rarely occurs, and therefore the experience is more prolonged and causes more patient anxiety. With the onset of symptoms, the patient becomes intensely aware that something is wrong during a surgical procedure. It is a frightening experience. The situation must be managed quickly and efficiently, or the patient will lose confidence in the surgeon.

The first hint of the syndrome is often a vague sensation of malaise and lightheadedness. Then the patient's skin appears ashen or pale and is damp, moist, and clammy; beaded perspiration and dilation of pupils may be seen. Within moments the patient experiences abdominal or epigastric distress, tachypnea, weakness, and confusion. The cardiac monitor reveals a relative bradycardia and confirms the diagnosis. Clinical examination reveals hypotension.

The OR staff should always be ready to treat an episode of vasovagal near-syncope. All the necessary items should be gathered together and easily accessible near the OR, such as an emesis basin and a prefilled syringe of atropine. Treatment of vasovagal syncope or near-syncope is 0.5 mg of IV atropine.

The primary concern is that patients may sustain injuries resulting from syncope before, during, or after surgery. The surgical team must take precautions to prevent such injuries. Preoperative photographs should be taken with a nurse standing next to the patient, ready to provide assistance if the patient becomes lightheaded.

Prevention.   The question, "Do you ever become lightheaded or feel faint when blood is taken for a laboratory test?" is a sensitive predictor of vasovagal near-syncope in the OR. If the patient has a positive history of fainting or lightheadedness that occurs with phlebotomy, a preemptive or prophylactic dose of IV atropine (0.3 to 0.4 mg) is given before surgery, as soon as IV access is established. An effective protocol consists of preparing a syringe by adding 1 mg of

1. Remove postoperative compression garments slowly and if possible with someone's assistance. Take garments off one at a time, waiting a minute or two before removing successive garments.
2. Stand up slowly after urinating.
3. Have someone in the bathroom for assistance when showering for the first time.
4. If feeling dizzy or lightheaded, immediately sit or lie down in the shower or on the floor until free of symptoms.
5. Do not be alarmed by a large amount of blood-tinged drainage on the absorptive pads; the more drainage, the less bruising and swelling.
6. Do not remove the garments with a completely empty stomach. To avoid hypoglycemia, which may increase the risk of postoperative syncope, eat before removing garments to take a shower and change the dressings.
7. Do not lock the bathroom door when showering or urinating.

atropine (1 mg/ml) to 9 ml of bacteriostatic saline, which yields atropine at 1 mg/ 10 ml = 0.1 mg/ml.

Also, when inserting the IV catheter through the skin, the surgeon should inject a tiny bleb of plain lidocaine with bicarbonate into the dermis using a 30-gauge needle. Anesthetizing the skin before placing the IV catheter decreases the incidence of pain and anxiety and thus near-syncope.

SYNCOPE AT HOME

Female patients in particular may experience lightheadedness, dizziness, near-syncope, or syncope at home after liposuction. This typically occurs in the bathroom on the morning after surgery, when the patient first removes her elastic compression garments. She may experience decompression orthostatic hypotension. The sight of the blood-tinged drainage on the absorptive pads may also contribute to the emotional stimuli that can precipitate vasovagal syncope. Urination followed by suddenly standing up may also contribute to the incidence of this "morning-after-liposuction syncope." Postliposuction syncope causing a fall with head and neck trauma in a postliposuction patient has resulted in the subluxation of the second cervical vertebra and complete quadriplegia.

This morning-after-liposuction syncope is somewhat analogous to the common postpartum orthostatic postmicturition lightheadedness or dizziness that women experience the first two or three times they stand up to walk to the toilet after giving birth. It is said that 90% of women in the immediate postpartum period experience some degree of this orthostatic micturition near-syncope. Maternity ward nurses often have a vial of ammonia (smelling salts) taped to their name tag and ready for immediate use should a new mother faint.

Prevention. Liposuction surgeons should be aware that patients may faint after being discharged home. Postoperative instructions for the first 24 hours after liposuction should include suggestions for preventing syncope and the trauma resulting from a fall (Box 8-1).

COMMON UNWANTED CONSEQUENCES

Common unwanted consequences of liposuction are relatively minor problems that can usually be repaired. With skill, care, and experience the incidence of undesirable results can be minimized, but such problems can confront any surgeon. Even the most experienced surgeons must be alert and constantly vigilant to avoid the many potential pitfalls in liposuction technique.

MINOR SUPERFICIAL IRREGULARITIES

Lipotrop. Lipotrop is the excessive and uneven removal of fat that results in depressions, dimples, and grooves in the skin. The lipotrop is the most common undesirable effect of liposuction. Surgeons with an overaggressive surgical approach have attitudes that predispose to this abecedarian complication. It is usually the result of (1) excessively superficial and uneven liposuction using oversized cannulas, (2) overaggressive or clumsy technique, (3) inappropriate intraoperative patient positioning, (4) poor cannula selection, and (5) carelessness, inexperience, or haste.

Some patients might be predisposed to lipotrops in the sense that their fat is aspirated so effortlessly that more fat is removed than anticipated. Certain cannulas remove fat so quickly that an inattentive surgeon can easily remove an excessive volume. Lipotrops are usually apparent to both the surgeon and the patient within weeks.

Liponot. Liponot is a focal area of insufficient liposuction. Liponots that become apparent within weeks or months after surgery are typically the result of a grossly uneven liposuction technique.

Some subtle liponots may only appear years later after the patient has gained weight. There is a particular risk of creating liponots when too much fat has been removed from a wide area, for example, when a surgeon attempts to remove all the fat in an area, leaving skin and muscle fascia in direct contact. In attempting to achieve this goal, the surgeon will invariably leave small areas of thin fat deposits, which become apparent only after the patient has gained weight. Areas with no residual fat remain devoid of new fat after a weight gain, whereas adjacent areas with thin residual fat deposits increase in thickness as the patient gains weight and deposits fat in existing fat cells.

Irregularities, dents, waviness, and furrows are types of liponots and lipotrops.

TEMPORARY LUMPINESS

Transient nodular lumpiness is a common sequela of liposuction, typically first noticed by the patient 1 to 2 weeks after surgery. The condition becomes most pronounced be-

Microseroma (postliposuction panniculitis) on lateral hip several days after surgery and cessation of drainage.

Figure 8-9

Flushing reaction on face, neck, and upper chest after liposuction. This reaction is transient, usually less than 24 hours, and completely benign.

tween 2 and 4 weeks after surgery. This lumpiness may be the result of impaired lymphatic drainage and may be part of the normal healing process after liposuction.

The intensity of this tender condition can be minimized using open drainage and bimodal compression, which also decreases the duration of this phase in the postliposuction healing process.

POSTLIPOSUCTION PANNICULITIS

Postliposuction panniculitis is a peculiar variety of postoperative inflammation that results from microseroma formation due to incomplete drainage of blood-tinged tumescent anesthetic solution. Microseromas have become rare with the use of open drainage and bimodal compression.

Microseromas occur more frequently when drainage is inadequate. They are usually solitary, but occasionally several areas may be involved. The typical lesion appears as a discrete, pink, warm, tender, flat area of subcutaneous inflammation. These lesions are sterile, but an infection must be considered in the differential diagnosis.

Typically the patient complains of localized warmth, swelling, and tenderness, with visible erythema. The onset occurs after the drainage has ceased. Postliposuction panniculitis is more common when incisions are closed with sutures, thus entrapping the inflammatory blood-tinged anesthetic solution. It is less likely to occur when drainage is facilitated by open drainage and bimodal compression (Figure 8-8).

Bacterial culture and sensitivity testing are usually negative after incision and drainage of these localized subcutaneous lesions. If the surgeon cannot aspirate fluid for Gram stain or bacterial culture and the patient feels well, without other signs or symptoms of an infection, treatment of the inflammation can begin. First the patient is given oral antibiotics for a possible low-grade infection. Several days later, if there is no clinical change or evidence of an infection (fever,

elevated polymorphonuclear leukocyte count, significant malaise), 10 mg of prednisone daily decreases inflammation in 2 days. Postliposuction panniculitis responds quickly to treatment with antibiotics and prednisone. Nonsteroidal antiinflammatory drugs (NSAIDs) are less effective.

When in a clinical situation that suggests postliposuction panniculitis, the surgeon must rule out the possibility of a localized infection before treatment with corticosteroids. Most patients show definite clinical improvement within 48 hours of treatment with prednisone. In addition, once an infection has been ruled out, the patient can receive NSAIDs (e.g., ibuprofen). NSAIDs can impair leukocyte function and are therefore relatively contraindicated in the clinical setting of a possible postoperative infection.

FACIAL FLUSHING

A transient, often subtle, and totally benign flushing of the face, neck, and chest can occur after tumescent liposuction, usually within 18 to 36 hours. Typically persisting for 12 to 48 hours, besides a redness of the affected skin, the flushing is asymptomatic and often unnoticed. Occasionally the flushing is obvious and often prompts a telephone call to the surgeon's office. No treatment is required.

The process is probably mediated by prostaglandins generated by the inflammatory response to the tissue trauma. Surgical trauma and inflammation can generate prostaglandins, which are known to cause flushing (Figure 8-9).
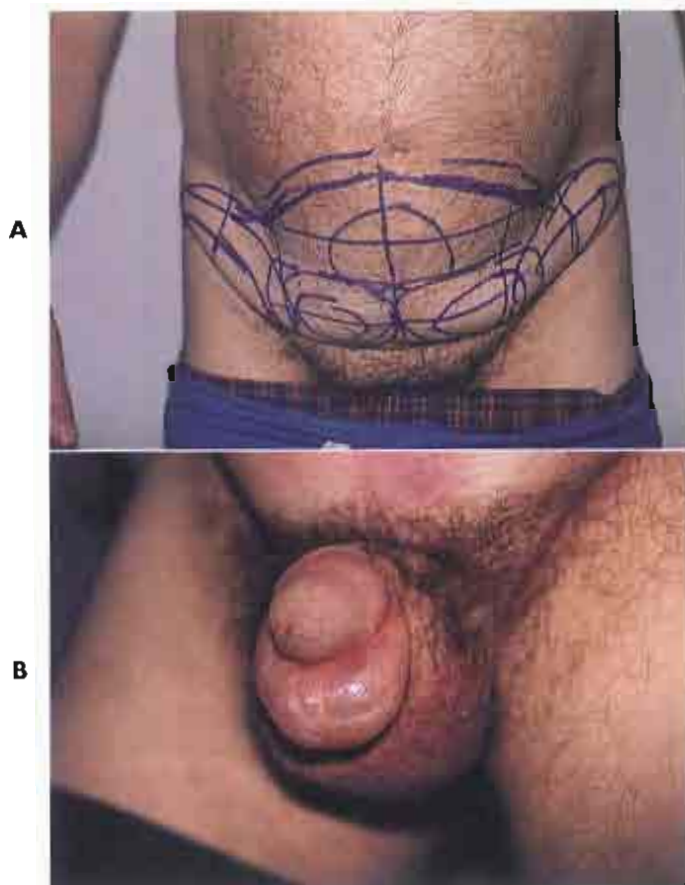
Figure 8-10

Edema of genitals is common sequela of liposuction of lower abdomen and suprapubic area after tumescent liposuction. **A,** Lower abdomen shows area of liposuction. **B,** Penile and scrotal edema typically resolves in 3 to 4 days. In females, labial edema can occur after lower abdominal liposuction.

Figure 8-11

Hematoma and bruising of male breast resulting from inadequate postliposuction compression. Patient returned because of asymmetric bruising and bleeding approximately 6 hours after liposuction. Treatment included brief aspiration by liposuction, which removed approximately 60 ml of bloody fluid. Absorption pads held in place with two 6-inch torso binders provided high compression. Patient had no further bleeding, and problem resolved without further treatment.

TEMPERATURE ELEVATION

A minimal temperature elevation, less than 1° C, may occur in the first 24 hours after surgery. The pathogenesis of this mild febrile reaction is probably related to the systemic effects of prostaglandins generated by surgical trauma and inflammation. Prescribing acetaminophen (1 g) by mouth every 6 hours for at least the first 2 days after surgery seems to attenuate this febrile response.

Infections are extremely rare with tumescent liposuction. Nevertheless, the surgeon cannot ignore a possible infection when a patient reports a slight fever. Careful questioning over the telephone is usually sufficient to rule out infection. With no localized pain and tenderness, focal erythema, or malaise, infection is unlikely. If the surgeon cannot rule out an infection, the patient must have an immediate examination and clinical evaluation.

A significant elevation of body temperature after liposuction may be the result of an influenza-type viral syndrome.

Typically the patient mentions a history of flulike symptoms among family or friends.

EDEMA AND ECCHYMOSIS

Legs and Ankles. Edema of the legs and ankles can occur after liposuction on any part of the lower extremity; this pitting edema is usually mild to moderate in degree. The risk of this distal edema increases with circumferential liposuction of either the leg or the thigh. Placing sutures in liposuction incision sites promotes and prolongs this edema. Pitting edema results from a combination of cannula-induced injury to subcutaneous lymphatics and postoperative edema, causing compression and occlusion of these lymphatic vessels.

The incidence of distal edema is greatly reduced by using open drainage and bimodal compression and avoiding circumferential liposuction of the thigh or leg.

Genitals. Swelling and bruising of the genitalia after abdominal liposuction result from blood-tinged fluid tracking distally under the effect of gravity and being funneled to-

Figure 8-12

Different degrees of bruising 5 days after tumescent liposuction in two patients. **A,** Greater degree of bruising without open drainage and bimodal compression. **B,** Minimal bruising with open drainage.

ward the genitalia by Scarpa's fascia. Immediately after passing over the inguinal ligament, Scarpa's fascia blends into the deep muscle fascia of the thigh. Scarpa's fascia extends over the lower abdomen into the pubic area, where it is continuous with the fascia that envelops the female vulva and the male penis and scrotum (Figure 8-10).

This dependent postoperative edema of the genitals can be minimized with 2-mm *adits* and adequate compression. Before surgery, patients should be told that this edema is a common sequela of abdominal liposuction and resolves in 2 to 3 days.

Postoperative Soreness.   Postoperative swelling, soreness, and ecchymosis can be dramatically reduced using open drainage and bimodal compression for postoperative care. Using sutures to close the incisions for cannula access increases postoperative edema and bruising. Prolonged high-compression dressings impair lymphatic drainage and thus prolong postliposuction edema (see Chapter 11).

With the tumescent technique, postoperative hematomas are rare and usually associated with inadequate compression during the first 12 postoperative hours (Figure 8-11; see also Chapter 30).

Typical postoperative bruising in any given patient is usually symmetric, with minimal variation between sides in terms of intensity and extent of ecchymosis. Symmetric bruising in-

dicates that the bruising is not the result of a random injury to blood vessels.

On the other hand, the degree of bruising in individual patients varies greatly despite identical intraoperative and postoperative care. The variability among patients may be caused by endogenous or exogenous factors. Possible endogenous factors include genetic biochemical differences in the coagulation system. Exogenous sources include substances that affect platelet function, such as red wine, large quantities of garlic, or vitamin E supplementation.

Postoperative care that includes open drainage and bimodal compression minimizes bruising, swelling, discomfort, and tenderness (Figure 8-12).

PERIOPERATIVE TACHYCARDIA

Perioperative tachycardia can result from anxiety, epinephrine in the local anesthetic solution, and oral medications (e.g., ephedrine-like nasal decongestants). Patients with no significant history of cardiac dysrhythmias may have a genetic or congenital predisposition to tachydysrhythmias. An uncomfortably full bladder can also cause tachycardia and hypertension. Patients should be advised to avoid ephedrine-like drugs preoperatively.

Minimizing the exposure to epinephrine by limiting the dose contained in the tumescent local anesthetic solution is

Figure 8-13

Full-thickness skin necrosis resulting from hematoma in patient with adult-onset diabetes. **A,** Eschar on left lower abdomen 4 weeks after surgery. **B,** Wound after debridement and wound contracture. During preoperative examination and immediately before surgery, patient repeatedly denied taking aspirin. After excessive intraoperative bleeding forced termination of liposuction surgery, patient admitted, "I never take aspirin. I only take baby aspirin." Hematoma may have decreased cutaneous perfusion in this patient with impaired microvascular circulation.

helpful. On most areas of the body an epinephrine concentration of 0.65 mg/L provides sufficient hemostasis and delayed absorption of lidocaine. On other areas, such as the medial abdomen, scapular back in women, breasts, and chin/neck areas, an epinephrine concentration of at least 1.0 mg/L is recommended. The preoperative history should specifically focus on any possibility of mitral valve prolapse, palpitations, or tachycardia. Clonidine, 0.1 mg by mouth immediately preoperatively, attenuates the tendency for tachycardias and provides sedation without the risk of respiratory depression seen with benzodiazepine sedatives.

VASCULAR LACERATIONS

Vascular injury by the liposuction cannula is rare when microcannulas are used. Good postoperative compression for the first 24 hours postoperatively should preclude any significant bleeding from veins. Significant arterial or venous bleeding is rare with liposuction. Exceptions may be the result of impaired platelet function, such as from aspirin, vitamin E, red wines, and high-dose garlic supplementation. Diabetic patients have an increased incidence of small vessel insufficiency, which might predispose to local tissue or skin necrosis after an otherwise insignificant injury to a blood vessel (Figure 8-13).

Fascia. Cannula-induced laceration of muscle fascia has been reported but likely is rare. Microcannulas reduce the risk of significant fascial damage. Patients are more likely to notify the surgeon of a fascial injury if awake and alert versus anesthetized by general anesthesia or heavy IV sedation.

MENSTRUAL IRREGULARITY

An occasional patient experiences transient menstrual irregularity. Typically the onset of menstruation is 1 or 2 weeks earlier than expected. No treatment is necessary, and the menstrual cycle returns to its predictable course within 1 or 2 months. The phenomenon is probably the result of posttraumatic perioperative prostaglandins. The use of corticosteroids in the early postoperative period also increases the incidence of breakthrough bleeding.

SKIN EXCISIONS

Modern liposuction techniques have made an anachronism of large, disfiguring skin excisions as an adjunct to body contouring (Figures 8-14 and 8-15). Excisions of skin after liposuction often produce scars and disappointing results. Skin excision is a last resort in cosmetic surgical body contouring. Liposuction should be done first and then an excision considered only if the results of liposuction are unsatisfactory. Liposuction can usually achieve superior cosmetic results. Disappointment in the appearance of the scars often outweighs any cosmetic improvement.

Most abdominal liposuction patients are satisfied with the results of simple liposuction. When liposuction is insufficient, abdominoplasty can be done as a secondary procedure. If skin excision and rectus muscle plication are found to be necessary despite previous liposuction, an abdominoplasty, done as a secondary, separate procedure, will minimize postoperative discomfort and the risk of complications.

Figure 8-14

Cosmetically displeasing scars on three patients who had skin excision for surgical body sculpturing. Such excisions usually are unnecessary and are not always a cosmetic improvement. **A** and **B,** Scars on abdomen and back after abdominoplasty and removal of "excessive" skin on waist. **C,** Scar after posterolateral thigh lift. **D,** Scars on proximal thigh after medial thigh lift.

Figure 8-15

Dermal necrosis after abdominoplasty resulting from liposuction and skin excision that compromised cutaneous vascular supply.

Figure 8-16

Bilaterally symmetric dimples of lateral thigh are unusual. Patient may not notice a preexisting unilateral dimple until after liposuction.

PSEUDOCOMPLICATIONS

Pseudocomplications are problems unrelated to liposuction that the patient or surgeon might perceive as complications of liposuction. They occur independent of liposuction, however, or the anesthesia used for liposuction.

DIMPLES AND MUSCLES

Dimples of the thigh are easily visible and are not always a function of voluntary control. Dimples in this area are uncommon but not rare. The surgeon should mention a preex

isting dimple to the patient before liposuction is attempted. A patient who only becomes aware of a dimple after liposuction may suspect the dimple is the result of inept surgery (Figure 8-16).

Voluntary dermal dystrophy is seen in patients who can voluntarily cause extensive dimpling of the skin. When a patient flexes the muscles, subcutaneous attachments between skin and muscle fascia cause dimpling and deformity that mimic the appearance of excessive or incompetent liposuction. It is important to identify and document this deformity preoperatively. Liposuction in an area affected by voluntary dermal dystrophy might exacerbate the situation (Figure 8-17).

Figure 8-17

A and **B,** Voluntary dermal deformity of buttocks, before and after tightening buttock muscles. **C** and **D,** Voluntary dermal deformity of lateral thigh and buttock area. **E** and **F,** Another voluntary dermal deformity of buttocks.

IDIOPATHIC LIPOATROPHY

Idiopathic localized lipoatrophy is characterized by loss of adipose tissue without antecedent clinical inflammation. The terms *fat atrophy, lipoatrophy,* and *lipodystrophy* are often used as synonyms in the dermatology literature. Lipoatrophies, either generalized or localized, are uncommon conditions affecting the subcutaneous fat.

Localized involutional lipoatrophy is a common pattern of fat tissue response characterized by diminutive fat lobules resembling embryonic adipose tissue and macrophage infiltration. It is often associated with IM or intraarticular corticosteroid injections and antibiotic injections into the affected subcutaneous fat. The buttock and proximal extremities are most frequently involved.[16]

Generalized lipoatrophy is usually associated with some type of systemic disease, such as autoimmunity, inflammatory diseases, idiopathic conditions, and renal disease.[17] Insulin lipoatrophy is a direct consequence of local insulin injections; this condition can improve with time if the patient can avoid repeated injection in the affected area. Other types of localized fat atrophy include connective tissue panniculitis, granulomatous lipoatrophy, α_1-antitrypsin deficiency, scleroderma, lupus erythematosus, juvenile rheumatoid arthritis, lichen sclerosus, and dermatomyositis.[18]

Several well-recognized forms of lipoatrophy are not localized. *Total lipoatrophy* (Lawrence-Seip syndrome) is a rare acquired, congenital, or familial condition with total atrophy of visceral and subcutaneous fat. Familial cases appear to be autosomal recessive, with homozygous patients affected by the full syndrome. Associated conditions include hepatomegaly, increased bone growth, hyperlipidemia, and progression to diabetes mellitus. *Partial lipoatrophy* (Barraquer-Simons syndrome) characteristically is associated with cadaveric facies and often with glomerulonephritis and C3 hypocomplementemia.[19] *Lipoatrophic diabetes mellitus* (Dunnigan syndrome) is a rare condition characterized by insulin-resistant diabetes and generalized lipoatrophy.[20,21]

Although idiopathic localized lipoatrophies are uncommon, liposuction surgeons should be aware of the various types of idopathic conditions that have been identified. When an idiopathic fat atrophy occurs at a site that is distant from any previous liposuction surgery, liposuction patients still might incorrectly conclude that the disfiguring localized loss of fat loss was caused by the liposuction procedure. To avoid such an accusation, the surgeon should document the areas treated by liposuction, using photographs of the preoperative topographic markings (Figure 8-18).

Semicircular Lipoatrophy. Semicircular lipoatrophy, or *lipoatrophia semicircularis*, is an unusual but well-described form of idiopathic localized lipoatrophy. The peculiar appearance, symmetric distribution, and unique and identical location of this localized fat atrophy are remarkable. It affects only the anterolateral thighs and is characterized by a bandlike semicircular depression 2 to 4 cm in width.[22-24] I have seen two patients with this problem (Figure 8-19).

If semicircular lipoatrophy occurred in a patient after liposuction, most surgeons who are unaware of this clinical entity might conclude that the disfiguring localized fat atrophy was caused by liposuction.

Distal Lipoatrophy. Two unrelated patients with idiopathic distal lipoatrophy had complete absence of subcutaneous fat in the forearms and distal arms as well as in the legs and distal thighs (Figure 8-20). The condition had been present for years in both patients. The face was not affected, there was no family history of similar involvement, and neither patient was aware that the condition was unusual. Both patients were rather thin and had a truncal accumulation of subcutaneous fat. The distal fat atrophy of all four extremities produced the appearance of diproportionate central deposition of fat on the trunk.

Figure 8-18

Forms of idiopathic fat atrophy are pseudocomplications that may first become apparent months or years after liposuction. Because idiopathic fat atrophy may easily be confused with true lipotrop, patient might wrongly attribute defect to excessive liposuction. **A,** Idiopathic focal fat atrophy on right thigh. **B,** Morphea, or localized scleroderma, on buttock of patient who never had liposuction. Focal hypopigmentation overlying this peculiar form of lipoatrophy histologically shows marked degree of fibrosis within superficial subcutaneous fat.

Both patients were otherwise healthy, and no specific medical workup was indicated. Both requested liposuction of the abdomen. Because I did not understand the long-term prognosis for this condition, however, they were both advised that liposuction might not be in their best interest.

Several patients with adult-onset insulin-dependent diabetes mellitus had lipoatrophy that affected only the buttock and lower extremities.

Figure 8-19

Idiopathic semicircular lipoatrophy is characterized by bandlike semicircular depression 2 to 4 cm in width affecting anterolateral thighs.
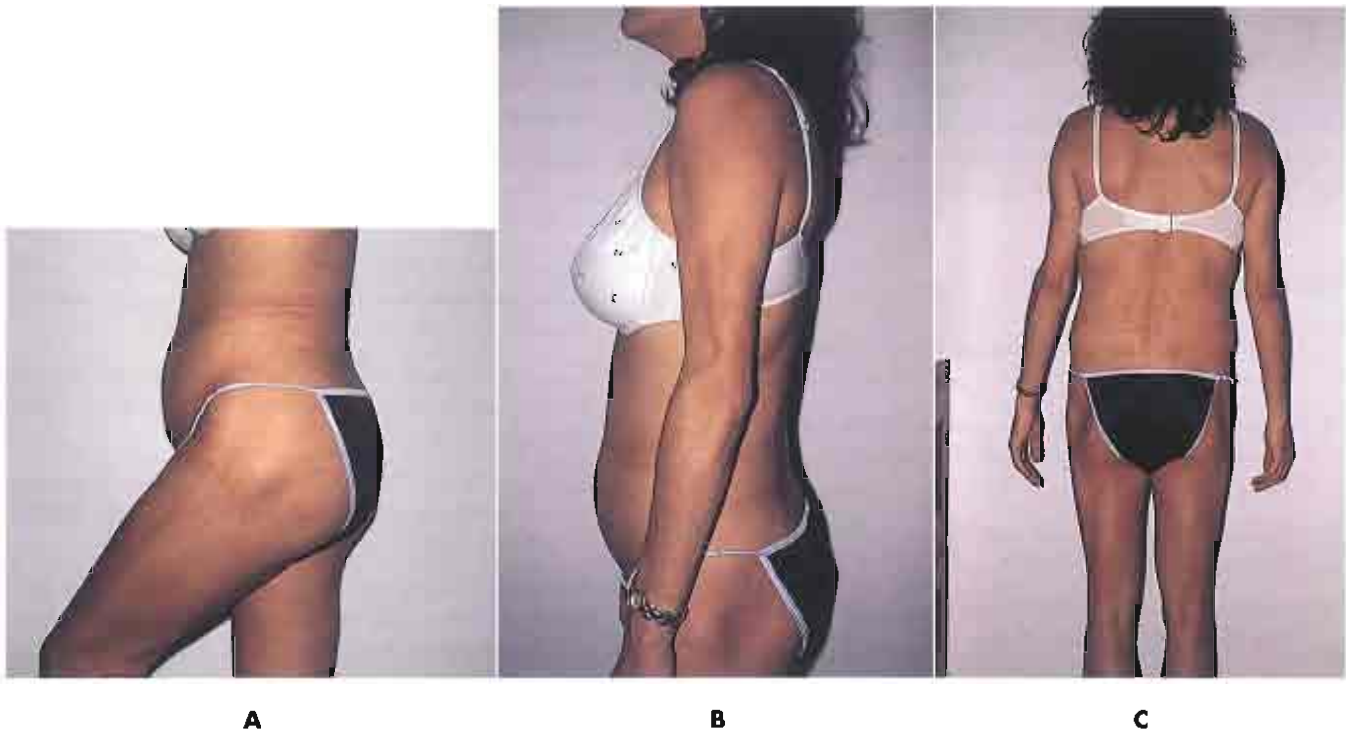
A   **B**   **C**

Figure 8-20

Idiopathic distal fat atrophy of all four extremities, with compensatory relative degree of truncal obesity. **A,** Complete loss of subcutaneous fat overlying lateral thigh and trochanteric tubercles. **B,** Upper extremity fat atrophy contrasts with relatively fat abdomen and torso. **C,** Posterior view demonstrates contrast between extremities with fat atrophy and unaffected torso.

Posttraumatic Lipoatrophy. Posttraumatic localized lipoatrophy is probably caused by localized inflammation of subcutaneous fat, which results in the replacement of fat lobules by fibrosis. This atrophy may be associated with liposuction, blunt trauma, or injections. When localized blunt trauma induces localized fat atrophy, the onset is usually delayed.

Posttraumatic localized lipoatrophy is rarely seen in association with liposuction. In my experience, only one patient might have had this localized lipoatrophy as the result of liposuction.

PATIENT MISPERCEPTIONS OF DRAINAGE

Patients are told that open drainage and bimodal compression are specifically designed to encourage copious postoperative drainage. Despite these careful explanations, some patients become concerned that the drainage of blood-tinged anesthetic solution is whole blood. The resulting telephone call from a concerned patient or spouse requires serious consideration. Careful questioning, evaluation, and reassurance usually are sufficient to resolve the problem, but some patients still require examination by either the surgeon or an experienced staff nurse.

With the opposite type of "anxiety," the patient is concerned that insufficient drainage of blood-tinged anesthetic solution will result in excessive swelling or delayed healing. This concern is usually unfounded. In any case, no serious long-term consequences occur from less-than-maximal drainage. Simple reassurance should allay the patient's concern.

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Superwet Liposuction and Pulmonary Edema

The routine use of intravenous (IV) fluids is unnecessary and relatively contraindicated with tumescent liposuction. Liposuction patients have died from unnecessary administration of IV fluids. This chapter examines the kinetics of tumescent fluids and the pathophysiology associated with unnecessary IV fluid infusions.

Substances such as sodium chloride (NaCl) have a crystalline structure and are known as *crystalloids*. Unlike a colloid substance, a crystalloid substance in solution (e.g., lactated Ringer's) can easily pass through membranes.

Superwet liposuction uses general anesthesia or IV sedation-analgesia, infusion of significant volumes of IV crystalloids, and infiltration of moderate volumes of subcutaneous crystalloids.[1] A syndrome of *superwet disseminated intravascular coagulation* (superwet DIC) can result from the combination of excessive liposuction trauma, general anesthesia with hypothermia, and hemodilution from excessive IV fluid infusion (see Chapter 14). Each of these factors alone can precipitate a consumption coagulopathy. When they are combined in a single surgical misadventure, the result may be a fatal episode of DIC.

NO THIRD SPACE

In the true tumescent technique for liposuction, or liposuction totally by local anesthesia, subcutaneous fluids routinely produce hemodilution. If IV fluids are infused as well, a significant risk of systemic fluid overload and pulmonary edema exists.

The traditional theory of liposuction assumes that tissue damage as a result of surgery creates a "third space" phenomenon, in which intravascular fluids are lost into a "black hole" of traumatized tissue. An excessive loss of intravascular fluid precipitates loss of cardiac output, loss of blood pressure, and death. With safe volumes of tumescent liposuction, there is no third space phenomenon. The assumption that tumescent liposuction creates a third space may prompt surgeons to overcompensate and give the patient potentially life-threatening doses of IV fluids.

The tumescent technique prevents the creation of a third space. Tumescent infiltration fills the local interstitial tissue with isotonic fluid and preempts the need for filling the wound with intravascular isotonic fluid. Epinephrine constricts arterioles, decreasing intravascular hydrostatic pressure, which in turn decreases local hemorrhage and distal transcapillary leakage of plasma; the tumescent hydrostatic pressure compresses venules and veins and further decreases hemorrhage.

Intravascular fluid deficits occur with tumescent local anesthesia principally because of excessive amounts of liposuction. These deficits are prevented by avoiding excessive liposuction, not by overcompensating with IV fluids. Administration of IV fluids to prevent intravascular fluid loss is especially dangerous when intravascular fluid volume is already increased as a result of systemic absorption of subcutaneous tumescent fluids.

FLUID VOLUME AND OVERLOAD

The sodium-potassium (Na-K) pump maintains a sodium concentration gradient between the intracellular fluid volume and the extracellular fluid volume (ECFV) such that intracellular sodium ion (Na^+) concentration is approximately 10% of the Na^+ concentration in the ECFV. Because of the osmotic pressure gradient created by the Na-K pump, most of a dose of isotonic crystalloid, such as lactated Ringer's solution (LR) or 0.9% NaCl (IV infusion or subcutaneous tumescent infiltration), will be distributed throughout the ECFV. The difference is that an IV infusion is rapidly redistributed, whereas a subcutaneous tumescent dose is slowly absorbed and distributed. The duration of the expansion of the ECFV is limited by the rate of renal excretion of sodium and water.

Because plasma is only 20% of the ECFV, any IV or tumescent dose of LR or normal saline (NS) will increase the blood volume by only 20% of the volume given.[2] The residual 80% of the given volume enters the interstitial space. For example, a 3-L dose of NS will produce only a 600-ml expansion of the intravascular space, whereas 2400 ml will enter the interstitial space, including the pulmonary interstitium.

TUMESCENT FLUID AND HEMODILUTION

When delivered into subcutaneous fat by tumescent infiltration, physiologic saline (0.9% NaCl) or LR can be regarded pharmacologically as a drug. This is best represented by a one-compartment pharmacokinetic model, with the pharmacokinetic volume of distribution essentially equal to the ECFV.

Subcutaneous infusion of the tumescent technique, without IV fluid supplementation, results in moderate hemodilution.[3] For example, when a 75-kg female was given 35 mg/kg of tumescent lidocaine in 5.25 L of NS (500 mg of lidocaine/L), sequential measurements revealed that the maximum decrease in hematocrit was approximately 10% with or without liposuction. After tumescent liposuction, no clinical evidence indicates an intravascular fluid deficit. The urine specific gravity is not decreased, and hourly urine output is more than 70 ml/hr.

When a reasonable volume of supranatant fat is removed with tumescent liposuction (3% to 4% of total body weight or less than 4 L), no third space is clinically detectable. Any significant IV infusion is unnecessary and can produce intravascular fluid overload and pulmonary edema.

The tumescent technique essentially eliminates problems associated with the shift of IV fluids out of the intravascular space. Thus replacing significant volumes of IV fluids is unnecessary.[4] Only minimal amounts of IV fluids are given, although IV access is always established to administer emergency medications. Patients need only an IV access maintained by a heparin lock, flushed with plain physiologic saline containing no heparin.

I recommend *no IV fluids* during or after tumescent liposuction surgery. If a liposuction patient requires perioperative IV fluids, it is likely that the liposuction removed an excessive volume of aspirate or that tumescent infiltration was insufficient.

INTRAVENOUS CRYSTALLOIDS AND THE LUNGS

A dose of IV crystalloid (e.g., LR, NS) enters the pulmonary interstitial space by a circuitous route. When a large IV dose (2 L/hr) of LR or NS is infused, it flows directly to the right side of the heart, through the lungs, and into the left side of the heart. Standard doses of LR do not cause pulmonary edema in healthy persons, which indicates that most of the dose merely flows through the pulmonary vessels back to the left side of the heart, finally entering the arterial circulation. For humans the maximum pulmonary lymphatic flow rate is only 200 ml/hr. If a significant proportion of the IV dose of LR did enter the pulmonary interstitial space on its first pass

through the lungs, the result would be fulminant and fatal pulmonary edema.

A limited amount of IV crystalloid can be safely infused before the risk of pulmonary edema becomes significant. After IV infusion of just 1 L of 0.9% NaCl, sufficient fluid enters the pulmonary interstitium to cause decreased pulmonary compliance.[5] The infusion of 3 to 5 L of LR or NS into an adult increases the risk of pulmonary edema.[6]

Any IV infusion of LR is rapidly redistributed into the interstitial space. In young men, for example, to achieve a steady-state 10% blood volume dilution, the infusion rate must be at least 50 ml/min for at least 40 minutes (2000 ml); in healthy females, IV infusion of LR at 100 ml/min over 15 minutes causes symptoms of fluid overload.[7] The risk for iatrogenic pulmonary edema (pulmonary interstitial fluid overloading) is proportional to the degree of excess fluid in the interstitial space. Any IV infusion of crystalloid enters the interstitial space so rapidly that it is generally unnecessary and potentially dangerous with tumescent technique.

If a large volume of IV crystalloid solutions is given to a patient after a significant dose of subcutaneous crystalloid, the postoperative ECFV will be larger than the preoperative ECFV. Healthy patients usually tolerate large volumes of IV crystalloid infusion well. High-compression garments over infiltrated areas increase interstitial fluid pressure and shift ECFV out of the compressed interstitial space and back into the intravascular space, where it is redistributed to other interstitial tissues, including the pulmonary interstitium. This increases the risk of pulmonary edema.

INTERSTITIAL EDEMA

Interstitial edema is the result of excessive water accumulating in the interstitial space. The lymphatic system is the principal means of removing extravasated plasma proteins from the interstitial space. Extravasated plasma proteins increase the colloid osmotic pressure of the interstitium, which in turn tends to draw even more water out of the vascular space and into the interstitial space. When the rate of plasma flowing into the interstitium exceeds the lymphatic system's ability and capacity to remove these proteins, the result is interstitial edema (see Chapter 11).

Large molecules located in the interstitial tissues cannot readily diffuse across the capillary endothelium of blood vessels and enter the intravascular space. An extravasated plasma protein molecule reenters the intravascular space by first entering, then being transported by, lymphatic vessels. Edema fluid resulting from tissue trauma and inflammation has a high content of large plasma protein molecules. If the lymphatic vessels have been impaired by trauma, the proteinaceous edema fluid cannot easily return to the intravascular space.

Thus edema fluid in most traumatized tissues is functionally isolated from the intravascular fluid volume. It is also physically isolated from most of the body's interstitial space. In essence, therefore, the edema fluid in traumatized and inflamed tissues is functionally a third compartment that is dis-

tinct and isolated from the intravascular space and the peripheral interstitial space.

The greater the volume of liposuction-induced tissue damage (greater the number of areas suctioned or greater the volume of fat aspirated), the greater is the potential for problems with ECFV homeostasis.

TUMESCENT VASOCONSTRICTION

Beta-adrenergic agonists such as epinephrine cause arteriolar and capillary vasoconstriction. In adipose tissue, extremely dilute tumescent epinephrine (1 mg/L or less) produces profound vasoconstriction. This tumescent vasoconstriction not only produces hemostasis and greatly delays systemic lidocaine absorption, but also minimizes extravasation and "third spacing" of intracellular water.

Hydrostatic Vasocompression. The trauma of liposuction disrupts blood vessels, causing hemorrhage into treated areas and release of inflammatory mediators. The combined physical and biochemical insult to vascular endothelium increases capillary permeability to plasma proteins. The free flow of plasma proteins into the interstitium equalizes the intravascular and extravascular colloid osmotic pressure. With equilibrated colloid osmotic pressure, the hydrostatic pressure gradient determines the direction of transcapillary fluid exchange. Capillaries and venules remain patent only when the intravascular blood pressure exceeds the interstitial pressure. Tumescent infiltration elevates interstitial hydrostatic pressure above capillary blood pressure.

Tumescent hydrostatic pressure causes a net flow of water from the interstitial space into the intravascular space. At the periphery of a globular mass of tumescent adipose tissue, where vasoconstriction is less than complete, the elevated tumescent hydrostatic pressure produces a net intravascular absorption of crystalloid. After absorption into the systemic circulation, the tumescent solvent is redistributed throughout the ECFV, including the interstitial fluid volume. In essence, the tumescent liposuction patient is somewhat overhydrated. This is substantiated by the observation that the postoperative urine specific gravity is typically decreased compared with the preoperative urine.

Tumescent hydrostatic pressure prevents third spacing of intravascular fluid. In effect, tumescence provides a net increase in intravascular volume and eliminates the need for perioperative IV crystalloid infusions.

Hemostatic Effects. Tumescent vasoconstriction is the net effect of tumescent hydrostatic vasocompression and beta-adrenergic vasoconstriction. Tumescence is unique in simultaneously providing arteriolar, capillary, and venular vasoconstriction. Tumescent arteriolar vasoconstriction is mediated by epinephrine and shrinks arterioles and capillaries. Tumescent venular vasocompression is mediated by hydrostatic pressure and collapses capillaries, venules, and small veins. In essence, tumescent vasoconstriction shuts off the vascular supply of the infiltrated adipose tissue. The combi-

nation of no blood flowing from the upstream capillary bed and tumescent hydrostatic pressure causes even the larger veins within tumescent fat to collapse.

The net effect of tumescent vasoconstriction is an unprecedented type of hemostasis that not only conserves red blood cells, but also preempts massive shifts of extracellular water out of the intravascular space into the interstitial space.

The tumescent vasoconstrictive effects are well balanced. Too little tumescent vasoconstrictive effect would increase surgical hemorrhage, increase the local inflammation, and increase postoperative healing time; it would also increase the risk of hypovolemia, the need for IV crystalloid replacement, and thus the risk of iatrogenic pulmonary edema. Too much (excessively prolonged) vasoconstriction would cause local tissue necrosis. Only the adipocytes' meager oxygen requirement prevents anoxic necrosis.

Careful, deliberate tumescent infiltration maximizes the hemostatic effect. Rapid, haphazard infiltration provides less complete local anesthesia and vasoconstriction.

Tumescent vasoconstriction is responsible for (1) isolation of tumescent lidocaine from the systemic circulation and (2) pharmacokinetic behavior (one-compartment model) of the tumescent technique.

INTRAVENOUS FLUID OVERLOAD

The tumescent technique for local anesthesia and IV fluid infusion is a potentially dangerous combination. Again, IV fluids are relatively contraindicated with tumescent liposuction. Unawareness of the fluid kinetics (rate of intravascular absorption) of the tumescent anesthetic solution from the subcutaneous compartment can lead to fluid overload.

Former liposuction techniques with general anesthesia required large volumes of perioperative IV fluids. Loss of intravascular fluid because of third spacing was one of the greatest risks. Management of these liposuction patients included infusion of significant volumes of IV fluids, plasma expanders, and autologous blood transfusions. For example, for every liter of aspirate, 1 to 2 L of IV fluids was infused.

After adopting the superwet technique, some clinicians have continued to inundate patients with IV fluids. Infusion of significant IV fluid volumes into normovolemic patients who just underwent tumescent liposuction can result in dangerous IV fluid overload and pulmonary edema.

PULMONARY EDEMA

The classic findings on physical examination in the setting of pulmonary edema include basilar rales, jugular venous distension, orthopnea, and frothy pink sputum. To prevent pulmonary edema with tumescent liposuction, the surgeon should not use IV fluids.

The etiology of pulmonary edema is similar to that of edema throughout the body. With simultaneous IV fluid overload and acute cardiovascular stress, however, the onset of pulmonary edema can be extremely rapid and fatal. The

distance separating the capillary blood from the alveolar air sac is so short, 0.5 μm, and the volume of the pulmonary interstitial space so small, 200 ml or less, that any fluid leaking from the pulmonary capillary will rapidly fill the alveoli.

Types and Causes

Many different types of injury and physical stress to lung tissue can result in pulmonary edema. The different causes of pulmonary edema can be classified in several ways (Box 9-1).

Intravascular fluid overload from excessive IV crystalloid infusion precipitates a *high–capillary pressure pulmonary edema*, the most common iatrogenic form of pulmonary edema in a liposuction patient. It is one of the most common causes of liposuction-related mortality. Any condition that predisposes to systemic fluid overload, such as chronic cardiac, hepatic, or renal insufficiency, will predispose to perioperative high–capillary pressure pulmonary edema.

Cardiogenic pulmonary edema is the result of left-sided heart failure from cardiac valvular insufficiency, idiopathic or drug-induced dysrhythmia, acute myocardial infarction, or atherosclerotic cardiovascular disease. As the direct result of a relative IV fluid overload, cardiogenic pulmonary edema can also occur during liposuction surgery. An unexplained, acute-onset pulmonary edema in an otherwise healthy young patient should raise the suspicion of cardiogenic pulmonary edema.

Despite up to 7 years of surgical training, few surgeons have the clinical experience to diagnose and manage this condition. The surgeon, not the anesthesiologist, is responsible for screening patients for relevant predisposing conditions and, when appropriate, obtaining preoperative clearance

from a specialist in internal medicine. Although most liposuction patients are healthy and have no significant surgical risk factors, the surgeon must always be alert for potential problems. Surgeons must realize their limitations and seek medical consultation as appropriate to assist in the preoperative evaluation of some patients.

Inflammation-mediated pulmonary edema, or adult respiratory distress syndrome (ARDS), may be viewed as a form of low–capillary pressure pulmonary edema. In the liposuction patient, especially with general anesthesia, ARDS can be associated with drug reactions, sepsis, gastric aspiration, fat embolism, transfusion reaction, or massive blood transfusion. Other causes of ARDS are burn-inhalation injury and acute pancreatitis.

In an otherwise healthy patient, IV fluid overload, cardiac dysrhythmia (drug induced or otherwise), and acute left ventricular failure can produce abrupt pulmonary edema, with frothy pink sputum, dyspnea, panic, and sudden death. The combination of IV fluid overload and acute bupivacaine toxicity (intractable ventricular fibrillation) is a risk of the superwet liposuction technique.

Pulmonary edema has two stages. The first stage, *interstitial pulmonary edema,* involves edema of the pulmonary interstitial space. Within certain limits, the pulmonary lymphatics can accommodate a gradually increased interstitial fluid load by increasing lymph flow and thus can compensate for interstitial edema. When the rate of interstitial fluid production exceeds the capacity of the pulmonary lymphatics, the result is the second stage, *alveolar pulmonary edema.* Fluid crosses the capillary endothelium, then the interstitial collagen, and finally the alveolar epithelium, filling the alveoli with fluid. Alveolar edema prevents pulmonary gas exchange and causes local hypoxia.

BOX 9-1 Etiology of Pulmonary Edema

High Capillary Pressure
Iatrogenic (extrinsic)
   Excessive IV crystalloid infusion
   Peritoneal or bladder irrigation
Left-sided heart failure (intrinsic)
   Cardiac valvular insufficiency
   Atherosclerotic cardiovascular disease
   Acute myocardial infarction
   Dysrhythmia

Inflammation mediated (Adult Respiratory
   Distress Syndrome)
Drug reaction
Sepsis
Gastric aspiration
Fat embolism
Transfusion reaction
Massive blood transfusion
Burn-inhalation injury
Acute pancreatitis

Prevention

The prevention of pulmonary edema resulting from IV fluid overload is the most basic aspect of applied physiology. In a healthy patient who is already somewhat overhydrated by tumescent fluids, infusion of excessive IV fluids poses a substantial risk of fluid overloading and pulmonary edema. Surgeons continue this practice apparently because they do not appreciate the rate and extent of systemic absorption of subcutaneous crystalloid (NS, LR) after tumescent infiltration.

Among cosmetic surgeons there is widespread failure to recognize that (1) safety requires biostatistical validation and (2) safety can never be *proved* by one anecdotal report. On the other hand, a single sentinel case report can establish the dangers inherent in a surgical procedure. The fact that one healthy liposuction patient survived a 15-L dose of parenteral fluids (IV plus tumescent fluids) is not sufficient proof that such a high dose generally is safe in all patients. The risk of such a high dose was demonstrated when an 80-kg (176-pound) male patient developed pulmonary edema after liposuction using the superwet technique. He had been given 7900 ml of subcutaneous fluid and 2200 ml of IV fluids during liposuction of 1150 ml of supranatant fat.[8]

The volume of isotonic crystalloid infiltrated in the subcutaneous space with tumescent technique more than compensates for the trauma of liposuction. With tumescent liposuction, urine specific gravity is typically greater before than after surgery, indicating that the intravascular space is not volume depleted. With true tumescent liposuction the patient is alert and fully conversant and can drink fluids at will. No need exists for IV fluid supplementation. A patient who requires IV fluids after tumescent liposuction indicates either too much liposuction or too little tumescent anesthesia.

To my knowledge, pulmonary edema has never been associated with liposuction using the true tumescent technique.

PULMONARY LYMPHATIC SYSTEM

The pulmonary lymphatic system is an important compensatory mechanism of maintaining pulmonary interstitial fluid homeostasis. The distal pulmonary lymphatic capillaries meander just below the basement membrane of the alveolar epithelium. Lymphatic capillaries coalesce proximally to form small canaliculi that course through the lung tissue parallel and adjacent to arterioles and bronchioles; larger lymphatic vessels subsequently follow the path of pulmonary arteries and bronchi into the large, collecting hilar trunk vessels. Chest radiographs identify pulmonary interstitial edema by the classic butterfly pattern of hilar fullness.

The kinetics of fluid exchange between the pulmonary vasculature and interstitial space seem to obey Starling's law. Under normal conditions the net effect of lymphatic drainage, hydrostatic pressures, and colloid osmotic pressures on the diffusion of water into and out of capillaries is creation of a pulmonary interstitial fluid pressure that is slightly negative relative to atmospheric pressure. Healthy persons have a small pulmonary lymph flow of about 20 ml/hr. Anything that elevates the pulmonary interstitial pressure into the positive range will precipitate sudden interstitial edema and flooding of the alveoli with free fluid.

In patients with chronic conditions, the lung lymphatics have a tremendous capacity to augment lymph flow gradually and prevent pulmonary edema. In acute left ventricular insufficiency, however, the pulmonary lymphatics are quickly overwhelmed, precipitating acute alveolar pulmonary edema.

ASSOCIATED CONDITIONS

Hypoxic and Acidotic Vasoconstriction. A decrease in alveolar, but not arterial, oxygen pressure below 70 mm Hg causes a marked contraction of the vascular smooth muscle in the walls of small pulmonary arterioles. This contraction elevates pulmonary arteriolar pressure. At very low alveolar oxygen tension the local blood flow may be abolished.

Low pulmonary arterial blood pH (acidosis) causes vasoconstriction. This effect is augmented by alveolar hypoxia.

Hypoxia at high altitude may cause generalized pulmonary vasoconstriction, a large rise in pulmonary arterial pressure, and acute pulmonary edema with cough and frothy pink sputum. This situation is typically associated with inadequate acclimatization and extreme exertion, such as hiking, jogging, mountain climbing, or skiing at high altitude.

Acute Heart Failure. Heart failure consists of low cardiac output, high pulmonary venous pressure, or both. The early stage of heart failure is typically first manifested as shortness of breath on exertion. In advanced heart failure, symptoms can occur at rest. Left ventricular failure causes increased left atrial pressure, which in turn causes increased pulmonary venous pressure. When pulmonary venous pressure is sufficiently high, it causes pulmonary interstitial edema and eventually pulmonary alveolar edema.

The pulmonary alveolar epithelium is fragile and has minimal tensile strength. The alveolar epithelial membranes rupture, and pink fluid pours into the alveolar space when the interstitial fluid volumes increases by 100 ml, which represents more than 50% of the normal interstitial fluid volume. Even 1 mm Hg of positive pressure in the interstitial fluid space relative to atmospheric pressure may cause immediate rupture of the alveolar epithelium.[9]

A sufficiently abrupt and large increase in pulmonary capillary pressure can forcibly pull apart the delicate gap junction between adjacent endothelial cells. The pulmonary capillaries actually leak very dilute blood into the alveoli through rents in the pulmonary capillary endothelium. Trapped alveolar air and the exudation of blood-tinged fluid leaking from pulmonary capillaries combine to produce pathognomonic frothy pink sputum and dyspnea.

Abrupt Cardiac Decompensation. The most common cause of pulmonary edema in healthy liposuction patients is IV fluid overload. The additional insult from drug-induced cardiac dysrhythmias greatly increases the risk of alveolar pulmonary edema. Rapid systemic absorption of bupivacaine and epinephrine-induced tachycardia have produced ventricular fibrillation with frothy pink sputum and sudden death in at least one liposuction patient. The general anesthetics propofol, halothane, isoflurane, and enflurane are all associated with a significant risk of cardiac dysrhythmias. Mixing excessive IV fluids with general anesthesia is a high-risk recipe for iatrogenic edema.

Mitral Valve Disease. As many as 7% of women have some mitral valve prolapse. Most cases are subclinical and undiagnosed. The more severe forms of mitral valve disease have a high probability of causing pulmonary edema. Both mitral valve regurgitation and mitral stenosis cause excessive left atrial pressure, a marked predisposition to elevate pulmonary venous pressure, and thus edema. Mean left atrial pressure greater than 30 mm Hg can be rapidly fatal. With subacute or chronic elevation of left atrial pressure, the pulmonary lymphatics can greatly increase lymph drainage and compensate for atrial pressures up to 40 mm Hg.

Physiologic compensation for elevated left atrial pressure maintains cardiac output by increasing blood volume. With increased blood volume, however, the functional cardiac reserve decreases. Any abrupt fluid overload may easily precipitate

acute pulmonary edema. Liposuction surgeons must be aware of their patients' preoperative left atrial pressure. They must know the risk of an acute IV fluid overload in a patient who already has excess intravascular fluids from subcutaneous infiltration of tumescent anesthesia.

In humans the normal pulmonary capillary pressure is 7 mm Hg, and plasma osmotic pressure is 28 mm Hg. Canine studies have shown that pulmonary edema appears abruptly as soon as the pulmonary capillary pressure exceeds the plasma colloid osmotic pressure. Extending this finding to humans, a safety factor of 21 mm Hg seems to protect against pulmonary edema. When the pulmonary capillary pressure abruptly exceeds 40 to 50 mm Hg, however, fulminant and rapidly fatal pulmonary edema can ensue.

LETHAL CYCLE

The volume of IV fluid necessary to precipitate acute pulmonary edema is predictable by multifactorial, probabilistic dose-response function. In other words, the volume that might correspond to a median lethal dose (LD_{50}) of IV fluids should be determinable. Similarly, there is a dose of IV fluids that should produce fatal pulmonary edema in 1:1000 patients. Unfortunately, this threshold dose for toxicity is unknown. Because IV fluids are not necessary with the true tumescent technique, it is safer simply to avoid IV fluid infusions.

The patients most susceptible to acute pulmonary edema will likely have multiple predisposing factors, including mitral valve disease (mitral stenosis or regurgitation), drug interactions causing dysrhythmias or acute cardiac decompensation, preexisting cardiopulmonary vascular disease, metabolic or respiratory acidosis, metabolic effects of surgical trauma (e.g., inflammatory mediators), and fat emboli.

The interaction between excessive IV fluids and systemic anesthetic drugs may be the most common predisposing factor to acute liposuction-related pulmonary edema. As emphasized earlier, administration of large IV fluid doses to patients already fluid overloaded from the tumescent infiltration is dangerous. Anesthesiologists should be familiar with the fluid physiology of tumescent anesthesia to prevent serious problems.

Swan-Ganz Studies. Although some anesthesiologists have proposed it to study the intravascular fluid status of tumescent liposuction patients, Swan-Ganz catheterization is too dangerous to be used merely to determine the maximum safe volume of IV fluids. In Orange County, California, for example, four deaths within 6 years resulted from faulty Swan-Ganz catheter placement in patients with cardiac disease.[10] Since many more liposuction surgeries are performed than Swan-Ganz catheterizations, the risk of catheter placement is much greater than that of liposuction.

SUMMARY

The tumescent liposuction of less than 4 L of supranatant fat and less than 3% of body weight does not require IV fluid supplementation. By the time the surgeon has done so much liposuction that the patient requires IV fluids, the amount of liposuction is excessive, by definition. With true tumescent liposuction, no rationale exists for giving IV fluid supplementation.

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CHAPTER 10

Thrombosis and Embolism

Pulmonary embolism (PE) is probably the leading cause of death associated with liposuction. It occurs most frequently with general anesthesia or heavy intravenous (IV) sedation; unnecessary perioperative IV fluid infusion, causing hemodilution; and excessive liposuction.

Thrombosis is a manifestation of a complex series of events leading to vascular inflammation. Recent advances in understanding the pathogenesis of thrombosis have identified common triggering events, including surgery (especially with systemic anesthesia), infection, pregnancy, and malignancy. A relationship may exist between the risk of thromboembolism and surgical or anesthetic techniques. New information may permit the liposuction surgeon to identify more easily and thus avoid patients at increased risk (Box 10-1).

Pulmonary thromboembolism is a major cause of death in surgery patients under general anesthesia for more than 30 minutes.[1] A large prospective multicenter study found a 1% incidence of fatal PE among all general surgery patients.[2] Another study of postoperative surgery patients found an 18% incidence of abnormal lung scans, consistent with PE.[3]

The major risk factors for postoperative PE include a history of previous deep venous thrombosis (DVT), trauma, obesity, age greater than 40 years, prolonged immobility, varicose veins, and inherited molecular defects in several hemostatic components. These factors are often found in liposuction patients.

DEEP VENOUS THROMBOSIS

Since fatal pulmonary emboli are usually the direct result of a DVT, researchers have focused on assessing its incidence. The accuracy of detecting a DVT depends on the diagnostic methodology. Ascending venography is the gold standard, but it is time consuming, invasive, and expensive. Radiolabeled fibrinogen uptake testing and duplex ultrasonography are less accurate.

Excessive liposuction appears to be associated with an increased risk of DVT and fatal pulmonary emboli. A *pulmonary embolus* is a plug of material, such as a thrombus or fat embolus, that is transported by the bloodstream from a distant site to the lungs.

An acute massive pulmonary embolus or *embolon* (large embolus) can cause sudden death in the postoperative period. The typical scenario involves an asymptomatic postoperative patient who, on arising from bed, suddenly collapses and dies. The actual pathophysiology is complex.[4] The sudden dislodgment of a large, distal venous thrombus and its transportation through the right ventricle into the pulmonary artery can cause a complex pulmonary artery occlusion, tremendous right ventricular strain, autonomic reflex-mediated dysrhythmia, and cardiac arrest. A massive shower of multiple, small pulmonary emboli may have the same effect by initiating widespread mechanical endovascular irritation and precipitating reflex pulmonary arteriolar vasospasm.

Without perioperative antithrombotic prophylaxis, at least 30 cases of DVT diagnosed by phlebography can be expected among 100 patients who have had general surgical procedures of moderate severity.[5] Intensive care unit patients have a high rate of DVT.[6] Also, patients with DVT have such a high incidence (40%) of asymptomatic PE that some authors believe DVT and PE should be considered a single disease.[7,8] DVT of the lower extremity is responsible for almost 90% of all pulmonary emboli.[9] Other sources of PE are the deep pelvic vein, renal veins, and inferior vena cava.

Among hospitalized patients with various causes of death, 64% of consecutive autopsies found evidence of subclinical PE.[10] Another autopsy study found DVT in 65% of fatally injured trauma patients, and PE was the cause of death in 20%.[11] Venous thromboembolism is a common complication in patients with major trauma. DVT in the lower extremities was found in 201 (58%) of 349 trauma patients with adequate venographic studies; before venogra-

BOX 10-1 RISKS OF THROMBOEMBOLISM AND POSSIBLE CONTRAINDICATIONS FOR LIPOSUCTION

Thrombophilia
Autoimmune disorders
Malignancies
Chronic inflammatory diseases
Congestive heart failure
Atrial fibrillation
Nephrotic syndrome

BOX 10-2 RISK FACTORS FOR LIPOSUCTION-ASSOCIATED THROMBOEMBOLISM

Prolonged surgery under systemic anesthesia
Multiple concomitant cosmetic surgical procedures
Circumferential thigh liposuction
Massive trauma of excessive liposuction
Thermal trauma of ultrasonic liposuction
Obesity
Hemodilution (unnecessary IV fluids)
Age: 45 years or older
Smoking
Large varicose veins
Therapeutic estrogen (≥ 35 µg/day)
Immobilization (e.g., from paraplegia, polio)

phy, only three patients with DVT had clinical symptoms suggesting DVT.[12]

When properly diagnosed and treated, PE is an uncommon cause of death,[13,14] but the diagnosis of DVT and PE is often missed. An untreated DVT in a thigh has at least a 50% chance of leading to PE and 10% for a fatal PE. The long-term morbidity of the postphlebitic syndrome is valvular incompetence, collateral reflux, chronic venous hypertension, stasis dermatitis, and ulcerations. Without prophylaxis, the frequency of fatal PE has been estimated at 0.1% to 0.8%.[2,15,16] The safest approach in cosmetic surgical patients is to minimize the risks (Box 10-2).

SYSTEMIC ANESTHESIA

In this discussion, systemic anesthesia includes inhalational as well as IV sedation-analgesia that precludes a patient from ambulating to the bathroom to urinate. When all major surgeries required systemic anesthesia, the question of whether or not it was a predisposing factor for DVT and fatal PE was merely of academic interest. With the advent of the tumes-

cent technique for liposuction totally by local anesthesia, however, the question has become more important.

Within the past 15 years, clinicians have begun considering the possible association of systemic anesthesia with DVT, PE, and fatal PE. Because of the relatively high incidence of DVT and PE associated with surgery for hip fractures and elective hip replacement surgery, some of the most revealing studies appear in the orthopedic literature.

The mechanism by which systemic anesthesia predisposes to DVT is not precisely known. Venostasis and impaired venous flow rates have been suggested as mechanisms for precipitating DVT. General anesthesia decreases lower extremity blood flow rates by approximately 50%.[17,18] Blood hypercoagulability is significantly greater with general anesthesia than with epidural anesthesia in orthopedic surgery that uses tourniquets.[19] General anesthesia for cesarean section is associated with accelerated coagulation compared with spinal anesthesia.[20] Blood hypercoagulability is thought to predispose to thromboembolism.[21,22] Moderate surgical trauma with blood loss greater than 300 ml can activate thrombin generation with hypercoagulability and fibrinolysis.[23]

The incidence of pulmonary thromboembolism after total hip replacement with general anesthesia or regional anesthesia (epidural block) was assessed prospectively with random allocation of patients in two studies ($n = 60$ and $n = 94$ patients, respectively).[24,25] In both studies, using perfusion lung scans, the incidence of PE was 33% with general and 10% with regional anesthesia.

The incidence of DVT after total hip replacement, diagnosed by both venography and fibrinogen uptake, was 53% ($n = 47$) under general anesthesia and 29% ($n = 38$) under subarachnoid block.[26] Another study of DVT using venography found an incidence of 76% with systemic anesthesia ($n = 21$) and 40% with subarachnoid block ($n = 20$).[27]

A revealing study of total knee replacement found that the incidence of DVT diagnosed by venography was 59% for general anesthesia and 19% for regional anesthesia.[28] Both groups used tourniquets for hemostasis, and both groups had prolonged exposure to local anesthesia through low-dose bupivacaine for analgesia.

Among liposuction patients, systemic anesthesia is the greatest risk factor for DVT and PE. I reviewed a number of cases of liposuction-associated fatal PE, and each was associated with systemic anesthesia. Any surgical procedure requiring 30 minutes or more of general anesthesia significantly increases the risk of pulmonary thromboembolism.[29]

Local anesthesia itself may protect against DVT. In elective hip replacement surgery by general anesthesia, when a lidocaine IV infusion was continued for 6 days postoperatively, the incidence of DVT was 14%, whereas control patients had a 78% incidence.[30] Local anesthetics have been shown to inhibit platelet aggregation[31] and platelet adhesion.[32] Prolonged presence of low-concentration lidocaine with tumescent liposuction could offer an extra margin of safety compared with the tumescent technique using epinephrine but without lidocaine.

SURGICAL COMPLICATIONS

HEMODILUTION

Hemodilution may act as an acquired form of thrombophilia. One study has shown that hemodilution by an IV infusion of either lactated Ringer's (LR) solution or normal saline (NS) during surgery may predispose to DVT.[33] Among patients given only minimal oral fluids after surgery, only 7% developed DVT; in contrast, 30% of patients who had an IV infusion of crystalloids developed a DVT.

Hemodilution can cause hypercoagulability.[34,35] In vitro a 30% hemodilution with NS significantly increases coagulability.[36] Hemodilution may produce abnormal hemostasis before any compromise of tissue oxygen delivery.[37]

HYPOTHERMIA

Hypothermia is known to predispose to a hypercoagulable state. The delicate biochemical reactions that maintain procoagulant and anticoagulant homeostasis are altered, shifting reaction toward the procoagulant process.

Hypothermia associated with general anesthesia or chilled solutions of tumescent anesthesia may predispose to a consumptive coagulopathy. Hypothetically, the hypothermia resulting from general anesthesia might increase the risk of DVT.

TRAUMA

Trauma is a known predisposing factor for thromboembolism.

Multiple Concomitant Procedures. Numerous cases of liposuction-related thromboembolism and death have been reported. Exposing a patient to the cumulative trauma and physiologic stress of multiple surgical procedures performed on a single day may increase the risk of thromboembolism. Liposuction surgeons must be aware of the risks associated with exposure to prolonged and extensive surgical trauma and with prolonged exposure to systemic anesthesia.

Serial liposuction is the practice of dividing an extensive amount of liposuction into two or more separate surgical procedures that are performed sequentially and several weeks apart. Small, individual liposuction procedures performed serially is safer than one traumatic, large-volume liposuction. Similarly, liposuction usually should not be combined with other, unrelated cosmetic surgical procedures.

Circumferential Thigh Liposuction. In my experience, every case of DVT or PE after liposuction has been associated with concomitant liposuction of the inner and outer thighs or with abdominoplasty.

Circumferential liposuction of the thigh with a single, extensive surgical procedure causes prolonged focal lymphedema and distal pedal edema. When this liposuction is separated into two or more serial procedures, the incidence of distal edema is dramatically reduced. The risk of DVT might be reduced by avoiding circumferential thigh liposuction, with its associated pedal edema and lower extremity venostasis.

Excessive Liposuction. Venous thromboembolism is a common complication of major trauma.[38-40] The number of areas treated by liposuction and the volume of fat removed are linearly related to the degree of surgical trauma from liposuction, duration of exposure to general anesthesia, and duration of postoperative immobilization. These in turn are directly related to the risk of postoperative DVT, PE, and fatal PE.[41,42]

Surgeons who use systemic anesthesia for liposuction are faced with a difficult dilemma: is it more dangerous to subject a patient to one aggressive total-body liposuction or to multiple exposures of general anesthesia? No scientific studies support either decision. The dilemma can be avoided by doing liposuction totally by local anesthesia.

Thermal Trauma. Hip surgery is associated with the greatest incidence of DVT and subsequent PE. General anesthesia, direct trauma to veins, extensive exposure of capillary endothelium with local activation of the coagulation cascade, and thermal injury from the heat of polymerizing acrylic may precipitate proximal venous thrombosis.

Extensive liposuction surgery exposes the patient to similar insults. The thermal trauma associated with internal ultrasound-assisted liposuction may increase the risk of DVT and PE. Ultrasonic liposuction machines generate heat and increase the temperature of the subcutaneous tumescent fluid.

RELATIVE RISKS

Pregnancy. Pregnancy is a well-recognized risk factor for thromboembolism. The relative risk appears to return to normal 4 weeks after the woman gives birth.

Oral Contraceptives and Estrogens. Current pharmacoepidemiologic data indicate no clinically significant increased risk of thromboembolism with an estrogen dose of less than 35 µg/day. Therefore women can continue taking low-dose estrogen oral contraceptives (OCs) before liposuction.

Also at present, data are insufficient to support the discontinuation of postmenopausal estrogen replacement therapy before liposuction surgery. The doses of estrogens used for treating menopausal symptoms are typically less than the already low doses used for OCs. Most liposuction surgeons do not discontinue low-dose estrogen therapy before liposuction. If a patient has a personal or family history of DVT or thromboembolism, however, the surgeon might consider discontinuing estrogens 4 weeks before surgery.

The first OCs in the 1960s, which contained 150 µg of estrogen, and those of the early 1970s with 80 to 100 µg of

estrogen were associated with an increased risk of thromboembolic disease.[43-45] Low-dose OCs such as Triphasil contain 30 to 35 μg of estrogen, however, and are now recognized as posing little increased risk for thromboembolism. An odds ratio for stroke of 1.18 has been estimated for users of low-dose oral OCs.[46] Studies of subarachnoid hemorrhage have found odds ratios of 0.89,[47] 1.5,[48] and of 1.1 for fatal subarachnoid hemorrhage in low-dose OC users.[49] Because stroke is more accurately diagnosed than DVT, epidemiologic data on strokes provide useful clinical information regarding the risk of DVT and PE with OCs.

The U.S. Food and Drug Administration (FDA) requires manufacturers to state that OC users have a twofold to sixfold risk of developing thromboembolic disorders and that OCs should be discontinued 4 weeks before and 2 weeks after elective surgery associated with thromboembolism. Based on the new data for low-dose OCs, the FDA information appears to be outdated.

Smoking. Smoking is believed to increase the risk for thromboembolism. Liposuction patients should be encouraged to discontinue smoking several weeks before surgery. Informed consent should include a warning that cigarette smoking increases the risk of blood clots in the legs, lungs, and brain.

Immobility. The patient should be encouraged to ambulate frequently before and after liposuction, especially during long trips in an airplane or automobile.

THROMBOPHILIA

The term *thrombophilia* refers to a group of disorders characterized by an inherited or acquired biochemical, molecular defect that predisposes to thrombosis. Thrombophilia should be suspected in any patient with a personal or family history of an unusual thrombosis, such as thrombosis at an early age (45 years or younger), thrombosis in an unusual site (cerebral, mesenteric, axillary), or multiple recurrent thromboses (Box 10-3).

These patients may or may not have the other well-recognized risk factors for thromboembolic disease (see Box 10-1). A number of thrombophilias have recently been identified, and new laboratory tests are available in specialized laboratories that can identify specific molecular defects.

The common causes of thrombophilia and the relative prevalence among thrombosis patients include antithrombin III deficiency (2% to 10%); protein C deficiency (2% to 10%); protein S deficiency (2% to 10%); the combined group of patients with either homocystinemia, antiphospholipid syndrome, occult malignancy, or heparin-induced thrombosis (5%); and activated protein C resistance (40%). The remaining 40% result from unknown causes. Preclinical cancer among middle-age patients is a risk factor for PE.[50]

When thrombosis occurs in a patient with a familial form of thrombophilia, the physician should endeavor to identify

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BOX 10-3 INDICATIONS FOR PRELIPOSUCTION LABORATORY TESTS FOR THROMBOSIS/ THROMBOEMBOLISM RISKS

Personal history
Family history
    Early age at diagnosis: 45 years or younger
    Unusual site(s): cerebral, mesenteric, or central retinal vein
    Recurrent thromboembolic events
Obesity
Immobilization
Oral contraceptives
Pregnancy

BOX 10-4 PREVALENCE OF GENETIC CAUSES FOR THROMBOPHILIA

Protein C deficiency (2%-10%)
Protein S deficiency (2%-10%)
Antithrombin III deficiency (2%-10%)
Activated protein C resistance (20%-50%)
Prothrombin (factor II) mutation, 20210A allele (1%-4%)
Homocystinemia (≤1%)
Antiphospholipid antibody syndrome (≤1%)

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and reduce or eliminate the associated risk factors before surgery.

Thrombophilia is not an absolute contraindication for liposuction. Prospective patients with thrombophilia should be identified and provided with information that will permit an informed decision about the risks of liposuction. Liposuction risks can be minimized by minimizing the extent (amount of body surface area) and the degree (volume of supranatant fat) of liposuction. Similarly, concomitant cosmetic procedures, the use of systemic anesthesia, postoperative immobility, and postoperative inflammation should be avoided or minimized.

As mentioned, a number of genetic causes of thrombophilia have recently been identified (Box 10-4). Other identifiable hypercoagulable states are now recognized as surgical risks, including the antiphospholipid syndrome (lupus anticoagulant syndrome, anticardiolipin antibody syndrome[51]), and a few rare forms of dysfibrinogenemia.

Understanding the clinical indications for preoperative laboratory tests to screen for heritable thrombophilia requires up to date knowledge (Box 10-5). The annual incidence of recurrent venous thromboembolism is highest during the first years after a first episode, then declines over time.[52] Thrombophilia interacts with predisposing environmental factors, resulting in thrombosis. A predisposing factor

was observed in 84% of patients with factor V Leiden (Arg506Gln) mutation who developed thromboembolism.[53]

ANTITHROMBIN III DEFICIENCY

Antithrombin III (ATIII) inhibits thrombin and activated factors IXa and Xa. ATIII is a natural anticoagulant glycoprotein that is greatly enhanced by heparin. This is the mechanism for the use of heparin in antithrombotic therapy.

Hereditary ATIII deficiency is inherited as an autosomal dominant trait associated with either a quantitative or a qualitative deficiency. Acquired ATIII deficiency can result from decreased synthesis and increased loss of protein. Acquired ATIII deficiency is associated with hepatic disease, disseminated intravascular coagulation (DIC), medications (L-asparaginase, heparin, estrogens), nephrotic syndrome, hemodilution (unnecessary IV fluids), and malnutrition.

Patients with ATIII deficiency have evidence of continuous factor Xa generation and activation of prothrombin in vivo, leading to high plasma concentrations of prothrombin fragment 1.2. Because of other antithrombotic mechanisms, such as protein C/protein S pathway, overt thrombosis is not as common with ATIII deficiency. When these pathways are suppressed by surgery, systemic anesthesia, or sepsis, however, sufficient thrombin is generated to cause thrombosis.

Women with an inherited ATIII deficiency, deficiencies of proteins C or S, or activated protein C (APC) resistance have an increased risk of pregnancy-associated venous thrombosis and an increased risk of fetal loss. This risk appears to be greatest for some types of ATIII deficiency.[54]

PROTEINS C AND S

Protein C and protein S are produced by the liver. They are the principal molecules of the major anticoagulant system involved in maintaining the natural homeostatic balance between procoagulants and anticoagulants. Both protein C and protein S require vitamin-K–dependent posttranslational modification to function.

Protein C circulates in an inactive form. During the coagulation process, prothrombin (factor II) is converted to thrombin, which then interacts with an endothelial surface protein known as *thrombomodulin*. On forming the thrombin-thrombomodulin complex, the substrate specificity of thrombin changes from fibrin to protein C, resulting in the conversion of protein C to APC.

Protein S, when located on phospholipid surfaces, is a cofactor for APC. The APC–protein S complex inactivates coagulation factors Va and VIIIa by proteolytic cleavage, thus attenuating the clotting process.

Patients who are heterozygous for protein C deficiency or protein S deficiency have an increased risk of recurrent venous thrombosis at a young age (less than 40). Patients who are homozygous for protein C or S deficiency have neonatal purpura fulminans, manifested by generalized microvascular thrombosis.

These deficiencies may be either *quantitative* (decreased amount of normally functioning protein) or *qualitative* (normal amounts of dysfunctional protein). A genetic mutation can cause a qualititative protein deficiency. Vitamin K deficiency causes dysfunctional proteins C and S; thus preoperative vitamin K might prevent bleeding diatheses and help maintain anticoagulant-coagulant homeostasis.

These deficiencies may be either an autosomal dominant genetic trait or an acquired disorder associated with hepatic disease, surgery, inflammation, sepsis, and possibly estrogens. Familial protein S deficiency has been reported in association with decreased concentrations of free (unbound) protein S.[55] Combined protein C and protein S deficiency increases the risk for thrombophilia.[56]

Acquired Deficiencies. An acquired deficiency of protein C or protein S can lead to an increased production of thrombin and thus an increased risk of thrombosis and thromboembolism.

The protein C pathway is affected by inflammation. Inflammation causes a decrease in the concentration of free protein S. Similar to drugs that are highly protein bound, only the free fraction of the total circulating protein is available to participate in biochemical reactions. Determination of protein S activity and antigens allows separation of qualitative and quantitative protein deficiencies.[57]

Pregnancy is another example of acquired decrease in the concentrations of protein C and protein S. Pregnancy reduces

protein S by 40% to 50% of normal levels, but it is not certain whether this lowered protein S concentration is responsible for the increased risk of thromboembolism in pregnant women.[58]

A disease association has been reported in a patient with acquired immunodeficiency syndrome (AIDS), protein S deficiency, and intracranial thrombosis.[59]

The fraction of protein S bound to tissue or to circulating molecules is essentially a reservoir for protein S, which becomes available as the free fraction is consumed. A fraction of the circulating protein S is bound to circulating *C4b binding protein* (C4bBP), where C4b is a regulatory protein of the complement system. Increased inflammation augments the concentration of C4bBP, which binds a greater proportion of protein S and thus reduces the active unbound (free) fraction.

Sepsis has been reported in association with an acquired decrease in protein C and protein S in an 11-year-old girl heterozygous for the Arg506Gln mutation of factor Va (APC resistance).[60] Endotoxins (sepsis) and cytokines (inflammation) inhibit the expression of protein C receptors on activated monocytes and endothelial cell surfaces, stimulating the expression of coagulation tissue factors. This shifts the biochemical equilibrium toward production of more thrombin.

Another study found that three of five children with steroid-resistant nephrotic syndrome had an acquired form of protein S deficiency with reduced free protein S in plasma.[61]

Since inflammation or anesthesia induces an acquired state of thrombophilia, the risk of surgical thromboembolism might be reduced by modifying surgical techniques to decrease perioperative inflammation and exposure to offending drugs.

Certain surgical practices might help induce a clinically significant deficiency of important procoagulant molecules. Likely factors include some forms of general or systemic anesthesia, excessive surgical trauma, hemodilution from excessive IV fluids, and postoperative inflammation. In particular, postliposuction inflammation from ultrasonic thermal tissue damage, as well as prolonged subcutaneous accumulation of blood-tinged tumescent fluid, might predispose to thrombosis.

ACTIVATED PROTEIN C RESISTANCE (FACTOR V LEIDEN)

APC resistance is either inherited (factor V Leiden) or acquired. In the absence of factor V Leiden, APC resistance has been observed in pregnancy, in patients taking OCs, in the presence of antiphospholipid antibodies, and in patients with ischemic stroke. A recent report suggests evidence for an acquired antibody against APC. Thus anti-APC antibodies may be a potential cause of thrombosis.[62]

High-density lipoprotein (HDL) enhances the anticoagulant protein C pathway in vitro, which may explain one of HDL's beneficial effects.[63] Also, heparin and APC might act synergistically to inactivate factor V.[64]

APC resistance was described as a predisposing factor for thromboembolism in 1993.[65] This disorder might account for a significant proportion of spontaneous DVT and thromboembolic disease in young, healthy, cosmetic surgical patients. APC resistance is associated with a threefold to sevenfold increase in the risk for DVT, and venous thrombosis occurs in 40% of patients with APC resistance.

Most patients with APC resistance have an abnormality of coagulation factor V (Arg506Gln) that causes factor Va to resist degradation by APC. Genetic analysis of 15 patients with APC resistance revealed nine (60%) who were positive for the Arg506Gln mutation affecting factor V.[66] The genetic mutation Arg506Gln is a nucleotide substitution in which arginine (Arg) is replaced by glycine (Gln) at position 506 of the gene encoding for coagulation factor Va.

The defective factor Va that results from Arg506Gln is referred to as *factor V Leiden*, after the city where it was discovered. Laboratory evaluation of factor V Leiden is commercially available. The risk of thromboembolic events is significantly higher in carriers of factor V Leiden than in patients without this abnormality.[67] This mutation increases the risk of DVT by a factor of 10 in heterozygotes and 50 in homozygotes. Approximately 10% of patients with DVT and APC resistance do not have the factor V Leiden (Arg506Gln) mutation.

The cumulative risk of recurrent thrombosis in patients with APC resistance is 71% without long-term anticoagulation therapy. APC resistance affects 5% of the general population and 40% of Caucasians who have a familial form of thrombosis. Other ethnic groups (e.g., Africans, Asians) have a much lower incidence of the Arg506Gln mutation. APC resistance is the most prevalent abnormality of inherited thrombophilia.[68]

The prevalence of factor V Leiden in the general European population is estimated to be 5% to 6%.[69] This mutation is significantly more frequent in patients with chronic venous insufficiency and venous leg ulcers.[70]

PROTHROMBIN

A novel sequence variation in the 3'-untranslated region of the prothrombin (factor II) gene, a G-to-A transition at nucleotide position 20210, has recently been identified as a risk factor for familial thrombophilia with DVT and PE. It is found in approximately 1% to 4% of subjects in Western Europe.[71] An increased frequency of nucleotide 20210 G→A mutation is associated with factor V Leiden.[72,73] The risk of recurrent DVT is similar among carriers of factor V Leiden and patients without this mutation. Carriers of both factor V Leiden and the G20210A prothrombin mutation have an increased risk of recurrent DVT after a first episode and are candidates for lifelong anticoagulation.[74]

HYPERHOMOCYSTINEMIA

Heterozygous hyperhomocystinemia is a significant independent risk factor for venous occlusive disease, in addition

to its better known reputation as a predisposing factor for arterial disease.[75] Patients with hyperhomocystinemia (95th percentile or greater) have twice the risk of DVT as normal controls.

Hyperhomocystinemia is caused either by genetic mutations in genes encoding for the enzymes for homocystine metabolism (e.g., cystathionine beta-synthetase, methylenetetrahydrofolate reductase) or by nutritional factors (e.g., folate deficiency).

The free sulfhydryl group on homocystine makes it a highly reactive amino acid that may be directly toxic to vascular endothelium. Therefore homocystine may inhibit thrombomodulin expression, inhibit protein C activation, suppress heparin sulfate expression, and impair expression of nitric oxide.

ANTIPHOSPHOLIPID ANTIBODIES

The antiphospholipid antibody syndrome affects a heterogeneous group of patients with thrombosis, recurrent abortion, or thrombocytopenia who have antiphospholipid antibodies that are either lupus anticoagulant (LA) or anticardiolipin (ACL) antibodies. Cell membranes contain procoagulant anionic phospholipids that are important in phospholipid-dependent coagulation reactions.

The *annexins* are a family of proteins described in 1990 and characterized by repetitive homologous domains consisting of sequences of about 70 amino acids. The annexins share the property of binding calcium and phospholipids. Annexin V forms a protective shield over the procoagulant anionic phospholipids and inhibits phospholipid-dependent coagulation reactions. Patients with antiphospholipid antibody syndrome have immunoglobulin G (IgG) antibodies against phospholipid-binding protein annexin V.[76] Without adequate functioning annexin V to shield the phospholipids on cell membranes, the exposed phospholipids are available to accelerate coagulation reactions. Thus the annexins may have a unique role in regulating coagulation.[77]

Antiphospholipid antibodies, which can be detected by coagulation tests and immunoassay methods, are considered an acquired risk factor for thromboembolism.

CASE STUDIES

Recently I had a rather obese patient who was hospitalized overnight for diagnostic workup of a superficial thrombophlebitis of the distal greater saphenous vein after liposuction of the hips and outer thighs. The patient was treated with aspirin and discharged home. On questioning, this patient admittted having some pain in her leg for more than a week before surgery, but she did not think it was sufficiently bothersome to mention it to me.

As with this case example, Case Reports 10-1 to 10-4 emphasize the need for careful patient selection and monitoring during liposuction to avoid potential risk factors for DVT, PE, and fatal PE.

FAT EMBOLISM (EMBOLUS) SYNDROME

The fat embolus syndrome is a poorly understood clinical entity that might have clinical relevance for the liposuction surgeon. Fat emboli have been reported in association with inhalational anesthesia.[78] There are no reports of fat embolism syndrome when liposuction was the only surgical procedure; reports of the syndrome occurring with liposuction are usually associated with a concomitant abdominoplasty. To my knowledge, no case of fat embolism has occurred with tumescent liposuction totally by local anesthesia.

CASE REPORT 10-1 Fatal Pulmonary Embolism

A female in her early 20s who was taking Triphasil OCs had liposuction of her outer thighs, inner thighs, and inner knees. Local anesthesia consisted of 1200 mg of lidocaine and 1.2 mg of epinephrine in 750 ml of saline. Using a 5-mm cannula with 1.5- to 2-cm incisions, the total volume of supranatant fat was 300 ml, with 20 ml of blood-tinged infranatant. Incision sites were sutured and high-compression postoperative garments applied. The procedure was performed in the surgeon's office on a Sunday, with only a licensed practical nurse as an assistant. Postoperative medications included erythromycin and Percocet.

The morning after surgery the patient felt dizzy, fainted, and was transported by ambulance to a hospital. Alert and oriented, she complained of nausea and profound weakness. Physical examination was remarkable only for a blood pressure of 82/60. Preliminary diagnosis was syncope and weakness, probably from medication. After 5 hours of observation, while being discharged, the patient had a seizure, loss of consciousness, cardiac arrest, and was pronounced dead after attempted cardiac resuscitation. The coroner listed the cause of death as bilateral PE of unknown origin.

Discussion. OCs are less likely to be associated with DVT than concurrent liposuction of the outer and inner thighs. Important information in this case probably was not reported, since only 750 ml of anesthetic fluid was infiltrated in the course of aspirating 300 ml of fat. Such a small volume of anesthetic solution to anesthetize such a large area indicates that this was not the tumescent technique. Also, a 5-mm cannula is much too large and painful for tumescent liposuction by local anesthesia.

The surgeon's assistant should be at least a registered nurse. Both surgeon and nurse should have the equivalent of Advanced Cardiac Life Support (ACLS) certification.

CASE REPORT 10-2   Concomitant Surgical Procedures

A 42-year-old, healthy, athletic female with four children had a Marshal-Marchetti-Krantz (MMK) bladder suspension procedure under general anesthesia performed by a gynecologist. While she was still under general anesthesia, a plastic surgeon performed liposuction of thighs and abdomen and then an abdominoplasty. The patient did receive IV fluid infusion, but the degree of hemodilution was not documented.

Patients typically ambulate immediately after an MMK procedure. This patient remained confined to bed, however, because of pain associated with abdominoplasty. On the third postoperative day the patient collapsed and died suddenly. Autopsy showed a massive PE.

Discussion.   PE is rare with the MMK procedure and with liposuction by local anesthesia. Thromboembolism is not rare after an abdominoplasty. Liposuction by the superwet technique with general anesthesia, accompanied by multiple procedures, increases the risk of DVT and PE. The safest course is first to do liposuction totally by local anesthesia, postponing any decision on abdominoplasty until the patient has evaluated the cosmetic results of the abdominal liposuction. Two or more months after abdominal liposuction, an abdominoplasty with rectus muscle plication can be accomplished totally by tumescent local anesthesia. These patients have minimal postoperative pain, can ambulate immediately, and can return to work in a few days.

CASE REPORT 10-3   General Anesthesia and Thromboembolism

A 27-year-old female had liposuction of the abdomen and a breast augmentation during 2½ hours of general anesthesia. Using the superwet technique, the surgeon infiltrated 1000 ml of subcutaneous lactated Ringer's solution containing 1 mg/L of epinephrine, infused 2600 ml of IV Plasmalite solution, and removed 2000 ml of supranatant fat, plus 500 ml of infranatant blood-tinged fluid.

Approximately 23 hours after surgery the patient collapsed and died at home. Autopsy revealed a large pulmonary embolus; her heart valves were unremarkable. The patient was taking OCs, but their estrogen content was not known. She did not smoke and had no family history of DVT.

Discussion.   Although the specific cause of this case of fatal PE is not known, the episode illustrates the association between prolonged general anesthesia and pulmonary embolism. Although an association exists between OCs and pulmonary thromboembolism, death occurred less than 24 hours after surgery, indicating some association with general anesthesia and surgery.

CASE REPORT 10-4   Popliteal Phlebitis

Two patients developed popliteal phlebitis approximately 2 weeks after liposuction of the thigh area. Both were hospitalized, and the diagnosis of thrombophlebitis was made with noninvasive studies. The first patient had a history of phlebitis during pregnancy. She developed a small PE that did not affect her arterial blood gases. The second patient had no personal history of phlebitis, but her mother had required warfarin therapy for phlebitis 20 years earlier. The patient had the flu shortly after tumescent liposuction and remained in bed postoperatively.

Discussion.   Both patients had either a personal history or a family history of DVT.

Fat embolism syndrome is an uncommon clinical entity that consists of pulmonary insufficiency, coagulopathy, neurologic impairment, and clinical evidence of circulating fat globules. The syndrome most often occurs with bone trauma and orthopedic surgery but has also been reported with hemorrhagic pancreatitis, carbon tetrachloride poisoning, extracorporeal circulation, rapid high-altitude decompression, liver trauma, blast concussion, bone marrow transplantation, and closed-chest cardiac massage.

Almost every fracture produces a degree of fat embolism. Only 1% patients with a single fracture develop clinical pulmonary distress, coagulopathy, and neurologic symptoms of fat embolism syndrome, whereas 5% to 10% of patients with pelvic or multiple long bone fractures develop symptoms.[78] Symptoms can develop within 2 hours after the traumatic event but typically are delayed for 1 to 3 days, presenting as respiratory distress, lethargy, confusion, and other symptoms of brain injury. Mortality from fat embolism syndrome is estimated at 10% to 15%.

Unlike the syndrome, the incidence of fat embolism is an extremely common pathologic finding after fatal accidental trauma.[79] The incidence of fat embolism in an autopsy study of 300 accident victims ranged from 80% to 100%, with the higher incidence occurring in patients who survived for 12 hours or more after injury. In other studies the incidence ranged from 26% with single fractures to 44% of patients with multiple fractures.

PATHOPHYSIOLOGY

The source of the fat globules is controversial and not well understood. Several unrelated sources of intravascular lipid globules may exist, and several distinct clinical syndromes may simply be grouped under one name. In trauma victims, fat globules from the marrow of fractured bones may enter the circulation through lacerated vessels. When fat embolism is diagnosed in the absence of trauma or surgery, the fat glob-

ules may result from the coalescence of plasma chylomicrons or a disturbance of plasma lipid chemistry that precipitates liposome-like globules.

The ultimate source of tissue injury is also controversial.[80,81] The theory that physical occlusion of the microvascular circulation is the source of pathologic tissue injury is overly simplistic. Tissue injury and platelet activation probably cause the release of significant circulating inflammatory mediators, including prostaglandins, cytokines, free fatty acids, and tissue lipases. Within limits, fatty acids in the blood are bound to albumin; when trauma or hypermetabolism generates excessive circulating free fatty acids, the carrying capacity of albumin may be exceeded, exposing tissues to a systemic inflammatory response.[82] The ingestion of fat emboli by pulmonary macrophages may release free fatty acids and precipitate an intense inflammatory response.[83]

Patients who have sustained severe trauma are at risk for both DIC and fat embolism syndrome. Although blood coagulation factor XII is activated by saturated fatty acids in vitro, it is not clear if this represents a cause-and-effect relationship in the pathogenesis of DIC associated with fat embolism.[84]

PREVENTION

DEEP VENOUS THROMBOSIS

No evidence indicates that a prophylactic treatment of liposuction patients with low-molecular-weight heparin is safe or effective in preventing DVT. Although such prophylaxis has an intuitive appeal and its benefits appear plausible, routine heparin use in liposuction patients might be more dangerous than no treatment at all. Because of the extensive trauma to subcutaneous capillaries, liposuction cannot be considered analogous to most other surgical procedures where heparin might be used.

The safest means to prevent DVT is to minimize exposure to the greatest risk factors, such as general anesthesia, circumferential thigh liposuction, and too much liposuction.

PULMONARY EMBOLISM

Three important strategies exist to reduce the risk of fatal PE among liposuction patients. One strategy is the early diagnosis of DVT and nonfatal PE, but this is both expensive and ineffective in preventing fatal PE. Another strategy is to identify patients at high risk for postoperative PE and treat prophylactically with subcutaneous low-dose heparin. As noted, however, heparin may be relatively contraindicated in liposuction because of the associated bleeding tendency. The only reasonable approach is prevention.

The most important aspect of prevention is prudent patient selection. Patients at significantly increased risk must be identified. The liposuction surgeon must ask every patient about a personal or family history of blood clots in the legs or

BOX 10-6 PREVENTIVE MEASURES AGAINST POSTLIPOSUCTION THROMBOEMBOLISM

- Reduce postliposuction inflammation.
  Employ open drainage and bimodal compression.
- Avoid general/systemic anesthesia.
  Consider local/tumescent anesthesia.
- Avoid excessive surgical trauma on any one day.
  Avoid treating too many areas.
  Avoid liposuction of excessive volumes of fat.
- Avoid actions that might induce prolonged bed rest.
  Avoid causing excessive postoperative pain.
  Avoid postoperative narcotic analgesics.
  Encourage rapid postoperative ambulation.
- Discontinue high-dose estrogen replacement ($\geq$35 µg/day).
  Be aware of personal/family history, oral contraceptives, and pregnancy.
- Encourage patients to discontinue smoking.

lungs. Patients who have a suspicious history should have a hematologic consultation to identify better the degree of the relative risk.

The next step in prevention is the exercise of prudent surgical decisions. Many risk factors for iatrogenic thromboembolism are not well recognized. It seems prudent to minimize suspected risks for iatrogenic thrombotic disease, such as exposure to general anesthesia or to thermal injury associated with ultrasonic liposuction. Exceedingly large-volume liposuction procedures (too many areas or too much volume) are unnecessarily dangerous; again, sequential liposuctions are safer than a single, huge-volume procedure.

Box 10-6 lists other measures to reduce the risk of thromboembolism.

SUMMARY

If surgeons have concerns about liposuction-related pulmonary emboli, they should learn about the proximal causes. If general anesthesia is a significant cause of DVT and fatal pulmonary emboli, surgeons and patients must be aware of this danger. Surgeons and anesthesiologists who use systemic anesthesia should cooperate with epidemiologists to investigate the hypothesis that general anesthesia increases the risk of fatal pulmonary emboli.

Surgeons should learn how to do liposuction totally by local anesthesia. If liposuction can be accomplished totally by local anesthesia, patients should be informed of the alternative choices for liposuction anesthesia.

Cosmetic surgeons ultimately want to assess all factors that predispose a liposuction patient to DVT. The immediate concern is not DVT, however, but the relative risk for postliposuction fatal PE, with and without general anesthesia.

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CHAPTER 11

Postliposuction Edema

Extracellular postliposuction edema occurs when excessive fluid fills the extracellular space postoperatively. The two factors responsible for extracellular edema are impaired lymphatic drainage and excessive capillary filtration. Lymphedema is distinct from venous capillary edema,[1] and the treatments for these conditions also differ.

Maximum postliposuction edema occurs when egress of subcutaneous fluid is prevented (1) by trapping the maximum amount of bloody fluid within the subcutaneous space and (2) by simultaneously blocking all lymphatic drainage. This situation is produced by closing incisions with sutures, then applying a high degree of external compression to collapse lymphatic capillaries.

In contrast, open drainage with bimodal compression minimizes postliposuction edema. *Open drainage* refers to expedited drainage of blood-tinged anesthetic solution through incisions not closed by sutures. *Bimodal compression* refers to two sequentially applied degrees of postoperative compression: (1) relatively high-grade compression that accelerates the drainage through open incisions and (2) low-grade compression, employed after drainage has ceased, that is mild enough not to collapse the lymphatic capillaries but adequate to increase interstitial hydrostatic pressure.

LYMPHATIC FUNCTION AND LYMPHEDEMA

To facilitate optimal healing after liposuction, the surgeon must have a thorough understanding of the pathophysiology of edema and the relevant vocabulary. The body fluids are solutions consisting of water as the solvent and two types of solutes, crystalloids and colloids (Box 11-1).

IMPAIRED LYMPHATIC DRAINAGE

The surgical effect of liposuction on the lymphatics is unique in two respects. First, liposuction disrupts or destroys most lymphatic capillaries within the targeted adipose tissue. Second, lymphatic damage from liposuction is not permanent; lymphatic capillaries regenerate within a few weeks after being torn asunder by a liposuction cannula. In contrast, lymphatic damage is permanent after surgical lymph node dissection.

Damaged lymphatics are not able to transport excess interstitial fluid back to the blood. Lymphatic insufficiency can cause severe swelling and edema. The persistence of extravasated plasma proteins increases the interstitial fluid osmotic pressure and draws even more fluid out of the capillaries.

The lymphatics are the safety valve that prevents severe edema. The lymphatic system is critical to the homeostasis of interstitial fluid protein concentration, interstitial fluid volume, and interstitial fluid pressure. The lymphatic system controls and compensates for interstitial fluid overflow by returning excess interstitial fluid and protein to the circulation.

Under normal circumstances, 2 to 3 L of lymph fluid containing large molecules is removed each day from the interstitial space and returned to the blood by way of the lymphatics. The lymph fluid that is derived from interstitial fluid has a protein content of about 20 g/L. The removal of protein from the interstitial space is essential; without functioning lymphatics, death would occur in 1 or 2 days.

EXCESSIVE CAPILLARY FILTRATION

Excessive capillary filtration, or fluid shift from the intravascular to the interstitial space, is influenced by (1) increased capillary permeability, (2) decreased plasma colloid osmotic pressure, and (3) increased capillary hydrostatic pressure.

Increased capillary permeability occurs after liposuction as a result of trauma, ischemia, and associated inflammatory mediators (e.g., prostaglandins, histamines). Massive trauma to subcutaneous hematic capillaries allows the leakage of large molecules out of intravascular spaces and into interstitial spaces. The resulting relative increase in interstitial osmotic pressure escalates the osmolar edema.

Decreased plasma colloid osmotic pressure occurs after liposuction as a result of (1) loss of plasma protein through ruptured capillaries, (2) consumption of hemostatic procoagulant proteins, (3) iatrogenic hemodilution with unnecessary intravenous (IV) fluid crystalloids, and (4) possible hemorrhage.

BOX 11-1 PHYSIOLOGY OF SOLUTIONS: DEFINITIONS

crystalloid: Substance capable of being separated from a solution in the form of crystals; distinct from a colloid. Crystalloids in solution can pass easily through semipermeable membranes. Most important physiologic crystalloids are the electrolytes Na^+, K^+, Cl^-, and HCO_3^-.

colloid: Substance characterized by little or no tendency to diffuse through animal membranes or vegetable parchment. Colloids do not readily crystallize, have appearance of glue, and are relatively inert chemically but not very stable. Proteins and large, organic, hydrophilic molecules are examples of colloids. Most important physiologic colloid molecule is albumin.

osmosis: Tendency of fluids, separated by porous septa or membrane, to diffuse and pass through the membrane and mix with each other.

osmotic pressure: Excess pressure that must be applied to a solution to prevent entry of pure solvent when they are separated by a semipermeable membrane, or excess pressure that develops in the solution when osmosis is allowed to occur in such circumstances. Solutions that have identical osmotic pressures are *isotonic solutions*. Numeric unit is the *osmol*, as in osmols (Osm) or milliosmols (mOsm) per liter.

oncotic pressure: Osmotic pressure exerted by a colloid, especially plasma proteins. Starling demonstrated that colloids in a liquid solution or suspension exert a small osmotic pressure. This oncotic pressure fluctuates widely, however, because colloidal molecules or aggregates called *micellae* vary considerably.

mole: Unit of measurement that specifies the number of objects as a multiple of Avogadro's number (6.023×10^{23}). A mole of any particular substance has a mass expressed in grams that is numerically the same as its molecular or atomic weight. For example, a mole of carbon 12 contains 6.023×10^{23} atoms and weighs 12 grams. If each molecule of a solute ionizes into two ions, each of which is osmotically active, 1 mol of solute equals 2 osmols.

molarity (M): Number of moles of solute per liter of solution.

osmolarity: Number of moles of osmotically effective, dissolved particles per liter of solution.

The molarity of a given solution varies in general with temperature. Experiments show that osmotic pressure (π) of a solution is a function of its molarity: $\pi = rMT$, where r is the gas law constant, M is the molarity of the solution (i.e., number of moles of solute per liter of solution), and T is Kelvin temperature.

molality (m): Number of moles of solute per kilogram of solvent.

osmolality: Number of moles of osmotically effective, dissolved particles per kilogram of solvent.

It is easy to prepare a solution of given molality by accurate weighing procedures. When one mole of any substance is dissolved in a kilogram of water, the solution produced freezes at $-1.850°$ C. From this, osmolality of a sample of serum or tumescent fluid can be determined. Normal subjects have an initial serum osmolality between 273 and 293 mOsm/kg of water.

Osmolarity determines the osmotic pressure of a solution. Osmolality is easily measured by freezing point depression. When solubility is very small, molarity and molality of the solution are approximately the same.

Increased capillary hydrostatic pressure occurs after liposuction as a result of general anesthesia and secondary immobilization of limbs, with loss of sympathetic vascular tone. Acute renal failure, as seen in patients with excessive blood loss before the advent of tumescent liposuction, causes kidney retention of salt and water.

Other causes of increased capillary filtration must be included in the differential diagnosis of edema (Box 11-2). Causes of increased capillary permeability include bacterial infections and vitamin C deficiency. Causes of decreased plasma protein and plasma colloid osmotic pressure include proteinuria, liver disease, and serious malnutrition. Causes of increased capillary pressure include excessive salt retention by the kidneys, as in chronic renal failure and mineralocorticoid excess (Cushing syndrome); high venous pressure, as in heart failure, muscle paralysis, and failure of venous valves; and decreased arteriolar resistance, as from hyperthermia or vasodilator drugs.

LYMPHEDEMA

Lymphedema is edema caused by inadequate lymphatic function resulting from agenesis, destruction, or obstruction of lymph vessels or lymph nodes. These causes include *primary* lymphedema from developmental dysgenesis (impaired development, idiopathic obliteration of the lymphatics) and *secondary* lymphedema from acquired physical destruction (surgery, radiation, infection) or obstruction (malignancy, parasitic infection). Postliposuction lymphedema is unique in that it usually resolves spontaneously with time, typically within 2 to 6 months. The more common causes of lymphedema are chronic and usually not self-limited.

On a molecular level, lymphedema is the result of a failure of the lymphatics to remove large-molecular-weight proteins from the interstitial space. Whereas both hematic and lymphatic capillaries reabsorb interstitial water, the lymphatic capillaries are the only route for absorbing proteins from interstitial tissue. No other route is available for the removal of excessive interstitial fluid proteins. The excess proteins simply accumulate indefinitely, along with a proportionate increase in osmotically attracted interstitial water.

The lymphatic capillaries throughout the adipose tissue undergo damage from cannulas. Lymph capillary injury is an inevitable consequence of liposuction, but the extent and the duration of liposuction lymphedema can be significantly reduced by rational postoperative care. Early and aggressive efforts to expel as much blood-tinged anesthetic fluid as possi-

EXCESSIVE CAPILLARY FILTRATION
A. Increased capillary hydrostatic pressure caused by in-
   creased venous pressure
   1. Congestive heart failure (CHF)
   2. Prolonged dependency
   3. Valvular venous insufficiency
   4. Arteriovenous fistula
   5. Venous obstruction
      a. Extrinsic: constricting band, tumor
      b. Intrinsic: thrombosis, mass
B. Increased capillary permeability
   1. Inflammation: bacterial toxins, allergic reactions
   2. Physical injury: trauma, burns, freezing, radiation
   3. Ischemia
   4. Physiologic stimuli
   5. Chemical
      a. Exogenous poisons or drugs
      b. Endogenous electrolyte abnormalities
C. Decreased plasma colloid osmotic pressure in capillary;
   decreased reabsorption of interstitial fluid
   1. Hemodilution with excess IV fluids
   2. Protein-losing disease nephropathy, gastrointestinal
      enteropathy
   3. Protein loss from skin burn
   4. Malnutrition with hypoproteinemia
   5. Hemorrhagic plasma protein loss
   6. Hypoproteinemia of cirrhosis
D. Increased osmotic pressure in interstitial fluid
   1. Excessive IV saline
   2. Lymphatic obstruction with accumulation of proteins
   3. Increased capillary permeability, allowing protein
      leak
   4. Salt retention response to stress, hypertension, CHF, or
      renal disease

LYMPHEDEMA
A. Primary: agenesis/dysgenesis
   1. Impaired development
   2. Destroyed lymphatics
B. Secondary: lymphatic obstruction or insufficiency
   1. Trauma
   2. Surgery
   3. Tumors
   4. Parasites

ble are immediately beneficial. Once the drainage fluid is al-
lowed to become trapped within interstitial microloculations,
the edema becomes persistent, resolving only when the in-
jured lymphatic capillaries regenerate.

Pitting Versus Nonpitting Edema.   The acute lymph-
edema that occurs soon after liposuction demonstrates pit-
ting on firm digital pressure. The lymphedema of recent on-
set, especially in a young patient, may be associated with

pitting edema. After years of accumulated interstitial depo-
sition of protein, however, chronic lymphedema gradually
becomes a nonpitting edema.

In general, pitting edema is usually associated with venous
capillary edema caused by excessive capillary filtration of in-
travascular water. Pitting edema is present when a firm, con-
tinuous pressure of a finger pressing on the affected skin
causes a distinct temporary depression that can last for many
minutes. Chronic lymphedema of the skin and subcutaneous
tissue has the clinical appearance of a brawny, coarse, nonpit-
ting edema. Chronic lymphedema causes an accentuation of
adnexal pores and hair follicle ostia, giving the overlying skin
an orange peel (peau d'orange) appearance.

Treatment.   The best therapeutic approach to lymphedema
is a vigorous effort at prevention. The open drainage and bi-
modal compression technique will prevent most of the edema
that might otherwise follow tumescent liposuction. Even
with this technique, however, some postliposuction edema
occurs and may require weeks or months to resolve.

Treatment of lymphedema not associated with liposuction
is less than satisfactory. In mild cases of primary lym-
phedema, treatment is high elevation of the affected limb,
with simultaneous elastic support, and intermittent pneu-
matic compression. With secondary lymphedema, treatment
is usually symptomatic.

NORMAL FUNCTION

Proteins and other large molecules are too large to be ab-
sorbed into the blood directly across capillary membranes.
Lymphatic capillaries have large gaps between adjacent en-
dothelial cells that permit passage of large-molecular-weight
substances. Lymphatic endothelial cell edges slightly overlap
each other, forming minute unidirectional endothelial valves
into the lymphatic capillary lumen. In addition, some lym-
phatic capillary endothelial cells overlap to a much greater
degree and form internal bivalvular flaps that act as one-way
valves inside the lymphatic capillary. This valve structure in-
hibits retrograde lymph flow (Figure 11-1).

Microscopic Structure.   The wall of a terminal lymphatic
capillary has an interior layer formed by a single, thin en-
dothelial cell and an external, widely fenestrated basal lam-
ina. In many places, wide gaps exist between adjacent en-
dothelial cells. These holes in the lymphatic capillaries
facilitate the uptake of macromolecules: proteins, bacteria,
blood cells, and tumor cells.[2] Blood capillaries, with contin-
uous basement membranes and relatively tight intracellular
junctions, resist absorption of large molecules.

Anchoring fibrils connect the lymphatic endothelial cells
to the surrounding collagenous connective tissue.[3] These an-
choring fibrils reinforce the valvular function of individual
lymphatic endothelial cell edges. The anchoring fibrils on the
upstream edge of the lymphatic capillaries tend to spread
the cell's edge and facilitate the entry of interstitial fluid into
the lymphatic capillary.
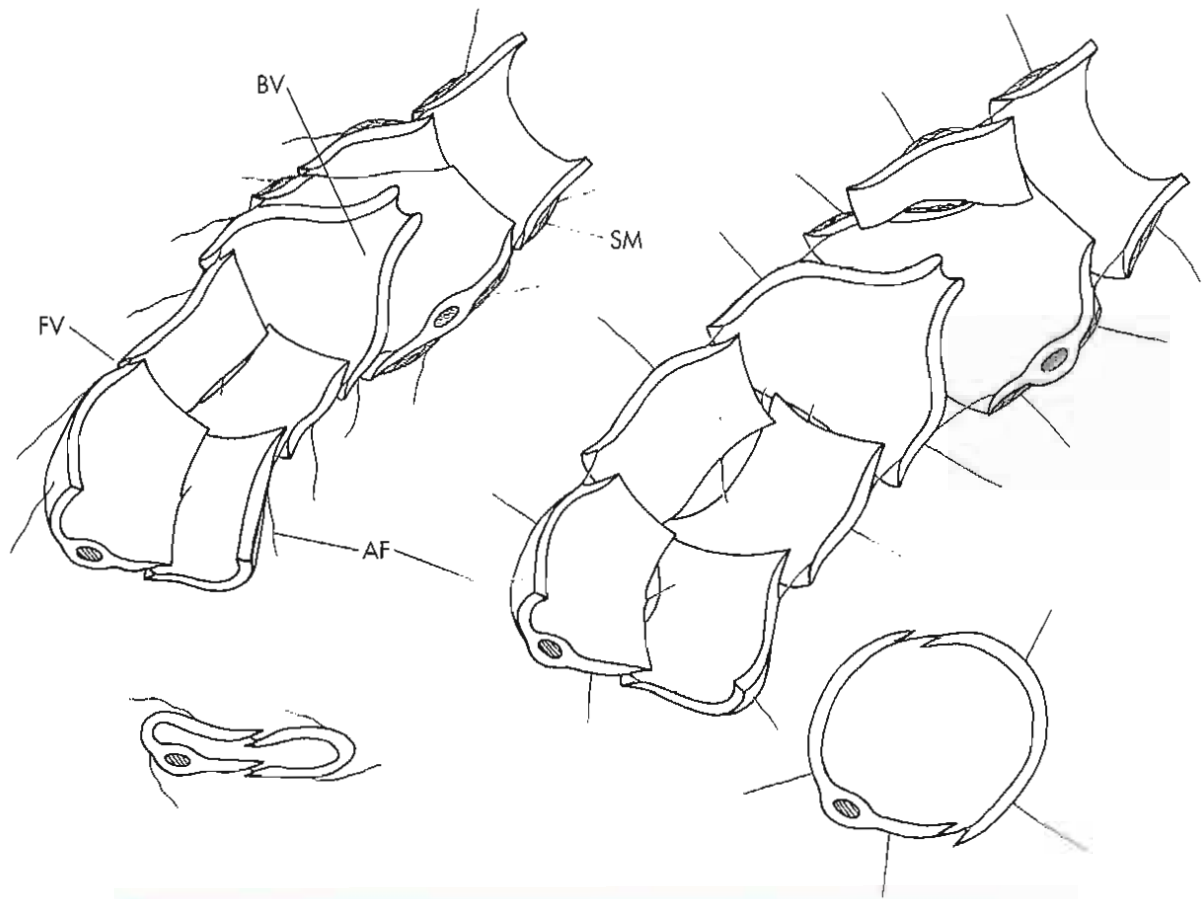
Lymphatic capillary structure permits one-way passage of high-molecular-weight substances through gaps in basement membrane, between lymphatic endothelial cells (open junction flap valves, *FV*), and into lumen of lymphatic capillary. *One-way valves* (bileaflet valves, *BV*) within lymphatic capillary are formed by specialized, overlapping endothelial cells located along terminal lymphatic capillaries. *Pressure-sensitive smooth muscles (SM)* encircle collecting lymphatic capillaries; when a collecting capillary becomes sufficiently distended with lymph, smooth muscles contract, forcing lymph to travel proximally through one-way valves. *Anchoring filaments (AF)* provide attachments between lymphatic capillary endothelial cells and collagenous connective tissue matrix of interstitial space. With interstitial edema, anchoring filaments pull outward on lymphatic endothelial cells, increasing inside diameter of lymphatics and thereby facilitating and increasing rate of lymph flow to compensate for edema.

Effects of Edema and Compression. An important distinction exists between (1) the effects of increased interstitial pressure caused by edematous fluid overload and (2) the effects of external compression that elevates interstitial hydrostatic pressure (Figure 11-2).

In the first situation, expansion of the swollen interstitial tissue causes the inside diameter of the lymphatic capillary to dilate. Edema causes each point within the tissue compartment to move farther apart from every other point; this includes the lymphatic endothelial cells. In effect, as the collagenous infrastructure of the interstitial tissue expands, the anchoring fibrils tug on the lymphatic epithelial cells and ex-

pand the inside diameter of the lymphatic capillaries. The expanded inside diameter of the lymphatic capillary facilitates homeostatsis by increasing lymph flow, which tends to reduce the edema. With progressively more edema, however, the anchoring fibrils literally pull on the individual lymphatic endothelial cells to such a degree that the capillaries no longer function as a tubular channel. The lymphatic capillary becomes nonfunctional.

In the second situation, external compression squeezes the interstitial tissue and can compress the capillary lumen. This constriction limits the flow of lymph and ultimately impairs the lymphatic capillary's ability to reduce edema.
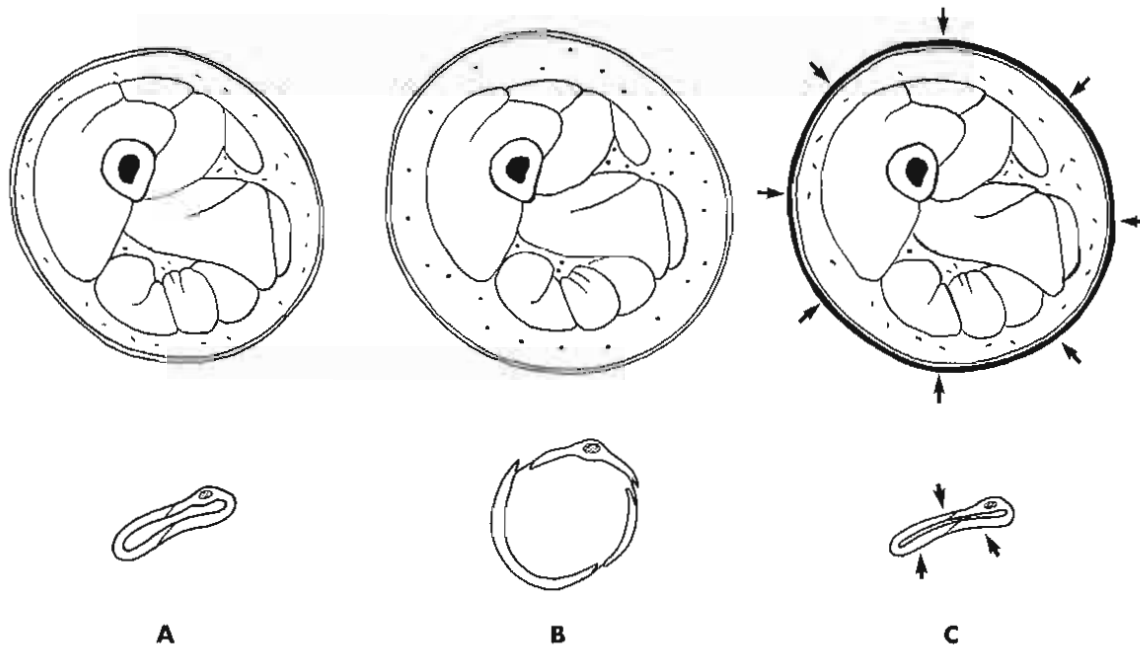
Figure 11-2

Three cross-sectional views of a lymphatic capillary within subcutaneous fat of thigh represent distinct degrees of interstitial edema that might occur in tumescent liposuction patient. **A,** Under normal circumstances, subcutaneous lymphatic capillaries help maintain interstitial fluid homeostasis by transporting lymphatic fluid at same rate as it is produced. Without excessive interstitial fluid or edema, lymphatic capillaries are neither engorged nor compressed. **B,** Because of anchoring fibrils that connect lymphatic capillary endothelial cells to interstitial collagen matrix, internal diameter of lymphatic capillaries expands as tumescent infiltration expands subcutaneous interstitial volume and increases interstitial pressure. **C,** Postoperative compression garment augments subcutaneous interstitial pressure and compresses both hematic and lymphatic capillaries. During first 48 hours, hematic capillary compression increases hemostasis and decreases bruising. After 48 hours, lymphatic capillary compression promotes lymphostasis and increases edema.

Lymphatic Pump Mechanism.   The rate of lymph flow is determined by the lymphatic pump mechanism and interstitial fluid pressure. The one-way lymphatic capillary valves allow a degree of lymphatic pumping when lymphatic capillaries are compressed *intermittently* by an external force, such as large muscles of a limb, body movements, arterial pulsation, and external massage.

When larger lymphatic vessels become stretched with lymph fluid, the smooth muscle in the wall of the vessels contracts automatically, forcing the lymph fluid through the proximal valve and into the next segment of the lymphatic vessel. As this newly filled segment of lymphatic vessel is stretched with fluid, its intrinsic smooth muscles contract, advancing the fluid into the next segment. This sequential segmental lymphatic contraction is the basis for the lymphatic pumping mechanism, which generates the negative interstitial fluid pressure.

For the liposuction patient, excessive external pressure from compressive postoperative garments may be counterproductive. Continuous compression from a high-compression garment may cause the delicate lymphatic capillaries to collapse, impede lymph flow, and effectively block lymphatic drainage.

Interstitial Fluid Pressure.   The normal interstitial fluid pressure is subatmospheric and ranges from -6 to 0 mm Hg (relative to atmospheric pressure). Experimental measurements in dogs show that the rate of lymph flow varies as a function of interstitial fluid pressure.[4] Minimal lymph flow occurs below -6 mm Hg. Between -6 and 0 mm Hg the rate of lymph flow increases exponentially. Lymph flow reaches a maximum of 1 or 2 mm Hg. The rate of flow at 0 mm Hg is 20 times greater than at -6 mm Hg.

When interstitial pressure exceeds 1 or 2 mm Hg, the lymph flow rate reaches a plateau. Lymph flow fails to increase with higher interstitial fluid pressures, probably because of excessive tissue pressure compressing the outside area of larger lymphatic vessels, thereby impeding lymph flow. Therefore a high-compression postoperative garment is unlikely to increase the rate of lymph flow after liposuction.

FLUID OSMOLALITY

The clinical laboratory measurement of serum osmolality requires that a serum sample be frozen as soon as possible after it is obtained. A long delay in freezing the sample exposes the

serum proteins to temperature-dependent proteolysis. By effectively multiplying the number of solute particles in solution, proteolysis amplifies the osmolality of a sample.

The trauma from tumescent liposuction allows plasma proteins to leak out of injured capillaries and into the subcutaneous wound space. Once a protein molecule has entered the subcutaneous wound space, it can only reenter the blood by way of lymphatic absorption. Between adjacent capillary endothelial cells are intercellular clefts or pores about 6 to 7 nm in width, slightly smaller than the diameter of an albumin molecule. The size of a plasma protein molecule determines the probability that it will diffuse through a gap between capillary endothelial cells. Gaps in the capillary wall are generally too small to permit the reentry by diffusion of extravasated plasma proteins back into the intravascular space.

Fresh wound fluid has an osmolality of approximately 10 mOsmol greater than serum. This osmotic pressure gradient tends to draw water from intravascular space, across the capillary wall, and into the wound space. Incubating residual blood-tinged tumescent fluid at body temperature increases the osmolality of fluid over time. This exacerbates postliposuction edema by an osmotic amplification by incubation.

The rate at which water-soluble molecules diffuse through capillary membrane is 80 times as great as the rate at which water molecules flow linearly along the capillary. Thus the water of interstitial fluid and that of plasma are rapidly interchanged. Iatrogenic hemodilution by infusion of IV crystalloid fluids increases intravascular hydrostatic pressure and thus augments edema.

The degree to which external compression influences the intravascular uptake of water after tumescent liposuction is unknown. Opposing the osmotic gradient with applied external compression is the same as with augmented interstitial hydrostatic pressure. External compression counteracts the effects of intravascular hydrostatic pressure but hinders the lymphatic uptake of wound fluid that contains protein molecules.

Study: Fluid Incubation. The difference between serum osmolality and osmolality of liposuction aspirate was studied in eight patients. The mean serum osmolality was 294.6 mOsm/L (range 290 to 297). The mean osmolality of an immediate sample of infranatant blood-tinged anesthetic solution was 307.5 mOsm/L (range 300 to 313). The mean osmolality of a 24-hour incubated (37° C) sample of infranatant was 311.5 mOsm/L (range 306 to 319).

Thus the difference is (307.5 − 294.6) 12.9 mOsm/L between a patient's serum osmolality and the residual blood-tinged tumescent anesthetic solution that remains within the subcutaneous tunnels of suctioned fat. Assuming that serum osmolality is unchanged, the theoretic gradient between serum and the incubated drainage fluid entrapped within a subcutaneous wound for 24 hours is (311.5 − 294.6) 16.9 mOsm/L. The incubation of entrapped drainage fluid augments the osmotic gradient between the intravascular space and the subcutaneous space. Closing incisions with sutures and preventing the drainage of blood-tinged anesthetic solution therefore amplify the liposuction edema.

THIGHS AND ABDOMEN

Postliposuction edema can be particularly common in certain situations. For example, circumferential liposuction of the thigh can theoretically cause prolonged postoperative edema by precipitating a vicious cycle and temporarily obliterating a significant portion of lymphatic drainage from the lower limb. This liposuction-induced edema produces a mild compartment syndrome with local hematic capillary ischemia, decreasing delivery of oxygenated blood, augmenting anaerobic metabolism, and increasing capillary permeability. This increased capillary permeability produces still more edema.

The hematic capillary edema further compresses the lymphatic capillaries and inhibits the lymphatic clearance of proteinaceous edema fluid. Postoperative swelling is ultimately prolonged unnecessarily for many weeks.

The abdomen tends to require more time than other areas for resolution of postliposuction edema. When the entire abdomen is treated by tumescent liposuction, a significant volume of drainage must be accommodated by the drainage ports along the inferior abdominal margin. Premature closure of slit incisions on the abdomen will entrap a considerable volume of blood-tinged anesthetic solution. The result is prolonged lower abdominal swelling and tenderness. Placing punch excisions or adits along the lower abdomen tends to facilitate more complete drainage.

AMPLIFIED LIPOSUCTION EDEMA SYNDROME

Every liposuction patient has some degree of postoperative edema as the result of leakage of intravascular plasma proteins from traumatized capillaries, along with some liposuction-induced impairment of subcutaneous lymphatic function. This can be minimized by using postoperative care that includes open drainage and bimodal compression.

Excessive liposuction may be associated with massive postoperative edema, referred to as amplified liposuction edema (ALE). A combination of factors predisposes to this dangerous type of edema. In its mild form, ALE is generally localized to the areas treated by liposuction. In progressive degrees this massive edema can spread to areas distant from the site of tissue trauma, resulting in massive weight gain and systemic complications such as acute renal failure and effusions (pleural, peritoneal, pericardial). In extreme cases, patients can have fatal pulmonary edema and end-stage central nervous system edema.

Therefore ALE is a type of multifactorial edema that can increase progressively. This generalized edema is most likely to occur after extensive or excessive liposuction that overwhelms compensatory homeostatic mechanisms.

CONTRIBUTING FACTORS

Lymphatic Impairment. Massive lymphatic dysfunction is caused by (1) liposuction cannula–induced lymphatic obliteration, (2) lymphatic system overload with excessive,

highly osmotic interstitial fluid drainage, and (3) lymphatic vessel occlusion by excessive external compression.

As discussed, lymphatic impairment is the most significant cause of edema. The lymphatic system acts as the physiologic safety valve that protects against edema. When challenged by impending edema, the lymphatics compensate and increase lymph flow by 10-fold to 50-fold. The sudden onset of a multifactorial edema and the simultaneous loss of effective compensatory lymphatic function after liposuction can result in an unprecedented degree of edema.

Fluid Leak. Overwhelming plasma protein leakage from surgically ruptured capillaries can result from massive liposuction trauma. Normal hemostasis of ruptured capillaries involves the formation of a primary platelet plug and secondary fibrin deposition. The body's supply of platelets and fibrinogen is finite, however, and can be exhausted by massive trauma of capillaries. An insufficient hemostatic plug permits ongoing leakage of both plasma and red blood cells.

This traumatic thrombocytopenia and hypoprothrombinemia can lead to a subacute consumptive coagulopathy. Because of insufficient plugging of ruptured capillaries, significant quantities of osmotically active molecules ooze into the subcutaneous space. After extensive liposuction, inflammatory proteins, tissue fragments, cellular debris, plasma, and erythrocytes all contribute to increased oncotic pressure within the subcutaneous wound and interstitial space. The ultimate result is a massive, osmotically mediated, subcutaneous edema.

Sutures. Sutured incisions prevent the drainage of the blood-tinged anesthetic solution and entrap a massive accumulation of highly osmotic, subcutaneous edema fluid. Closing all incisions with sutures is one way of managing the copious drainage of blood-tinged anesthetic solution. Although closing incisions with sutures does simplify postoperative care, it dramatically worsens and prolongs postliposuction edema.

Inflammatory Mediators. Trapped within the edema fluid, mediating substances ultimately exacerbate postliposuction edema. The blood-tinged anesthetic solution contains erythrocytes and other inflammatory mediators, which promote increased capillary permeability and plasma protein leakage.

Proteolysis. Temperature-dependent proteolysis of plasma proteins and the proteinaceous inflammatory debris causes progressive increases of the osmolality of the trapped edema fluid. Incubation of wound drainage at 37° C (98.6° F) within the subcutaneous space promotes the temperature-dependent cleavage of extravasated plasma proteins, which amplifies the postliposuction edema.

Hemodilution. Iatrogenic hemodilution from IV crystalloids (physiologic saline or lactated Ringer's solution) further promotes edema by the following:
1. Providing an abundant supply of water, which diffuses specifically into the traumatized tissue as a result of el-

evated oncotic pressure in wound tissue from extravasated plasma proteins
2. Diluting the intravascular protein concentration, thereby diminishing the intravascular-extravascular oncotic pressure gradient
3. Providing a surfeit of intravascular isotonic solution, 80% of which will redistribute into the interstitial space throughout the entire body, including the liposuctioned tissue

PREVENTION: CASE STUDIES

A surgeon may unknowingly cause ALE syndrome. As mentioned, postliposuction care may even promote edema (1) by closing all incisions with sutures, thereby trapping the high osmotic drainage in the subcutaneous wound space, and (2) by applying a highly compressive garment that collapses any remaining functional lymphatic capillaries and prevents lymphatic transport of the protein-laden edema fluid.

The risk of causing ALE syndrome is minimized by (1) avoiding excessive liposuction, (2) using open drainage and bimodal compression, and (3) not giving IV fluids. Case Reports 11-1 and 11-2 further illustrate ALE risk factors and preventive measures.

CASE REPORT 11-1 Excessive Liposuction and Progressive Edema

A 39-year-old healthy, athletic female weighing 46 kg (102 pounds) had liposuction of the abdomen, hips, waist, back, and thighs under general anesthesia using tumescent technique for hemostasis. Five liters of fluid and fat was aspirated with 3-mm and 4-mm cannulas. Total volume of supranatant fat and total dose of lidocaine were not documented. For the first 48 hours the patient was in moderate discomfort but ambulated regularly, wearing a tight postoperative compressive garment that covered the torso and lower extremities.

On the third postoperative day the patient noted onset of swelling, which progressed to significant pitting edema of the lower extremities and fingers. For the next 2 days, despite treatment with furosemide (40 mg by mouth twice daily), urine output was minimal. By the fifth postoperative day the edema was severe, and the patient was given a single oral dose of furosemide (120 mg), and urine output was more than 3 L over the following 8 hours. Her subsequent course was unremarkable, with no evidence of anemia at any time.

Discussion. Too much fat removed by liposuction, too many areas treated by liposuction, closing incisions with sutures, and excessive compression all contribute to ALE. In this patient the use of furosemide proved helpful in treating the oliguria and suggests the possibility of transient renal insufficiency. The preventive approach would have been to do less liposuction, treat fewer areas on a single day, and allow the incision to remain open.

CASE REPORT 11-2 ALE Syndrome: Obesity, Foam, Other Factors

A 49-year-old obese female weighing 96 kg (211 pounds) had liposuction of the abdomen, circumferential thighs, back, flanks, buttocks, knees, and arms using tumescent technique for hemostasis plus a mastopexy, all under general anesthesia. Preoperative hematocrit was 39.2%. The volume of tumescent anesthesia was 8400 ml. Intraoperative IV fluids consisted of 2600 ml of crystalloid and 2000 ml of colloid (Plasmalite). The volume of aspirated fluid and fat was 14,680 ml, using 3-mm and 4-mm cannulas. After the 10-hour surgery, all liposuction incisions were closed with sutures, and Reston foam was applied to the treated areas. A compression garment was applied to the torso and lower extremities. Reston foam, tape, and Coban dressings were applied to the arms.

On the first postoperative day the patient ambulated slowly. On the second postoperative day, however, the patient could not bend her legs because of lower extremity edema. Later the same day, approximately 48 hours after surgery, edema had progressed; swollen fingers prevented her gripping the hand of a friend. When the compression garment was cut off in an attempt to relieve pain, large blisters were noted along the margins of the Reston foam. By the third postoperative day the patient was so swollen that she could not arise from the couch. In an attempt to go to the bathroom, she fell and could not get up, and was forced to defecate on the floor.

On the fourth postoperative day the Reston foam was partially removed, causing extreme pain; multiple denuded bullae were apparent, and the patient reported a low-grade fever. The next day the swelling had begun to lessen, but orthostatic dizziness and lightheadedness persisted. On the sixth postoperative day the patient was instructed to soak off the remaining Reston foam, clean deepithelialized skin wounds with hydrogen peroxide, and apply Silvadene cream. On the seventh day the patient telephoned to report a temperature of 102° F (39° C), and ciprofloxacin (250 mg three times daily) was prescribed.

From the fifteenth to twentieth postoperative days she was hospitalized for treatment of cellulitis of the left thigh and leg.

Cultures were positive for *Pseudomonas* and *Escherichia coli.* The patient reported that several days before her admission, her weight was 116 kg (256 pounds), or 20 kg greater than her weight just before surgery. Several days after admission, a hospital nutrition assessment report noted a weight of 105.5 kg (232 pounds), or 9 kg above her preoperative weight.

Discussion. This case demonstrates ALE syndrome resulting from excessive volume of liposuction, too many areas treated, incisions closed with sutures, and excessive compression. It also shows risk factors associated with use of Reston foam and hydrogen peroxide.

The most common cause of cutaneous bullae after liposuction is excessive superficial liposuction that injures the subdermal vasculature. Rasping the underside of the dermis will produce an epidermal bulla and prolonged dyschromia. Inattention to the delicate subdermal vascular plexus and aggressive scraping of fat from the undersurface of the dermis will produce some degree of dermal injury, which can include full-thickness dermal necrosis. Denuded traumatized dermis is a likely medium for infectious cellulitis and necrotizing fasciitis. Occluding an ischemic wound with Reston foam increases the risks of infection.

Reston foam can cause an intense irritant, traumatic, or allergic contact dermatitis; a bullous reaction can result in a persistent, disfiguring, postinflammatory hyperpigmentation. Although the foam attenuates the appearance of bruising, it does *not* improve the postoperative recovery, reduce pain or tenderness, or shorten the healing process. No evidence suggests that the ultimate aesthetic results of liposuction are improved by the application of this foam. More importantly, Reston foam prevents the patient from showering daily, which also may predispose to wound infections. The foam obscures the visual examination of the skin and may delay the diagnosis of a cutaneous infection.

NOT "THIRD SPACING"

ALE and tumescent infiltration are *not* analogous to the phenomenon of posttraumatic "third spacing" of sequestered fluid in the extracellular space, a well-recognized consequence of tissue trauma (see Chapter 9). Traumatic injury to an extremity results in the mobilization of fluids and electrolytes to the area of injury. Third spacing after nonthermal traumatic injury occurs immediately and is maximal by 5 to 6 hours.[5] ALE is maximal 24 to 72 hours after surgery.

Tumescent infiltration of physiologic saline and dilute epinephrine is not analogous to third-space sequestration of fluid. The constituent solutes of the third-space fluid are in dynamic equilibrium with the functional or exchangeable extracellular fluid. For example, in the third-space phenomenon of a pleural effusion, the concentration of electrolytes or drugs is in equilibrium with their concentration in nearby extracellular fluid.

In contrast, the profound vasoconstriction of the tumescent technique precludes rapid chemical transfer and equilibrium of lidocaine and epinephrine between tumescent and surrounding nontumescent tissues. This chemical isolation, along with slow diffusion of drugs out of the tumescent tissue, is the basis for the therapeutic success of the tumescent technique.

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CHAPTER 12

Infections

Liposuction surgeons who use only local anesthesia seem to have a much lower rate of serious postoperative infections than those who use systemic anesthesia. For example, virtually every case of postliposuction necrotizing fasciitis has occurred in association with general anesthesia or heavy IV sedation.

The risk of postoperative infection is a multivariate function of characteristics of the surgeon, patient, procedure, surgical setting,[1] and anesthetic agent.[2,3] The risks of postoperative pneumonia and intravenous (IV) site infection are determined by anesthetic technique and the type of postoperative analgesia. General anesthesia is often associated with hypothermia, which in turn is associated with increased incidence of postoperative wound infections.[4]

The tumescent technique minimizes the risk of infections. For example, commercial lidocaine is bactericidal, and lidocaine neutralized with sodium bicarbonate has even more bactericidal action (see Chapter 17). Also, vasoconstriction, hemostasis, and rapid drainage of blood-tinged anesthetic solution minimize the incidence of hematomas and seromas, which further reduces the risk of infection. Nevertheless, localized minor postoperative cutaneous infections have occurred after tumescent liposuction (Figures 12-1 and 12-2).

PROPHYLACTIC ANTIBIOTICS

Many surgeons routinely recommend prophylactic antibiotics before tumescent liposuction, even though it has an extremely low incidence of infection. Presently, patients receive cephalexin, cefadroxil, or doxycycline, starting the day before surgery and continuing for 6 days.

My preference for preoperative antibiotics derives from a clinical research project on percutaneous absorption of hydrocortisone. After 6-mm suction blisters were created on the volar surface of both forearms, hydrocortisone cream was applied. The blisters were sequentially aspirated and the fluid assayed for hydrocortisone. One patient returned 1 day after the procedure with all eight deepithelialized blister wounds apparently infected. The patient had a sore throat on the day

of the experimental procedure. The infections resolved with antibiotic therapy after cultures of her throat and blister wounds demonstrated streptococcal infection.

Pretreatment with antibiotics might minimize the risk of a similar event affecting a liposuction patient and causing liposuction incisions to become infected.

Antibiotics are associated with risks. In addition to allergic drug reactions, liposuction patients who take antibiotics are also at risk for *Clostridium difficile*–associated, pseudomembranous enterocolitis.

Cautious, proper use of prophylactic antibiotics together with constant adherence to rational infection prevention procedures will minimize the risk of postoperative infections. The risk for wound infection for surgical procedures categorized as clean and clean contaminated was 2.1% and 3.3%, respectively, in the United States from 1987 to 1991.[5] I estimate that tumescent liposuction has an infection rate of less than one per 2000 cases.

MITRAL VALVE PROLAPSE

Mitral valve prolapse (MVP) is more common in females; as many as 7% of women may have echocardiographic evidence of MVP. The spectrum of clinical severity is wide ranging, from a minimal systolic click murmur to severe mitral regurgitation. The condition may progress over years, but most patients are asymptomatic for their entire lives (see Chapter 9).

MVP is the most common cause of isolated severe mitral regurgitation. The most common symptoms are dysrhythmias. Ventricular premature contractions and paroxysmal supraventricular or ventricular tachycardias may cause palpitations, lightheadedness, and syncope. Atypical chest pain may be vague, substernal, prolonged, poorly related to exertion, and unlike that of angina pectoris. Transient ischemic attacks may be caused by microemboli originating on the roughened mitral valve surface and should be treated with antiplatelet mediations such as aspirin and dipyridamole.

Infective endocarditis may occur in patients with severe MVP and mitral regurgitation. Preoperative antibiotic prophylaxis is appropriate for patients with MVP.

Figure 12-1

Early staphylococcal infection on left medial thigh first presented as simple local inflammation. Previous attempt to aspirate fluid for bacterial culture was unsuccessful. Staphylococcal abscess eventually developed and was diagnosed. Outpatient treatment consisted of incision and drainage and oral antibiotics, with almost no residual scarring.

Figure 12-2

Inflammation of medial knee after liposuction was early cellulitis or sterile inflammatory seroma. Bacterial culture was negative, but condition resolved with oral antibiotics. Infections are rare with tumescent local anesthesia.

PREDISPOSING CONDITIONS

Excess fluid in the subcutaneous tissue after liposuction is free to move about, as evidenced by postoperative drainage and pitting edema. Bacteria that are suspended in collections of subcutaneous fluid can perform their pathogenic functions, such as multiplying and producing toxins. Because leukocytes must crawl from place to place and cannot swim and intercept invading bacteria, leukocytes are at a disadvantage when defending against an underwater attack from bac-

teria. Postoperative care that implements open drainage and bimodal compression will rapidly eliminate free subcutaneous fluid and thus minimize the incidence of postliposuction infection.

Infections with tumescent liposuction are extremely rare. As mentioned, certain factors associated with tumescent liposuction totally by local anesthesia minimize the risk of infection. These include the following:

1. Profound tumescent hemostasis, open drainage, and bimodal compression minimize the risk of hematomas and seromas, which predispose to infection.
2. Since lidocaine is bactericidal, diffuse infiltration of lidocaine directly into treated tissue reduces the risk of infection.
3. With an alert, awake patient, diagnosis of inadvertent visceral penetration by a cannula is not delayed.
4. Elimination of sutures minimizes foreign body reaction, wound inflammation, and incision site infections.
5. Postoperatively, patients are instructed to shower and bathe daily.

Every liposuction patient is at risk for an infection, and therefore every reasonable precaution against infection should be considered. The most serious infections associated with liposuction include toxic shock syndrome, necrotizing fasciitis, cellulitis, staphylococcal abscess, and rapidly growing atypical mycobacteria (see later discussions).

TOXIC SHOCK SYNDROME

Toxic shock syndrome (TSS) is a potentially life-threatening manifestation of *Staphylococcus aureus* infection. Symptoms include high fever, diarrhea, nausea, vomiting, hypotension, oliguria, conjunctival hyperemia, and a diffuse erythematous rash. TSS has been reported in association with a case of liposuction and abdominoplasty and with a case of abdominal liposuction and fat transfer to the face to treat facial atrophy.[6] Perioperative blood transfusions increase the rate of TSS infection from 4% to 25%.[7]

ABDOMINAL PERFORATION AND PERITONITIS

Delayed diagnoses of abdominal perforation with necrotizing fasciitis, IV fluid overload with pulmonary edema, and pulmonary thromboembolism are the three most common fatal complications of liposuction.

With liposuction under general anesthesia, a high probability exists for delayed diagnosis of an inadvertent penetration of the abdominal cavity, with intestinal laceration. If a liposuction cannula causes a bowel perforation under general anesthesia, it might not be immediately appreciated. When the patient awakes after general anesthesia, any complaint of abdominal pain may be dismissed as the expected consequence of abdominal liposuction. Delay beyond 18 to 24 hours results in a serious risk of peritonitis, sepsis, or necrotizing fasciitis. Intraabdominal penetration with intestinal perforation by a liposuction cannula has a mortality rate probably exceeding 50%.

With liposuction totally by local anesthesia, little possibility exists for missing the proper diagnosis after a traumatic bowel perforation. A high suspicion of an intestinal perforation should be followed immediately with an evaluation by a general surgeon. Prompt diagnosis and surgical intervention greatly reduce the risk of a life-threatening infection.

Liposuction is contraindicated immediately after any surgical procedure of the abdomen (e.g., peritoneoscopy) that creates a tract into the peritoneal cavity.[8,9] Similarly, a periumbilical hernia is a relative contraindication for abdominal liposuction.

NECROTIZING FASCIITIS

Necrotizing fasciitis is an infection of the subcutaneous fat (fascia) that usually extends to the overlying dermis.[10] The most serious infectious complication of liposuction, it can result from a perforation of an abdominal viscus, inadequate sterilization of surgical instruments, or direct wound contamination by the patient or another person. Early diagnosis and aggressive treatment offer the best chance for survival. Thus the liposuction surgeon must know its clinical presentation and when to suspect the diagnosis and must be aggressive in investigating and confirming the diagnosis and then in implementing treatment.

Necrotizing fasciitis can be suspected but not diagnosed clinically; it should be considered a surgical, anatomic, and pathologic diagnosis. Such a diagnostic process usually requires intense, aggressive efforts. A delay of an hour or two in the diagnosis can mean the difference between life and death.

Necrotizing fasciitis is a rare complication of liposuction surgery. Because the consequences can be rapidly fatal if not diagnosed and treated early, every liposuction surgeon must be aware of this potential problem.

There are two clinical types of necrotizing fasciitis. *Type I* is a polymicrobial or mixed infection caused by aerobic and anaerobic bacteria. It occurs most often after surgical procedures, in diabetic patients, or in those with severe peripheral vascular disease. The portal of entry can be the skin or a mucous membrane of the mouth, gastrointestinal (GI) tract, or urinary tract.

Severe bacterial infections have been reported in four French patients. Three had areas of skin necrosis, and one had septic shock. A pathogenic bacterium was identified in only two of the patients; one had group A *Streptococcus* and the other *Peptostreptococcus.*[10a]

Type II necrotizing fasciitis is caused by group A beta-hemolytic streptococci. In contrast with type I, patients with type II usually are younger, often do not have serious medical problems, but do have a history of recent surgery or trauma (blunt or penetrating).[11] The skin is the portal of entry but frequently has no apparent break.

EPIDEMIOLOGY

In the general population, most spontaneous nonsurgical cases of necrotizing fasciitis involve some degree of impaired immunity, such as old age, peripheral vascular disease, diabetes, alcoholism, renal failure, liver disease, human immunodeficiency virus (HIV) infection, or immunosuppressive drugs, including chemotherapy, corticosteroids, and nonsteroidal antiinflammatory drugs (NSAIDs). The use of NSAIDs suppresses leukocyte function and early signs and symptoms of group A streptococcal infection, with a possible delay in treatment.

Bacterial contamination from localized infected skin wounds accounts for 80% of cases of necrotizing fasciitis. The remaining cases are the spontaneous result of hematogenous spread.

Mixed aerobic and anaerobic bacteria are present in 70% of all patients with necrotizing fasciitis, aerobic bacteria in 10%, and anaerobes in 20%.[12] On average, three to five organisms are isolated per culture specimen. Polymicrobial infections usually reflect the flora present at the site of trauma or surgery, such as the lower GI tract, mouth, or nasal mucosa. The typical aerobic pathogens include group A *Streptococcus pyogenes*, *Staphylococcus aureus*, *Escherichia coli*, and other enterobacteriaceae. Anaereobic bacteria include *Bacteroides*, *Clostridium*, *Peptostreptococcus*, and *Fusobacterium* species. The initial antibiotic therapy for necrotizing fasciitis involves a broad-spectrum antibiotic. Then the medications are adjusted based on the results of culture and sensitivity.

Approximately 10% of all cases of necrotizing fasciitis are caused by a group A streptococci, with a mortality of 30%[13] to 70%.[14] Up to half these patients are otherwise healthy. An association with preexisting streptococcal pharyngitis is seen in 10% of patients. For this reason, preoperative oral antibiotics are begun the day before surgery.

GROUP A STREPTOCOCCI

Invasive group A beta-hemolytic streptococcal infections can present with a spectrum of clinical manifestations, ranging from "streptococcal toxic shock–like syndrome" to necrotizing fasciitis. The necrotizing fasciitis is characterized by a rapid course with shock, sepsis, multiorgan failure, soft tissue infection, and a high mortality rate. Younger, healthy patients are most often affected after minor local trauma. High-dose antibiotic therapy, intensive care monitoring, and aggressive debridement of necrotic soft tissue are necessary to save the patient's life.[15]

An association between group A beta-hemolytic streptococcal necrotizing fasciitis and varicella in children has been recognized for more than 50 years. Necrotizing fasciitis occurs after direct laceration or in contused areas with secondary hematogenous spread.[16]

Since the 1980s there has been an increased awareness of streptococcal TSS caused by highly invasive, group A beta-hemolytic streptococcal and of group A streptococcal infections associated with shock and organ failure, with or without necrotizing fasciitis.[17] Purpura fulminans can also occur.[18] Strains of these group A beta-hemolytic streptococci that cause invasive necrotizing fasciitis have been predominantly M-protein types 1 and 3 and produce pyogenic exotoxin A, B, or C or a combination of these.

Group A streptococcal necrotizing fasciitis has occurred in liposuction patients (see Case Reports 12-1 and 12-2) as well as with other cosmetic surgical procedures, including blepharoplasty[19] and reduction mammoplasty.[20]

An important interaction between group A streptococci virulence and host defense mechanisms probably determines the ultimate manifestation of the disease. Two cases have been reported of cervical necrotizing fasciitis as the initial presentation of HIV infection.[21] Similarly, group A streptococcal necrotizing fasciitis can occur with diabetes, alcoholism, chronic renal failure, and drug abuse.

Fatal postoperative infections are a risk of any surgery. Surgical training, surgical experience, or hospital surgical facilities cannot eliminate this risk. When an infection does occur, survival depends on earliest possible diagnosis and treatment. Any suspicion of necrotizing fasciitis requires an immediate (emergency) consultation by a general surgeon.

Although necrotizing fasciitis has been reported in association with a purported case of tumescent liposuction, a careful reading of the case report provides no evidence that the procedure was true tumescent liposuction.[22] More likely the report represents a case of excessive liposuction of too many areas (thoracic roll/flanks/hips, abdomen, medial thighs, knees) done under systemic anesthesia.

CASE REPORT 12-1   Fatal Necrotizing Fasciitis

A 25-year-old male had liposuction of the abdomen, flanks, and posterior thighs by systemic anesthesia in a hospital outpatient facility. Immediately after liposuction, the treated areas were infiltrated with 1000 ml of lactated Ringer's solution (LR) containing bupivacaine and 200 mg of triamcinolone. The incision sites were closed with sutures, and Reston foam was applied to the overlying skin. The patient had risk factors for HIV infection, but there was no laboratory determination of HIV status.

The day after surgery the patient complained of pain in the thighs that was so severe that he could not sleep. Physical examination by the surgeon was unremarkable, and the patient was treated with acetaminophen, codeine, and diazepam. Two days after surgery the patient became lethargic and intermittently incoherent; on examination he was tachypneic and dehydrated with mottled skin. He was admitted to the hospital, but despite debridement of necrotic tissue, he died the next day, 4 days after surgery, from fulminant streptococcal necrotizing fasciitis, septicemia, and renal failure.

Discussion. Severe pain was the presenting symptom for this case of necrotizing fasciitis. Despite rigorous aseptic operating room conditions, this patient died from a streptococcal infection. The surgeon, the surgical staff, and the patient's roommate all had negative bacterial cultures.

Reston foam is applied to skin over areas treated by liposuction to minimize bruising; its application may hinder a subsequent clinical examination of the skin. The indication for postliposuction intralesional triamcinolone is not well defined. Some physicians might be concerned about a corticosteroid adversely affecting phagocytosis and cellular immune response. Antibiotics were not taken the day before surgery, but whether this might have prevented the infection cannot be known. Unusual infections are a risk with any surgery, despite every reasonable precaution.

CASE REPORT 12-2   Streptococcal Necrotizing Fasciitis

A 28-year-old female 152 cm (5 feet) tall and weighing 70 kg (154 pounds) with previous abdominal liposuction had liposuction of the abdomen, hips, and anterolateral thighs for her second liposuction procedure. After subcutaneous infiltration of 2500 ml of LR with lidocaine and epinephrine, liposuction removed 2750 ml of aspirate. Incisions were closed with 6-0 nylon, and Reston foam and a compression garment were applied.

Approximately 36 hours after liposuction the patient was seen at midnight because of continued burning pain in her left outer thigh, which had not improved with ice packs and Vicodin. Skin examination revealed normal-appearing skin comparable to her right leg, but she had tenderness over the outer thigh. She was given 8 mg of morphine and a Compazine suppository to take home.

Later that morning (approximately 48 hours after surgery) the patient was brought to the surgeon's office because of bleeding from the right thigh. Examination showed swelling and bluish discoloration of the left thigh. In particular the medial thigh had necrotic skin, and needle aspiration yielded serous fluid and air (or gas). Also, discoloration and bleb formation were seen on the left hip and buttock area beyond the area of liposuction. Blood pressure was 70/palpable.

The surgeon correctly diagnosed necrotizing fasciitis, and the patient was transferred to a major medical center for definitive care. The patient survived severe streptococcal necrotizing fasciitis after left hip disarticulation and extensive debridement of the abdomen, left buttock, back, flank, and right anterior thigh.

Discussion. Although the specific type of liposuction was not specified, the surgeon may have used ultrasonic-assisted liposuction (UAL) on the abdomen. UAL has been recommended for use in areas that have previously been treated by liposuction, such as the abdomen in this case. Intense ultrasonic energy can cause local tissue necrosis, injure nutrient blood vessels and lymphatic vasculature, and impair the normal inflammatory response to bacterial contamination. UAL may predispose to necrotizing fasciitis.

In both these cases of group A streptococcal necrotizing fasciitis, incisions were closed with sutures, Reston foam was applied, and compression garments were used. The first hint of prodromal necrotizing fasciitis was intense pain requiring narcotic analgesia. The early clinical appearance of the skin was unremarkable, and the correct diagnosis was delayed until the appearance of visible skin changes. Reston foam might have obscured an adequate early clinical examination of the skin.

IMMUNOSUPPRESSIVE DRUGS

Immunosuppressive drugs may predispose to postoperative necrotizing fasciitis. Necrotizing fasciitis was reported in an 80-year-old female with blepharospasm and a low leukocyte count after chemotherapy for chronic myeloid leukemia following botulinum toxin injection.[23] Antiinflammatory drugs such as NSAIDs, steroids, and combinations of these have been reported in association with group A streptococcal necrotizing fasciitis.[24] With the exception of acetaminophen, antiinflammatory drugs and corticosteroids should be avoided during the first 3 to 4 days in the immediate postoperative period to minimize the risk of infections.[25,26]

NSAIDs suppress white blood cell function and can impair host immunity to streptococcal infection. Acetaminophen is preferred over NSAIDs for analgesia after liposuction.

LIPOSUCTION CAUSES

Liposuction patients are presumably healthy and have a robust immune system. Postliposuction necrotizing fasciitis can be considered an opportunistic infection, most often the result of either polymicrobial contamination or group A streptococcal infection. The polymicrobial form is often the result of the delayed diagnosis of a perforated intestine after abdominal liposuction under general anesthesia. Polymicrobial necrotizing fasciitis has been associated with internal ultrasound-assisted liposuction (internal UAL), perhaps as a result of ultrasound-induced tissue necrosis (see Chapter 29).

Other causes of necrotizing fasciitis include (1) improper sterilization of liposuction cannulas, (2) avascular tissue necrosis of skin or subcutaneous tissue from excessively superficial liposuction or ultrasonic injury, and (3) a pharyngeal carrier of streptococcus, such as the patient or operating room personnel.

CLINICAL SUSPICION

Successful treatment of necrotizing fasciitis depends on a high degree of clinical suspicion and early diagnosis. Early presumptive clinical diagnosis of necrotizing fasciitis is the key factor in maximizing the rate of patient survival. The earliest clinical diagnosis of postoperative necrotizing fasciitis is made by the clinician using an attentive ear rather than a discerning clinical eye. A history of extreme pain is often the earliest hint of a serious problem.

If necrotizing fasciitis is misdiagnosed and treated as cellulitis, the patient will not improve despite appropriate antibiotics. A mistaken diagnosis of deep venous thrombosis (DVT) will also delay appropriate treatment.

The earliest and most common initial symptom of necrotizing fasciitis is severe local pain greater than might be expected based on the skin's clinical appearance. Therefore, when a postoperative liposuction patient telephones and complains of unusually severe pain, the surgeon must consider the possibility of necrotizing fasciitis. If the clinical history is not sufficient to exclude fasciitis, the surgeon is obligated to examine that patient as soon as possible.

If the surgeon cannot rule out the possibility of necrotizing fasciitis, an immediate consultation and evaluation by another surgeon should be considered. Necrotizing fasciitis is a surgical disease, and patients admitted to a nonsurgical service will have delayed surgical treatment. By the time that the skin has developed the typical woody consistency, discoloration, or bullae, the disease is usually far advanced and the chance of survival poor.

Early signs of necrotizing fasciitis, which may be subtle and difficult to see, include skin that first appears slightly red and edematous. The presence and proximity of a cutaneous wound or surgical incision site, no matter how small in size or trivial in appearance, may be the best evidence distinguishing infection from DVT.

CLINICAL SIGNS

The earliest visible clinical lesions appear pale, blue-gray, or purple.[27] Often, bullae formation eventually appears. A rapidly spreading area of painful induration with dusky or bright-red ecchymoses and violaceous bullae often indicates an advanced stage of an invasive streptococcal infection. The presence of bullae and severe pain together with other risk factors should be sufficient to trigger an aggressive diagnostic workup with blood cultures, laboratory studies, soft tissue radiographs, aspiration of bullae and subcutaneous tissue for bacterial culture and Gram stain, and early surgical exploration.

By the time that the cuticular lesions are plainly visible, the disease is rather widespread. When skin lesions are visible, palpation of the affected subcutaneous tissue may reveal a hard, woody consistency. Crepitance is present in 30% of patients and is especially common in those with diabetes.

The diagnosis is easily made late in the course of necrotizing fasciitis. The late clinical signs and significant evidence of necrotizing fasciitis include (1) a hard tactile density that extends beyond the visible margins of the affected tissue, (2) rapid onset of bullae and necrotic skin, (3) crepitus palpation, (4) absence of ascending lymphangitis, (5) failure to respond after 24 to 48 hours of antibiotic treatment for cellulitis, and (6) lack of response to treatment for DVT.

LABORATORY DIAGNOSIS

Patients with necrotizing fasciitis often show elevated levels of serum creatinine, creatine phosphokinase, and aspartate transaminase. These laboratory findings, as well as polymorphonucleocytosis with a left shift, in the appropriate clinical setting, should be sufficient to justify prompt surgical exploration.

The definitive diagnosis requires direct surgical examination of the fascia. A biopsy is done for histologic analysis by frozen section, as well as careful cultures for aerobic and anaerobic bacteria. Early, accurate diagnosis of necrotizing fasciitis has been reported using a frozen-section tissue biopsy obtained at the bedside by an open incisional biopsy.[28] Punch biopsies should not be used because of the risk of false-negative results caused by insufficient sampling. Histologic analysis typically shows severe intravascular coagulation within affected tissue.[29]

Blood cultures should be obtained before beginning therapy with IV antibiotics.

Gram-positive cocci found by fine-needle aspiration of subcutaneous fluid or skin bullae should lead to early surgical intervention.[30] Needle aspiration for culture and sensitivity testing will help refine the optimal selection of antibiotics. The standard rapid streptococcal diagnostic kit typically used for the diagnosis of streptococcal pharyngitis has been reported to be a useful adjunct in the diagnosis of group A streptococcal necrotizing fasciitis.[31]

Standard radiographic views should be obtained as soon as possible but should not delay surgical exploration. Radiography typically shows gas and abscess formation in necrotizing fasciitis. Delayed surgical treatment is more common in the absence of suspicious radiographic findings. Negative x-ray findings also should not delay surgical exploration.

Magnetic resonance imaging (MRI) with gadolinium contrast is more accurate in predicting necrosis or pyomyositis than laboratory tests, such as myoglobinuria or elevation of serum creatine kinase or lactate dehydrogenase. MRI is extremely useful in confirming the diagnosis, determining the need for surgical intervention, and delineating the extent of the necrotizing fasciitis.[32] MRI is also a valuable tool for establishing the diagnosis of group A streptococcal necrotizing fasciitis, but it should not delay early surgical intervention.[33]

Computed tomography (CT) can reveal asymmetric fascial swelling, fat stranding, gas tracking, and abscesses and thus can assist in the diagnosis of suspected necrotizing fasciitis.[34]

TREATMENT

As soon as the diagnosis of group A streptococcal necrotizing fasciitis is seriously considered, the patient should be immediately admitted for intensive care (e.g., burn unit) and for surgical exploration. The polymicrobial profile and the fulminating clinical course require initial treatment with high doses of IV antibiotics. IV fluid replacement and nutritional and blood pressure support are essential. Rapid confirmation of the tentative diagnosis is vital and must be followed immediately by aggressive surgical debridement.

Initial Antibiotic Therapy. High-dose IV antibiotic therapy should be initiated with broad-spectrum antibiotics. The antibiotic mix can be modified later according to the results of the preliminary bacterial culture and sensitivity testing. The choice of antibiotic therapy should be made after consultation with an infectious disease specialist. The Gram stain will guide initial therapy pending the results of the culture and sensitivity.

For group A streptococcal infections, clindamycin suppresses both toxin and M-protein synthesis and is more effective than penicillin.[35] Combination therapy, consisting of clindamycin and an appropriate cephalosporin or vancomycin, is a reasonable initial treatment for gram-positive infections. Mixed gram-negative and gram-positive infections require antibiotics such as ticarcillin-clavulanate or ampicillin-sulbactam.

The ability of azithromycin, erythromycin, clarithromycin, or cefuroxime to modify the course of group A streptococcal or *S. aureus* soft tissue infection has been compared in a mouse model. All antibiotics were effective against *S. aureus* infections, with no significant differences among the four antibiotics. In contrast, in streptococcus-infected mice given azithromycin, fewer demonstrated dermonecrosis ($P = 0.0004$). The effectiveness of azithromycin in these mice may be related to the high and sustained tissue concentrations achieved with this antibiotic.[36]

Other therapeutic considerations include intramuscular gamma globulin. Hyperbaric oxygen treatment is controversial and has not been shown to be significantly helpful.

Surgical Treatment. Definitive treatment of necrotizing fasciitis requires surgical debridement and antibiotics. A clinical continuum exists between aggressive soft tissue infections (streptococcal necrotizing fasciitis) and less destructive local infections that produce systemic toxicity (streptococcal TSS). These two processes cannot be distinguished by clinical examination. Thus every patient with localized evidence of aggressive soft tissue infection should be explored surgically for evidence of a necrotizing process.

Immediate surgical exploration is imperative to visualize directly the fascia and underlying musculature and to obtain sufficient issue for the mandatory Gram stain and culture. Patients with necrotizing fasciitis who undergo surgery within 24 hours of admission have a 6% mortality rate. With further surgical delay, mortality can be as high as 70%.

Surgical incision, blunt dissection, and packing of the wound with wet gauze are done at least once daily. Additional incisions beyond the infected tissue are usually required to detect the extent of peripheral spread of infection. Widespread radical debridement and amputation are not unusual (Figure 12-3).

Figure 12-3

Sequelae of necrotizing fasciitis. Large granulating wound on abdomen is healing by secondary intention after aggressive surgical debridement of necrotizing fasciitis. Infection was precipitated by excessive superficial liposuction, which devascularized skin, causing large bullae and subsequent full-thickness dermal necrosis. Large area of denuded, necrotic, devitalized skin has high risk for infection.

RAPIDLY GROWING MYCOBACTERIA

Rapidly growing mycobacteria (RGM) are diagnostically distinguished from other mycobacteria, such as *Mycobacterium tuberculosis*, by their relatively rapid growth in culture. RGM usually infect skin and subcutaneous tissue, but disseminated disease and localized pulmonary and osteoarticular infections also occur.[37-39]

The three clinically important species of atypical RGM are *Mycobacterium chelonei (chelonae)*, *M. fortuitum* (recently divided into three subspecies), and *M. abscessus* (see following discussion). A fourth pathogenic, rapid grower is *M. mucogenicum*. Appearing as diphtheroid on Gram stain, these RGM require several days to 2 weeks to grow on initial culture plating. On subculture, however, regrowth always occurs in 5 days or less.

The RGM are important nosocomial pathogens associated with traumatic and postsurgical skin and subcutaneous wound infections. The rapidly growing acid-fast bacteria are clinically indistinguishable, and biochemical separation is usually of interest only for epidemiologic purposes.

The RGM are increasingly recognized as a source of chronic nosocomial infections. The first description of a nosocomial infection caused by RGM was a 1938 report of a postinjection cutaneous abscess.[40] Subsequently, numerous reports have attributed postinjection cutaneous abscesses to RGM.[41-50] RGM also have been associated with deep surgical wounds involving the sternum and endocarditis.[51-52] Automated endoscope-disinfecting machines may become highly contaminated with mycobacteria that resist usual disinfection, causing contamination of bronchoscopes and GI endoscopes.[53,54]

TAXONOMIC AND CLINICAL DISTINCTIONS

Previously the rapidly growing mycobacteria were divided into two species: *M. fortuitum* and *M. chelonae (chelonei)*, with *M. chelonae* subdivided into two subspecies, *M. chelonae chelonae* and *M. chelonae abscessus*. Before 1992, many clinical studies did not distinguish between *M. chelonae* and *M. abscessus*. After 1992, based on deoxyribonucleic acid (DNA) homology studies, the RGM have been divided into the three distinct species *(chelonei, abscessus, fortuitum)*.[55,56] Less than 70% DNA homology exists between *M. chelonei* and *M. abscessus*. DNA studies are important in epidemiologic investigations of mycobacterial outbreaks.[57-59]

Important clinical differences are seen between *M. chelonei* and *M. abscessus*. *M. chelonei* has often been associated with disseminated skin disease in patients with corticosteroid-induced immunosuppression.[60] In contrast, besides being associated with surgical wound infections, *M. abscessus* has been responsible for more than 90% of chronic otitis media infections after placement with tympanotomy tubes.[61] Whereas *M. chelonei* is highly resistant to cefoxitin, *M. abscessus* tends to be susceptible to cefoxitin.[62,63] Both are uniformly susceptible to clarithromycin.

LIPOSUCTION EQUIPMENT

RGM are unique in that subcultures grow rapidly (within a few days), whereas the initial culture from tissue biopsies may take several weeks before cultures grow. Atypical RGM infections associated with liposuction are most likely the result of inadequately sterilized surgical equipment. These mycobacteria are notoriously resistant to chemical disinfectants. All surgical instruments must be adequately steam sterilized (Case Report 12-3).

Ubiquitous in the environment, RGM have been cultured from tap water, distilled water, and the walls, furniture, and other surfaces within hospitals and medical clinics. *M. chelonei* and *M. fortuitum* are highly resistant to antibiotics and disinfectants. In particular, RGM are not killed by antibacterial liquids used for "cold sterilization." Nine liposuction patients in eight different hospitals in Caracas, Venezuela, were reported to have acquired RGM infections as a result of cold sterilization of liposuction cannulas. All infections manifested within 2 months after liposuction.[64]

Steam autoclaving is the only reliable method of sterilization. All liposuction cannulas must be steam sterilized under the high pressure of a medical autoclave. Other forms of sterilization are inadequate and below liposuction standards of care.

An international standard of care mandates that all liposuction cannulas be sterilized using a steam autoclave. Similarly, all aspiration tubing, infiltration tubing, syringes, collection canisters, collection bottles, and needles must either be disposable, single-use items or be adequately sterilized in a steam autoclave. Patients expect that all surgical instru-

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CASE REPORT 12-3 Mycobacterial Infection

A surgeon had at least 34 liposuction patients develop postoperative clinical signs of cutaneous and subcutaneous RGM infections. Twelve of these patients had positive RGM cultures; other patients had negative cultures but positive tissue smears with stains for acid-fast bacteria. Most patients had typical clinical skin lesions that did not respond to antistaphylococcal antibiotics but *did* respond to antimicrobial therapy directed at RGM.

During this same period, no other forms of postliposuction bacterial infections were seen, as often occurs when a surgeon attempts to sterilize surgical instruments by soaking them in a cold antiseptic solution. RGM are notoriously resistant to chemical sterilization and liquid disinfectants.

Discussion. Apparently the surgeon was using liposuction cannulas that contained a rubber O-ring that functioned as a gasket between the cannula and its handle. Because rubber O-rings do not tolerate the high temperatures of a steam autoclave, the surgeon opted to sterilize his cannulas by soaking them in a cold antiseptic solution. It was also alleged that the surgeon's office procedures for steam autoclave sterilization were inadequate and that the surgeon reused aspiration tubing after washing it with tap water. During an epidemiologic investigation an identical strain of RGM was cultured from the office tap water.

ments and equipment have been adequately sterilized. It is improper to reuse any tubing, needles, canisters, syringes, or cannulas that have not been adequately steam sterilized.

Cold sterilization of a liposuction cannula, tubing, syringes, canisters, and needles does not meet the internationally accepted standard of care. As noted, cold sterilization does not sterilize certain species of mycobacteria, such as the atypical RGM. Postoperative RGM infections are always a risk, but careful sterilization of instruments and aseptic technique will minimize such risks.

CLINICAL PRESENTATION

Atypical RGM should be suspected in a postliposuction patient who manifests persistent lesions within a liposuctioned area despite empiric treatment with antistaphylococcal antibiotics. The onset may be delayed for several weeks or months after surgery, and new lesions may continue to appear for many months. At least one patient developed new lesions a year after liposuction surgery. Patients receiving long-term oral corticosteroid therapy appear to be predisposed to cutaneous infections with atypical mycobacteria.

The typical lesion in a liposuction patient is a pink or skin-colored papule or subcutaneous inflammatory nodule that progressively increases in size. As lesions grow progressively larger, they appear more inflamed and erythematous and become abscessed and fluctuant. After aspiration or routine swabbing of an abscess, routine bacterial culture and sensitivity tests show no growth.

Lesions typically appear clinically as tender, erythematous, subcutaneous and cutaneous nodules that progress to focal or interconnected abscesses. Surgery may be delayed weeks to months after clinical appearance of the lesions (Figures 12-4 to 12-8).

Hematogenous spread is uncommon except in immunosuppressed patients. The apparent spread of atypical RGM beyond the site of liposuction has been observed in at least one patient (Figure 12-8, C).

Postoperative RGM infections probably are underdiagnosed among cosmetic surgical patients, including liposuction patients. The diagnosis of postliposuction RGM infection requires a high degree of clinical suspicion and the clinical ability to recognize the characteristic cutaneous lesions. Before the surgeon can initiate the process of obtaining tissue for RGM culture, the surgeon must recognize the clinical possibility of a postoperative RGM infection. The diagnosis of postliposuction RGM infections might be missed for the following reasons:

1. Many surgeons are unfamiliar with the typical dermatologic appearance of cutaneous RGM. Unless laboratory personnel are provided with a clinical differential diagnosis that includes RGM, the laboratory might not use the specific culture and tissue smear techniques.
2. Many surgeons might be unaware of the optimal laboratory methods used to confirm the clinical diagnosis of

Figure 12-4

Rapidly growing, atypical, mycobacterial infection. Thirty-four patients, all of whom had liposuction by the same surgeon, developed *Mycobacterium chelonei* infections. Infected lesions appear within skin overlying areas treated by liposuction, such as this woman's abdomen.

Figure 12-5

This patient demonstrates range of characteristic postliposuction lesions of atypical mycobacteria, varying from Kaposi-like nodules and erythematous fluctuant subcutaneous abscesses to superficial ulcerations. Tissue cultured at room temperature grew *Mycobacterium chelonei*.

Figure 12-6

This patient had one nonspecific, subtle, pink, scaly plaque on lower abdomen for more than 5 months after liposuction surgery. Bacterial cultures were negative, and common antibiotics were of no apparent benefit. Tissue smear and stain for acid-fast bacteria (bacilli) were positive, whereas tissue cultures and fixed-tissue, histologic Fite stain were negative.

Figure 12-7

Pink-purple fluctuant periumbilical lesion is one of several on this patient with atypical mycobacterial infection. This woman and those in Figures 12-4 to 12-6 were treated by same liposuction surgeon, who soaked cannulas in chemical disinfectant rather than using steam sterilization.

RGM infection. Obtaining tissue for RGM culture requires special technique (see following section).

3. A high incidence of false-negative mycobacterial cultures occurs among patients with postliposuction RGM infection. I have diagnosed RGM in seven patients, all of whom had liposuction by the same surgeon. In fact, this surgeon had 34 liposuction patients who developed postoperative cutaneous lesions consistent with RGM infection, although positive cultures were obtained from only 12 patients. If positive cultures were required to treat RGM infection, many patients might not be adequately treated.

In my experience with patients who have had positive cultures for RGM, acid-fast bacteria (AFB) have not been detected after routine histologic processing with stains for AFB. Occasionally, a patient suspected of having a RGM infection will have negative RGM cultures but a positive tissue smear for AFB.

LABORATORY DIAGNOSIS

Culture and antimicrobial drug sensitivity testing are important and require special procedures. Culture of a RGM is necessary for an accurate diagnosis. Because mycobacteria are often resistant to antibiotics, obtaining good antibiotic sensitivity data is essential.

On clinical suspicion, one or more inflammatory nodules or abscesses should be biopsied. Fluid aspirated from a cutaneous RGM abscess is often negative on culture. The highest probability of obtaining a positive culture requires tissue obtained using at least a 4-mm punch biopsy. The tissue sample should be obtained using local anesthesia consisting of extremely dilute lidocaine and epinephrine; for example, a dilution of less than 1 mg of lidocaine (1 ml of 1% lidocaine and epinephrine) in 10 ml of normal (0.9%) saline (nonbacteriostatic) should be adequate, while also minimizing the antibacterial effects of lidocaine. Bacteriostatic saline should not be used to dilute the lidocaine and should not be substituted for lidocaine for local anesthesia. Although the benzyl alcohol in bacteriostatic saline does produce brief cutaneous local anesthesia after intradermal injection, it might also inhibit the growth of RBG on culture media.

The biopsy specimen should be transported immediately to the laboratory in a sterile, chemical-free test tube containing preservative-free normal saline, which is then placed on ice. Placing the test tube in a plastic bag containing a few ice cubes should suffice.

The selection of the microbiology laboratory to perform the RGM culture and smear should be based on its experience with mycobacteria. Typically the county or regional public health laboratory will have this expertise because of its experience with *M. tuberculosis*. One should telephone the laboratory in advance to arrange for reception of the specimen and its expeditious processing.

It is important to notify the laboratory when an atypical mycobacterium is suspected because of the special procedures and growth requirements of RGM. Routine culture procedures for *M. tuberculosis* might suppress the growth of atypical mycobacteria. For example, the optimal temperature for culturing rapid growing atypical mycobacteria is 28° to 30° C (82° to 86° F), which is lower than that normally used for in-

A

B

C

Figure 12-8

Atypical mycobacteria (M. fortuitum). These two patients had liposuction by the same surgeon. **A,** Incision and drainage (I&D) of abscesses may accelerate healing of mycobacterial abscesses. **B,** Scars from aggressive I&D of lesions. Not all infections require surgical drainage. Some minor infections may be treated with 6-month course of oral clarithromycin. Aggressive infections may require months of IV therapy with amikacin and gentamicin. **C,** After abdominal liposuction, this patient developed a new subcutaneous abscess on left breast consistent with distant spread of M. fortuitum beyond site of original surgery. New lesion appeared several months after patient had completed 6 months of oral clarithromycin and IV amikacin therapy.

cubation. The laboratory decontamination process used for *M. tuberculosis* is too harsh for rapidly growing acid-fast bacteria, and false-negative results are likely unless special procedures are used. Bactec AFB (Becton-Dickinson) is a growth medium that uses a carbon radiometric method to identify acid-fast bacteria.

TREATMENT

The optimal treatment for cutaneous infection from RGM is not yet well defined. In general, cutaneous abscesses should be incised and drained, with extreme care not to contaminate the environment.

One well-studied outbreak of *M. abscessus* infection was associated with local injections of lidocaine given in a single physician's office.[65] Over 5 months, 350 (18%) of approximately 2000 patients injected with lidocaine developed localized cutaneous abscesses or cellulitis; of the 210 abscesses cultured, 205 were positive for *M. abscessus*. Therapy with combined surgical excision and 3 to 6 months of treatment with clarithromycin was successful for 95% of 148 patients. In contrast, therapy was successful for less than one third of patients treated with surgery or clarithromycin alone. Cla-

rithromycin may be the drug of choice for disseminated infection by *M. chelonei*.[66]

A minimum of 6 months of antibiotic treatment is recommended because of drug resistance. In otherwise healthy patients who have only a few localized foci of infection or abscesses, treatment with oral antibiotics with incision and drainage may be sufficient. In most cases, clarithromycin is the drug of choice for localized cutaneous and subcutaneous infections. The reference laboratory at the University of Texas Health Center at Tyler has found that about 20% of the cultured organisms are sensitive to either ciprofloxacin or doxycycline. Some physicians prescribe doxycycline as a second oral antibiotic even if it has not been effective with in vitro testing. An occasional mycobacterium is sensitive to cefoxitin.

The recommended dose of clarithromycin for RGM associated with liposuction is 500 mg orally, twice daily, for at least 6 months. Some clinicians recommend polydrug therapy (e.g., doxycycline, 100 mg twice daily, with clarithromycin) to minimize the possibility of developing drug resistance.

More serious or extensive infections may require daily IV antibiotic treatment with either tobramycin or amikacin. The nephrotoxicity and ototoxicity of these aminoglycoside

antibiotics require careful evaluation before committing a patient to prolonged use.

M. chelonei wound infections have been reported after cosmetic plastic surgery employing contaminated gentian-violet skin-marking solution.[67] Treatment required repeated incision and drainage, as well as long-term antibiotics.

The clinical course can be prolonged and frustrating, with new lesions continuing to appear even after months of antibiotic treatment for RGM. At the conclusion of treatment, clinically apparent lesions should be biopsied again and tissue submitted for culture.

VIRUSES

HIV-positive patients may have a relatively increased risk for perioperative infections after liposuction. Thus HIV infection is a relative contraindication for cosmetic surgery.

Furthermore, protease inhibitor drugs are metabolized by cytochrome P450 3A4, which also metabolizes lidocaine. The potential for an adverse drug interaction between protease inhibitors and lidocaine is another relative contraindication for tumescent liposuction.

Hepatitis C virus (HCV) was identified relatively recently, and much is still unknown about its mode of transmission. No available immunization protects health care workers from hepatitis C. Because HCV infections can lead to fatal chronic infections and have been associated with malignant hepatomas, liposuction may be contraindicated in an HCV-positive patient. Medical staff should not be exposed to a potentially fatal infection merely for a cosmetic surgical procedure.

Laboratory tests for hepatitis C antibody are available, but a certain percentage of HCV-positive tests are false-positive results. A positive test should be followed up by a more specific immunologic test.

DERMATOLOGIC ASEPTIC TECHNIQUE

Different specialties have different approaches to aseptic surgical technique. In skin cancer surgery, for example, surgeons who use local anesthesia for office-based surgery certainly use different techniques than those who use general anesthesia or heavy IV sedation in a hospital setting.

Dermatologic surgical aseptic technique often does not conform to hospital operating room standards. Many dermatologic surgeons do not always wear masks, caps, or full sterile gowns when excising large skin cancers and performing complex repairs. Nevertheless, hospital infection control nurses would be envious of dermatologists' low rate of postoperative wound infections.

I experienced one troubling postliposuction wound infection, a small staphylococcal abscess on the medial thigh. I had mistaken the focal erythema, warmth, tenderness, and swelling for a postoperative panniculitis and treated the patient with prednisone, 10 mg daily. Within a few days an abscess developed, which was incised and drained on an outpatient basis. Subsequently the wound healed rapidly, and the patient had no visible scar or evidence of the postoperative infection.

Many years ago, when incisions were closed by sutures, I also encountered postoperative inflammation at an incision site on the distal medial knee on six occasions.

Dermatologic surgeons may find standard hospital operating room procedure and aseptic technique somewhat irrational as applied to liposuction. For example, before liposuction of multiple areas, nurses scrub the patient, and the surgeon dons a mask, hat, sterile surgical gown, and pair of sterile surgical gloves. Frequently, however, the surgeon wears the same pair of gloves throughout the procedure.

No matter how well a patient's skin is prepared with an aseptic scrub, bacteria readily contaminate a surgeon's glove after a few minutes of touching, squeezing, and grabbing the patient's skin. When such a contaminated glove grasps the shaft of a cannula, it is increasing the risk of a surgical infection. From my perspective, wearing a sterile surgical gown is not as important as changing gloves more frequently and not touching the shaft of a liposuction cannula.

Box 12-1 lists other measures to reduce the risk of infection after liposuction.

BOX 12-1 MINIMIZING THE RISK OF INFECTIONS

1. Perform open drainage and bimodal compression to reduce free fluid in the subcutaneous space and thus decrease the risk of rapidly spreading an infection.
2. Do not allow anything to touch a cannula shaft other than the skin at the incision site and the subcutaneous fat. Use a fresh, unused, sterile gauze pad to wipe off the cannula. Once the surgeon's gloved hand has touched the patient's skin, it should not touch the cannula shaft.
3. Change gloves more frequently, for example, each time the patient is placed in a different position or each time a new area is treated.
4. Use sterile, disposable, single-use suction tubing to connect the liposuction cannula handle to the suction apparatus.
5. Always autoclave cannulas. It is never sufficient simply to soak a cannula in a cold sterilizing solution.
6. Immediately before tumescent liposuction of a given area, scrub the area with surgical soap and disinfectant, such as chlorhexidine gluconate. Scrub the area again if the patient touches the surgical area or if contamination is suspected.
7. Encourage patients to shower and wash with antibacterial soap every day after surgery.
8. Avoid placing incisions too close to the perineal area during liposuction of the inner thighs.
9. Begin antibiotic prophylaxis with oral medication the day before surgery.

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Hypothermia and Cryoanesthesia

Some surgeons seem to believe that "coldness" improves the quality of local anesthesia. For example, some incorporate chilled saline (less than 4° C [25° F]) in a modification of the tumescent technique, presumably to improve hemostasis or local anesthesia. In fact, warm tumescent anesthetic solution (37° C [98.6° F]) provides complete local anesthesia[1] and profound hemostasis and is more comfortable for the patient.[2-4]

Hypothermia and cryoanesthesia are unnecessary and present significant dangers to the liposuction patient. Employing "coldness" in tumescent liposuction is seldom justified.

HYPOTHERMIA

Hypothermia, a medical emergency, occurs when the core or central body temperature is 35° C (95° F) or lower.[5] Below 30° C (86° F), refractory ventricular fibrillation may occur. Loss of consciousness usually occurs below 26.6° C (80° F). Coma and areflexia occur below 25° C (77° F). Hypothermia has potent toxic effects on coagulation of blood and hemodynamics, with excessive oxygen consumption.[6]

Hypothermia is associated with potentially fatal cardiac dysrhythmias.[7-9] Relatively mild degrees of hypothermia, as when a naked patient under general anesthesia is exposed to cold operating room temperatures, have been shown to predispose patients to sepsis.[10] Hypothermia has been associated with increased surgical bleeding.[11] Hypothermia also may decrease the rate of hepatic lidocaine metabolic transformation by impairing enzymatic activity.

Lactic acidosis is typically associated with hypothermia. Increased hemoglobin-oxygen affinity (dissociation curve shifted to the left) and decreased tissue perfusion cause hypoxemia. Some patients show serum amylase elevation, and pancreatitis may be noted at autopsy.

Hypothermia may delay healing, increase the risk of surgical wound infections, and prolong hospitalization.[10] Mild hypothermia associated with anesthesia lowers guinea pig resistance to infection by *Escherichia coli*[12] and *Staphylococcus aureus*.[13] Mild perioperative hypothermia (approximately 2° C below the normal core body temperature) is a common result of anesthetic-induced impairment of thermoregulation, exposure to cold, and altered distribution of body heat. Mild core hypothermia can directly impair immune function, such as granulocyte chemotaxis and phagocytosis, macrophage motility, and antibody production.[14] Intraoperative hypothermia during surgery under general anesthesia can be avoided by actively warming the patient.[15]

CARDIAC EFFECTS

When body temperature is less than 34° C (93.2° F), intracardiac conduction velocity decreases. This is manifested on the electrocardiogram (ECG) by prolonged PR and QT intervals, widened QRS complex, T-wave changes, and characteristic J waves (Osborne waves) at the QRS complex–ST segment junction. Atrial fibrillation is common.

Hypothermia increases sympathetic arterial tone, left and right ventricular afterload, heart rate, stroke volume, cardiac output, and blood pressure, which increases myocardial oxygen consumption. Ultimately, this may decrease cardiac output.[16] Shivering also increases metabolism, oxygen consumption, and cardiac work.

Patients who arrive in the intensive care unit with temperatures less than 35° C (95° F) have a significantly higher incidence of postoperative myocardial ischemia (36% versus 13%) than normothermic patients.[17] Furthermore, despite similar perioperative risk factors, hypothermic patients have a higher rate of postoperative angina (18% versus 1.5%).

Adverse cardiac events are the major cause of morbidity and mortality after noncardiac surgery. In patients undergoing noncardiac surgery, early postoperative myocardial ischemia is an important correlate of adverse cardiac outcomes.[18] Mild hypothermia (33° C [91.4° F]) can attenuate nitroglycerin-induced vasodilation.[19]

GENERAL ANESTHESIA

Mild perioperative hypothermia is a common sequela of general anesthesia and heavy intravenous (IV) sedation because of the pharmacologic inhibition of thermoregulation and the patient's exposure to the cool environment. Undetected hypothermia is also common during regional, spinal, and epidural anesthesia because core temperature is rarely monitored and because patients usually do not feel cold.[20,21]

Anesthesiologists play an important role in monitoring a patient's body temperature and maintaining normothermia (37° C).[22]

IMPAIRED COAGULATION

Hypothermia has been associated with increased surgical bleeding.[11] Although focal hypothermia causes local vasoconstriction, the systemic effects of hypothermia may cause a serious bleeding diathesis.[23] Hypothermia impairs enzymatic activation of coagulation factors, accentuates fibrinolysis, and may cause disseminated intravascular coagulation (DIC)[24] (Case Report 13-1). Decreased body temperature is associated with increased activity of heparin-like factor Xa inhibitor, which is not neutralized by protamine.[25,26] Hypothermia causes reversible platelet sequestration in the spleen.[27]

Patients with essential (mixed) cryoimmunoglobulinemia of immunoglobulins G and M (IgG, IgM) and those with monoclonal cryoglobulinemia may be more susceptible to intravascular thrombi formation.

CRYOANESTHESIA

Cryoanesthesia is the process of lowering tissue temperature and thus inducing a degree of cutaneous insensitivity. Cryoanesthesia predisposes to hypothermia. Deliberate cryoanesthesia for liposuction is produced by subcutaneous infiltration with a chilled anesthetic solution or by direct application of ice to a patient's skin. Using a chilled tumescent solution or packing the patient in ice has no significant benefit.

Infiltrating with chilled saline and tumescent anesthetic solution has been promoted, but no comparative studies have documented any advantage.

Chilled anesthetic solution is unnecessary, is potentially dangerous, and *should not be used* as part of the tumescent technique. The subcutaneous infiltration with a tumescent anesthetic solution at or slightly less than 37° C produces sufficient clinical vasoconstriction.

Occasionally, cryoanesthesia is associated with morbidity. Cryoanesthesia causes shaking chills and significant patient discomfort that usually necessitates ancillary IV sedation. Hypothermia can result from the parenteral infiltration of large volumes of chilled (4° C [39.2° F]) liquids, such as chilled tumescent anesthetic solution.

Most surgeons who use cryoanesthesia for liposuction do not monitor core body temperature. Monitoring core temperature during cryoanesthesia, however, is just as important as monitoring oxygen saturation during administration of drugs that depress respiration.

CASE REPORT 13-1   Hypothermia, Superwet Technique, and Death

A 43-year-old female had liposuction of multiple areas in an outpatient setting. Anesthesia consisted of IV midazolam (Versed, 15 mg), IV methohexital (Brevital) with several liters of a *chilled* solution of "tumescent" local anesthesia, and 4 L of IV fluids. During recovery the patient became severely hypotensive. After 15 minutes of cardiopulmonary resuscitation (CPR), paramedics arrived to find the patient apneic, pulseless, and asystolic.

At the hospital the emergency room (ER) physician noted pink, frothy sputum through the endotracheal tube, bleeding from the nose, and sutured surgical sites. The rectal (core) temperature was 33.5° F (about 1° C). After CPR for 10 minutes, she recovered spontaneous pulse and blood pressure. Treatment of ventricular fibrillation included lidocaine.

Laboratory values included hematocrit, 8.1 ml/dl; hemoglobin, 2.8 g/dl; platelets, 84,000/mm³; prothrombin time (PT), 25 seconds; and partial thromboplastin time (PTT), 144 seconds. Vigorous CPR included 4 units whole blood, 5 units fresh-frozen plasma to correct coagulopathy, and 1.5 L crystalloid used for drug delivery. No Foley catheter was used, despite administration of IV furosemide (Lasix, 100 mg). Even with hemodialysis in the ER in an effort to remove excess fluid (pulmonary edema, no urine output), the patient died. Causes of death listed by ER physician included pulmonary edema (fluid overload), hypothermia, DIC, coma, hypotension, renal failure, and metabolic acidosis.

Discussion. This case illustrates several unnecessary, severe physiologic insults. Cryoanesthesia and IV general anesthesia contributed to significant hypothermia; excessive IV fluid produced pulmonary edema and hemodilution. All these insults resulted in superwet DIC (see Chapter 9). Hypothermia is well known to cause DIC, cardiac dysrhythmias, and surgical infections.

Chilled saline is contraindicated for tumescent liposuction. Using cryoanesthesia requires continuous monitoring of core body temperature. No scientific data or published reports support the use of cryoanesthesia for liposuction. Any IV fluid supplementation is contraindicated with tumescent liposuction if it exceeds the absolute minimum volume.

Bretylium might be preferred to lidocaine for the initial treatment of ventricular dysrhythmias in the patient with potential local anesthetic toxicity. Although the plasma lidocaine concentration resulting from the tumescent anesthesia was probably not near the threshold for toxicity in this case, additional IV lidocaine to treat ventricular fibrillation might not be my first choice.

CONTRAINDICATIONS

Deaths have occurred associated with using chilled anesthetic solution for cryoanesthesia during liposuction. Cryoanesthesia may be a reasonable adjunct to piercing the ear, but it is contraindicated for liposuction.

Two major reasons exist not to use cryoanesthesia. First, patients are more comfortable when the tumescent solution is approximately 37° C. With the true tumescent technique, the anesthetic solution is heated 37° to 39° C (98.6° to 102.2° F) in a blanket warmer before infiltration. Second, warmed tumescent solution provides such profound vasoconstriction and such exquisite hemostasis that using a dangerous additional treatment modality such as cryoanesthesia is unnecessary.

The ethical use of cryoanesthesia requires full, written, informed patient consent that includes all the risks and alternatives to cryoanesthesia.

COLD COMPRESSES AND DERMAL NECROSIS

Some surgeons believe cryoanesthesia for liposuction is safe and effective. I believe that the prolonged application of ice to the skin of a liposuction patient is contraindicated. Some surgeons have covered their patients in ice packs or plastic blankets containing frozen gel in an attempt to achieve subcutaneous vasoconstriction and minimal surgical anesthesia. Postoperative ice compresses are advocated for reduction of swelling and inflammation. Additionally, conventional tumescent anesthesia with lidocaine and epinephrine has been "augmented" by chilling the solution to below 4° C before infiltration into the patient's subcutaneous fatty tissues.

Prolonged cutaneous contact with ice or prolonged immersion in ice water results in full-thickness necrosis.[28] In frozen tissue, ice crystal formation and development of strong salt solutions disrupt cell membranes. Significant cold injuries lead to vascular stasis and a fulminating inflammatory vascular reaction, resulting in tissue damage similar to that produced by burns.[5]

It is now well known that treating *snakebite* by immersion of an affected limb in ice water can result in massive tissue slough, often necessitating amputation.[29-31] Because of unnecessary damage to healthy tissue, experts agree that cryotherapy should never be used to treat snakebite.[32]

The pathologic sequela of *frostbite* is primarily the result of irreparable damage to blood vessels. The vasculature of frozen dermis and subcutaneous tissue becomes occluded by agglutinated cells and thrombi, and blood flow ceases. In this setting, tissue damage is aggravated by trauma and other factors that compress tissue and decrease blood flow.

Because patients do well without application of cold compresses, the risk of cryotrauma is unnecessary. The idea that cold compresses will "decrease inflammation" is an inappropriate, potentially dangerous application of unsubstantiated clinical dogma. Cold compresses are unlikely to decrease inflammation directly by inhibiting the generation of inflammatory mediators (e.g., prostaglandins) on a molecular level. At best, cold compresses will decrease extravasation of blood into traumatized tissues. If the skin and subcutaneous tissues are already vasoconstricted, cold compresses offer little incremental benefit.

Excessive use of cold compresses postoperatively may have disastrous consequences for liposuction patients. Any factor that injures or compromises the subdermal vascular plexus may predispose skin to unexpected injury. Superficial liposuction, profound localized pharmacologic vasoconstriction, or an endogenous cryoglobulinemia may result in severe skin necrosis.

Cold compresses are usually innocuous, but patients may not understand or follow instructions for postoperative care. For example, one liposuction patient with unrecognized cryoglobulinemia applied ice packs under an elastic support garment, resulting in full-thickness necrosis of the affected skin.

CRYOGLOBULINS

Cryoglobulins are cold-insoluble serum proteins or protein complexes that undergo reversible precipitation at low temperatures. Many connective tissue, autoimmune, infectious, and neoplastic diseases are associated with cryoglobulinemia.[33] Several unrelated proteins, such as fibrinogen and immune complexes, are cryoprecipitable under certain conditions. Cryoimmunoglobulins and immunocomplexes are clinically the most important.

Cryoglobulins may consist of monoclonal proteins, as seen in multiple myeloma, Waldenström's macroglobulinemia, or occasionally in other lymphoproliferative disorders.[34] Mixed immunoglobulin complexes usually consist of IgM, which precipitates at lower temperatures (cryoprecipitate) and is directed against normal endogenous IgG, as in connective tissue diseases, autoimmune diseases, infectious diseases, and neoplastic diseases.

Cryoglobulinemia. The term *essential mixed cryoglobulinemia* applies when no underlying disease can be identified in association with the cryoglobulinemia. One of the causes of typical cutaneous hypersensitivity vasculitis (leukocytoclastic lymphocytic cutaneous vasculitis) is essential mixed cryoglobulinemia.

Cryoglobulinemia can be pathogenic in a number of vasculitic syndromes. When immune complexes containing IgG and IgM precipitate into vascular lumina, the classic complement pathway is activated, and tissue-specific pathology can ensue. Biopsy of a skin lesion shows precipitates of the cryoglobulin within dermal vessels.

The most common symptoms of cryoglobulinemia result from exposure to low environmental temperatures, inducing cryoprecipitation within the capillaries of the skin, which in turn impairs cutaneous blood flow.[35] Cold exposure can lead to exacerbations of the disease, which often presents as ulceration and necrosis, hemorrhagic infarcts of skin, purpura, Raynaud's phenomenon, cold urticaria, or livedo reticularis.

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CHAPTER 14

Perioperative
Bleeding Disorders

Surgical blood loss was the greatest danger of the first lipo-suction techniques. Because of blood loss, any liposuction aspirate of more than 1500 to 2000 ml was indication for an autologous blood transfusion. For example, among 108 patients who had large-volume suction lipectomy under general anesthesia with no tumescent vasoconstriction, 30% to 45% of the aspirate volume was blood. This patient population required 227 units of autologous blood and 2 units of heterologous blood for transfusion.[1]

The tumescent technique for liposuction has eliminated most of the risks of surgical bleeding previously associated with liposuction. However, unusual causes of blood loss with tumescent liposuction remain. Undiagnosed inherited bleeding disorders, such as von Willebrand's disease or hemophilia, can also cause unexpected bleeding. Common over-the-counter drugs can impair normal coagulation and cause significant bleeding problems even with the tumescent technique.

The tumescent technique, first presented in 1986 and published in January 1987, allows liposuction with virtually no blood loss. The tumescent technique was ignored by many liposuction surgeons until 1993, however, when it was published in the plastic surgery literature for the first time. Thus surgical bleeding remained a significant problem for liposuction well into the 1990s, when the most common indication for autologous blood transfusion in Beverly Hills, California, was liposuction. The slow assimilation of a dermatologic surgical technique by plastic surgeons is revealing regarding information exchange between cosmetic surgical specialists.

The original description of tumescent liposuction reported on 22 patients with a mean volume of yellow (bloodless) supranatant fat of 915 ml. The report emphasized that all patients had been treated using local anesthesia instead of general anesthesia. This was also the first published report of the remarkable hemostasis associated with the tumescent technique. The mean volume of infranatant blood-tinged anesthetic solution was 252 ml and contained less than 1.5%

packed red blood cell (RBC) volume. Assuming whole blood contains a 40% RBC volume, a simple calculation revealed an average of 10.25 ml of whole blood was aspirated per liter of supranatant fat.[2] Therefore most patients lost more blood with the preoperative laboratory evaluation than during the entire liposuction procedure.

Liposuction surgeons, even those who use the tumescent technique, must be aware of the continued dangers of unanticipated surgical and postoperative bleeding.

DISSEMINATED INTRAVASCULAR COAGULATION

Disseminated intravascular coagulation (DIC) is a form of systemic bleeding characterized by a depletion of clotting factors and associated with few if any intravascular thrombi. Common causes of DIC include shock, massive tissue trauma, hemorrhage with hemodilution, crush injuries, burns, sepsis, hypothermia, obstetric complications, and transfusion reactions. Excessive liposuction using the superwet technique can also cause DIC. To my knowledge, DIC has not occurred with tumescent liposuction totally by local anesthesia.

In healthy patients the procoagulant and anticoagulant systems maintain a well-balanced state of intravascular homeostasis, with neither system predominating. When multiple factors favor a shift of these biochemical reactions toward coagulation, however, the intravascular consumption of coagulation factors can proceed unchecked. In extreme cases, DIC develops. DIC has been reported in association with general anesthesia, hemodilution, trauma, and hypothermia, all of which are sequelae of excessive liposuction together with infusion of excessive IV fluids.

The clinical diagnosis of DIC is notoriously difficult and is rarely suggested simply by the patient's appearance. The clin-

ical diagnosis of DIC is usually first suspected with an unexplained abrupt deterioration of the patient's condition in a clinical setting known to be frequently associated with DIC. A suspected diagnosis of DIC can be confirmed by laboratory tests that show reduced fibrinogen, elevated fibrin degradation products, and a greatly decreased platelet count. Unless DIC is suspected and confirmed with specific laboratory tests, the diagnosis is usually not made while the patient is alive.

HEMODILUTION

Hemodilution can predispose to DIC. The natural homeostatic control of intravascular blood coagulation involves a continuous, delicate, well-balanced interaction between procoagulant and anticoagulant factors.

Hemodilution has been noted to induce a hypercoagulable state.[3,4] In vitro a 30% hemodilution with saline significantly increases coagulability.[5] Hemodilution may produce abnormal hemostasis before any compromise of tissue oxygen delivery.[6] Hemodilution associated with intravenous (IV) lactated Ringer's solution or normal saline during surgery may predispose to deep venous thrombosis.[7]

The mechanisms by which hemodilution predisposes to hypercoagulability are not well understood. Hemodilution may disturb the ratio of thrombin to antithrombin III.[8] Some preliminary evidence indicates that antithrombin III is decreased to a greater extent after hemodilution than is predicted by calculating the effect of hemodilution alone.[9-9b]

Hemodilution decreases the concentration of several other anticoagulant factors, thereby inducing acquired forms of protein C deficiency and protein S deficiency. Both deficiencies favor the procoagulant process and contribute to an intravascular consumption of coagulation factors (see Chapter 10).

A hemorrhage is typically followed by hemodilution as interstitial fluid is recruited from the interstitial space into the intravascular space. Similarly, hemorrhage would also be expected to result in homeostatic coagulation. Thus, from a cause-and-effect or teleologic perspective, it is reasonable to associate hemodilution and hypercoagulability.[10] If hemodilution is associated with the conversion of prothrombin to thrombin, homeostasis would require that antithrombin be consumed by a thrombin-antithrombin interaction. A relative deficiency in antithrombin would then favor intravascular coagulation.

Tumescent Hemodilution. The infusion of large volumes of crystalloids delivered by both IV infusion and tumescent hypodermoclysis can cause systemic fluid overload and contribute to iatrogenic DIC. In general, if the surgeon anticipates the need for IV fluids with tumescent liposuction, the anticipated volume of liposuction is probably excessive. Prophylactic infusion of IV crystalloids is contraindicated with tumescent liposuction.

Again, as emphasized throughout, the tumescent technique eliminates the need for supplemental IV fluids. When the tumescent technique is used for liposuction, the routine use of IV fluid supplementation is contraindicated.

Tumescent infiltration causes hemodilution with or without subsequent liposuction. A 75-kg (165-pound) female received a total of 5.25 L of physiologic saline in the subcutaneous space by the tumescent technique on two occasions, receiving 35 mg/kg lidocaine each time.[11] On the first occasion no liposuction was done; 2 weeks later liposuction produced 1550 ml of supranatant fat. On each occasion the tumescent infiltration of 5.25 L of saline produced significant hemodilution, which was maximal 12 to 24 hours after infiltration. Without liposuction the hematocrit decreased from 35.3 to 32.6 ml/dl; after liposuction it decreased from 36.2 to 32.0 ml/dl. The patient had no evidence of an intravascular fluid deficit, with or without liposuction. On both occasions the tumescent technique produced a postoperative decrease in urine specific gravity and resulted in cumulative urine volumes greater than 70 ml/hr, both of which are evidence of hemodilution.

LIPOSUCTION TRAUMA

Increasing degrees of liposuction trauma produce increasing areas of exposed endothelial surfaces, which activates a greater proportion of circulating platelets and induces progressive intravascular coagulation. In animal studies, increasing amounts of trauma are directly correlated with increasing degrees of thrombosis.[12] It is reasonable to assume that the greater the area of the body's subcutaneous tissue traumatized by liposuction, the greater the amount of intravascular coagulation factors consumed. In addition, increasing surgical trauma induces increased systemic inflammation, which in turn decreases the concentration of circulating free protein S. Acquired or genetic protein S deficiency is a well-established cause of a procoagulant state and thromboembolism (see Chapter 10).

HYPOTHERMIA

The continuous homeostatic balance between intravascular procoagulation and anticoagulation is a temperature-dependent biochemical process. Hypothermia disturbs this balance and can lead to consumption of coagulation factors. Hypothermia produces marked prolongation of the bleeding time.[13]

Thrombosis in multiple organs is a common postmortem finding associated with hypothermia. Hypothermia in experimental dogs induces DIC with consumption of multiple clotting factors, and treatment with heparin prevents the decrease in fibrinogen.[14] Hypothermia causes DIC in the newborn.[15,16] Hypothermia in adults has been reported to cause DIC and pancreatis,[17] as well as DIC and thrombocytopenia.[18]

Both general anesthesia and heavy IV sedation frequently produce mild to moderate perioperative hypothermia as the result of pharmacologic inhibition of thermoregulation and exposure of the patient to the cool operating room environment. The hypothermia associated with the general anesthesia used with the superwet technique for liposuction can precipitate DIC. Undetected hypothermia is also common during regional, spinal, and epidural anesthesia because core temperature is rarely monitored and patients usually do not feel cold.[19]

SUPERWET TECHNIQUE

The superwet technique for liposuction is characterized by the following:

1. General anesthesia
2. Subcutaneous infiltration containing dilute epinephrine without lidocaine
3. Suboptimal volume of subcutaneous infiltration
4. Compensation for the suboptimal subcutaneous infiltration by infusing large volume of IV fluids
5. Compensation for not using tumescent lidocaine by postoperative infiltration of bupivacaine

Recall that, by definition, the tumescent technique for liposuction precludes doing such large volumes of liposuction that the patient requires IV fluids and general anesthesia. Tumescent liposuction totally by local anesthesia specifically employs serial liposuction procedures rather than a single, huge-volume liposuction procedure. Whereas tumescent liposuction avoids DIC by avoiding excessive liposuction, the superwet technique can precipitate DIC through excessive or huge-volume liposuction or even megaliposuction.

Liposuction surgery has a profound effect on the body's hemostatic mechanism. In particular, superwet liposuction by systemic anesthesia with IV fluid infusion, extensive trauma, and secondary hypothermia can produce DIC. Early liposuction, especially the dry and wet techniques, effectively opened the intravascular space and allowed its contents to flood the subcutaneous wound. The blood loss was great and highly visible.

The hemorrhagic effects of excessive tumescent liposuction are much more subtle. Even with the profound vasoconstriction of the tumescent technique, the disruption of huge numbers of capillaries exposes subendothelial surfaces and tissue thromboplastin to platelets and blood coagulation factors. This exposure precipitates the degranulation and aggregation of a significant proportion of the circulating platelets. With any liposuction, tissue damage simultaneously activates the coagulation, complement, fibrinolytic, and kinin systems. Excessive liposuction may induce a hypercoagulable state.

Underreporting. The association between excessive liposuction and DIC is underreported. The lack of reported cases of DIC with liposuction is not proof that liposuction deaths are not associated with DIC. At least two cases of DIC have resulted from the combination of huge-volume liposuction, general anesthesia, hypothermia, and IV fluid infusion (Case Report 14-1; see also Case Report 13-1). DIC may even be one of the most common causes of death associated with liposuction under general anesthesia.

Originally, liposuction surgery was limited by visible blood loss. The tumescent technique has eliminated the grossly hemorrhagic liposuction aspirate. The combination of general anesthesia and tumescent infiltration, however, has fostered a cavalier attitude toward the risks of overaggressive liposuction. No obvious threshold exists to limit the amount of liposuction. Several new hemorrhagic postoperative syndromes are the direct result of excessive liposuction. Yellow

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CASE REPORT 14-1 Superwet Disseminated Intravascular Coagulation and Death

A 46-year-old white female had a preoperative weight of 68.2 kg (150 pounds) and was taking Synthroid, Premarin, and Claritin. Her surgery lasted 10½ hours and included liposuction, blepharoplasty, minor facelift, endoscopic brow-lift procedure, laser surgery to face, and fat transfer to buttock. Total aspirate removed by "tumescent" liposuction was 10.9 L, and total urine output was 775 ml.

Over the course of the surgery the patient received a tumescent subcutaneous infiltration of "14 to 15 liters of warmed xylocaine, epinephrine, Ringer's lactate Solution." No written orders specified the lidocaine dose, but according to the county coroner's forensic toxicologist, the total dosage of lidocaine was 95 mg/kg. In addition, the anesthesiologist gave 18,800 ml of LR plus 1000 ml of Hespan.

About 2½ hours after surgery, paramedics took patient to local hospital, where she was described as grossly edematous and bleeding from sutured incision sites. Laboratory values were platelet count, 20,000/mm^3; hemoglobin, 2.1; hematocrit, 6.8; and with agonal electrocardiographic rhythm. The patient received 8 units of whole blood and 6 L of physiologic saline in the emergency room, where she died.

At autopsy the patient weighed 82.7 kg (182 pounds), an increase of 14.5 kg, most of which is attributable to excessive IV fluids.

Discussion. Significant postoperative anemia and thrombocytopenia are diagnostic of DIC associated with hemodilution, general anesthesia, and excessive trauma. Diagnosis of DIC was not considered until after the patient's death. Serial surgeries would have been safer.

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supernatant fat and delayed DIC with massive subcutaneous bleeding may result from excessive liposuction by the superwet technique.

Information and analysis of cosmetic surgical deaths should be shared so that surgeons can learn from others' mistakes. Every cosmetic surgical death is unexpected, and an iatrogenic death is particularly disturbing because it was the result of an elective procedure.

OCCULT HEMORRHAGE

The fat removed by tumescent liposuction is a bloodless yellow, and a delayed occult hemorrhage can occur from a platelet and prothrombin deficiency. Because of the hemodilution, the hemorrhagic bleeding may be mistaken for normal tumescent anesthetic drainage. With massive hemorrhage, patients with postliposuction DIC and hemorrhage may appear pale. Pallor may be the initial clinical indication of a potentially life-threatening anemia.

The most reasonable solution to this problem is prevention, as follows:

1. Limit total volume of supranatant fat that is aspirated to less than 3 to 4 L.
2. Limit the total body surface area treated by liposuction to approximately 20%.
3. Use tumescent anesthetic solution at body temperature.
4. Avoid excessive IV fluid infusion.

PREDISPOSING DISORDERS

A number of inherited and acquired disorders can predispose to excessive surgical bleeding. Tumescent infiltration cannot be expected to eliminate all risks of perioperative bleeding. Avoiding such dangers requires a knowledge of potential problems.

von Willebrand's Disease

von Willebrand's disease (vWD) is the most common inherited bleeding disorder, with a prevalence of 1 in 800 to 1000 persons. The acquired forms of vWD are less common than the inherited forms. Usually autosomal dominant, it is a heterogeneous disease, but all syndromes share common features.

Patients who have vWD are missing the plasma glycoprotein von Willebrand factor (vWF). vWF is a disulfide-linked, high-molecular-weight multimer present in plasma, platelets, and vascular subendothelium. vWF is necessary for platelet adhesion to subendothelial collagen. vWF also serves as a plasma binding protein that carries factor VIII; thus there is diminished factor VIII:C (procoagulant) activity associated with vWD.

Patients with mild vWD are asymptomatic, except with surgery or trauma, and may have laboratory values that fluctuate between normal and abnormal over time; for example, the bleeding time may be normal or prolonged on any given occasion. Patients with severe vWD may have spontaneous epistaxis and mucosal (oral, gastrointestinal, genitourinary) bleeding.

Typical laboratory profiles show (1) prolonged bleeding time, (2) low plasma vWF concentration, (3) low ristocetin activity (diminished platelet aggregation in response to ristocetin), and (4) low factor VIII activity.

Treatment for vWF includes cryoprecipitate transfusion or an infusion of 1-desamino-8-D-arginine vasopressin (desmopressin, DDAVP). Transfusion with cryoprecipitate, which is rich in vWF, carries a risk of infection from bloodborne pathogens. DDAVP infusion increases vWF concentration in patients with mild vWD. Response to DDAVP is variable, and prophylactic treatment before surgery requires preoperative testing to confirm the benefits of DDAVP.

Acquired vWD is caused either by antibodies that inhibit vWF function or by tumors that selectively adsorb vWF onto their surface (e.g., lymphoid tumors, Waldenström's macroglobulinemia, Wilms' tumor).

Hemophilia

Hemophilia A, the classic hemophilia, is a sex-linked recessive disorder, caused by a deficiency in factor VIII:C, the coagulation portion of the factor VIII complex. England's Queen Victoria was a carrier, and the disease affects approximately one in every 5000 to 10,000 males in the United States. Individuals with severe, moderate, or mild hemophilia have 1% or less, 1% to 5%, or 5% or greater, respectively, of normal factor VIII:C activity in their blood.

Hemophilia B, clinically indistinct from hemophilia A, is also a sex-linked recessive disorder. It causes 15% of all hemophilias and has a factor IX defect.

Patients with mild hemophilia may not be detected until they experience surgery or trauma, whereas severe hemophilia is usually manifested by severe bleeding in infancy. Typical laboratory findings for hemophilia show extremely prolonged partial thromboplastin time (PTT), with normal prothrombin time (PT) and platelet count.

Mild hemophilia is the most dangerous type of hemophilia that a liposuction surgeon can encounter. Patients with severe hemophilia are unlikely to seek liposuction. A patient with mild, previously occult hemophilia, however, may slip by a surgeon who does not require preoperative PT and PTT. Occult hemophilia and liposuction can be a life-threatening combination. Bleeding that begins on the first postoperative day is characteristic of thrombocytopenia and mild occult hemophilia.

Vitamin K Deficiency

Vitamin K deficiency can predispose to prolonged bleeding and attendant surgical complications. *Phylloquinone* (phytonadione), or vitamin K_1, is a yellow fat-soluble oil that is present in green leafy vegetables and is important in blood clotting. To some extent, phylloquinones are absorbed intact from the intestines, and they have some vitamin K activity. Most of the ingested phylloquinone is altered by intestinal bacteria, which remove the side chain to produce menadione. After menadione is absorbed, a new side chain is constructed to create *menaquinone,* the principal form of vitamin K found in animals.

Vitamin K_2, which is formed by some bacteria, differs from phylloquinone only in the substituent in the 3 position of the naphthoquinone ring.

Vitamin K is an important cofactor for enzymes that effect posttranslational (postribosomal) gamma (γ-) carboxylation of glutamic acid in proteins. This γ-carboxylation, which is essential for the biologic activity of many proteins, occurs in hepatocytes and is mediated by hepatic microsomal enzyme systems. The resulting γ-carboxyglutamic acid residue is secreted by hepatocytes into the blood. Liver disease may impair vitamin K metabolism.

Clotting factors II, VII, IX, and X, and the coagulation inhibitors (anticoagulant) proteins C and S are vitamin K-dependent proteins. Warfarin (Coumadin) is an anticoagulant drug that competes with vitamin K and inhibits

γ-carboxylation of the precursor to prothrombin and causes hypoprothrombinemia. Salicylates such as aspirin can cause hypoprothrombinemia, which can be inhibited by vitamin K.

In normal circumstances, 80% of dietary vitamin K is absorbed from the small bowel. Vitamin K deficiency can occur in association with intestinal malabsorption of fat. In patients who have a limited dietary intake of vitamin K, long-term treatment with oral antibiotics may eliminate intestinal bacteria as a source for vitamin K and may precipitate a vitamin K deficiency. Obstructive jaundice or biliary fistulas may decrease vitamin K absorption and may lead to hypoprothrombinemia.

Patients who drink too much alcohol and do not eat enough green leafy vegatables may have clinically significant vitamin K deficiency. This situation is probably not rare, and therefore it is reasonable to prescribe 2 weeks of vitamin K supplementation to all liposuction patients before surgery.

Phytonadione (Mephyton, USP vitamin K_1) is available in 5-mg tablets. In normal animals and humans who are not vitamin K deficient, phytonadione is devoid of any pharmacologic activity.

No evidence indicates that vitamin K predisposes patients to thromboembolism. On the contrary, vitamin K deficiency can produce an acquired form of deficiency in protein C and protein S, which in turn can predispose to thromboembolism. Large amounts of vitamin K can block the effects of oral anticoagulants and, when given to pregnant women, can cause jaundice in the newborn.

NORMAL AND IMPAIRED HEMOSTASIS

Normal hemostasis can be divided into two stages. The first stage is platelet plug formation, which is initiated within seconds of a vascular injury that exposes subendothelial tissue. The second stage is activation of the plasma coagulation cascade, which results in fibrin formation. These two processes are closely interlinked, and one can stimulate and accelerate the other.

Platelet plug formation involves three important phases: platelet adhesion, platelet granule release, and platelet aggregation. Platelet plug formation can be impaired by various aspirin-like drugs. Plasma coagulation depends on normal vitamin K metabolism and the presence of normal circulating proteins, which are part of the coagulation process that produces fibrin.

NONSTEROIDAL ANTIINFLAMMATORY DRUGS

A number of commonly prescribed drugs and nonprescription drugs can predispose to surgical bleeding. The most common of these, the nonsteroidal antiinflammatory drugs (NSAIDs), are widely available without prescription (Box 14-1).

Patients must be warned to avoid these drugs before surgery. Liposuction surgeons must understand that patients often take NSAIDs as a reflexive response to any discomfort. Any patient is at risk of taking an aspirin or NSAID before

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BOX 14-1 COMMON TRADE AND GENERIC DRUGS AVAILABLE IN THE UNITED STATES THAT CAN CAUSE PERIOPERATIVE BLEEDING

Advil	Cephalgesic	Empirin	Indomethacin	Oruvail	Sine-Off
Alcohol	Cheracol Caps	Emprazil	Ketoprofen	Oxybutazone	Sodium thiosalicylate
Aleve	Children's aspirin	Endodan	Ketorolac	Oxyphenbutazone	Soma Compound
Alka-Seltzer	Choline salicylate	Excedrin	Lortab ASA	Oxaprozin	Sulindac
Amigesic	Clinoril	Feldene	Magan	Pamprin	Synalgos DC
Anacin	Congesprin	Fenoprofen	Magnesium salicylate	Pepto-Bismol	*Tanacetum*
Anaprox	Cope	Feverfew	Meclofenamate	Percodan	*(Chrysanthemum)*
Anaproxin	Coricidin	Fiorinal	Meclofen	Persantine	*parthenium*
Ansaid	Corticosteroids	Flurbiprofen	Medipren	Phenaphen	Tolectin
APC	Coumadin	4-way cold tablets	Mefenamic	Phenylbutazone	Tolmetin
Argesic-SA	Darvon ASA	Froben	Menadol	Piroxicam	Toradol
Arthra-G	Darvon Compound	Garlic capsules	Midol	Ponstel	Trandate
Arthrapan	Daypro	Gelpirin	Mobidin	Prednisone	Trendar
A.S.A.	Depakote	Genpril	Mono-Gesic	Quagesic	Trental
Ascodeen	Dexamethasone	Genprin	Motrin	Relafen	Trigesic
Ascriptin	Diclofenac	Ginko Biloba	Nabumetone	Rexolate	Trilisate
Aspergum	Dipyridamole	Goody's Body Pain	Nalfon	Robaxisal	Tusal
Aspirin	Disalcid	Halfprin	Naprosyn	Roxiprin	Vanquish
Baby aspirin	Divalproex	Haltran	Naproxen	Rufen	Vitamin E
Bayer	Doan's Pills	Ibuprin	Norgesic	Saleto	Voltaren
BC Powder	Dolobid	Ibuprofen	Norwich Extra-Strength	Salflex	Warfarin
Brufen	Dristan	Ibuprohm	Nuprin	Salsalate	Willow bark
Bufferin	Easprin	Indameth	Ocufen	Salsitab	Zactrin
Butazolidin	Ecotrin	Indocin	Orudis	Sine-Aid	Zorprin

surgery despite repeated warnings. Patients may so embarrassed about having forgotten the warnings that they deny taking an NSAID and place themselves and the surgeon at risk of excessive surgical bleeding.

Aspirin and other NSAIDs impair the hemostatic function of platelets.

Cyclooxygenase. Cyclooxygenase exists in two isozyme forms in mammalian cells. Both forms of cyclooxygenase activity are involved in the synthesis of prostaglandins, prostacyclins, and thromboxanes. Human platelets contain cyclooxygenase type 1 (COX-1), whereas blood vessels, synovial cells, bone marrow, and other tissues contain cyclooxygenase type 2 (COX-2).

COX-1 is a platelet-derived enzyme that catalyzes the production of arachidonic aid, the cyclic endoperoxide precursor of thromboxane A_2 (TXA_2). When platelets are appropriately stimulated, they produce TXA_2, which induces platelet aggregation and vasoconstriction. Vascular TXA_2 production plays an important role in the maintenance of hemostasis.[20] Different NSAIDs have different degrees of pharmacologic selectivity for COX-1 and COX-2.[21]

Antiplatelet drugs such as aspirin and other NSAIDs are used in clinical medicine to prevent thromboembolic complications of cardiovascular diseases. Aspirin is an approximately 150-fold to 200-fold more potent inhibitor of the constitutive isoform of the platelet enzyme (COX-1) than the inducible isoform (COX-2), which is triggered by the actions of cytokines, inflammatory stimuli, and some growth factors. This explains the different dosage requirements of aspirin as an antithrombotic agent (COX-1) and an antiinflammatory drug (COX-2).

Aspirin Effects. The most common cause of unexpected bleeding during liposuction is an aspirin-induced, nonreversible defect in platelet function. Aspirin inhibits platelet cyclooxygenase and prevents the production of TXA_2 and thromboxane B_2, the stable metabolite of TXA_2. Aspirin covalently acetylates the functionally important amino acid residue serine 529 near the active site of cyclooxygenase. This prevents the access of the substrate (arachidonic aid) to the catalytic site of the enzyme at tyrosine 385 and results in an irreversible inhibition of platelet-dependent thromboxane formation.[22] Other NSAIDs bind to platelets in a reversible manner, and much of the cyclooxygenase inhibition dissipates 4 to 5 days after administration.

Platelets, fragments of megakaryocytes, are not complete cells and are incapable of synthesizing new proteins. Therefore aspirin is permanently bound to platelet cyclooxygenase and inactivates cyclooxygenase for the life span of the platelet (half-life of 7 days). As little as 80 mg of aspirin can produce prolongation of skin bleeding time and cause dangerous perioperative bleeding. An alternate-day regimen of 100-mg aspirin produces functional platelet inhibition.[23]

Aspirin and NSAIDs are taken more often than is generally appreciated. Among patients who undergo unanticipated surgery, as many as 50% may have biochemical evidence of recent aspirin ingestion.[24] If a patient admits to having ingested aspirin less than 7 days or ibuprofen less 4 days before surgery, the surgeon must consider rescheduling the surgery. The surgical staff must maintain a friendly, nonjudgmental attitude toward patients to encourage them to admit having taken an aspirin or NSAID. Rescheduling a surgery is inconvenient for all concerned, but it is even more inconvenient when an ashamed patient denies taking aspirin.

Patients should be advised to avoid aspirin (e.g., Anacin, Bufferin) or any medications that contain aspirin for 7 to 10 days before surgery. Similarly, NSAIDs, such as ibuprofen (e.g., Advil, Motrin, Nuprin), naproxen (e.g., Aleve), or any medications that contain these drugs, should be avoided for 4 to 7 days before surgery. These drugs promote significant bleeding during liposuction surgery.

To prevent unintentional ingestion of aspirin, NSAIDs, or aspirin-like substances, patients should be told to check the labels on all medications, including over-the-counter drugs. Similarly, patients should be advised to remove any products containing aspirin from their medical supplies. Inadvertently taking aspirin-containing oral pain medications can precipitate immediate intraoperative bleeding or delayed bleeding on postoperative days 2 to 7, especially in patients who have a platelet disorder or hemostatic defect.

Prospective patients should be asked if they are taking aspirin, aspirin-like drugs, antiarthritis medications, or blood-thinning anticoagulants.

VITAMIN E

Vitamin E is a mixture of organic alcohols known as *tocopherols*, which are yellow oily liquids remarkably stable to heat. Vitamin E is any or all of a group of closely related fat-soluble compounds that occur in plant oils and are antioxidants essential in the diets of many animals and probably of humans.

Vitamin E supplementation has been shown to reduce platelet adhesion significantly.[25] Clinically, at doses of 400 international units (IU), vitamin E can cause noticeably increased bleeding during tumescent liposuction. The relatively low dose of vitamin E in multivitamin tablets does not seem to cause any unusual surgical bleeding. Similarly, the amount of vitamin E contained in a healthy diet has not been found to inhibit platelet aggregation greatly in vivo.[26]

Of the eight naturally occurring tocopherols that possess vitamin E activity, alpha-tocopherol is the most widely distributed in foods and the most biologically active. Vitamin E probably acts as an antioxidant rather than a cofactor for enzyme-mediated biochemical reactions. Diets containing large amounts of polyunsaturated fatty acids increase the need for vitamin E. Newborns have 20% of the maternal levels, and maternal milk (but not cow's milk) provides infants with adequate amounts of vitamin E.

RED WINE

Red wine, but not white wine, contains a relatively high concentration of polyphenols and has been shown to reduce

aggregation of platelets significantly. Red wines greatly inhibit the synthesis of TXA_2, and its metabolite thromboxane B_2, whereas white wines have little effect on the mediators of platelet aggregation.[27]

Alcohol can also have an inhibitory effect on platelet function. Ingesting alcohol, especially red wine, should be discontinued at least 4 to 5 days before surgery.[28]

DIETARY SUPPLEMENTATION

Some dietary supplements may predispose to perioperative bleeding. Garlic powder, garlic tablets, and raw garlic are widely used as health food supplements. *Allicin*, a heat-sensitive component of garlic, inhibits platelet aggregation. Dietary garlic used as a condiment probably has no adverse effect on surgical bleeding. Garlic supplementation in the form of high-dose garlic powder or garlic extract, however, is associated with an increased risk of perioperative bleeding.[29]

Ginkgo Biloba, widely used in Europe, is derived from a tall tree native to China and Japan. It is a potent competitive inhibitor of platelet activating factor (PAF) that displaces PAF from its binding sites.

Willow bark, derived from the white willow tree (*Salix* species), contains the precursor to acetylsalicylic acid (aspirin) and has therapeutic and platelet effects that are similar to those of NSAIDs.

Tanacetum (Chrysanthemum) parthenium (feverfew) is used to treat headaches, arthritis, and allergies. It is thought to inhibit the synthesis of arachidonic acid, a precursor of prostaglandins. In a manner similar to the effects of NSAIDs, feverfew impedes platelet aggregation.

SUMMARY

The potential for serious bleeding disorders in cosmetic surgical patients is different from that of traditional therapeutic surgery. The surgeon must always be alert to the prospective patient who, motivated by an intense desire to be rid of unsightly fat deposits, may deny having a potential for excessive bleeding. Because of this real possibility, the cosmetic surgeon needs to know when to suspect a patient's veracity. All prospective liposuction patients should be suspected of having a hemorrhagic diathesis until proved otherwise. Appropriate preoperative laboratory tests should be done.

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Maximum Safe Dose of Liposuction

Safety is the state of being free from danger and exempt from harm. The foremost ethical principle of medicine is "First, do no harm." In cosmetic surgery this principle is paraphrased by the statement, "Excessive liposuction is unsafe and therefore unethical."

The safety of liposuction can be described as a function of the following independent parameters:

1. Proper judgment in patient selection
2. Duration and intensity of exposure to systemic and local anesthesia
3. Amount of surgical trauma per month
4. Effectiveness of postliposuction care

The safety of removing a huge volume of fat or undermining a large portion of the cutaneous surface during a single liposuction procedure has not been well studied. Clearly, however, removing 1 L of fat is relatively safe compared with removing 10 L of fat. Also, liposuction of 5% of the body surface area (BSA) is safer than liposuction of 40% BSA. Unnecessary exposure of patients to excessive surgery and excessive anesthesia is unethical, but it seems impossible to define precisely the boundary between safe liposuction and excessive liposuction.

This chapter focuses on the problem of determining a useful clinical definition of "excessive liposuction trauma."

LIPOSUCTION TRAUMA

The following concepts from earlier chapters are discussed further here to help define volume (dose) limits of liposuction and prevent trauma-associated complications.

DOSE-RESPONSE FUNCTION

The concept of toxicity is associated with the dose-response phenomenon (see Chapter 6). The effects of most toxic chemicals can be described by a dose-response function. Increasing doses of a toxin can be expected to produce increasing risks of a toxic response.

Alcohol-induced intoxication is a universal example of a dose-response function. Most individuals can drink a small amount of alcohol without any detectable effect. With increasing doses of alcohol, the drinker passes through a series of thresholds that manifest additional symptoms. For example, beyond a no-effect or subthreshold range, increasing acute doses of alcohol first produce a mild subjective effect, then mild intoxication (inebriation), followed by moderate intoxication (drunkenness) and dangerous intoxication (debilitation, unconsciousness, coma, death). The subthreshold level for alcohol varies among individuals, and no distinct threshold for blood alcohol concentration defines alcohol intoxication.

Although trauma is not a chemical, a dose-response function defines the risk of increasing degrees of trauma. Burns can be quantified in terms of not only the depth of skin necrosis but also the BSA. The probability of death increases with increasing BSA affected by a full-thickness burn.

The same type of dose-response function can be applied to liposuction trauma. The risk of death increases with increasing trauma affecting the body's subcutaneous tissue as a result of liposuction. In a manner similar to the effects of imbibing alcohol, small amounts of liposuction will rarely produce any serious adverse effects. With increasing amounts of liposuction the patient can be expected to cross over a series of toxic (traumatic) thresholds. The ultimate thresholds for excessive liposuction trauma are unconsciousness, coma, and death.

Liposuction surgery is analogous to cancer chemotherapy. With chemotherapeutic drugs, the goal is to maximize beneficial results and minimize toxic side effects. Although it might be more convenient for the patient and the oncologist to give one large dose of chemotherapy, it is usually safer and more effective to give anticancer drugs in divided doses over

weeks to months. Similarly, although one large liposuction procedure might seem more convenient it is usually safer and more effective to do serial liposuction procedures, spaced at least a month apart.

VOLUME VERSUS SAFETY

The motivation for developing tumescent liposuction totally by local anesthesia was to improve patient safety and comfort. However, some surgeons and anesthesiologists saw the tumescent technique as an opportunity to maximize the volume of fat removed during a single surgery.

Liposuction of 6 L or more of fat in a single liposuction procedure is unnecessarily aggressive and potentially life threatening. Some publications have advocated "megaliposuction" but do not provide detailed information about complications or ultimate aesthetic results. Such articles typically state that no serious complications occurred, without bothering to define "serious complication." Some consider death to be the only serious complication.

Although megaliposuction procedures are essentially experimental with unproven benefit, participation by investigational review boards or research committees on human subjects has been minimal. Hospitals, licensed surgical facilities, and academic institutions have permitted excessive liposuction with virtually no objection from credentialing committees. Among some surgeons, excessive liposuction has become a de facto standard of care.

A procedure cannot be considered "safe and effective" simply because it has been performed a certain number of times without serious complications. The safety and efficacy of a therapeutic procedure can only be defined relative to alternative procedures.

Anecdotal evidence alone is inadequate to establish safety of a procedure. Studies must provide reproducible results that demonstrate superior safety compared with alternative procedures. Surgeons who advocate huge-volume liposuction must provide convincing evidence that one massive liposuction surgery is as safe and effective as two more sequential liposuctions.

RADICAL EMPIRICISM

Ethical cosmetic surgery demands *proof* of any elective procedure's safety and efficacy. The argument that "no published data refute the presumption of safety" is insufficient. Ethical cosmetic surgery demands a radical empiricism in which every dogma or underlying assumption is regarded as a hypothesis that must be verified. The dogma that liposuction by general anesthesia is safe or the assumption that huge-volume liposuction is effective and provides long-lasting results must be verified.

Academic surgeons and anesthesiologists who do liposuction by systemic anesthesia believe the safety of liposuction by systemic anesthesia is not open to question. Therefore it is unnecessary to conduct research that documents the safety of liposuction by systemic anesthesia. These surgeons and anes-
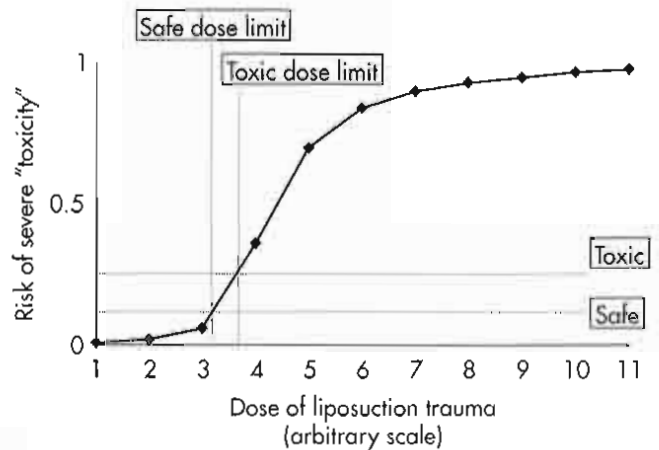
Figure 15-1

Threshold range between safe and toxic "doses" (volumes) of liposuction. Increasing doses of liposuction (excessive iatrogenic surgical trauma) carry significant risks of toxicity (severe postoperative complications). Below a "safe dose limit" of liposuction, risk of postoperative complications is minimal. Above some "toxic dose limit," risk of severe postoperative complications is unacceptable.

thesiologists respond to an assertion that "virtually all liposuction deaths are associated with systemic anesthesia" by declaring they are unaware of any published report documenting such an association.

SAFE/TOXIC THRESHOLD

Every toxin has a "safe" range of small dosages within which the risk of toxicity is insignificant. Similarly, each has a "toxic" range of relatively large dosages within which every dose has a significant risk of toxicity. Between these low and high dosage ranges is a *threshold range* of dosages within which the exact risk of toxicity is not immediately apparent (Figure 15-1).

Lethal Dose. The concept of measuring the average lethal dose (LD) of a substance is familiar to physicians. A common means of expressing this probability function is that a given dose LD_p will produce a lethal effect in p percent of the test animals. Thus the LD_{50} for lidocaine in mice is the dose that would be expected to kill 50% of the test animals.

What is the LD_1 (or LD_{50}, $LD_{0.1}$, $LD_{1/10,000}$) of liposuction, or what is the dose of liposuction that will, on average, cause death in 1% of patients?

The BSA affected by a burn can be used to predict the probability of death. By analogy, the proportion of the subcutaneous surface that is traumatized by liposuction should help predict the risk of death from liposuction. As noted, the greater the number of areas treated by liposuction at any one time, the greater is the risk of iatrogenic surgical death.

For liposuction, the estimate of LD_p depends on the health of the targeted population. Because the risk of perioperative complications increases with increasing degrees of obesity, obese people are relatively poor candidates for a megaliposuction.

High-to-low Extrapolation. Experimental toxicology using high doses of a toxin requires relatively few animals to estimate LD_{50}. As the dose of a toxin is decreased, however, the probability of death also decreases. Therefore the number of experimental animals required to detect a true toxic effect increases.

The process by which "toxicity at high doses is used to estimate the toxicity at much lower doses" is known as high-to-low extrapolation. The task of defining an estimate for a clinically safe amount of liposuction trauma is a high-to-low extrapolation problem.

EXCESSIVE LIPOSUCTION

Excessive liposuction is defined as a volume of liposuction that is unnecessarily or unreasonably dangerous. This definition is intentionally nonspecific and vague. Excessive liposuction is defined subjectively according to each clinical situation.

The designation of excessive liposuction depends on the patient's size and health. Excessive liposuction may be less than 1 L if the patient is a 50-kg (110-pound), muscular, lean female athlete with little adipose tissue. On the other hand, removing 4 L of supranatant fat in one procedure might not be excessive in an otherwise healthy 100-kg (220-pound) female patient.

The body cannot tolerate an unlimited amount of trauma. Increasing degrees of liposuction-associated trauma produce progressive capillary endothelial damage and platelet activation. Beyond a certain threshold of liposuction trauma the risk of hypercoagulability, such as disseminated intravascular coagulation (DIC), or thromboembolism may be significant. The greater the area of the body's subcutaneous surface that is traumatized by liposuction, the greater the degree of systemic inflammatory response. This results in decreased levels of free protein S, which is associated with increased risks of thromboembolism. Excessive liposuction is associated with excessive morbidity, prolonged postoperative recovery, and greater risk of disappointing cosmetic results.

No absolute threshold or cutoff line exists above which all volumes are considered excessive. I believe, however, that it is usually unwise to remove more than 4 L of supranatant fat under any circumstances. It is safer to divide the case into two separate procedures, which can be accomplished several weeks apart.

When total aspirate volume exceeds 5000 ml, "the operation becomes more physically disruptive, and patients should be kept overnight in the hospital."[1] A dangerous procedure performed in the hospital is still dangerous. Performing excessive liposuction in a hospital cannot compensate for a poor clinical decision. Unnecessarily dangerous liposuction procedures in the hospital might explain why 70% of liposuction-related malpractice cases have been done in hospitals.[2]

I rarely remove more than 3 L of supranatant fat. The most supranatant fat I have ever removed was 4.2 L. I have removed 4.0 L or more of supranatant fat on only five occasions. When the surgeon has underestimated the actual aspirated volume, the 4-L limit allows for a small margin of safety.

CONCURRENT PROCEDURES

Liposuction can also be excessive when patients undergo concomitant, unrelated surgical procedures. Subjecting a patient to multiple cosmetic procedures is rarely a problem when local anesthesia is used. An awake patient usually complains and declines further surgery long before the surgery becomes excessive.

The risk of perioperative complications increases with increasing duration and intensity of the surgical insult. Conservative surgeons do not advise patients to undergo two simultaneous, unrelated therapeutic surgeries. Elective hysterectomy is rarely contemplated in conjunction with some other elective therapeutic procedure, such as gallbladder surgery, joint replacement, herniorrhaphy, or laminectomy. In contrast, well-trained surgeons and concurring anesthesiologists often advocate multiple concurrent cosmetic surgical procedures, such as liposuction, facelift, and breast augmentation. The rationale for such unnecessarily excessive cosmetic surgery is obscure.

ASPIRATE VOLUME

In the early era of dry and wet techniques for liposuction, the volume of aspirated material (blood plus fat) was directly correlated with the volume of surgical blood loss and the necessity for postoperative blood transfusions.

Among surgeons not using the tumescent technique, a standard rule was that 1.5 to 2.0 L of aspirate was the threshold for requiring an autologous blood transfusion.[3] Without tumescent vasoconstriction, each liter of liposuction aspirate contained 15% to 50% whole blood. With such a conspicuously bloody visual reminder, the volume of liposuction aspirate became indelibly associated with the estimated risk of liposuction surgery.

Even after the tumescent technique had eliminated surgical blood loss as the limiting variable for liposuction, surgical tradition has continued to regard the total volume aspirated as the standard measure of liposuction trauma.

Total aspirate volume is an inaccurate measure of surgical trauma for several reasons. First, the total aspirate volume is not an accurate predictor of the risk of serious complications. It does not account for the size of the patient, and the risks associated with a given total aspirate depend on the patient's size. The removal of a 4-L total aspirate volume for a 50-kg woman is not the same as removing it from a 100-kg woman. Furthermore, total aspirate volume is no longer closely correlated with blood loss; the tumescent technique has essentially eliminated acute surgical hemorrhage as a common risk of liposuction.

Second, the significance of the total aspirate volume is diminished because it is the sum of both the *supranatant* fat floating in the collection cannister on top and the *infranatant* blood-tinged anesthetic solution layered below the fat. The volume of the aspirated infranatant blood-tinged anesthetic solution does not reflect the degree of liposuction trauma, and the volume of the infranatant fluid varies widely from patient to patient and from surgeon to surgeon. This large random variation confounds the precision of any prediction based on total aspirate volume. The supranatant fat volume (S) is the more relevant variable. The infranatant fat volume (I) is an irrelevant, or confounding, variable. The total aspirate volume (T) where $T = S + I$, is the sum of two independent variables. From a biostatistical perspective, S is a much more efficient estimate of liposuction risk than T.

Third, when ultrasonic liposuction is used, the supranatant fat becomes emulsified (dispersed in small droplets) and suspended within the infranatant anesthetic solution. For example, if a vibrating internal ultrasonic probe is placed into a beaker containing 500 ml of supranatant fat and 500 ml of infranatant solution, the resulting emulsion will appear as 900 ml of supranatant fat that persists for many hours. This phenomenon completely obscures the distinction between S and I.

True Threshold Is Indeterminate

A plausible estimate of the threshold for excessive liposuction trauma can be constructed by using a sophisticated, probabilistic, multivariate dose-response function. Elaborate criteria that define a safe dose of liposuction can be used in increasing degrees of complexity and theoretic precision.

Ultimately, however, such elaborate criteria are merely academic exercises. No amount of biostatistical erudition can ever accurately define a safe maximum dose of liposuction. Too many patient-dependent and surgeon-dependent variables exist. The vagaries of real-life cosmetic surgery result in an indeterminate threshold for safety.

Telephone Calls as Threshold. Some dermatologic surgeons consider a nighttime telephone call from a patient to be a significant postoperative complication. This call is a reasonable, prudent threshold for defining excessive liposuction trauma.

If the surgeon regularly receives after-hours telephone calls from postoperative patients because of discomfort, pain, nausea, vomiting, or anxiety, the amount of liposuction has probably been excessive. The probability that a patient will need to telephone later because of the effects of too much liposuction should ideally approach zero.

If a liposuction surgeon does not expect every patient to be ambulatory within 30 minutes of completion of the surgery, the liposuction and anesthetic technique probably are excessive. Liposuction is excessive if the following occur:

1. Pain confines the patient to bed.
2. Nausea prevents the patient from eating a normal meal soon after surgery.
3. Discomfort prevents the patient from returning to desk-type work 1 or 2 days after surgery.

Patients should be well enough to manage their postoperative care. Every effort should be made to minimize the trauma of liposuction to the level where their telephone calls or unscheduled postoperative office visits are a rare occurrence.

MEGALIPOSUCTION

Liposuction of more than 3 L of supranatant fat is probably excessive in most patients. I define the liposuction or more than 6 L of supranatant fat as megaliposuction, which is dangerous in all patients. A dose-response relationship exists between the volume or extent of liposuction and the incidence of postliposuction complications. Again, serial liposuction procedures are much safer than a single megaliposuction procedure.

The invention of tumescent liposuction was motivated by a need to increase the safety of liposuction, not the volume of liposuction. I believe megaliposuction is a misguided extension of the tumescent technique.

Because patients have died as a result of megaliposuction, it cannot be regarded as safe. The intense conviction that huge-volume liposuction is both safe and justifiable does not prove the conviction's validity. A patient should not be given unsubstantiated assurance that megaliposuction is safe or is an effective treatment for morbid obesity. Massive liposuction of the abdomen, flanks, buttocks, arms, and lower extremity has been reported in association with bilateral lumbar artery laceration.[4]

Experimental Procedure

It is reasonable for a surgeon to present a series of 10 cases of megaliposuction at a cosmetic surgery meeting and propose that the procedure might be a treatment for morbid obesity. It is misguided, however, for a surgeon in the audience to conclude that megaliposuction is now a legitimate treatment for morbid obesity. The first surgeon proposed a hypothesis. The second surgeon concluded, without adequate clinical evidence, that the hypothesis had been proved.

An anecdotal report cannot prove the relative safety of a procedure. A series of megaliposuction cases must be compared to a series of serial liposuction procedures, with both having removed comparable volumes of fat, before the relative safety can be determined.

Standard of Care

As with any experimental surgical procedure, megaliposuction should be confined to a clinical setting, where its indications, the completeness of informed consent, and the adequacy of postoperative care are subject to peer review. As an experimental procedure, every case of megaliposuction should have documentation of important preoperative, perioperative, and long-term postoperative data. The surgeon who advocates megaliposuction has a responsibility to provide evidence from the literature that documents the procedure's safety.

The safety and efficacy of megaliposuction have yet to be established. To my knowledge, no published controlled clinical

studies support the assumption that huge-volume liposuction is effective and safe. In other words, no standard of care exists for megaliposuction. An anesthesiologist should not condone megaliposuction unless there is proof of its safety and efficacy. A hospital surgical credentials committee should determine whether megaliposuction is a safe and reasonable procedure. Liposuction privileges should not be construed as permission to do megaliposuction.

FINANCIAL CONFLICTS OF INTEREST

The following situations make it difficult for a surgeon to avoid the appearance of a financial conflict of interest when recommending megaliposuction.

The procedure is dangerous, and no data have established the long-term safety and efficacy of megaliposuction.

Prospective megaliposuction patients are psychologically desperate and therefore vulnerable to unsubstantiated claims. Truly informed consent for megaliposuction is often nonexistent. If the liposuction surgeon is unaware of the dangers of a megaliposuction, the patient is unlikely to be given a reasonable or accurate view of its dangers. Similarly, obese patients who are desperate may be incapable of making an objective decision regarding huge-volume liposuction.

The same surgeon who assumes primary responsibility for informing prospective patients about the risks and benefits of the megaliposuction also profits by performing the surgery.

Safer alternatives to megaliposuction are available. For example, performing serial liposuctions on separate occasions is safer than one extensive and intensive traumatic procedure.

No longitudinal studies justify megaliposuction as an effective treatment for morbid obesity. Any claim of a therapeutic benefit must be supported by evidence that the result has a long-lasting effect. Megaliposuction has not been shown to produce a long-term decrease in body weight in a significant majority of patients.

Solution. To avoid the appearance of a financial conflict of interest, an ethical surgeon would require that potential megaliposuction patients have preoperative evaluation by another qualified physician consultant. This consultant should know about the health risks of obesity, the surgical risks associated with obesity, and the risks and benefits of megaliposuction. Finally, the consultant must give written recommendation for the surgery.

Codes of ethics require that a surgeon avoid performing a procedure that involves a financial conflict of interest. A surgeon's financial interests should not outweigh concerns for patient safety.

SEQUENTIAL LIPOSUCTION

It is safer to remove 3 L of supranatant fat in three separate surgeries than 9 L of fat on a single day. It is naive or self-serving to rationalize that "patients want to have their surgery accomplished during one procedure."

Market forces are not an indication for agreeing to do the more dangerous of two possible cosmetic surgical procedures. A reasonable, ethical surgeon will inform any prospective patient that it is unsafe to do too much liposuction at one time.

I believe that aspirating 6 L or more of supranatant fat on a single day has a mortality rate that is approximately 100 to 1000 times greater than doing liposuction of less than 3 L of supranatant fat. Sequential liposuction procedures accomplished several weeks to months apart are safer than a single large, aggressive procedure. The ethics of doing huge-volume liposuction as a single procedure are questionable.

Most healthy patients are likely to survive an unnecessarily voluminous liposuction. The surgeon may eventually learn, however, that megaliposuction is associated with many complications and megalitigation.

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CLINICAL PHARMACOLOGY

Pharmacology of Tumescent Technique

Part III of this book focuses on the unique aspects of lidocaine pharmacology as it applies to the tumescent technique using local anesthesia, with subcutaneous infiltration of extremely dilute lidocaine and epinephrine. The pharmacokinetics of tumescent lidocaine, which involves the fate of dilute lidocaine, dilute epinephrine, and the isotonic solvent after delivery into subcutaneous fat, is not widely appreciated.

Every surgeon and anesthesiologist knows that lidocaine is potentially toxic. Some physicians are unaware, however, that the tumescent delivery of large volumes of subcutaneous isotonic solutions of electrolytes obviates the need for intravenous (IV) fluid supplementation with tumescent liposuction. The greatest danger of the tumescent technique is not potential for lidocaine toxicity but lack of knowledge. Surgeons and anesthesiologists who use tumescent anesthesia may not appreciate (1) the risks of IV fluid overload leading to pulmonary edema and (2) the dangers of excessive liposuction that are independent of the risks of blood loss.

This chapter considers the clinical toxicology of tumescent lidocaine and the determination of the optimal effective lidocaine dilution. The following chapters consider the statistical, philosophic, and ethical criteria for estimating a maximum safe dose of lidocaine for tumescent liposuction.

LIDOCAINE DOSE RECOMMENDATIONS

What is the maximum safe dose of tumescent lidocaine? This question has no simple, well-defined numeric answer. Instead, several acceptable answers exist, depending on objective pharmacology, statistical estimation, and subjective medical ethics.

Such answers do not remain valid over time. With more clinical experience and new insights into the pharmacoki-

netics of the tumescent technique, this estimate will need to be reassessed periodically. The current answer is based on both objective clinical research and subjective clinical experience.

As explained later, lidocaine toxicity correlates directly with the magnitude of plasma lidocaine concentration. The smaller the peak plasma lidocaine concentration, the smaller is the risk of lidocaine toxicity. The fundamental reason for the great safety of tumescent anesthesia is the slow rate of lidocaine absorption. For any given mg/kg dosage of lidocaine, the slower the rate of lidocaine absorption, the smaller the peak lidocaine plasma levels, and thus the smaller is the probability of a toxic event.

My present recommendation for the maximum dosage of tumescent lidocaine in healthy, young *female* patients is as follows:

45 mg/kg (thin patients)
50 mg/kg (average to overweight patients)
Lidocaine doses must be reduced by at least 30% to 40% in patients who are taking drugs that interfere with lidocaine metabolism (e.g., sertraline, erythromycin, ketoconazole).

The following three reasons explain the dramatically slow rate of absorption of tumescent lidocaine from subcutaneous fat:

1. Subcutaneous fat has a low volume of blood flow.
2. Dilute epinephrine produces a prolonged and profound degree of vasoconstriction.
3. Lidocaine is lipophilic and is readily sequestered in fat.

Males, whose percentage of body fat is usually 10% to 20% less than females, have a smaller volume of distribution for lidocaine. Therefore the maximum allowable dose should be reduced by about 10% for males.

Younger patients tolerate more lidocaine than older patients. This is attributed to the decrease in cardiac output and resulting decrease in hepatic perfusion associated with

advancing age. Thus older patients should be given smaller doses of tumescent lidocaine.

OBESE VERSUS THIN PATIENTS

Based on clinical experience, obese patients seem to tolerate higher mg/kg doses of lidocaine better than relatively thin patients. A higher incidence of lidocaine toxicity occurs among coronary care unit patients weighing less than 70 kg (150 pounds).[1] Thus thin patients may have a smaller volume of distribution for lidocaine. In other words, given identical mg/kg dosages of lidocaine, the thinner patient may have a greater peak plasma lidocaine concentration than the obese patient.

Although uncommon, thinner patients seem more likely to complain of nausea, dysarthria, mild confusion, and unsteadiness of gait at doses that exceed 50 to 55 mg/kg. Three of my patients, all relatively thin, have experienced such symptoms; in each case the plasma lidocaine levels were below 3.2 mg/L. Because these symptoms can be attributed to either lidocaine or benzodiazepines, tumescent liposuction patients should not take a benzodiazepine within 18 hours after surgery.

In some situations even an obese patient might not tolerate 50 mg/kg of lidocaine. An obese female undergoing liposuction was also taking the antidepressant and selective serotonin reuptake inhibitor sertraline (Zoloft) and the benzodiazepine flurazepam (Dalmane). Both these drugs inhibit the hepatic enzyme cytochrome P450 3A4, which is responsible for lidocaine metabolism. This patient had a plasma lidocaine concentration of 6.1 mg/L 12 hours after 59 mg/kg of tumescent lidocaine (see Chapter 18).

TOXICOLOGIC METHODOLOGY

Studying the maximum safe dose for lidocaine is essentially a toxicologic study. A scientific study of a drug's toxicity involves some type of statistical estimation of the "average toxic dose." If toxicity is defined in terms of lethality, a statistical approach to quantifying the lethality would be to estimate the LD_{50} dose for lidocaine, that is, the *median lethal dose* that causes death in at least 50% of the animals tested.

Because lidocaine-induced seizures occur long before lidocaine-induced cardiac arrest, human studies have preferred to estimate the ED_{50} dose of lidocaine, that is, the *median epileptogenic dose*. If the occurrence of an epileptiform seizure is used to define a drug's toxicity, the drug's ED_{50} can be used to predict toxicity. The ED_{50} is the dose that will cause a seizure in at least 50% of the test subjects.

In the 1960's this research design was used for studying the toxicity of lidocaine as an antiarrhythmic drug in human volunteers. At present the use of human volunteers to explore the safety of IV lidocaine raises serious ethical questions. The process of establishing a safe maximum recommended dose of lidocaine for tumescent liposuction cannot use the same statistical methodology as in estimating ED_{50}.

The toxicity of a local anesthetic is a function of its peak plasma concentration, which in turn depends on such factors as rate of systemic absorption and total mg/kg dosages.[2] Different routes of lidocaine delivery produce different rates of lidocaine absorption and have different dosage limits.

The rapid subcutaneous infiltration of lidocaine for a facelift proved fatal at a dose of 2.5 g at a commercially available concentration.[3] Instantaneous absorption occurs with an IV injection of lidocaine, and a dosage of 20 mg/kg can produce cardiovascular collapse and generalized convulsions.[4] On the other hand, when lidocaine is given as tumescent anesthesia, the slow systemic absorption permits safe dosages of 50 mg/kg or more.

Traditional pharmacokinetic studies of local anesthesia have largely been limited to regional anesthesia injected deeply into highly vascular tissues to block nerves in the axillary, intercostal, or epidural spaces. Anesthesiology literature has largely ignored the study of the pharmacokinetics of lidocaine with epinephrine infiltrated into relatively avascular subcutaneous fat. Larger subcutaneous doses were known to be safe, but specific limits were never defined.

For local anesthesia the traditional dosage limit for lidocaine is 7 mg/kg when used with epinephrine. This limitation arbitrarily groups all sites and types of local anesthesia into one generic category. It makes no distinction between the highly vascular epidural space, where lidocaine absorption is rapid, and the subcutaneous fat, where absorption is significantly slower.

On first learning about the tumescent technique, many physicians are startled at the magnitude of the lidocaine dosages that are given safely. The initial published estimate of a safe tumescent dosage for subcutaneous lidocaine was 35 mg/kg.[5] This remains a conservative estimate for the maximum safe dosage of lidocaine.

After years of careful clinical experience, some dermatologic surgeons are cautiously using 50 to 55 mg/kg as a maximum safe lidocaine dosage for tumescent liposuction. Because there is significant interpatient variability in lidocaine pharmacokinetics, cautious clinical judgment is always needed when using these relatively high dosages.

TRUE TUMESCENT ANESTHESIA

The effect of tumescent anesthesia on sensory nerves is a function of the product of the local anesthetic concentration and the length of the nerve exposed to the anesthetic solution.

Tumescent anesthesia is different from all other forms of local anesthesia. Tumescent anesthesia is *not* a field block. Most field blocks would be inadequate at concentrations of local anesthetics employed with the tumescent technique.

Tumescent anesthesia is *not* systemic anesthesia. If the proper technique is used, the effects of tumescent anesthesia are local, not systemic. Some surgeons claim, however, that tumescent anesthesia is indeed systemic anesthesia. These surgeons may not be able to perform "tumescent liposuction"

without systemic anesthesia. Using systemic anesthesia or systemic (IV) fluid infusions with tumescent infiltration carries a risk of systemic complications. Surgeons who assert that tumescent local anesthesia is systemic anesthesia usually have not achieved adequate tumescence.

The following chapters focus on the safety of using lidocaine and other local anesthetics, as well as ancillary drugs that can be used in conjunction with tumescent liposuction. The information should help physicians develop a better understanding of how to evaluate safety and avoid toxicity.

DEFINITIONS

An important convention used in this book distinguishes between the words *dosage* and *dose*. All the pharmacologic discussions assume the following definitions.

Dosage.   Dosage is expressed in *mg/kg* units, where mg = milligrams of the drug and kg = patient's weight expressed in kilograms. In general, this book uses dosage to describe the amount of a drug given to a patient as expressed in units that are "normalized" with respect to the patient's total body weight. The normalized aspect of dosage, in contrast to dose, facilitates the clinical comparison of specified therapeutic interventions among patients. Dosage can refer either to a single administration or to the sum of many administrations within a specified time interval.

By multiplying the dose (total milligrams) of a drug given to a patient by the inverse of the patient's weight (1/kg), one obtains the dosage of the drug. Expressing amount of an administered drug in terms of mg/kg dosage also facilitates comparison of drug effects by eliminating the patient's weight as a confounding variable.

Normalized.   A mathematical entity (a series, function, or variable) is said to be normalized when it has been multiplied by a factor that facilitates making comparisons between different entities. In mathematics, for example, every nonzero vector can be normalized by multiplying the vector *(v)* by the inverse of its magnitude (1/|v|). This results in a normalized vector having direction only, with a magnitude equal to 1, thereby facilitating comparison of vectors in terms of their direction, without regard to their magnitude.

Dose.   Dose is expressed in mg units, where mg = total milligrams of drug given to a patient. Dose does not take into account the patient's total body weight. Dose describes the total amount of the drug that is administered but ignores the basic pharmacokinetic parameters, such as *volume of distribution*.

Thus, when dose is used to specify the amount of drug that has been administered, it is difficult to predict either therapeutic effect or toxicity, both of which depend pharmacokinetically on the amount of drug per kilogram of a patient's body weight. Dose can refer either to a single administration or to the sum of many administrations within a specified time interval.

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Pharmacology of Lidocaine

A review of the basic pharmacology of lidocaine is helpful before attempting to understand the more complex qualities of tumescent lidocaine. Box 17-1 lists physical properties of lidocaine.

CHARACTERISTICS OF LIDOCAINE

LIPOPHILIA

Lidocaine is a lipophilic molecule that is highly soluble in lipids such as subcutaneous fat. After thoroughly mixing an aqueous solution of lidocaine with an equal volume of the lipophilic solvent octanol, then allowing the mixture to separate by gravity, most of the lidocaine has diffused out of the water and into the octanol. The lidocaine concentration ratio for octanol/water is 43:1, with the water at 25° C (77° F) and buffered to a pH of 7.4. The lidocaine partition coefficient for n-octanol/water (P) is 43/1, and log P is 1.64.

The lipophilic nature of lidocaine accounts for the rapid redistribution of lidocaine into peripheral tissue after an intravenous (IV) injection. The fat/blood concentration ratio at equilibrium is an estimated 1:1 to 2:1.[1] Lidocaine lipophilia probably plays a role in the uniquely slow absorption of lidocaine from the tumescent subcutaneous fat into the systemic circulation.

The safety of the relatively large doses of tumescent lidocaine used for tumescent liposuction is the result of a dramatic delay of lidocaine absorption into the systemic circulation. "The big difference in absorption kinetics when highly diluted lidocaine (0.05% [500 mg/L] to 0.10% [1.0 g/L]) is infiltrated subcutaneously arises from lipid binding, buffering lidocaine molecules for delayed release."[2] Since liposuction removes only 20% to 25% of the infiltrated tumescent lidocaine, while liposuction simultaneously removes a much greater percentage of tumescent fat, the lidocaine-lipid binding phenomenon does not entirely explain the unprecedented

delay of lidocaine absorption that is so characteristic of tumescent local anesthesia.

In terms of molecular structure, lipophilicity of a local anesthetic is primarily determined by the aromatic group. The addition of carbon atoms to the amide local anesthetic molecule also tends to increase its lipophilia (Figure 17-1).

pK_a and pH. The pK_a is a constant characteristic of a drug. For lidocaine the pK_a is 7.9. Knowledge about lidocaine pK_a allows one to generalize about how pH will affect the movement of drugs across a tissue membrane.

According to the *pH partition hypothesis,* only the nonionized nonpolar form of a drug is sufficiently lipophilic to be able to diffuse across a biologic bilayer lipid membrane. This hypothesis is probably not completely accurate but does provide a qualitative view of what might be happening to lidocaine diffusion at a cellular level. An uncharged lidocaine molecule diffuses across a neuron cell membrane more rapidly than a charged molecule.

The *Henderson-Hasselbalch equation* for bases states the following:

$$pH = pK_a + \log_{10} (B/BH^+)$$

where B is concentration of nonionized base, and BH^+ is concentration of a positively charged ionized base. When a lidocaine solution has a pH of 7.9, then pH = pK_a. Therefore:

$$\log_{10} (B/BH^+) =$$
$$\log_{10} ([\text{Nonion concentration}]/[\text{Ion concentration}]) = 0$$

Because $\log_{10} (1) = 0$, one can conclude that [nonion concentration]/[ion concentration] = 1. Thus, at pH = 7.9, the concentration of the nonionized lidocaine equals that of the ionized form of lidocaine.

The terminal amine group $-N-(CH_3)_2$ of lidocaine is a weak base and thus accepts a hydrogen ion, converting the

Amide linkage

Lipophilic
part
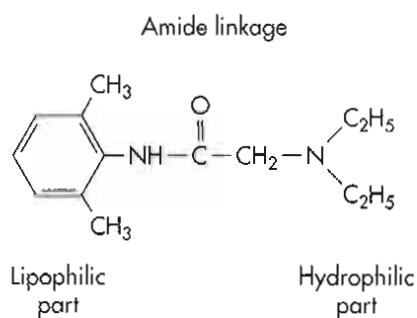
Hydrophilic
part

Figure 17-1

Lidocaine is representative of amide local anesthetics. Molecule has lipophilic aromatic fraction, which facilitates absorption into adipose tissue. Hydrophilic amino terminal portion of lidocaine molecule facilitates solubility in water as a salt of hydrochloride.

BOX 17-1   PHYSICAL PROPERTIES OF LIDOCAINE

Molecular weight of lidocaine base: MW (base) = 234.34
Molecular weight of lidocaine HCl salt: MW (HCl salt) = 270
1 mol lidocaine HCl = 270.8 g
1 g lidocaine HCl = 3.69 mmol (millimoles)
1 mM (millimolar) = 270.8 mg/L
Lidocaine pK_a = 7.90
Partition coefficient (P) for n-octanol/water = 43/1; log P = 1.98; potency = 2.0

anesthetic into the pharmacologically active, positively charged cationic form. In any solution of lidocaine the proportion of uncharged lidocaine base relative to the positively charged lidocaine cation is a function of the solution's pH.

The uncharged lidocaine base B is lipophilic and easily diffuses through the lipid bilayer of a cell membrane. The higher the pH of a lidocaine solution, the greater is the proportion of uncharged lidocaine base, and the more rapidly the lidocaine will enter a neuron's axoplasm. Thus the addition of sodium bicarbonate ($NaHCO_3$) to a solution of lidocaine will promote the entry of lidocaine into neurons. Increased diffusion is manifested clinically by a more rapid onset of anesthesia.

When comparing all amide-type local anesthetics, at any given pH the lower an anesthetic's pK_a, the greater is the proportion of its uncharged base. Also, the more rapid the anesthetic's diffusion into neurons, the more rapid is the onset of conduction blockage. Knowing that the pK_a for lidocaine is 7.9 and the pK_a for bupivacaine 8.2, one can predict that lidocaine will have a more rapid onset of anesthesia than bupivacaine.

The positively charged cationic molecule interacts with the neuron's local anesthetic receptor site. When only the pH of an anesthetic solution bathing mammalian nonmyelinated fibers is varied, a solution with a pH of 7.2 and one with pH of 9.6 will block and unblock the neurons, respectively. Thus,

with lidocaine toxicity, metabolic and respiratory acidosis is more dangerous than respiratory alkalosis. Acidosis and hypercapnia increase the central nervous system (CNS) toxicity of lidocaine.[3] When treating lidocaine toxicity, therefore, it is imperative to maximize ventilation and oxygen delivery.

LOCAL ANESTHETIC SOLUBILITY

An amine local anesthetic base such as lidocaine is poorly soluble in water and unstable when exposed to air. The lidocaine base is weakly basic and tends to combine with acids to form salts. Depending on the drug's pK_a and the pH of an aqueous solution, the salt of an amine local anesthetic is dissociated and exists in a state of equilibrium between the positively charged quaternary cation and the uncharged lipid-soluble, free-base tertiary amine.

Alkalinization of a amine local anesthetic solution with $NaHCO_3$ shifts the equilibrium toward an increase in the amount of uncharged free base. The rate of diffusion of a local anesthetic is a function of the concentration of its free base, which in turn is a function of the pH of the solution. The uncharged molecule more readily diffuses across the lipid cell membrane and accelerates the onset of local anesthetic action.

Too much alkalinization decreases the amine solubility, however, causing it to precipitate. Alkalinization can decrease the shelf life of an amine local anesthetic and increase the risk of precipitation. After an injection, any precipitation of a local anesthetic solution into tissue can cause injury to the local tissues.

An acidic solution of a local anesthetic has a larger proportion of positively charged quaternary cations, which is less effective because the molecules diffuse much more slowly.

Relative Local Anesthetic Potency.   The relative potency of two local anesthetics can be compared by measuring the minimum concentration necessary to block a ceratin nerve.[4] Bupivacaine is approximately four times as potent as lidocaine. An alkaline solution of lidocaine, however, might be more effective than an acidic solution of bupivacaine (Case Report 17-1).

pH OF TUMESCENT SOLUTION

Commercially available lidocaine is acidified with hydrochloric acid to protonate the amide nitrogen forming a cation. Nonionized lidocaine molecules, although relatively insoluble in water, are lipid soluble and can more readily cross the lipid cellular wall and enter a neuron.

To optimize the solubility of lidocaine and the stability of epinephrine, commercially available solutions are acidic: pH of 6.5 for lidocaine and pH of 4.5 for lidocaine with epinephrine.

Unfortunately, acidic solutions produce a painful stinging sensation on intradermal or subcutaneous injection. The stinging discomfort of an injection of lidocaine can be attenuated by the addition of $NaHCO_3$ to neutralize the pH of the

To decrease the amount of pain on injection, it is common practice to neutralize a commercial solution of lidocaine (pH 4 to 6) by adding a small amount of sodium bicarbonate (NaHCO$_3$). By analogy a surgeon added NaHCO$_3$ to a solution of bupivacaine. When a precipitate formed within the bottle of bupivacaine, the solution was discarded. Despite noting a precipitation on a second attempt to mix a neutralized solution of bupivacaine, the surgeon injected the solution into the glabella. The result was deep tissue necrosis and a permanent hypopigmented scar.

Discussion. Bupivacaine is more lipid soluble and less water soluble than lidocaine. Therefore bupivacaine will precipitate more readily than lidocaine on neutralization with the addition of NaHCO$_3$. This is an example of why lidocaine is safer than bupivacaine.

commercially available preparation.[5] Similarly, the use of sodium hydroxide to neutralize the pH of the anesthetic solution also reduces the pain on infiltration.[6] Commercially available solutions of lactated Ringer's solution (LR) do not provide relief from the stinging associated with acidic lidocaine solutions with epinephrine.

When the tumescent technique was originally conceived, it was not known that neutralizing the acid solution by adding NaHCO$_3$ would dramatically attenuate the pain on injection of the anesthetic solution. In the early days of tumescent liposuction the stinging pain on injection of the tumescent solution was so intense that it usually required supplemental intramuscular (IM) meperidine (Demerol) and diazepam (Valium). Adding NaHCO$_3$ to the dilute anesthetic solution eliminated most of the stinging sensation so that meperidine and diazepam could be discontinued. Eliminating narcotics and parenteral sedatives removed the risk of hypoventilation and hypoxemia. Neutralization with NaHCO$_3$ by reducing the need for narcotics is largely responsible for the dramatic safety of tumescent liposuction as an office procedure.

Epinephrine is unstable and will degrade spontaneously in a neutral (pH 7.0 to 7.4) solution, having a half-life of about 10 to 14 days. Because of this instability of epinephrine, tumescent anesthetic solutions for liposuction should be freshly mixed on the day of surgery.

The current formulation of tumescent lidocaine and epinephrine includes 10 mEq NaHCO$_3$/L solution. Sodium bicarbonate is available in several concentrations; for ease of measurement the preferred concentration is the 8.4% solution, which is equivalent to 1 mEq/ml.

MOLES, MOLAR MASS, AND MOLECULAR WEIGHT

The current trend in scientific literature is to specify amounts of a drug in terms of moles. The *mole* is a unit of measure-

ment for mass. A mole (abbreviated mol) of a substance is the number of units of that substance equal to the number of carbon atoms in exactly 12 g of pure ^{12}C. This number is well known as Avogadro's number, 6.022×10^{23}. One mole of something consists of exactly 6.022×10^{23} units of that substance. One mole of lidocaine base consists of 6.022×10^{23} molecules of lidocaine.

The *molar mass* of a substance is the mass in grams of 1 mol of the compound. Although the term *molecular weight* has been used for this concept, molar mass is scientifically more precise and is preferred in modern chemistry texts.[7] One mole of lidocaine base has a molar mass that weighs 234.34 g.

Lidocaine is more soluble in water as an ionic hydrophilic salt. Commercial preparations of aqueous lidocaine use hydrogen chloride as the salt. The molar mass (molecular weight) of lidocaine HCl is 270.8:

1 g lidocaine salt = (1 g)/(270.8 g/mol) =
(1/270.8) mol = (0.00369 mol) = 3.69 mmol

In other words, the following inverse relationship exists:

1 g lidocaine HCl = 3.69 mmol
1 mol lidocaine HCl = 270.8 g

Solution Composition: Molarity. A *solute* is the substance, such as lidocaine, being dissolved. The *solvent* is the dissolving medium, such as isotonic physiologic saline or LR. Qualitative terms such as *dilute* (relatively little solute) and *concentrated* (relatively large amounts of solute) are not sufficiently precise for pharmacologic or chemical calculations.

Modern scientific literature describes solutions in terms of molarity. By definition:

Molarity (M) = (Moles of solute)/(Liters of solvent)

Thus, for lidocaine:

1 M = 1 mol/L = 270.8 mg/L

Commercial preparations of lidocaine intended for subcutaneous injection specify concentration in terms of "grams percent." A typical commercial preparation is 1% lidocaine - 1 g/100 ml = 1000 mg/100 ml = 10 g/L = 36.9 mM solution. Thus:

1% lidocaine = 36.9 mM solution

The millimolar (mM) solution of a drug is determined as follows: first convert the milligram dose to gram dose by dividing the milligram dose by 1000, and then divide the gram dose by the molar mass (molecular weight) of the drug.

DILUTIONS: DEFINITIONS AND MEASUREMENTS

As noted, commercially available formulations of local anesthetics usually specify lidocaine concentration in "grams per

100 ml" (grams percent). Thus a 1% lidocaine solution contains 1 g of lidocaine per 100 ml of solution, which is equivalent to 10 mg/ml.

Similarly, the traditional specification for epinephrine concentration is defined as a ratio of 1 g of solute to the number of milliliters of solution required to provide the desired concentration. For example, a 1:1000 solution of epinephrine contains 1 g of epinephrine in 1000 ml of solution, or 1 mg per 1 ml. Thus a tumescent solution having an epinephrine concentration at 1:1 million contains 1 g per 1 million ml, or 1 mg/1000 ml.

These traditional designations are sufficient when a surgeon simply needs to specify which of the off-the-shelf local anesthetics is being ordered. When ordering the formulation of customized solutions for tumescent local anesthesia, however, this method of specifying dilutions requires mathematic calculations that are cumbersome and prone to error.

Tumescent Specifications. Formulations of tumescent lidocaine and epinephrine solutions should be specified in terms of milligrams per liter (mg/L). Similarly, the amount of $NaHCO_3$ is specified in terms of milliequivalents per liter (mEq/L).

This method of specifying the formulation of a dilute solution of local anesthesia is easy for staff to use and understand. When multiple bags of anesthetic are used on one patient, this also provides a clear method for keeping tract of the total dose (mg) of lidocaine that has been given.

The task of mixing solutions of tumescent local anesthetic is simplified because a 50-ml bottle of 1% lidocaine contains 500 mg, and therefore two 50-ml bottles contain 1 g of lidocaine. Similarly, a 1-ml ampule of epinephrine at 1:1000 contains 1 mg of epinephrine.

To obtain a tumescent anesthetic solution consisting of 1250 mg of lidocaine and 1 mg of epinephrine per approximately 1 L of isotonic saline for abdominal liposuction, 2.5 bottles (125 ml) of 1% lidocaine and 1 ampule (1 ml) of epinephrine 1:1000 are added to a liter bag of isotonic saline. A compulsively accurate specification of this dilution would show the volume of solution as follows:

1136 ml = 1 L isotonic saline + 125 ml lidocaine +
10 ml $NaHCO_3$ + 1 ml epinephrine

Because no clinically significant difference exists between the effects of 1250 mg of lidocaine in 1136 ml or 1000 ml of solution, there is no compelling need to end up with exactly 1000 ml of solution by first subtracting 136 ml of isotonic saline before adding the solutes.

Plastic bags are preferred over glass bottles, because bags can easily expand and accommodate the extra volumes that are added.

HYALURONIDASE COUNTERPRODUCTIVE

Attempts at vasoconstriction in the earliest days of liposuction used a mixture of undiluted lidocaine, epinephrine, and hyaluronidase, which was injected into the targeted fat af-

ter induction of general anesthesia. The rationale for using hyaluronidase was the drug's alleged ability to augment the diffusion of epinephrine. Although this attribute of hyaluronidase is not well documented, some surgeons still include it in their anesthetic formulations for tumescent liposuction.

Hyaluronidase does not improve the degree of anesthesia achieved by the tumescent technique. It accelerates the rate of absorption of lidocaine[8] and produces greater pain on subcutaneous infiltration. Hyaluronidase is a protein and can cause allergic reactions. Therefore it is not recommended for tumescent liposuction.

EFFECTS OF LIDOCAINE

PLASMA PROTEIN BINDING

Plasma protein binding of lidocaine occurs most importantly to α_1-*acid glycoprotein*, an acute-phase reactant protein (high affinity, low capacity). Lidocaine binding to albumin (low affinity, high capacity) is less important.[9] The affinity of lidocaine for protein binding sites can vary with changes in pH and hemodilution.[10]

The concentration of α_1-acid glycoprotein and the concentration of free (unbound) lidocaine can vary widely in the setting of clinical inflammation. Because of variability in serum protein binding with surgery and in certain disease states, one cannot predict free lidocaine simply by knowing the total (free plus protein-bound) lidocaine concentration.[11] Surgery, trauma,[12] postoperative inflammation,[13] cancer, smoking, and myocardial infarction[14] all increase α_1-acid glycoprotein and lidocaine protein binding, thus decreasing the proportion of free lidocaine. Such patients may tolerate higher doses of lidocaine before encountering toxicity.[15] Oral contraceptive agents decrease α_1-acid glycoprotein.

The ratio of free lidocaine to total plasma lidocaine levels affects the predictability of lidocaine toxicity based on lidocaine plasma concentrations.[16] The proportion of free, unbound lidocaine in plasma increases with increasing concentration. In the clinically therapeutic range of 1 to 4 μg/ml, 20% to 40% of lidocaine is free and not bound to plasma proteins.

SODIUM CHANNEL BLOCKING

Lidocaine inhibits the transmission of nerve impulses by blocking sodium ion (Na^+) flux across nerve membranes. Lidocaine blocks nerve membrane Na^+ channels in much the same way as calcium channel blockers block Ca^{++} channels. Blocking the Na^+ channels of nerves slows the rate of depolarization sufficiently to prevent the attainment of threshold potential and propagation of an action potential.

In canine papillary muscle, lidocaine displaces cocaine from the Na^+ channel receptor through competitive binding.[17] Lidocaine may prove to be beneficial in reversing cocaine-induced slowing of ventricular conduction. On the other hand, cocaine and lidocaine are synergistic in producing seizures.[18]

NERVE FIBER EFFECTS

Local anesthetics tend to block small nerve fibers sooner than larger fibers and nonmyelinated fibers sooner than myelinated fibers. Clinically this is manifested by the observation that small myelinated Aδ fibers that mediate pain and temperature are blocked more easily than the larger myelinated Aα (motor and proprioception), Aβ (proprioception and vibrations), and Aγ (muscle tone) fibers. Patients should not feel pain during tumescent liposuction after good tumescent anesthesia; however, they will often be aware of vibrations and a peculiar rasping sensation during liposuction of deeper planes.

Differential Onset of Neural Blockade. Deposition of the lidocaine very close to a sensory nerve produces immediate local anesthesia. Different types of nerve fibers have different degrees of myelinization and are affected by local anesthesia to a different degree. Autonomic nerve blockade precedes sensory nerve blockade.

Motor nerve activity is the least susceptible to the local effects of lidocaine. Clinical experience suggests that tumescent anesthesia of adipose tissue produces a rapid blockade of pain and temperature sensation, whereas proprioception and vibration sensation remain unaffected.

Neural Blockade as Function of Concentration. In myelinated nerve fibers, at least three consecutive nodes of Ranvier must be blocked before neural impulse propagation is interrupted.[19] In vitro the blockade of a nerve seems to be a simple function of the concentration of the local anesthetic; thin individual nerves are readily blocked by a lidocaine concentration of 100 μM.[20]

In vivo the anesthesia produced by the tumescent technique seems to be a function of two variables: the concentration of dilute lidocaine and the length of nerve exposed to the anesthetic.

Central Nervous System Effects. In experimental animals, lidocaine has significant antiepileptic activity at plasma concentrations of 0.5 mg/L to 4.0 mg/L, the therapeutic range for antiarrhythmic (antidysrhythmic) activity. At plasma levels greater than 7.5 mg/L, however, lidocaine can cause seizures.[21] Because the toxic effects of local anesthetics are additive, lidocaine should not be used to treat a seizure or cardiotoxicity caused by another local anesthetic.

Antiinflammatory Effect. Lidocaine inhibits granulocyte adherence and prevents granulocyte delivery to inflammatory sites after an IV infusion of lidocaine in rabbits with aseptic peritonitis.[22] In this regard, lidocaine is 10 times more effective than methylprednisolone.

ANTIBACTERIAL EFFECTS

Tumescent liposuction is associated with a low risk of postoperative infections. This clinical record provides strong evidence that in vivo tumescent local anesthesia is bacteriostatic and bactericidal.

Since 1985 I have documented only one postoperative wound infection among my patients (see Chapter 12). This infection, involving a localized subcutaneous *Staphylococcus aureus* abscess of the medial thigh, was treated by incision, drainage, and oral antibiotics. Few, if any, routine surgical procedures have a lower incidence of infection than tumescent liposuction.

Among cosmetic surgeons, the exceptionally low infection rate associated with tumescent liposuction is widely regarded as a clinical fact. Other surgical specialists, however, believe that the bactericidal effects of lidocaine are controversial. Consequently, studies have attempted to prove the bactericidal effects of lidocaine by in vitro experimentation.

Reports are conflicting regarding the concentration of lidocaine that is necessary to achieve bactericidal effects in vitro. In part this discrepancy may be explained by the in vitro methodology. The number of bacteria used in the inoculum is an important factor when using in vitro methods to estimate the antimicrobial potency of an antimicrobial agent.[23] On the one hand, if an inoculum is too large, an antimicrobial may be judged ineffective because of the high probability of a spontaneous mutation into resistant bacteria.[24] On the other hand, if the inocula are too small, too few colonies may be present among the controls to establish a statistically relevant bactericidal effect at 99.9% killing.[25,26] The preferred number of bacteria for an in vitro inocula is probably in the range of 10^5 to 10^6 bacteria or colony-forming units (CFU) per sample.[24,25]

One recent in vitro study found that prolonged exposure to 0.1% lidocaine is insufficient to inhibit 10^8 CFU/ml of various bacteria.[27] In contrast, two recent reports have found that dilute lidocaine in a concentration of 0.05% does have in vitro antibacterial activity. One study found this lidocaine dilution to be bacteriostatic for *S. aureus*.[28] The other study used suspensions of bacteria containing approximately 10^5 CFU/ml. All gram-positive organisms tested, including *S. aureus*, had significantly lower colony counts in 0.05% or higher concentrations of lidocaine diluted by propofol. All gram-negative organisms had significantly lower colony counts in lidocaine concentrations of 0.2% or higher.[29]

Some anesthesiologists add 10 mg of lidocaine to 20 ml of propofol, which is equivalent to 0.05% lidocaine, to decrease the pain on IV injection of propofol.[30] Higher lidocaine concentrations may be incompatible with the stability of propofol in emulsion.[31]

Lidocaine's antibacterial activity, in addition to its local anesthetic properties, has not been fully appreciated.[32] When first recognized as being bacteriostatic, clinicians were concerned that lidocaine might inhibit bacterial growth in cultures of tissue obtained by biopsy using local anesthesia.[33-39] In vitro evidence indicates that lidocaine is not only bacteriostatic but actually bactericidal for organisms isolated from skin lesions.[40] Recently it has been shown that adding $NaHCO_3$ to lidocaine augments this in vitro bactericidal activity.[41]

Lidocaine is antibacterial for both gram-negative and gram-positive bacteria. In gram-negative bacteria such as *Escherichia coli*, *Salmonella typhimurium*, and *Pseudomonas*

aeruginosa, lidocaine appears to act synergistically with antibiotics by depolarizing the bacterial cell membrane and increasing cell membrane permeability.[42]

Bupivacaine, which is structurally related to lidocaine, also has antibacterial properties. A mixture of racemic bupivacaine appears to have more in vitro antibacterial activity than levobupivacaine.[43]

From the point of view of dermatologic surgery, the significance of the bactericidal activity of lidocaine is that this local anesthetic agent might be responsible for preventing wound infections. Although no in vivo clinical studies have substantiated this presumed effect, this should not be ignored. When a surgical procedure is performed on skin using general anesthesia, concomitant use of lidocaine might be warranted.

The minimal incidence of postoperative infections associated with tumescent liposuction may be attributed to the following clinical factors:

1. In vivo bacteriostatic and bactericidal effects of lidocaine combined with epinephrine and bicarbonate
2. Low incidence of hematomas and seromas associated with tumescent liposuction
3. Moderation in terms of the surgical trauma inflicted during a single surgical procedure
4. Judicious selection of healthy patients

The last two factors are of critical importance. Common sense and moderation in liposuction are crucial to reduce postoperative complications, including infections.

NEUROTOXICITY

Local anesthetics, including lidocaine, can produce a concentration-dependent chemical toxicity to nerve tissue. Lidocaine induces a nonreversible loss of impulse activity in frog nerve in a progressive fashion with increasing drug concentration, beginning at a concentration of 1% (40 mM).[44]

Although the range of lidocaine concentration that produces toxicity in mammalian nerves is not known, clearly the least effective concentration is the safest.

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CHAPTER 18

Cytochrome P450 3A4 and Lidocaine Metabolism

Lidocaine toxicity can occur as a result of adverse drug interactions between lidocaine and agents that inhibit the hepatic enzymes cytochrome P450 1A2 (CYP1A2) and cytochrome P450 3A4 (CYP3A4), which metabolize lidocaine. One patient had a reduced rate of lidocaine metabolism after tumescent liposuction as a result of CYP3A4 inhibition by sertraline (Zoloft) and flurazepam (Dalmane).[1]

When two or three drugs are substrates for the same enzyme, an adverse drug reaction is possible when they are used simultaneously. Lidocaine is rapidly eliminated by hepatic CYP3A4. The newer antidepressant selective serotonin reuptake inhibitors (SSRIs), such as sertraline, are metabolized by the hepatic enzymes CYP3A4 and CYP2D6. The benzodiazepines, such as midazolam (Versed) and diazepam (Valium), are also metabolized by the CYP3A4 isoenzymes. The specific cytochrome P450 enzyme responsible for the metabolism of flurazepam has not been identified.

Since 1994, information has expanded rapidly about the specificity of hepatic microsomal enzymes of the cytochrome P450 family for the metabolism of different drugs. This new information permits a knowledgeable clinician to anticipate adverse drug interactions.

For several years, 60-mg/kg doses of lidocaine for tumescent liposuction had been widely regarded as the maximum dose. After my experience with lidocaine toxicity following a tumescent lidocaine dosage of 60 mg/kg, the maximum dose that I will use in any patient is now 50 to 55 mg/kg. When the need for a larger dose is anticipated, the surgical plan is reevaluated and the surgery divided into sequential procedures separated by at least 4 days. The two procedures are typically performed one month apart to allow the resolution of most of the postoperative effects from the initial procedure before subjecting the patient to additional surgical trauma.

The safety of tumescent lidocaine at a dose of 55 mg/kg has yet to be well documented by rigorous pharmacologic studies involving a large number of patients. Before Case Reports 18-1 and 18-2, we had performed tumescent liposuction on more than 400 patients using lidocaine doses in the range of 50 to 60 mg/kg without evidence of significant lidocaine toxicity.

CYTOCHROME P450 SYSTEM

The cytochrome P450 (CYP450) family of enzymes is essential for most drugs eliminated by hepatic metabolism.[2] These enzymes have 450 nm as the wavelength of maximum absorption in the reduced state when carbon monoxide is present; thus the "P450" designation. Based on the homology of amino acid sequences, the CYP450 enzymes have been categorized into families, subfamilies, and individual enzymes.[3]

Microsomes are the microvesicles formed from fragments of endoplasmic reticulum after liver tissue has been homogenized and centrifuged. The enzymes located in the endoplasmic reticulum are referred to as *microsomal enzymes*. Until recently, hepatic metabolism of drugs and metabolic drug interactions were usually studied in vitro using liver tissue.

Cytochrome P450 evolved as an important means of converting potentially harmful concentrations of lipid-soluble nutrients and environmental substances into water-soluble compounds that are more easily eliminated. In humans there are 12 known families of CYP450 isoenzymes, of which five are important in drug metabolism: 3A4, 1A2, 2C9, 2C19, and 2D6.

When two drugs, both requiring the same enzyme for metabolism, are given concurrently, one drug may inhibit or induce metabolism of the other, and thus an adverse drug

CASE REPORT 18-1 Sertraline and Lidocaine Toxicity

A 39-year-old female weighing 80 kg (176 pounds) underwent tumescent liposuction surgeries. Five years earlier, her breast cancer was treated by chemotherapy, radiation, and bone marrow transplantation. She had a long history of treatment with sertraline (Zoloft, 200 mg daily) for anxiety disorder, panic attacks, and mild depression. Sertraline was not discontinued before either surgery.

The first surgery, liposuction of the hips and outer thighs, was uneventful. Perioperative sedation consisted of 10 mg of oral zolpidem (Ambien). The dose of tumescent lidocaine totaled 59 mg/kg (lidocaine 800 mg/L, epinephrine 0.65 mg/L, sodium bicarbonate 10 mEq/L) in 0.9% NaCl at 37° C (98.6° F). Liposuction produced 2700 ml of supranatant fat and 250 ml of blood-tinged infranatant anesthetic solution.

One month later the patient returned for liposuction of the inner thighs, inner knees, and buttocks. Perioperative sedation on this occasion was 30 mg of oral flurazepam (Dalmane). Between 11:20 AM and 1 PM she received 58 mg/kg of tumescent lidocaine (lidocaine 900 mg/L, epinephrine 0.65 mg/L, bicarbonate 10 mEq/L) in 0.9% NaCl at 37° C. The liposuction was uneventful, yielding 1800 ml of supranatant fat and and 650 ml of blood-tinged infranatant anesthetic solution. The patient was discharged at 7:20 PM, alert and fully ambulatory.

Ten hours after completion of the tumescent infiltration of lidocaine, the patient experienced nausea, vomiting, unsteady gait, mild confusion, and dysarthria. Physical examination in a local emergency room revealed anxiety, short-term memory impairment, and slight pallor; otherwise the neurologic and cardiovascular findings, electrocardiogram, and routine laboratory studies were unremarkable. Blood drawn at 11:48 PM had a plasma lidocaine concentration of 6.3 mg/L by immunoassay (IA) and confirmed by gas chromatography (GC) as 6.1 mg/L. Lidocaine plasma levels greater than 6 mg/L are associated with an increased risk of toxicity. Admitted to hospital for overnight observation, she was discharged the next morning, with a 6:45 AM lidocaine level of 2.9 mg/L by IA and confirmed at 3.0 mg/L by GC.

Discussion. To our knowledge, this is the first documented case of tumescent liposuction totally by local anesthesia in which a standard dose of lidocaine, widely recognized as safe, has led to potentially toxic plasma lidocaine concentrations. It demonstrates the possibility of serious interactions between tumescent lidocaine and commonly used oral medications. Both sertraline and flurazepam have the potential for significantly reducing lidocaine clearance through inhibition of CYP3A4, thereby increasing plasma lidocaine concentrations above the threshold for toxicity. Whether the patient's prior treatment for breast cancer affected her ability to metabolize lidocaine is unclear.

Sertraline and flurazepam may have had an additive effect on reducing the rate of lidocaine metabolism. During the first surgery, when sertraline but not flurazepam was administered, the patient had no symptoms of lidocaine toxicity. Lidocaine plasma concentrations were possibly elevated asymptomatically.

CASE REPORT 18-2 Clarithromycin and Lidocaine Toxicity

After our report of the CYP3A4-mediated sertraline-lidocaine drug interaction case was published, a physician told me about another case of a CYP3A4-mediated toxic drug interaction. This patient developed nausea, vomiting, confusion, and disorientation after receiving 60 mg/kg of tumescent lidocaine.

Eleven days before the scheduled liposuction the patient started taking clarithromycin for an upper respiratory infection and discontinued it the day before surgery. At surgery the patient was not taking any drugs. Because of the long half-life of clarithromycin, however, lidocaine metabolism was sufficiently impaired to account for the toxic events.

interaction may occur. Many factors determine the relative effects of one drug on the metabolism of another drug. Drug concentration and relative enzyme affinity determine metabolic drug interactions.

Significant interpatient variability exists with respect to the enzymatic activity of the CYP450 isoenzymes. This makes it difficult to predict the probability of any specific drug interaction.[4]

HEPATIC METABOLISM OF LIDOCAINE

Lidocaine is rapidly eliminated by hepatic metabolism.[5] The liver metabolizes 70% of the lidocaine that enters the hepatic circulation at any given moment. When 1 L of blood passes through the hepatic circulation of a healthy volunteer, more than 700 ml of the blood is completely cleared of its lidocaine content.[6]

With a high hepatic extraction ratio of 0.7, lidocaine metabolism is said to be "flow rate limited." In other words, the rate of lidocaine metabolism usually depends on the rate of blood flow to the liver.

At typical, therapeutic plasma concentrations of lidocaine, metabolism of lidocaine is so efficient that it does not seem to cause any substrate inhibition of the enzymes CYP1A2 and CYP3A4. Lidocaine clearance can be reduced by any drug that inhibits CYP3A4 enzymes, such as erythromycin or ketoconazole (see Boxes 18-1 to 18-3). Similarly, any condition that reduces hepatic blood flow, such as shock or decreased cardiac output associated with congestive heart failure, will decrease lidocaine clearance. The beta-blockers,

BOX 18-1 CYTOCHROME P450 3A4 INHIBITORS AFFECTING LIDOCAINE METABOLISM

Acetazolamide
Alprazolam (Xanax)
Amiodarone (Cordarone)
Anastrozole (Arimidex)
Cannabinoids
Cimetidine (Tagamet)
Clarithromycin (Biaxin)
Cyclosporine (Neoral)
Danazol (Danocrine)
Diazepam (Valium)
Diltiazem (Cardizem)
Erythromycin
Felodipine (Plendil)
Fluconazole (Diflucan)
Fluoxetine (Prozac)
Fluvoxamine (Luvox)
Indinavir (Crixivan)
Isoniazid
Itraconazole (Sporanox)
Ketoconazole (Nizoral)
Metronidazole (Flagyl)
Mibefradil (Posicor)
Miconazole (Monistat)
Midazolam (Versed)
Naringenin (grapefruit juice)
Nefazodone (Serzone)
Nelfinavir (Viracept)
Nevirapine (Viramune)
Nicardipine (Cardene)
Nifedipine (Procardia)
Norfloxacin (Noroxin)
Norfluoxetine
Omeprazole (Prilosec)
Paroxetine (Paxil)
Quinidine (Quinaglute)
Remacemide
Ritonavir (Norvir)
Saquinavir (Invirase)
Sertinadole
Sertraline (Zoloft)
Stiripentol
Terfenadine (Seldane)
Triazolam (Halcion)
Troglitazone (Rezulin)
Troleandomycin (TAO)
Verapamil (Calan)
Zafirlukast (Accolate)
Zileuton (Zyflo)

Data from Park GR: *Br J Anaesth* 77:32-49, 1996.

BOX 18-2 CATEGORIES OF CYTOCHROME P450 3A4 INHIBITORS

ANTIFUNGAL MEDICATIONS
Fluconazole
Itraconazole
Ketoconazole
Miconazole

BENZODIAZEPINES
Alprazolam
Diazepam
Flurazepam
Midazolam
Triazolam

CALCIUM CHANNEL BLOCKERS
Amiodarone
Diltiazem
Felodipine
Nicardipine
Nifedipine
Verapamil

MACROLIDE ANTIBIOTICS
Clarithromycin
Erythromycin
Troleandomycin

PROTEASE INHIBITORS
Indinavir
Nelfinavir
Ritonavir
Saquinavir

SELECTIVE SEROTONIN REUPTAKE INHIBITOR (SSRI) ANTIDEPRESSANTS
Fluoxetine
Fluvoxamine
Nefazodone
Paroxetine
Sertraline

BOX 18-3 CYTOCHROME P450 1A2 INHIBITORS

Anastrozole (Arimidex)
Caffeine
Cimetidine (Tagamet)
Ciprofloxacin (Cipro)
Clarithromycin (Biaxin)
Diethyldithiocarbamate
Diltiazem (Cardizem)
Enoxacin (Penetrex)
Erythromycin
Fluvoxamine (Luvox)
Isoniazid
Ketoconazole (Nizoral)
Mexiletine (Mexitil)
Mibefradil (Posicor)
Naringenin (grapefruit juice)
Norfloxacin (Noroxin)
Omeprazole (Prilosec)
Paroxetine (Paxil)
Ritonavir (Norvir)
Tacrine (Cognex)
Zileuton (Zyflo)

such as propranolol, decrease lidocaine metabolism and elimination by decreasing cardiac output and therefore hepatic blood flow.[7] Cimetidine inhibits CYP3A4 and decreases hepatic blood flow.[8] Patients with cirrhosis of the liver have a reduced lidocaine clearance; in renal insufficiency, however, lidocaine clearance is normal.

Lidocaine Metabolites. The hepatic CYP1A2 and CYP3A4 microsomal isoenzymes alter lidocaine by a sequential process of oxidative *N*-dealkylation. First, oxidative deethylation of the amino nitrogen occurs, yielding monoethyl glycine xylidide (MEGX). Next, an additional oxidative reaction removes the residual ethyl group from MEGX, yielding glycine xylidine (GX).[9]

Both of these metabolites, MEGX and GX, have some local anesthetic effect and antidysrhythmic effect.[10] After 10 to 24 hours of lidocaine infusion, the ratio of total serum concentrations of MEGX to lidocaine ranges from 0.11 to 0.36 in cardiac patients without cardiac failure.[11] MEGX and GX are much less lipophilic than lidocaine, having octanol/buffer (pH 7.4) partition coefficients of 6:1 and 2:1, respectively. The lidocaine partition coefficient for octanol/water is 43:1. After prolonged intravenous (IV) infusion, less than 5% of lidocaine appears in the urine,[12] whereas most of MEGX is excreted by the kidneys. After

an oral dose, only 2% of lidocaine is excreted intact in the urine.[13] Ultimately, 73% of the dose appears in the urine as xylidine (Figure 18-1).

With prolonged systemic delivery, the rate of lidocaine metabolism and clearance decreases, possibly because of competition between lidocaine and its metabolites for the binding sites of hepatic enzymes. Lidocaine metabolism is a sensitive means for evaluating liver CYP450 function in a bioartificial liver.[14] Determining the amount of MEGX produced by a patient's liver has been used to measure the degree of liver dysfunction and to predict survival in critically ill patients.[15]

DRUG METABOLISM

The most abundant of all human cytochrome P450 enzymes, the isoenzyme CYP3A4, is responsible for the me-
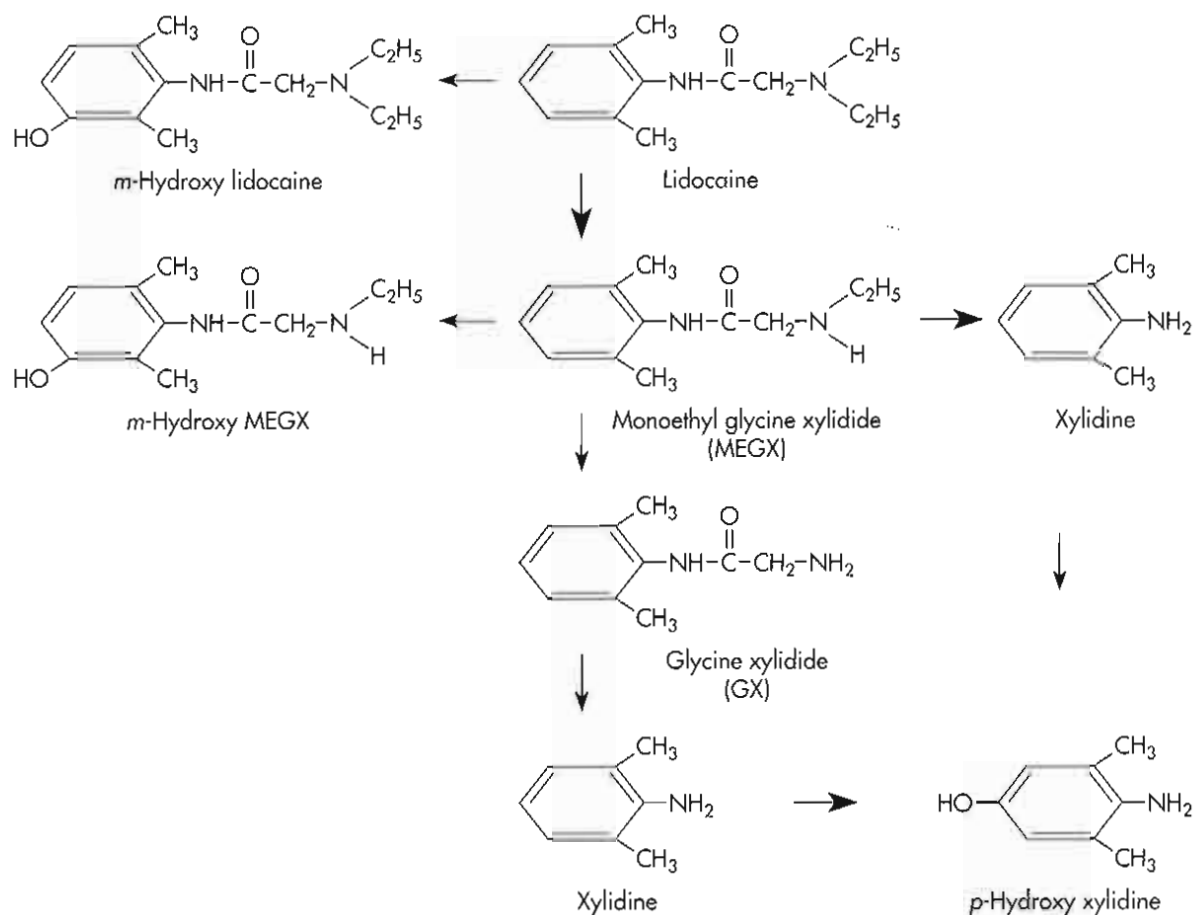
Figure 18-1

Lidocaine metabolism. (Modified from de Jong RH: *Local anesthetics*, St Louis, 1994, Mosby.)

tabolism of more drugs and a broader range of drugs than any other hepatic enzyme. CYP3A4 metabolizes such drugs as lidocaine, antidepressants, carbamazepine[16] (Tegretol), nifedipine[17] (Procardia), methadone (Dolophine), and alfentanil.[18,19]

Drugs that inhibit CYP3A4 or CYP1A2 are avoided or discontinued, if possible, before tumescent liposuction (Boxes 18-1 to 18-3). If these inhibitors cannot be discontinued, the total dosage of lidocaine should be reduced to 35 mg/kg or less.

Many substrate drugs are metabolized by CYP3A4 and CYP1A2 but do not significantly inhibit enzymatic function of these cytochromes. Under certain conditions, substrate drugs may adversely affect lidocaine metabolism. If multiple substrate drugs are used simultaneously, they have an additive effect, producing competitive inhibition of lidocaine metabolism. In addition to the inhibitor drugs, it is helpful to know which drugs are substrates for CYP3A4 and CYP1A2 (Boxes 18-4 and 18-5).

Certain drugs augment the enzymatic activity of CYP3A4. Rifampin (Rifampicin) induces CYP3A4 and augments the metabolism of lidocaine[20] and triazolam (Halcion).[21] An infusion of heme arginate induces CYP3A4 and augments lidocaine metabolism in patients with variegate porphyria.[22]

Whereas CYP3A4 is inducible by some drugs, CYP2D6 is not inducible but can be inhibited by certain drugs.[23] Potent in vitro inhibitors of both CYP3A4 and CYP2D6 include sertraline (Zoloft), fluoxetine (Prozac), fluvoxamine (Luvox), and paroxetine (Paxil), all of which are selective serotonin reuptake inhibitors (SSRIs).[24] Almost all the available newer antidepressants, including the SSRIs, as well as nefazodone (Serzone), an antidepressant unrelated to SSRIs, inhibit CYP3A4 and are associated with clinically significant drug interactions.

SSRIs are being used with increasing frequency. Antidepressants also are widely prescribed for nonpsychiatric conditions and may be taken by prospective liposuction patients; for example, fluoxetine (20 mg/day) is used in the treatment of premenstrual dysphoria.[25] Similarly, alprazolam (Xanax) has a role in the treatment of severe premenstrual syndrome (PMS).[26] Potential tumescent liposuction patients might be taking a combination of fluoxetine and

BOX 18-4 CYTOCHROME P450 3A4 METABOLIC SUBSTRATES

Alfentanil (Alfenta)	Dexamethasone (Decadron)	Methadone	Sildenafil (Viagra)
Alprazolam (Xanax)	Dextromethorphan	Methylprednisolone	Simvastatin (Zocor)
Amitriptyline (Elavil)	Donepezil (Aricept)	Midazolam (Versed)	Tacrolimus (Prograf)
Amlodipine (Norvasc)	Erythromycin	Nicardipine (Cardene)	Tamoxifen (Nolvadex)
Astemizole (Hismanal)	Estrogens	Nimodipine (Nimotop)	Terfenadine (Seldane)
Atorvastatin (Lipitor)	Felodipine (Plendil)	Nisoldipine (Sular)	Testosterone
Carbamazepine (Tegretol)	Fentanyl	Pentoxifylline (Trental)	Tetracycline
Cerivastatin (Baycol)	Flurazepam (Dalmane)	Pravastatin (Pravachol)	Theophylline
Chloramphenicol (Chloromycetin)	Fluvastatin (Lescol)	Prednisone	Thyroxine
Cisapride (Propulsid)	Imipramine (Tofranil)	Progestins	Valproic acid (Depakene)
Clomipramine (Anafranil)	Isradipine (DynaCirc)	Propafenone (Rythmol)	Warfarin (Coumadin)
Clozapine (Clozaril)	Losartan (Cozaar)	Rifabutin (Mycobutin)	Zileuton (Zyflo)
Cyclosporine (Neoral)	Lovastatin (Mevacor)	Rifampin (Rifampicin)	Zonisamide

BOX 18-5 CYTOCHROME P450 1A2 METABOLIC SUBSTRATES

Chlordiazepoxide (Librium)	Haloperidol (Haldol)
Clomipramine (Anafranil)	Imipramine (Tofranil)
Clozapine (Clozaril)	Riluzole (Rilutek)
Cyclobenzaprine (Flexeril)	Theophylline
Desipramine (Norpramin)	Warfarin (Coumadin)
Diazepam (Valium)	

alprazolam. The combination of an SSRI and a benzodiazepine might inhibit lidocaine metabolism in a way analogous to Case Report 18-1.

The metabolism of alfentanil, which is dependent on CYP3A4, is no different on menstrual cycle days 3 (menstruating phase), 13 (estrogen peak), and 21 (progesterone peak). This strongly suggests that a woman's menstrual phase does not affect the activity of CYP3A4.[27]

DRUG INTERACTIONS

Examples of drug interactions mediated by inhibition or induction of CYP3A4 are increasing. When two drugs require the same enzyme for metabolism, one drug may decrease the rate of metabolism of the others. For most cases, when a drug is metabolized by CYP3A4, it is not known how a drug and lidocaine might interact. Therefore, until a specific evaluation has been completed, one must assume that the drug will reduce the rate of lidocaine metabolism.

Rifampin induces and increases the metabolic activity of CYP3A4, whereas troleandomycin inhibits CYP3A4 activity. In human volunteers, alfentanil has clearance and elimination half-life of $5.3 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and 58 minutes, respectively. When alfentanil is administered with rifampin,

CYP450 activity is increased, and alfentanil clearance and elimination half-life are $14.6 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and 35 minutes, respectively. When troleandomycin is given concomitantly, alfentanil clearance and elimination half-life are $1.1 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and 630 minutes, respectively.[28] Thus, in human volunteers, drugs that affect CYP3A4 activity can produce significant alterations in the systemic clearance of alfentanil. Similar interactions can also affect lidocaine clearance.

Drug interactions mediated by CYP3A4 can have devastating consequences. For example, the nonsedating antihistamines terfenadine (Seldane) and astemizole[29] (Hismanal), as well as cisapride (Propulsid), used to treat nocturnal heartburn caused by gastroesophageal reflux disease, are metabolized by CYP3A4. Ketoconazole (Nizoral), itraconazole (Sporanox), erythromycin, and clarithromycin (Biaxin), however, are potent inhibitors of 3A4 and block the metabolism of terfenadine, astemizole, and cisapride. The resulting elevated plasma levels can cause fatal QT prolongation and torsades de pointes–type ventricular tachycardias.

Erythromycin inhibits the ability of CYP3A4 to metabolize midazolam. This interaction can result in a prolonged coma.[30]

Not all macrolide antibiotics inhibit CYP3A4. Azithromycin (Zithromax) and dirithromycin (Dynabac) are eliminated by a combination of hepatic metabolism and bilary excretion. There are no reports of the effects of azithromycin or dirithromycin inhibiting CYP3A4, but clinical pharmacologic studies have shown that these drugs do not cause elevated terfenadine blood levels.

Methadone is extensively metabolized by CYP3A4. Fluvoxamine, a newer SSRI antidepressant, is a potent mixed-type inhibitor of methadone metabolism. Conversely, the metabolism of nifedipine by CYP3A4 is potently inhibited by methadone.

The apparent decrease of CYP3A4 enzymatic activity with advancing age might be secondary to changes in liver blood flow, size, or drug binding and distribution with age.[31,32]

Dietary factors, such as grapefruit juice, can inhibit CYP3A4 found in intestinal mucosa. Grapefruit juice inhibits CYP3A4 located in intestinal wall tissue (but not hepatic CYP3A4), which decreases the rate of metabolism of substrate drugs in the gastrointestinal tract and augments the drugs' systemic absorption and bioavailability. For example, grapefruit juice increases the maximum plasma concentration of diazepam by a factor of 1.5. Grapefruit juice also appears to increase the bioavailability of oral doses of triazolam, midazolam, cyclosporine, and several dihydropyridine calcium channel blockers, such as felodipine, nifedipine, nitrendipine, and nisoldipine. The effects of grapefruit juice on intestinal CYP3A4 persist for about 3 days.

Fluoxetine, through its metabolite norfluoxetine, inhibits CYP3A4 and impairs the metabolism of warfarin (Coumadin).

In addition to diverse drugs inhibiting lidocaine metabolism, lidocaine may inhibit the metabolism of other drugs. For example, given intramuscularly for minor gynecologic surgery, lidocaine enhances the hypnotic effect of thiopental when it is given intravenously as an induction agent for general anesthesia.

SERTRALINE AND OTHER SSRIs

The majority of the newer SSRI antidepressants, including sertraline (Zoloft), are associated with clinically significant drug interactions mediated by the inhibition of cytochrome P450 enzymes.[33] Sertraline can inhibit both CYP2D6 and CYP3A4.

The usual oral dose of sertraline ranges from 50 to 200 mg once daily. Based on an elimination half-life of 26 hours, steady-state plasma sertraline levels are achieved after 7 days of once-daily dosing in patients with healthy hepatic metabolism. Conversely, in patients who have a healthy liver, 1 week is required for the body's content of sertraline to be 98% eliminated after discontinuing the drug. In patients with mild cirrhosis, more than 2 to 3 weeks is required for sertraline to be eliminated.

In vitro studies show that sertraline inhibits CYP3A4. However, sertraline does not necessarily affect the metabolism of all drugs metabolized by CYP3A4. In vivo, sertraline does not seem to affect the metabolism of diazepam.[34]

Sertraline is tightly bound to plasma proteins. It may competitively displace other protein-bound drugs, such as lidocaine, increasing the amount of free (unbound) drug and the potential for toxic reactions.

After discontinuing sertraline, the physician should wait 7 to 14 days before prescribing any drug known to have potential adverse CYP450 (metabolic pathway) interactions. SSRIs are known to interact with monoamine oxidase inhibitors (MAOIs) to produce fatal reactions. Fatal drug interactions have even occurred in patients who have discontinued an SSRI and were immediately started on an MAOI.

BENZODIAZEPINES

The benzodiazepines are often used for anxiolysis and sedation in conjunction with lidocaine for tumescent local anesthesia. Thus it is important to understand the effects of CYP3A4 inhibitors on benzodiazepines.

Benzodiazepines are metabolized by several different microsomal enzymes. Approximately 75% of the available benzodiazepines are significantly metabolized by CYP3A4, including alprazolam[36] (Xanax), triazolam[37] (Halcion), diazepam[38,39] (Valium), and midazolam[40] (Versed). Plasma concentrations of these benzodiazepines increase when they are administered with drugs that inhibit CYP3A4, including most newer SSRI antidepressants. The rate of metabolism of midazolam and triazolam varies considerably among healthy volunteers.

The specific CYP450 isoenzyme responsible for the metabolism of flurazepam (Dalmane) has not been identified.[35] The half-life of flurazepam in plasma is 2 to 3 hours, but its major active metabolite (N-desalkylflurazepam) has a half-life of 47 to 100 hours.

The antipsychotic clozapine (Clozaril) and the antifungal ketoconazole (Nizoral) noncompetitively inhibit midazolam metabolism through the inhibition of CYP3A4. The metabolism of midazolam is also decreased by itraconazole (Sporanox) and fluconazole (Diflucan).[41] The antipsychotic olanzapine (Zyprexa), however, has little effect on midazolam metabolism.[42] Fluoxetine appears to impair the metabolism of alprazolam but not clonazepam (Klonopin).[43]

Nefazodone (Serzone), an antidepressant, is a competitive inhibitor of CYP3A4 in the metabolism of alprazolam and triazolam. In contrast, the metabolic clearance of lorazepam (Ativan) depends on conjugation rather than hydroxylation, and thus it is not inhibited by nefazodone. Although fluoxetine (Prozac) may impair the metabolism of both diazepam and warfarin, it does not impair lorazepam or oxazepam (Serax).[44] Fluoxetine does not affect the metabolism of triazolam,[45] but the combination of the tricyclic antidepressant amitriptyline and triazolam has been associated with a fatality.[46]

I recommend lorazepam as the benzodiazepine of choice for tumescent liposuction. Lorazepam is the only benzodiazepine that is not metabolized by CYP450 enzymes and therefore is less susceptible to adverse drug interactions. In its initial metabolic reaction, lorazepam is conjugated to lorazepam- glucuronide, which has no central nervous system activity, and is excreted in the urine. Available in 0.5-mg, 1-mg, and 2-mg tablets, lorazepam at 2 mg is equivalent in peak effectiveness to 10 mg of diazepam. Lorazepam, 1 mg orally, is given the night before and the day of surgery to minimize anxiety before liposuction. Larger doses are not necessary and may cause nausea in some patients.

A 2-mg to 4-mg oral dose of lorazepam produces more consistent and longer-lasting anxiolysis, sedation, and anterograde amnesia, comparable to 10 to 20 mg of diazepam.[47,48] Lorazepam appears to increase respiratory drive and attenuate the respiratory depression associated with meperidine (Demerol).[49]

LIDOCAINE

Lidocaine is principally metabolized by CYP3A4, which oxidizes a diversity of substrates, including drugs, carcinogens, and steroids (see earlier discussion).[50,51]

By competitive inhibition or by enzyme induction, drugs can either inhibit or accelerate lidocaine metabolism. As noted, sertraline (Zoloft) has been shown to inhibit CYP3A4 in vitro, but the clinical significance of this has not been established. Lidocaine and the antidysrhythmic amiodarone (Cordarone) are both metabolized by CYP3A4, and each drug inhibits the metabolism of the other.[52] The combination of lidocaine and amiodarone is associated with bradycardia and seizures.[53]

Antiepileptic drugs appear to compete with lidocaine for CYP3A4 and slow lidocaine metabolism.[54] Although the clinical significance is not clear, lidocaine and propranolol exhibit mutual metabolic inhibition in rat liver microsomes.[55]

Drugs that inhibit enzymatic activity of CYP3A4 have the potential for elevating the plasma concentrations of lidocaine. With tumescent liposuction, in which patients' lidocaine blood levels are typically in the low therapeutic range of 1 to 3.5 mg/L, anything that causes a diminution of lidocaine metabolism can result in lidocaine levels above the 6-mg/L threshold for potential toxicity.

Drugs that interfere with lidocaine metabolism should be discontinued at least 1 or 2 weeks before using the tumescent technique when high doses of lidocaine are anticipated. If a drug that might interfere with lidocaine metabolism cannot be discontinued, the surgery should be limited and smaller total doses of lidocaine used.

See Chapters 16 and 21 for recommended maximum safe doses of tumescent lidocaine.

PROTEASE INHIBITORS

Antiretroviral medications are now widely used to treat patients with human immunodeficiency virus (HIV) and include indinavir (Crixivan), nelfinavir (Viracept), ritonavir (Norvir), and saquinavir (Invirase). CYP3A4 is responsible for up to 90% of the metabolism of protease inhibitors. The protease inhibitors also inhibit CYP3A4.

With other drugs that interact with CYP3A4, the patient can be asked to discontinue the medicine a week or two before surgery. Asking a patient to discontinue an antiretroviral medication (e.g., protease inhibitor) for cosmetic surgery, however, may not be an appropriate solution.

Protease inhibitors can increase the metabolism and thus decrease the plasma concentration of estradiol and theophylline. By increasing the metabolism of estradiol, protease inhibitors may impair the efficacy of oral contraceptives. Similarly, plasma levels of theophylline in asthma patients may be decreased.

Protease inhibitors appear to decrease the metabolism of lidocaine by approximately 50%, but the exact effect has not been adequately studied. Therefore, until more is known about the effects of protease inhibitors on tumescent lidocaine metabolism, tumescent liposuction is contraindicated in patients taking protease inhibitors.

MICHAELIS-MENTEN ENZYME KINETICS

In healthy patients the hepatic enzymes that metabolize lidocaine are so efficient that they do not become saturated at clinically relevant plasma lidocaine concentrations. The rate of hepatic lidocaine metabolism is perfusion rate limited, with a 70% extraction ratio. Thus, within the physiologic ranges of hepatic blood flow, the liver extracts lidocaine so quickly that for every liter of blood that flows through the liver, 700 ml of blood is completely cleared of all lidocaine. In other words, the hepatic enzymes CYP3A4 and CYP1A2 remove lidocaine as fast as lidocaine is presented to the liver. In vitro, enzymes extracted from human liver might demonstrate enzyme saturation when exposed to high concentrations of lidocaine. In vivo, however, no clinical evidence indicates that CYP3A4 or CYP1A2 become saturated.

Most mammalian enzymes that metabolize drugs can accommodate greater drug (substrate) concentrations than are ever achieved, even after an overdosage. Typically the rate at which an enzyme metabolizes a drug is linearly related to the drug's concentration. That is, the rate of enzymatic drug metabolism is proportional to the first power of the drug's concentration, which is known as a *first-order kinetic process.*

An occasional enzyme has only limited ability to process a substrate, and the enzyme's maximum capacity is readily exceeded. An enzyme is said to be *saturated* and shows *zero-order kinetics* when an increase in the substrate drug concentration does not change the rate of drug metabolism. A classic example of a saturated enzyme is alcohol dehydrogenase, which becomes saturated at very low concentrations of ethanol in the blood. At very low ethanol concentrations, alcohol dehydrogenase shows first-order kinetics. At relatively low but increasing blood ethanol levels, the rate of ethanol metabolism gradually changes, to the point where an increasing concentration of ethanol no longer increases the rate of metabolism. Saturable enzymes are said to show Michaelis-Menten kinetics.

At toxic concentrations of lidocaine, the enzymes that metabolize lidocaine are not saturated. The rate of lidocaine metabolism continues to increase with increasing plasma concentration.

Most of the drug metabolism mediated by CYP450 microsomal enzymes follow simple Michaelis-Menten kinetics; within certain limits of substrate concentration, a linear relationship exists between the concentration of the substrate and the initial velocity of the reaction. The enzyme kinetics of CYP3A4, however, often exhibits nonlinear or allosteric (sigmoidal) characteristics, which imply that each CYP3A4 molecule has more than one substrate binding site. In fact, CYP3A4 apparently has two active binding sites. Further-

more, access and binding affinity of the first substrate molecule of lidocaine to either site in an active pocket of CYP3A4 enhance the binding affinity and reaction rate of the vacant site for the second molecule of lidocaine.[56,57]

Lidocaine has such a high hepatic extraction ratio (0.7) that its elimination is limited by the rate of hepatic perfusion. The rate of lidocaine clearance is limited by the rate of blood flow to the liver, not by the rate of lidocaine metabolism by hepatic enzymes.

There is little risk of CYP3A4 becoming saturated at plasma lidocaine concentrations within the therapeutic range of less than 6 μg/ml.

RECENT TECHNICAL ADVANCES

Until recently, measuring the in vitro effects of CYP3A4 on drugs required a tedious process of obtaining fresh human liver tissue, extracting endoplasmic reticulum, assaying the CYP enzymatic activity on a control substance, then testing the enzymatic inhibition caused by an individual drug. Technical advances published in 1998 and 1999 promise to provide fully automated techniques for screening many drugs in clinical use and potential drug candidates.

Molecular biologic techniques now provide a means for rapid screening of multiple possible CYP-drug interactions. Recombinant human CYP450 enzymes expressed in *Escherichia coli* have been shown to be reliable surrogates for the native human liver enzymes, and such technology appears to be suitable for automated drug metabolism and CYP-drug interactions in humans.[58]

Hybridoma technology has been used successfully to produce monoclonal antibodies to human CYP1A2 and CYP3A4. This has been accomplished, for example, by infecting insect cells with recombinant baculoviruses encoded with human CYP3A4 complementary (copy) deoxyribonucleic acid (cDNA). When microsomal proteins derived from these cells are injected into mice, monoclonal antibody [mAb(3A4a)] specific to human CYP3A4 is produced. Monoclonal antibodies to human CYP3A4 promise to provide a precise tool for identifying the role of CYP3A4 in the metabolism of any drug.[59,60]

Fluorometric and radiometric analytic techniques using human liver microsomes allow rapid determination of inhibitory effects of any drug on CYP1A2, CYP3A4, CYP2C9, and CYP2D6.[61] A 1999 in vitro study suggests that CYP1A2 may be more important in the hepatic metabolism of lidocaine than CYP3A4.[62] Within a few years, new technology and studies should provide a more accurate perspective of the drug interactions that affect lidocaine metabolism.

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CHAPTER 19

Pharmacokinetics of Tumescent Lidocaine

T$his was sometime a Paradox, but now the time gives it proofe.*

—Shakespeare, *Hamlet*

The efficacy and safety of the large doses of lidocaine used in tumescent local anesthesia are perceived as a paradox by many physicians. Time-honored teachings about local anesthesia are difficult to reconcile with the principles of tumescent local anesthesia. Tens of thousands of tumescent liposuction patients have received 35 to 50 mg/kg of lidocaine with no known reports of deleterious effect, which has proved the safety of tumescent local anesthesia for liposuction. An understanding of the pharmacokinetics of tumescent lidocaine eliminates the paradox from the assertion that less (concentration) is more (effective and safe).

THE SCIENCE OF PHARMACOKINETICS

Pharmacokinetics is the branch of pharmacology concerned with the movement of drugs within the body. More specifically, pharmacokinetics is a science that studies the time course of drug concentrations and disposition in the body. In practice, pharmacokinetics uses mathematical models that describe the body in terms of one or more theoretic compartments and allows one to calculate and predict the time-dependent concentration of drugs in the blood. A good pharmacokinetic model permits an accurate estimation of both the maximum drug concentration (C_{max}) in the blood and the time (T_{max}) when the peak concentration will occur.

For lidocaine the risk of toxicity is closely correlated with the peak plasma lidocaine concentration. The ability to estimate the values of C_{max} and T_{max} allows one to anticipate or predict the risks of lidocaine toxicity. Important factors in determining these values are the rates of lidocaine absorption and metabolism.

To be useful, a pharmacokinetic model must be accurate and relatively simple. The accuracy of predictions depends on how accurately the model reflects the clinical reality. The simplicity of a mathematical model determines its usefulness. A pharmacokinetic model that is too complex may not be useful in many clinical situations.

This chapter is written for the "nonmathematical" physician who may be unfamiliar with pharmacokinetics. Bypassing the few sections on calculations will not impair an understanding of other concepts. This chapter provides the reader with an intuitive insight into the most important concepts involved in the pharmacokinetics of tumescent lidocaine. This presentation is heuristic rather than an elegant mathematical development. The mathematics sections at the end of this chapter provide more rigorous analyses and descriptions for interested readers.

DEFINITIONS

Elimination. Drug elimination refers to the irreversible removal of drug and metabolites from the body by all routes of elimination.

Half-life. The elimination half-life ($t_{1/2}$) of a drug is the length of time required for the elimination of half the total drug present in the body at any given time.

Clearance. Drug clearance (Cl_T), or *total body clearance*, refers to the process of drug elimination from the body without specifying any of the processes involved. From a conceptual perspective, clearance can be defined as the volume of plasma that is completely cleared of drug per unit time. Thus clearance has the dimensions of volume/time (e.g., ml/min or L/hr).

From a computational perspective, clearance can be defined as the rate of drug elimination divided by the plasma concentration:

$$Cl_T = \text{[Elimination rate]}/\text{[Plasma concentration (C)]}$$
$$= [dD/dt]/C$$
$$= [\mu g/min]/[\mu g/ml]$$
$$= ml/min$$

where D is the amount of drug that has been eliminated, and dD/dt is the instantaneous rate of elimination. Thus:

$$dD/dt = Cl_T \times C$$

Concentration. Drug concentration (C), unless otherwise specified, refers to the concentration $(mg/L = \mu g/ml)$ of a drug in plasma. As noted, C_{max} is the maximum or peak concentration of a drug during a specified time interval, and T_{max} is the exact point in time when C_{max} is achieved. Thus T_{max} is the length of time that has elapsed from the beginning of the drug administration to the point where the drug concentration achieves its peak value.

Distribution. Volume of distribution (V), or the apparent volume of distribution (V_D), is the theoretic volume within the body into which the drug is dissolved. In simple terms, V is defined by calculating X/C, where X represents the total amount of drug in the body and C the concentration of the drug in plasma at steady-state conditions. The volume of distribution represents a mathematical concept rather than a real anatomic space; in general, no well defined anatomic volume of tissues within the body corresponds to V.

As a purely mathematical concept, if the value of C is relatively small, V can exceed the volume of the body. For example, because lidocaine has a high degree of lipid solubility, a large proportion of lidocaine will be distributed into fat, and C will be relatively small. For any value of X, the smaller the value of C, the greater will be the value of the mathematical term X/C V.

SAFETY ISSUES

Three important safety issues involve the dosages and concentrations of lidocaine when used as a local anesthetic.

First, safe doses of tumescent (very dilute) lidocaine and epinephrine are not the same for commercial (considerably more concentrated) lidocaine. Whereas the safe maximum dosage of tumescent lidocaine (with epinephrine) at concentrations of 0.05% to 0.15% is 45 to 50 mg/kg, the traditional dosage limitation for commercial lidocaine (with epinephrine) at concentrations of 0.5%, 1%, or 2% remains valid at 7 mg/kg. All physicians should recognize this vital distinction.

Second, the surgeon must provide detailed written and signed orders explicitly specifying the concentration (mg/L) and maximum allowable total dosage (mg/kg) *before* the anesthetic solutions are prepared for tumescent liposuction.

Third, lidocaine concentrations in tumescent anesthetic solutions must *always* be specified in terms of milligrams of lidocaine per liter or bag of anesthetic solution. It is potentially dangerous to give orders in terms of volume (ml) of the commercial preparations of lidocaine multiplied by the concentration of the commercial preparation.

For example, when an order specifies 1000 mg of lidocaine and 1 mg of epinephrine in 1000 ml of normal saline, there is little risk of a dosage error or miscommunication between surgeon, nurse, or anesthetist. On the other hand, it is not immediately obvious how many milligrams of lidocaine have been given after half a bag containing "100 ml of 1% lidocaine (1%) with epinephrine (1:100,000)" has been infiltrated.

Furthermore, in several cases, surgeons have ordered "100 cc of lidocaine per liter" with the intention that 1% lidocaine be used, but instead the nurse used 2% lidocaine when mixing the anesthetic solution. This type of error is more easily avoided when dosages are specified in terms of *milligrams* rather than milliliters of lidocaine.

KINETIC STUDIES AND MODELS

For tumescent local anesthesia, pharmacokinetics provides a basis for predicting safe dosages and for understanding the factors that might increase the risk of lidocaine toxicity. A clinically useful prediction of the maximum plasma lidocaine concentration following a specific dose of tumescent lidocaine requires an accurate kinetic model.

The pharmacokinetics of lidocaine is based on the time course of concentrations of lidocaine measured at intervals in samples of peripheral blood. This is reasonable because of the close correlation between lidocaine concentrations in blood and in other tissues. Although lidocaine concentration in the blood is not the same as in other tissues, at steady-state conditions the concentrations differ only by a constant factor.

The essence of the tumescent technique is the direct infiltration of very dilute (0.05% to 0.15%) lidocaine with epinephrine into an area of subcutaneous fat, resulting in an unprecedented slow rate of systemic lidocaine absorption. The success of tumescent local anesthesia is based on the synergistic interplay between (1) the unprecedented slow rate of lidocaine absorption and (2) the well-known rapid rate of lidocaine metabolism by the liver and subsequent renal excretion of less toxic metabolites.

Table 19-1 lists pharmacokinetic parameters for tumescent lidocaine.[1,2]

RATE OF LIDOCAINE ABSORPTION

Before the tumescent technique, researchers assumed that lidocaine was always absorbed rapidly from the injection site and that the peak plasma lidocaine concentration (C_{max}) was always achieved within 2 hours of the injection. Before 1987, most pharmacokinetic studies of lidocaine were based on treatment of cardiac dysrhythmias or on peripheral nerve blocks.

Treatment of ventricular fibrillation involved the direct intravenous infusion of lidocaine and its instantaneous absorption into the intravascular space. Peripheral nerve blocks typically involved the injection of lidocaine directly into highly

TABLE 19-1 LIDOCAINE PHARMACOKINETIC PARAMETERS	
Parameter	Measurement
F_e (fraction of drug excreted unchanged)	0.02 ± 0.01
k_n (elimination rate constant)	0.39/hr
Oral availability (%)	35 ± 11
Urinary excretion (%)	2 ± 1
Bound in plasma (%)	70 ± 5
Clearance in a 70-kg person	640 ± 170 ml/min/70 kg $\cong 700$ ml/min/70 kg $= 10$ ml/min/kg
Volume of distribution (L) 70-kg person	1.1 L/kg 77 ± 28
Redistribution (α) half-life	8 min
Elimination (β) half-life	1.8 ± 0.4 hr
Toxic concentration	>6 μg/ml

vascular tissues, such as the epidural space, the spinal fluid in the subarachnoid space, the axilla, or the intercostal nerves. In the few studies that examined subcutaneous injections of lidocaine, plasma lidocaine concentrations were not measured beyond 2 hours.

Two-compartment Model. The rapid absorption of lidocaine into the blood is usually represented by a two-compartment model. First, as lidocaine is rapidly absorbed into the bloodstream and highly vascular tissues (*central compartment*), the plasma lidocaine concentration rapidly reaches its peak level, C_{max}. As the plasma lidocaine is redistributed into other less vascular tissues (*peripheral compartment*), the lidocaine concentration in the plasma falls precipitously until a lidocaine concentration equilibrium is established among all the tissues.

Second, after lidocaine has been distributed throughout the body, and after the plasma lidocaine concentration is in equilibrium with the lidocaine concentration in all the other tissues, the rate of decline in plasma lidocaine concentration is slowed considerably. Once an equilibrium has been established between the plasma and all other tissues, the further decline in plasma lidocaine concentration is entirely the result of metabolism and excretion of lidocaine. Thus, when lidocaine is rapidly absorbed, it behaves as if the body were divided into two theoretic compartments.

Because of the assumption that lidocaine was always rapidly absorbed from the injection site, it became unquestioned dogma that lidocaine behaved as a two-compartment pharmacokinetic model. For example, as stated in one of the most influential works on local anesthesia, "Lidocaine, for

certain, behaves in a kinetic sense as if man were a two- or even a three-compartment system."[3]

Anesthesiologists who assume that lidocaine can only behave as a two-compartment model cannot reconcile their view with the relatively large doses of lidocaine used in tumescent liposuction. Under this assumption, 50 mg/kg of lidocaine is an unacceptably large and potentially dangerous dose. The dogma of anesthesiology has assumed that 7 mg/kg of lidocaine with epinephrine is the true maximum safe dose for subcutaneous lidocaine. In fact, tumescent lidocaine behaves as a one-compartment model, so 50 mg/kg of tumescent lidocaine for liposuction totally by local anesthesia is much safer than expected.

As shown later, tumescent lidocaine is unique in that it behaves as if the body were a one-compartment pharmacokinetic model, which explains the safety of large tumescent doses.

Safety Limits. Although the tumescent technique permits an increase in the maximum safe dose of lidocaine, it does not permit unlimited or titanic doses of lidocaine. The maximum recommended dose of tumescent lidocaine is finite (45 mg/kg for thin patients and 50 mg/kg for heavier patients). Ignoring the estimated safe dose of tumescent lidocaine is dangerous and not in the patient's best interest. Caution is paramount.

The physician must always remember that, for any drug, a published estimate of a maximum safe dosage is merely an estimate. Any estimate may eventually prove to be inaccurate and may need to be adjusted.

DOSAGE LIMITS

From a traditional perspective, standard tumescent doses of lidocaine appear excessive, and concern about the risk of toxicity is legitimate. Surgeons and anesthesiologists are appropriately cautious about the "standard dose limitation of lidocaine" that has no rational scientific basis.

The standard lidocaine dose limitation of 7 mg/kg remains a reasonable limit for standard concentrations of commercial "out-of-the-bottle" lidocaine. The 7-mg/kg limit, however, is unnecessarily restrictive when very dilute (1.5 g/L = 0.15% or less) lidocaine with epinephrine is used.

Patients and physicians should be concerned about the risk of toxicity whenever an anesthetic is administered. Decisions regarding the relative safety of local versus systemic anesthesia should be based on modern scientific data, not on incomplete studies. An excessively conservative limit on the dose of tumescent lidocaine may expose the patient unnecessarily to the risks of general anesthesia.

The dosage limit of 7 mg/kg of lidocaine with epinephrine for local anesthesia is an example of a pharmacologic standard based on an unwarranted extrapolation of limited data (see Chapter 1). The only justification for 7 mg/kg is the letter to the U.S. Food and Drug Administration (FDA) stating that "the maximum safe dose of lidocaine is probably the same as for procainamide."

In fact, 7 mg/kg is probably an accurate estimate of a maximum safe dose of lidocaine with epinephrine at lidocaine concentrations in the range of 1% or 2%, when injected into highly vascular tissue (e.g., intercostal block). Again, however, this dosage limitation is unreasonably conservative for subcutaneous infiltration of very dilute lidocaine with epinephrine into fat. As a result, patients are exposed to general anesthesia for procedures that are more safely and less painfully accomplished by local anesthesia.

Dermatology and Local Anesthesia. In recent years, dermatology has been undergoing a transformation into a surgical specialty that relies almost exclusively on local anesthesia. Dermatologists have begun to examine critically the pharmacologic basis of local anesthesia infiltrated into the skin and subcutaneous tissues. This information is now starting "to diffuse across the semipermeable membrane" that separates surgeons of different specialties.

Having overcome the prejudice against using more than 7 mg/kg of lidocaine, specialties other than dermatology are beginning to appreciate the great potential for using dilute local anesthesia for procedures that have traditionally required general anesthesia.

The following sections explain the critical significance of delayed absorption for the safety and efficacy of tumescent local anesthesia.

TUMESCENT BULK SPREAD THROUGH FAT

The process of tumescent infiltration involves the spread of the local anesthetic solution through the interstitial space by a process known as *bulk flow*. This is simply the flow of liquid through a porous substance, such as the interstitial gel. The optimal distribution and spread of the tumescent anesthetic solution throughout the targeted compartment of fat are not instantaneous. Even with an optimal infiltration technique, it requires many minutes for local anesthesia to become completely effective and for hemostasis to become optimal.

Histologically, the individual adipocytes are not swollen beyond their usual size. The tumescent anesthetic solution is embedded within the interstitial connective tissue gel that envelops adipocytes.

On incising the skin and examining the gross appearance of tumescent fat, one appreciates a marbled appearance of pale-yellow lobules of fat embedded between the gray, glistening, diaphanous sheets of collagen and within the supersaturated interstitial tissue gel. The consistency of tumescent fat is gelatinous, soft, and jellylike; this is literally the interstitial colloidal *gel*. Grape-sized puddles of anesthetic solution are loculated within and between connective tissue septa, similar to a Swiss cheese or honeycomb pattern. These lakes of anesthetic solution act as physical reservoirs of lidocaine. As the liquid is dispersed through the interstitial tissue, some lidocaine is absorbed locally into the lipids within fat cells (see Chapter 26).

Based on clinical observation, optimal anesthesia and hemostasis do not occur for at least 15 to 30 minutes after tumescent local anesthetic infiltration. Typically, within 15 minutes of infiltration, sufficient anesthesia and vasoconstriction have occurred to permit painless liposuction without significant blood loss.

With a greater duration of time between the completion of infiltration and initiation of liposuction surgery, tumescent local anesthesia becomes increasingly effective. Also, the greater the delay after infiltration before starting surgery, the smaller is the volume of blood-tinged infranatant anesthetic solution that is aspirated and appears at the bottom of the collection jar containing the aspirate. The extra time permits more complete spreading and bulk flow of the anesthetic solution through the interstitial gel and along fascial planes. This results in more extensive diffusion of the lidocaine into sensory nerves.

Adequate delivery of tumescent anesthesia to a compartment of fat depends on the direct, physical spreading of the anesthetic solution by bulk flow.

LIDOCAINE DIFFUSION

True chemical diffusion only becomes important once the anesthetic solution is within a few millimeters of a targeted neural axon or a capillary wall.

The tumescent lidocaine, consisting of free and tissue-bound lidocaine, is slowly absorbed into the intravascular compartment by a process of diffusion. The unbound (free) fraction of tumescent lidocaine arrives in the systemic circulation by chemical diffusion across fibrous membranes and cells of the adipose tissue, through capillary endothelium and vascular walls, and into the intravascular space for transport throughout the circulation.

The time required for diffusion of a chemical from point A to point B, as it moves through a medium, depends on several physicochemical factors. For lidocaine, rate of diffusion through the interstitial tissue gel is a function of (1) the distance between points A and B and (2) the concentration gradient of free lidocaine (unbound to tissue) between points A and B. The rate of lidocaine diffusion out of the tumescent tissue and into the capillary lumen is delayed by the following:

1. Physical distance and isolation of lidocaine molecules created by the large volume of anesthetic solution within the interstitium of fat tissue
2. Minuscule lidocaine concentration gradient, resulting from the prodigious degree of dilution
3. Profound tumescent vasoconstriction

PHARMACOKINETIC COMPARTMENT

In reality the pharmacokinetic compartment is purely a theoretic or mathematical concept that assists in understanding the concentration of drugs in the body as a function of time. A basic pharmacokinetic assumption is that, at any point in time, the concentration of the drug is essentially uniform throughout the compartment.

Conceptually, a pharmacokinetic compartment is a group of tissues where the relative concentrations of a drug in different parts of the compartment are in constant equilibrium.

In other words, any change of lidocaine concentration in one tissue results in a rapid (essentially instantaneous) and proportional change of lidocaine concentration in all other parts of that compartment.

For tumescent lidocaine, the one compartment consists of intravascular space, certain interstitial tissues, and highly vascular organs such as the lungs, liver, and pancreas. Although the lidocaine concentration varies from tissue to tissue, the lidocaine concentrations in any two distinct tissues are always in equilibrium.

One-compartment Model.   The science of pharmacokinetics uses mathematical modeling to describe and predict the time-dependent course of a drug's concentration in blood and body tissues. Typically the body is represented by a system of hypothetic compartments that do not necessarily correspond to any true anatomic or physiologic entity. Such theoretic models represent a oversimplified totality of pharmacologic activity. Despite this, the resulting information is often valuable. Simple, linear differential equations can be used to describe the rate of change in lidocaine concentration within each compartment.

Deciding which is the most appropriate model depends on the route of administration. The fate of intravenous (IV) bolus lidocaine, with instantaneous systemic absorption, is best described by a two-compartment model.

The tumescent technique for subcutaneous delivery or slow IV infusion of lidocaine is best described using a one-compartment model. In this simplest kinetic model, the body is a single, homogeneous unit. In order for a one-compartment model to be a good representation of a drug's behavior, the following criteria must be satisfied:

1. A one-compartment model assumes that any change in plasma drug concentration corresponds to an immediate and proportional change of concentration in all other body tissues.
2. At any given time, the rate of drug elimination from the body is proportional to the amount of drug in the body (compartment) at that time.

Tumescent lidocaine satisfies the first requirement for a one-compartment model only because the blood-tissue equilibrium is "immediate" relative to the extremely slow rate of lidocaine absorption from tumescent fat. In reality, equilibrium between the lidocaine concentrations in blood and other tissues is not instantaneous. Limited by the rate of tissue perfusion, equilibrium is delayed 30 to 60 minutes after lidocaine enters the circulation. Relative to the many hours required for tumescent lidocaine to be absorbed from the subcutaneous space into the vascular space, however, blood-tissue equilibrium for lidocaine is achieved quickly.

Lidocaine also satisfies the second requirement. From experience with IV lidocaine used in treating cardiac dysrhythmias, lidocaine is indeed eliminated at a rate that is proportional to the total amount of lidocaine within the "body." Lidocaine is said to be eliminated by a *first-order process*, which occurs when the rate of a drug's elimination from the body is proportional to the amount of drug in the body.

In contrast, drug elimination is a *zero-order process* when the rate of drug elimination is constant and independent of the drug's concentration in the body. Ethyl alcohol metabolism and elimination represent an example of a zero-order elimination process.

Tumescent lidocaine kinetics can be described by a one-compartment model, two-compartment model, or more elaborate multicompartment model. The simplest model that explains the clinically observed events is usually the preferred model.

ABSORPTION, DISTRIBUTION, AND ELIMINATION

Three different but overlapping phases of lidocaine movement occur through the body: absorption, distribution, and elimination. The profoundly slow rate of lidocaine absorption into the systemic circulation after tumescent infiltration is the key to understanding the unique safety of the tumescent technique for local anesthesia.

When lidocaine is given as an IV bolus to treat a cardiac dysrhythmia, absorption is instantaneous. The other two processes of distribution and elimination, however, occur sequentially over time. The situation with tumescent lidocaine kinetics is more complex. After tumescent infiltration of lidocaine, the processes of absorption, distribution, and elimination all occur simultaneously.

ABSORPTION RATE

The absorption of tumescent lidocaine is exceptionally slow because of the following:

1. By elevating interstitial hydrostatic pressure above capillary intraluminal pressure, tumescent infiltration compresses and collapses capillaries and venules. With virtually no blood flowing through the capillaries within the tumescent tissue, the rate of lidocaine absorption is minimized even before the onset of β-adrenergic vasoconstriction.
2. The formation of the dilute lidocaine subcutaneous reservoir produces a physical separation of the lidocaine from the blood vessels, thus increasing the distance over which lidocaine must diffuse before it reaches a blood vessel.
3. The dilution of lidocaine reduces the lidocaine concentration gradient across the capillary endothelial wall, thereby minimizing its rate of absorption.
4. The profound capillary vasoconstriction minimizes capillary perfusion and thus decreases transcapillary absorption.
5. The relative avascularity of adipose tissue limits vascular absorption.
6. Because of the high lipid solubility of lidocaine, the subcutaneous fat acts as a reservoir for lidocaine and limits the amount of lidocaine available for absorption.

The sum of these additive effects accounts for the unprecedented slow rate of systemic lidocaine absorption. The combination of extremely slow systemic absorption of tumes-

cent lidocaine, rapid hepatic metabolism, and swift renal elimination results in significantly low lidocaine blood levels and thus minimal risks of lidocaine toxicity.

Analogy: Slow-release Oral Tablet. The absorption of lidocaine from the subcutaneous deposit of tumescent anesthesia is analogous to the absorption of a slow-release tablet taken by mouth. When the anesthetic solution is in the subcutaneous tissue, it is isolated from the systemic circulation. Similarly, the drug contained within a slow-release tablet is not immediately absorbed into the systemic circulation. In both cases the drug is contained within an isolated reservoir, is released gradually, and is absorbed incrementally.

A slow-release tablet does not dissolve immediately on entering the gastrointestinal (GI) tract. Instead, the outer portion is slowly eroded, layer by layer. Over many hours the drug is gradually released in small increments from the tablet. Thus, at any point in time, very little drug is available for systemic absorption.

A similar situation occurs with the slow release of lidocaine, which is only being absorbed from the peripheral external surface of the mass of subcutaneous tumescent solution. This mass is isolated because of the intense vasoconstriction throughout the tumescent fatty tissue. The capillary bed within the central portion of the tumescent tissue is so completely constricted that there is no significant blood flow through, and thus no significant absorption from, the central portion of the tumescent tissue.

The infiltrated subcutaneous fat containing the deposit of tumescent lidocaine is similar to the stomach or GI tract containing the slow-release tablet. Although the drug is technically inside the body, the anatomic site of drug absorption is kinetically distinct and isolated from the rest of the body.

Thus the kinetics of lidocaine after tumescent delivery is analogous to the one-compartment model for oral administration of a slow-release tablet.

Significance of Area under Curve. By plotting the graph of plasma lidocaine concentration at different points in time after a subcutaneous injection, one obtains a curve, designated mathematically by the term $C_{lido}(t)$ (Figure 19-1). Measuring the area under the curve (AUC) can provide important pharmacokinetic information. In terms of formal mathematics, AUC is simply the following integral:

$$AUC = \int_0^\infty C_{lido}(t)\, dt$$

where plasma lidocaine concentration $C_{lido}(t)$ is a continuous function of time, over the time interval from when the dose is given at $t = 0$, to the time when $C_{lido}(t)$ returns to 0, here represented by $t = \infty$. The shape of the graph of $C_{lido}(t)$, together with AUC, can provide valuable clinical information about tumescent lidocaine kinetics.

With present technology, lidocaine concentration cannot be measured continuously over time. Instead, lidocaine plasma concentrations are determined by taking samples of venous blood at discrete times (e.g., 1, 2, 4, 8, 12, 16, 24, 36,
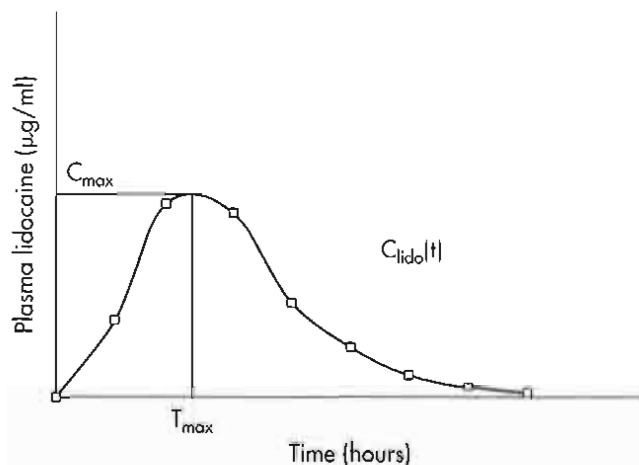
Figure 19-1

Graph of plasma lidocaine concentration, $C_{lido}(t)$, as a function of time after subcutaneous tumescent infiltration. Area under the curve (AUC) is equivalent to total amount of lidocaine absorbed over time into systemic circulation. Maximum or peak concentration of plasma lidocaine is designated by C_{max}. The term T_{max} is the exact point in time when C_{max} occurs. For a fixed value of AUC, the smaller the value of T_{max}, the greater is the value of C_{max}. Any factor that delays lidocaine absorption will decrease magnitude of peak concentration.

and 48 hours) after initiating lidocaine infiltration. By plotting the measured values of the plasma lidocaine concentrations $C_{lido}(t_i)$ at each time t_i, then sequentially connecting the points with straight-line segments, one obtains a graph of $C_{lido}(t)$ based on real data (Figure 19-2, *A*). The area under this graph is an approximation or an estimate of the true AUC.

AUC is equivalent to the total milligram amount of lidocaine that is absorbed into the systemic circulation. Thus, if identical amounts of lidocaine are given by two different routes of delivery (e.g., IV bolus dose and subcutaneous dose) and each yields 100% absorption, the total AUC for each route of delivery will be equal. The shapes of the graphs, however, will not necessarily be the same (Figure 19-2, *B* to *E*).

Peak Concentration. The maximum lidocaine plasma concentration after any given dose (C_{max}) is directly affected by factors that affect (1) rate of lidocaine absorption or (2) extent of lidocaine absorption (systemic bioavailability).

For any given dose of subcutaneous lidocaine, any factor that accelerates the rate of lidocaine absorption will result in a shorter time necessary to achieve C_{max} and will increase its magnitude. Not surprisingly, anything that slows lidocaine absorption will also delay the time (T_{max}) when C_{max} occurs and will diminish its magnitude (Figure 19-3).

Two triangles of equal area do not necessarily have the same base and height. The area of a triangle equals $\frac{1}{2}BH$, where B and H are the magnitude of the base and height, respectively. For two triangles having equal area, the triangle
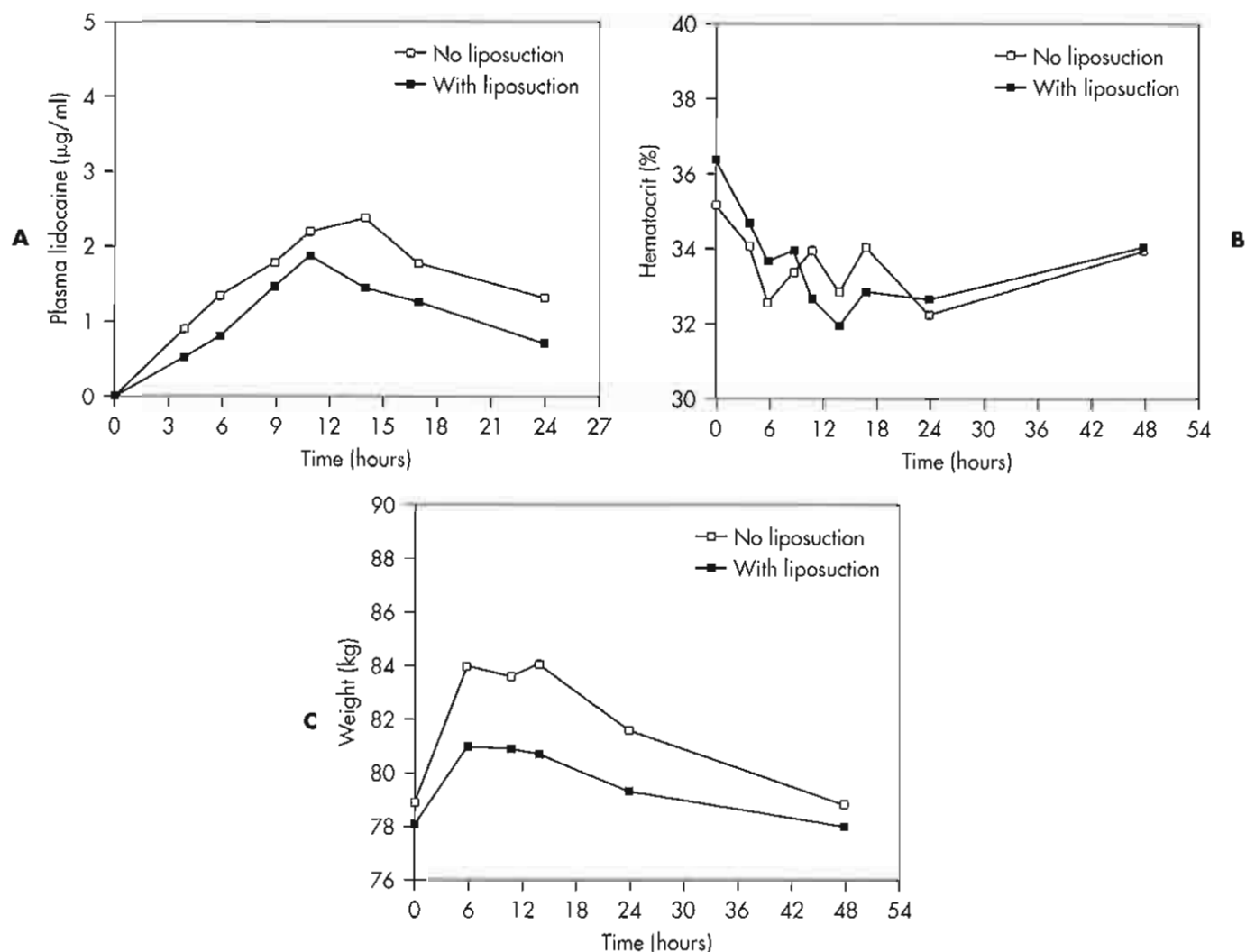
Figure 19-2

Kinetics of tumescent lidocaine and tumescent saline. On two separate occasions, 75-kg female had tumescent infiltration of 2625 mg of lidocaine (35 mg/kg) in 5 L of normal saline. On the first occasion, no liposuction was done. Two weeks later, infiltration was repeated using identical volume of saline and identical dosage of lidocaine, followed by tumescent liposuction of 1500 ml of supranatant fat. (Redrawn from Klein JA: *Plast Reconstr Surg* 92:1085-1098, 1993.) **A,** Effect of liposuction on concentration of plasma lidocaine. Two graphs of concentration (C_{lido}) of plasma lidocaine ($\mu g/ml$) as a function of time (*t*) are shown. The tallest graph, with largest area under curve (AUC), is a plot of sequential determinations of plasma lidocaine concentration after tumescent infiltration of 2625 mg of lidocaine in 5 L of solution without liposuction. Second graph has smaller AUC and represents sequential plasma lidocaine concentrations resulting from identical infiltration but differing from first because of liposuction. Difference in magnitude between two AUCs is attributed to effects of liposuction. Liposuction is responsible for reducing systemic absorption of tumescent lidocaine by approximately 20%. When this study was done, all incisions were closed with suture, with no open drainage. If open drainage had been used to remove additional lidocaine, reduction of AUC would have been more significant. Liposuction and open drainage contribute to reduced bioavailability and increased safety of tumescent lidocaine. **B,** Hematocrit changes after tumescent infiltration. Sequential measurement of hematocrit after tumescent infiltration of 5 L of saline with dilute epinephrine (0.5 mg/L) reveals much about systemic absorption of tumescent saline. Because hematocrit returns to preoperative value within 48 hours, change of hematocrit cannot be attributed to blood loss. No evidence indicates that tumescent liposuction produces hemoconcentration or that intravascular fluid deficit exists. Tumescent technique produces significant hemodilution with virtually no IV fluids. In this example, 10% decrease in hematocrit is consistent with 10% increase in volume of intravascular fluid compartment from hemodilution. Volume of intravascular fluid is maximum at same time (T_{max}) that concentration of tumescent lidocaine achieves its maximum, approximately 12 hours after beginning infiltration. Rate and magnitude of intravascular fluid augmentation and change of hematocrit are independent of whether liposuction is performed. Thus a decline in hematocrit in immediate postoperative period does not correlate with amount of surgical blood loss caused by liposuction. **C,** Patient's weight after infiltration and liposuction. At 48 hours after tumescent infiltration, patient's weight returns to preinfiltration value. Without liposuction, weight is increased by 5 kg, which corresponds to 5 L of saline infused. Patient drank fluids without restriction. After gaining approximately 1 kg/L of tumescent infiltration, all tumescent fluid remaining in patient after liposuction is eliminated via kidneys. The 48-hour interval is typical for a return to preoperative weight, with or without liposuction. *Continued*
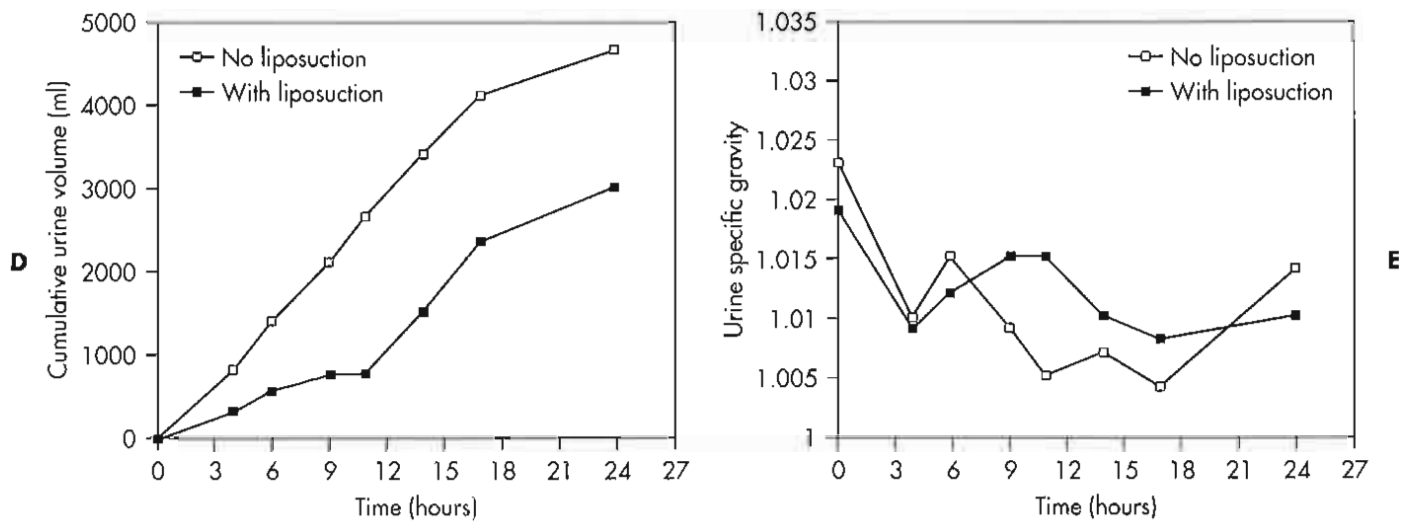
Figure 19-2, cont'd

D, Cumulative urine volume after tumescent liposuction. Patient's urine output was consistently greater than 70 ml/hr, with and without liposuction. This is a common threshold, below which physician becomes increasingly concerned about possible intravascular fluid deficiency, inadequate renal perfusion, renal insufficiency, or cardiac impairment. Patients are fully alert during tumescent liposuction and can drink clear liquids during and after surgery. No need exists for IV infusion of fluids because patients can drink fluids and because renal perfusion is adequate, as evidenced by continuously good urine output. **E,** Hourly urine specific gravity after tumescent liposuction. Typically, patient's urine specific gravity decreases after tumescent infiltration. This decreased urine specific gravity shows patient is well hydrated. Because tumescent infiltration produces relative systemic fluid overload, routine administration of IV fluids is potentially dangerous.

with the smallest base must have the greatest height. This concept provides the mathematic basis for using the AUC to help explain the relationship between a drug's rate of absorption and its peak plasma concentration.

The rate of absorption determines the length of the base of the AUC. Rapid lidocaine absorption will have a short base, whereas slow absorption will have a long base. If the AUCs are equal for two methods of lidocaine delivery, the short base will have a high peak (and thus a relatively higher risk of toxicity), and the long base will have a low peak plasma level (and a relatively lower risk of toxicity).

Suppose $C_{lido}(t)$ represents the graph of plasma lidocaine concentration over time, and AUC is the area under this curve. If a certain route of delivery produces rapid lidocaine absorption, the geometric figure that represents the AUC under the graph of $C_{lido}(t)$ will have a relatively short base and a high peak. If the same amount of drug is given in such a manner that the absorption is much slower, the base of the AUC will be much wider, and the peak will be relatively low. Both graphs will have the same AUC because the same total milligram dose of lidocaine has been absorbed with either route of delivery, even though the shapes of the curves are different.

This inverse relationship between C_{max} and the rate of absorption explains the safety of the relatively large doses of lidocaine that are used with tumescent liposuction. Suppose that an epidural dose of lidocaine is completely absorbed over 2 hours and that the corresponding peak lidocaine concentration is C_{max}. If a tumescent dose of lidocaine requires 24 to

36 hours to be completely absorbed, and if the tumescent dose should achieve the same C_{max} as the epidural dose, one can predict that the tumescent dose can be approximately 24 to 36 times greater than the epidural dose.

Absorption rate determines peak plasma concentration, which in turn determines probability of toxicity. Different routes of administration yield different rates of absorption and thus different likelihoods that plasma concentrations of the drug will exceed levels associated with toxicity. These concepts help in understanding how the slow rate of dilute lidocaine absorption associated with the tumescent technique allows higher doses of lidocaine with such a high degree of safety.

Duration of Toxicity. The rate of lidocaine absorption affects the length of time that the plasma lidocaine concentration remains above any specified concentration (Figure 19-4).

When a relatively small dose of lidocaine is absorbed rapidly, the peak level is achieved quickly, then the plasma concentration decreases rapidly. If a relatively small dose of lidocaine produces plasma concentrations that exceed the toxic threshold (6 μg/ml), toxicity is brief. After the rapid lidocaine absorption of an IV bolus dose, the pharmacokinetic behavior of lidocaine is a two-compartment model. The duration of toxicity after an IV bolus is relatively brief because of the rapid distribution of lidocaine into peripheral tissues. The plasma concentration rapidly achieves a peak in the central intravascular compartment, then rapidly decreases as the
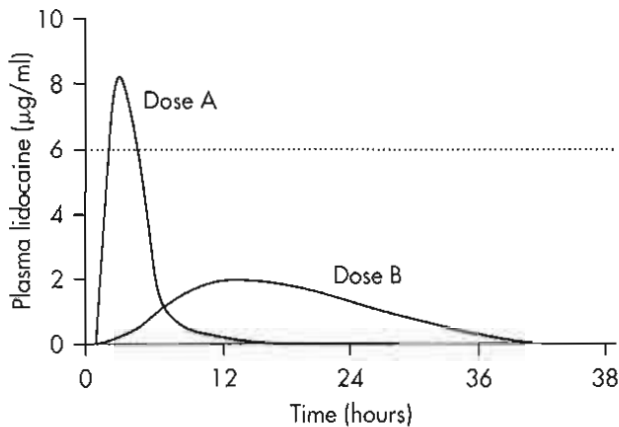
Figure 19-3

Figure 19-4

Rate of lidocaine absorption affects risk of toxicity. Consider hypothetic patient who, on two separate occasions, is given identical doses of lidocaine that differ only in concentration and site of injection. On each occasion, sequential lidocaine plasma concentrations are determined over ensuing 48 hours. Because two doses are of equal magnitude with 100% systemic absorption, their areas under curve (AUCs) of plasma lidocaine concentration are equal. Suppose dose A is epidural injection of concentrated lidocaine (2% = 20 mg/ml) and epinephrine that is completely absorbed into systemic circulation and completely eliminated in approximately 12 hours. Suppose dose B is injection into subcutaneous fat of very dilute lidocaine (0.1% = 1mg/ml) and epinephrine that is completely absorbed into systemic circulation and completely eliminated in approximately 36 hours. Because AUCs are equal, graph of dose A, with the shortest base, must have the highest peak. Similarly, graph of dose B, with the longest base, must have the lowest peak. Because magnitude of peak plasma lidocaine concentration is correlated with risk of toxicity, a more rapid rate of absorption carries a greater risk of toxicity.

Graph of dose A, with small AUC, represents relatively small dose of lidocaine that is rapidly absorbed. For example, if small epidural dose of lidocaine rapidly absorbed into systemic circulation produces toxicity, one can expect toxicity to be of short duration. Graph of dose B, with large AUC, represents relatively large dose of lidocaine that is slowly absorbed. Consider the example of a large dose of subcutaneous tumescent lidocaine that is slowly absorbed. If plasma lidocaine concentration exceeds toxic threshold, toxicity will be of relatively long duration.

lidocaine is absorbed into the tissues of the peripheral compartment. The result is that lidocaine toxicity is brief with less risk of serious complications if it occurs after rapid absorption of a relatively small lidocaine dose.

In contrast, after prolonged absorption, lidocaine behaves as if the body were a one-compartment system. If toxic threshold concentration is exceeded after slow absorption, peripheral tissues will already be in equilibrium with the blood lidocaine, and no rapid decrease in plasma lidocaine concentration will occur. When lidocaine absorption is slow, a relatively large lidocaine dose may never exceed the toxic threshold. If toxicity does occur after prolonged absorption, however, toxicity will persist relatively longer.

Absorption Rate Paradox. Obese patients tolerate larger mg/kg doses of IV lidocaine than thinner patients, possibly because obese patients have a larger apparent volume of distribution (V_D) for lidocaine. In other words, an obese patient has a greater amount of total body adipose tissue into which lidocaine can be partitioned.

For tumescent lidocaine the relative rate of absorption decreases with increasing obesity. In other words, for equal mg/kg doses of tumescent lidocaine, the greater the patient's supply of subcutaneous fat, the slower is the rate of lidocaine absorption.

The phenomenon in which obese patients tolerate higher mg/kg doses of tumescent lidocaine than thin patients is an unexpected paradox. As shown next, this absorption rate paradox might have another explanation.

Let A = surface area and V = the corresponding volume of a mass of tumescent fat. Clearly, V is proportional to the total dose of lidocaine. Assume that the rate of lidocaine absorption is proportional to external A of a mass of tumescent fat. Then the ratio A/V is proportional to the rate of absorption per unit dose (mg) of lidocaine.

If the shape of a tumescent compartment of fat is cuboid, ellipsoid, or even spheric, a doubling (increasing by a factor of 2) of V of a mass of tumescent fat produces an increase by a factor of (approximately) 1.6 of A of that volume (see mathematics section at the end of this chapter).

Consider two spheres (or cubes) having volumes V_{II} and V_I, where V_{II} is twice as large as V_I. Thus $V_{II} = 2V_I$, or (V_{II}/V_I) = 2.

Let the surface areas of these volumes be A_{II} and A_I, where $A_{II}/A_I = 1.5874 \approx 1.6$, or $A_{II} \approx 1.6 A_I$.

Consider the ratio A_{II}/V_{II} and substitute the terms $A_{II} \approx 1.6 A_I$ and $V_{II} = 2V_I$:

$$A_{II}/V_{II} \approx (1.6) A_I/(2)V_I = (0.8)A_I/V_I$$

Recalling that A/V is proportional to the rate of absorption per unit dose (mg) of lidocaine, we see that the rate of absorption per unit area for the larger volume (V_{II}) will be merely 0.8 times as fast as the smaller volume (V_I). Thus the geometric fact that $V_{II} = 2V_I$, implying $A_{II} = 1.6 A_I$, might be a partial explanation for the absorption rate paradox.

Consider the following example. An obese patient weighs 100 kg and a thin patient 50 kg. The same areas of each patient are treated by tumescent liposuction, using identical concentrations of anesthetic solution. If the obese patient requires twice the total milligram dose of lidocaine as the thin patient, both patients will receive the same mg/kg dose of lidocaine. The obese patient will have a volume V_{II} and the thin patient a volume V_I of tumescent fat, where $V_{II} = 2V_I$. The rate of lidocaine absorption, which is assumed to be proportional to the surface area of tumescent fat, will be relatively slower in the obese patient by a factor of 0.8.

Thus, at the same mg/kg dosage of lidocaine, the rate of lidocaine absorption will be relatively slower in the obese patient and faster in the thin patient. Finally, in conclusion, obese patients should tolerate relatively higher mg/kg doses of lidocaine than thinner patients.

Infiltration Rate. At the relatively high concentrations of commercial formulations of lidocaine, rapid infiltration produces rapid systemic absorption. At the low lidocaine concentrations of tumescent preparations, any increased rate of lidocaine absorption caused by rapid infiltration is clinically insignificant.

At relatively high lidocaine concentrations, a *rapid* subcutaneous injection quickly achieves plasma concentrations that can exceed the threshold for potential toxicity. A rapid subcutaneous injection of 1350 mg of lidocaine (1% and 0.5%) with epinephrine (1:100,000) produced a plasma concentration of 6.3 mg/L within 15 minutes.[4] Recall that 6.0 mg/L (6.0 µg/ml) of lidocaine is the recognized threshold for significant toxicity.

A *slow* injection of 1% lidocaine with epinephrine produces significantly lower and delayed peak blood levels. Thus 1000 mg of lidocaine (1%) with epinephrine (1:100,000) slowly injected subcutaneously over 45 minutes produced a C_{max} of 1.5 mg/L, which occurred 9 hours later (Figure 19-5).

A slow subcutaneous infiltration of lidocaine with epinephrine always slows the rate of lidocaine absorption. This effect is most important at the relatively high concentrations of commercial 1% lidocaine with epinephrine. Initiating a local anesthetic infiltration by first giving a slow injection of a relatively small volume of lidocaine with epinephrine, then allowing some vasoconstriction to occur before injecting a more significant volume, will reduce the absorption rate for both lidocaine and epinephrine. The result is a reduction of both the peak plasma lidocaine concentration and the incidence of tachycardia related to epinephrine.

For dilute tumescent solutions of lidocaine and epinephrine, lidocaine absorption is always rather slow. Surgeons who use systemic anesthesia for liposuction tend to accomplish the tumescent infiltration rapidly. It appears
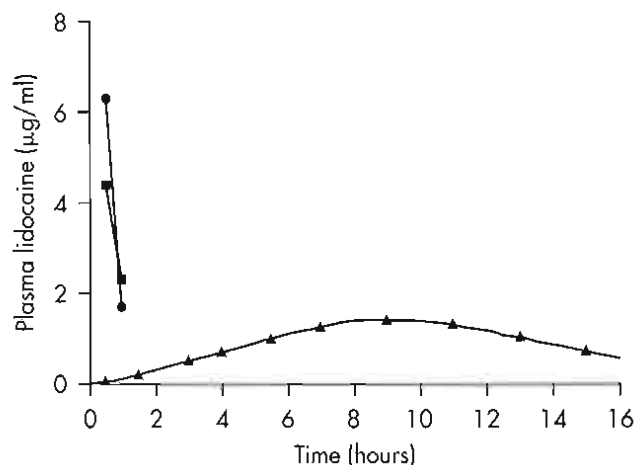
Figure 19-5

Rate of lidocaine infiltration can affect rate of absorption. Rapid infiltration of 1% and 0.5% lidocaine increases risk of toxicity. When combined 1% and 0.5% lidocaine, each with epinephrine concentration of 1:100,000, is infiltrated into subcutaneous fat within a short period (less than 5 minutes), systemic absorption can be rapid. Rapid infiltration of undiluted commercial concentrations of lidocaine with epinephrine can produce a peak plasma lidocaine concentration in excess of the 6 µg/kg threshold for potential lidocaine toxicity. Black straight line (•) represents serum lidocaine concentrations sampled at 15 and 30 minutes after total of 1350 mg of lidocaine had been infiltrated into targeted fat just before liposuction. Other straight line (■) represents similar result in another patient who received rapid injection of 800 mg of lidocaine. Gently curved graph (▲) represents much slower systemic absorption of tumescent lidocaine. After incremental infiltration over 45 minutes of 1000 mg of lidocaine (1%) with epinephrine, peak plasma lidocaine concentration was only 1.4 µg/ml. (Data for ■ from Piveral K: *Plast Reconstr Surg* 80:643, 1987 [letter].)

that lidocaine toxicity is not a significant risk despite rapid infiltration.

Nevertheless, a rapid infiltration of a tumescent solution of lidocaine and epinephrine does result in a rapid appearance of a small, brief peak in plasma lidocaine concentration. This transient early peak is the result of a delayed onset of vasoconstriction, which allows a brief interval for relatively rapid absorption of a small amount of lidocaine. The tumescent lidocaine diffusion rate across capillary endothelium is not rapid enough to cause toxicity, since the lidocaine concentration gradient is already relatively low because of the dilution inherent to the tumescent technique.

Surgeons must remember that rapid infiltration can be more uncomfortable than slow infiltration. Very rapid tumescent infiltration is usually done only when the liposuction patient is under systemic anesthesia.

Dilution. A volunteer study showed that 1% lidocaine was absorbed faster and had a higher peak than did 0.1% lidocaine, with total dose and infiltration rate held constant.
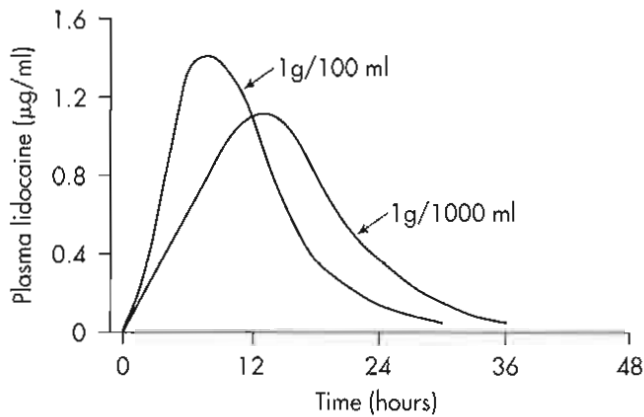
Figure 19-6

Concentration of lidocaine can affect rate of absorption. Dilution slows rate of lidocaine absorption. When 1 g of dilute lidocaine (1 g/L) and epinephrine (1 mg/L) is slowly injected into subcutaneous fat over 45 minutes, T_{max} = 14 hours and C_{max} = 1.2 µg/ml. Two weeks later, when 1 g of undiluted commercial concentration of lidocaine (1 g/100 ml) and epinephrine (1 mg/100 ml) was slowly injected into subcutaneous fat, rate of absorption was more rapid, with T_{max} = 9 hours and C_{max} = 1.5 µg/ml.

Figure 19-7

Tumescent solution without epinephrine. During infiltration for tumescent liposuction, there was no clinical evidence of blanching vasoconstriction, and blood-tinged anesthetic oozed from needle puncture sites. Patient had received 17.8 mg/kg of lidocaine when it was determined that epinephrine had been omitted from anesthetic solution. Sequential plasma samples were obtained over 18 hours after initiation of infiltration. T_{max} occurred in less than 3 hours, much sooner than usual 8 to 14 hours. Also, C_{max} of 2.1 µg/ml was unusually high.

In each case the total dose of lidocaine was 1000 mg and the total dose of epinephrine 1 mg; the time allowed for infiltration was exactly 45 minutes. For 1% lidocaine the magnitude of C_{max} was 1.5 µg/ml, which occurred at T_{max} of 9 hours. For 0.1% lidocaine, C_{max} was 1.2 µg/ml and T_{max} 14 hours (Figure 19-6).

The effect of a tenfold dilution of lidocaine on systemic absorption rate after a subcutaneous injection cannot be generalized to epidural spinal anesthesia. At higher absolute concentrations and in highly vascular tissues, dilution does not significantly delay lidocaine absorption. For example, there was no significant difference in the rate of lidocaine absorption when 1% and 10% concentrations of lidocaine were injected into the highly vascular tissue for epidermal anesthesia.[5]

Vascularity. Tissue vascularity affects the rate of lidocaine absorption. Absorption is slower from relatively avascular fat compared with highly vascular tissue of the gingiva or epidural space. A high blood flow rate through highly vascular tissue maintains the high concentration gradient across the vascular wall.

An injection of lidocaine and epinephrine into the highly vascular gingival mucosa for dental anesthesia may result in rapid epinephrine absorption and a brief but alarming tachycardia. Although patients typically interpret the experience as an allergic reaction, it is not an immune-mediated event but merely a predictable pharmacologic effect of epinephrine.

Lidocaine toxicity can also occur after rapid subcutaneous injection of commercial formulations of lidocaine. I once watched a surgeon infiltrate 1% lidocaine subcutaneously in an infant for local anesthesia before laser treatment of a hemangioma. The degree of vascularity of the site was one of the factors in the resulting lidocaine toxicity, as manifested by a generalized seizure.

Vasoconstriction. Epinephrine-induced vasoconstriction slows the rate at which blood can transport lidocaine away from the site of injection. The vasoconstriction induced by epinephrine is as vital for the safety of the tumescent technique as the dilute nature of tumescent local anesthesia. Vasoconstriction not only prolongs the duration of local anesthesia, but more importantly slows the rate of systemic absorption of lidocaine and thus significantly reduces the magnitude of C_{max} (Figure 19-7).

Lidocaine is a capillary vasodilator that has a rapid onset of approximately 1 minute. This is evidenced by the rapid appearance of erythema after a simple 0.1-ml intradermal injection of lidocaine (1%) without epinephrine. The vasodilator effect of lidocaine is caused by blockage of adrenergic neurotransmission and inhibition of vascular smooth muscle contraction.[6]

Epinephrine is a capillary vasoconstrictor requiring approximately 3 to 6 minutes for onset of action and about 10 to 15 minutes for maximal effect. The vasoconstriction of epinephrine takes longer to become clinically apparent than the vasodilation caused by lidocaine. Eventually the vasoconstriction of epinephrine overcomes the vasodilation of lidocaine. This phenomenon is seen clinically when a 0.1-ml intradermal injection of lidocaine (1%) with epinephrine (1:100,000) initially produces erythema, followed by blanching several minutes later.

DISTRIBUTION

After Bolus Infusion. The pharmacokinetic process can be simplified by focusing on the fate of lidocaine after a rapid IV bolus dose. Most knowledge about the time-dependent fate of lidocaine in the body is the result of studying lidocaine kinetics after an IV bolus in human volunteers and animals.

When given as an IV bolus, systemic lidocaine absorption is instantaneous. When studying the distribution kinetics of lidocaine as it spreads throughout the body, the process of absorption can be eliminated as a confounding variable by focusing on the distribution process after an IV bolus. The changes in lidocaine blood levels over time will reflect only the processes of distribution and elimination. Lidocaine distribution and elimination are independent of the absorption process, and therefore it is the same for an IV bolus as for subcutaneous tumescent infiltration.

In a mathematical model where no tissue-drug binding exists, one can assume that the rate of achieving blood-tissue equilibrium is a function of the rate of tissue perfusion. In this perfusion rate–limited model, drug concentration in a tissue is the same as its concentration in the venous blood leaving the tissue. Lidocaine distribution pharmacokinetics is considered to be perfusion rate limited.[7] For an IV bolus dose the kinetic model is a perfusion rate–limited, two-compartment model.

The fate of an IV bolus of lidocaine has two phases: (1) the *distribution phase*, or α-*phase*, and (2) the *elimination phase*, or β-*phase*. Immediately after an IV bolus of lidocaine, during the α-phase, a large proportion of the dose is rapidly redistributed out of the vascular space and absorbed into the peripheral tissues. The highly perfused organs, such as the lungs, kidneys, and spleen, followed by muscle, are the first tissues to achieve equilibrium with intravascular lidocaine. The lidocaine half-life during this distribution phase is approximately 8 minutes.[8] It takes more than 30 minutes for the levels of lidocaine in the blood to reach an equilibrium with lidocaine concentration in the myocardium and brain.

After distribution of lidocaine into peripheral tissues, the plasma lidocaine concentration is lowered as a result of elimination by hepatic metabolism during the β-phase (Figure 19-8).

Adipose tissue requires more time than other tissues to absorb enough lidocaine to achieve an equilibrium with blood because of the sparse vascularity of fat. Also, because lidocaine is highly lipophilic, fat has a relatively high capacity to store lidocaine.

After Tumescent Infiltration. The lidocaine distribution kinetics of slow IV infusion and that of the tumescent technique are similar. In either situation the lidocaine concentration in the blood increases so slowly that an equilibrium is maintained continuously between blood and peripheral tissues. Peak tissue and blood concentrations are achieved simultaneously. The rate of tissue perfusion is relatively fast compared with the rate of lidocaine absorption. Thus lidocaine distribution after tumescent delivery is not perfusion rate limited.
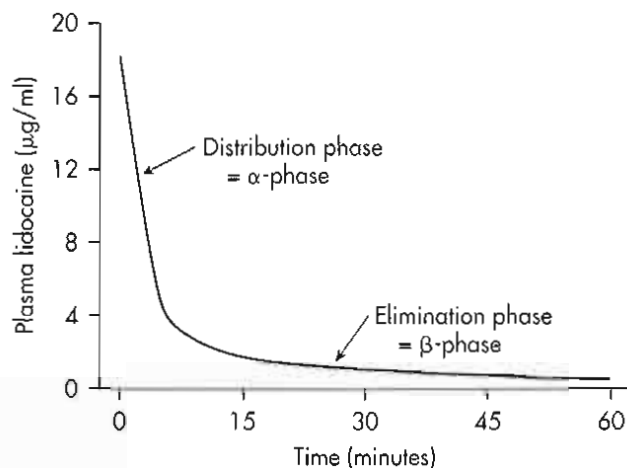
Figure 19-8

Pharmacokinetics of IV bolus of lidocaine. Graph represents plasma lidocaine concentration as it changes over time beginning immediately after IV bolus dose. Initial rapid decrease in lidocaine concentration primarily results from rapid removal of lidocaine from plasma as it is distributed (α-phase) into other tissues. After lidocaine has achieved equilibrium concentration among all body tissues, rate of declining plasma concentration principally results from more gradual process of elimination (β-phase) by hepatic metabolism (see text).

SIMULTANEOUS METABOLIC ACTIVITIES

As noted earlier, the key to understanding the pharmacokinetics of tumescent lidocaine is the interaction between (1) the rate of lidocaine absorption from the tumescent fat and (2) the rate of systemic elimination.

Tumescent absorption is slow and continuous, similar to a slow, continuous IV infusion. Six to eight hours after initiating a slow IV infusion of lidocaine, an equilibrium is reached between the lidocaine concentration in blood and that in peripheral tissues. When a slow IV infusion is discontinued, the residual of lidocaine in the body is eliminated at a rate identical to the elimination β-phase that follows an IV bolus dose. The half-life of this elimination phase is about 2 hours. Tumescent absorption cannot be terminated as abruptly as turning off an IV infusion; rather, it continues for more than 18 to 36 hours.

The rate of increase and then decrease of lidocaine concentration is determined by a complex interplay between simultaneous tumescent absorption and hepatic metabolism. The complexity of these two concurrent processes becomes apparent when one observes the qualitative differences between the graphs of $C_{lido}(t)$ for a low dose (15 mg/kg), a medium dose (35 mg/kg), and an exceptionally high dose (60 mg/kg) of tumescent lidocaine (Figure 19-9).

Smaller Tumescent Doses. With a relatively small tumescent dose of lidocaine, 15 to 35 mg/kg, the rate of lidocaine absorption increases to a well-defined C_{max} at T_{max}
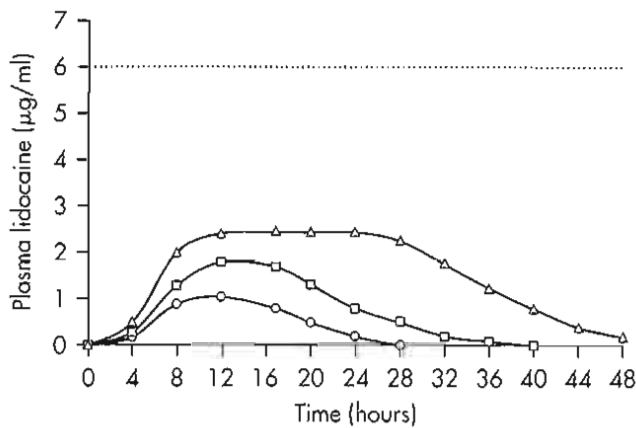
Figure 19-9

Total lidocaine dose determines its plasma concentration–time profile. Relationship between total dose of tumescent lidocaine and maximum plasma lidocaine concentration (C_{max}) is not linear. With increasing dosages (mg/kg) of tumescent lidocaine, shape of the graph of plasma lidocaine concentration as a function of time, $C_{lido}(t)$, tends to change. At lower dosages C_{max} appears as distinct peak; at high dosages C_{max} tends to become a plateau that may persist for several hours. O, 15 mg/kg; □, 35 mg/kg; △, 60 mg/kg.

and then decreases. At these doses the range of T_{max} is approximately 8 to 14 hours after initiating the infiltration.

As a first-order process, the rate of hepatic elimination of lidocaine increases and decreases in proportion to the plasma lidocaine concentration. Initially the absorption rate is much faster than the rate of elimination, and thus the lidocaine concentration increases. The rate of hepatic elimination is maximal when the plasma concentration achieves its maximal value, C_{max}.

Mathematically, T_{max} is exactly the point in time when the rate of absorption equals the rate of elimination. Before T_{max} the rate of lidocaine absorption from the tumescent fat is greater than the rate of hepatic elimination. After T_{max} the rate of lidocaine absorption from the tumescent fat slows down and is less than the rate of elimination (Figure 19-10).

Larger Tumescent Doses. Large doses of tumescent lidocaine behave differently than small doses. Thus, after tumescent liposuction, a graph of $C_{lido}(t)$ is qualitatively different from that at a smaller dose of lidocaine.

With relatively small doses of tumescent lidocaine (less than 35 mg/kg) the plasma lidocaine concentration reaches a well-defined peak at approximately 10 to 12 hours after beginning the infiltration. At relatively large doses, however, instead of a distinct peak, the lidocaine concentration seems to achieve a broad, level plateau that is maintained for 16 hours or more before declining. With a 60-mg/kg tumescent dose of lidocaine, a plateau is reached within 8 hours and persists for at least another 16 hours (Figure 19-11).

With continued absorption the amount of lidocaine remaining at the site of absorption decreases steadily. Subse-
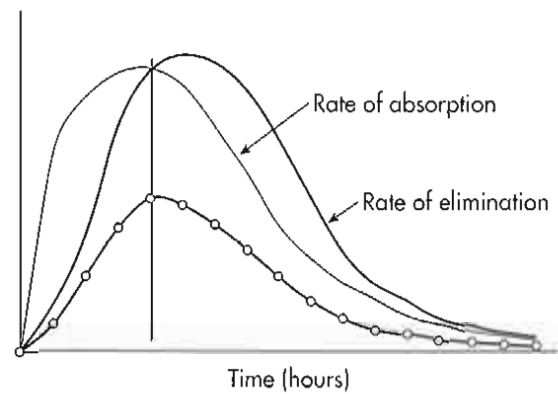
Figure 19-10

Maximum lidocaine concentration (C_{max}) occurs when rate of absorption equals rate of elimination. When rate of lidocaine absorption exceeds rate of elimination, plasma lidocaine concentration (o) is an increasing function of time. When rate of lidocaine elimination is greater than rate of absorption, plasma lidocaine concentration decreases with time. When rate of absorption equals rate of elimination, concentration = C_{max}.
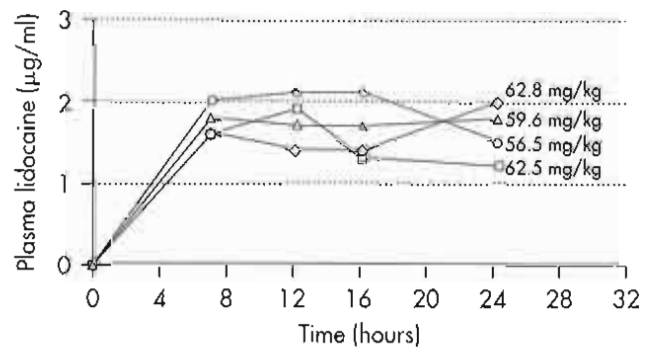
Figure 19-11

After liposuction using large dosages of tumescent lidocaine, plasma lidocaine concentration typically achieves extended C_{max} plateau rather than single peak maximum value.

quently, hepatic metabolism significantly reduces lidocaine blood levels, which approach 0 mg/L by 48 hours after beginning the tumescent infiltration.

The existence of a concentration plateau shows that, during the time that the lidocaine blood levels remain constant, the rate of lidocaine absorption is in a state of constant equilibrium with the rate of lidocaine elimination. Specifically, the rate of lidocaine absorption is exactly equal to the rate of lidocaine elimination. The concentration plateau indicates that the absorption rate from the tumescent tissues is constant and independent of the amount of lidocaine remaining at the absorption site.

ZERO-ORDER OR FIRST-ORDER PROCESSES

When a drug is absorbed at a constant rate, independent of the amount of drug remaining at the absorption site, the process is said to be a *zero-order absorption process*. An example is the long-acting oral tablet designed to dissolve on the outer surface of the tablet and thus slowly release drug at a constant rate for absorption into the systemic circulation. Thus, with tumescent liposuction, lidocaine absorption behaves as a zero-order absorption process, which is unique to the tumescent technique for subcutaneous injection.

In contrast, the absorption of oral drugs in a rapidly disintegrating dosage form that quickly dissolves into solution, as well as most injections into subcutaneous tissue and muscle, often approximates first-order kinetics. A *first-order absorption process* is characterized by an absorption rate that decreases over time and is proportional to the amount of drug that remains at the absorption site. This process is characterized by an *absorption rate constant* (k_a) and a corresponding absorption half life.

The phenomenon of zero-order lidocaine absorption is paramount in explaining the safety of the tumescent technique. The unexpected zero order absorption of tumescent lidocaine explains how the large doses of subcutaneous lidocaine are consistently associated with a low risk of toxicity.

The terminology referring to first-order and zero-order processes is derived from the differential equations that describe these two processes (see section at the end of this chapter). Pharmacokinetic studies of IV lidocaine given by rapid bolus or slow infusion provide much information about the elimination kinetics for lidocaine, with estimates for the volume of distribution *(V)*, clearance *(Cl)*, elimination half-life $(t_{1/2})$, and elimination rate constant *(k)*. Also, systemic elimination of lidocaine is a first-order process.

Cytochrome P450 3A4. Lidocaine elimination by hepatic enzyme cytochrome P450 3A4 (CYP3A4) is a first-order process. In healthy volunteers, lidocaine is so efficiently and rapidly metabolized by the hepatic enzymes that the rate of elimination is limited only by the rate of hepatic perfusion. In healthy patients, hepatic capacity to metabolize lidocaine is not saturated, and the rate of lidocaine elimination is proportional to lidocaine concentration in the blood. The greater the amount of lidocaine within its volume of distribution, the higher is the plasma concentration and the higher the rate of hepatic metabolism.

If the rate of lidocaine metabolism is reduced by 50%, C_{max} is approximately doubled. The relative safety of the tumescent technique for local anesthesia depends on the normal, high rate of liver metabolism of lidocaine (see Chapter 17). Anything that decreases the rate of lidocaine metabolism will increase C_{max} and increase the risk of toxicity. The following factors can reduce the rate of lidocaine metabolism:

1. Decreased CYP3A4 enzymatic activity caused by competitive drug interaction that inhibits CYP3A4
2. Decreased blood flow to the liver caused by decreased cardiac output from either excessive IV fluids precipitating congestive heart failure or drug-induced impaired cardiac output (e.g., with propranolol)
3. Impaired hepatic function resulting from hepatitis or cirrhosis

Drugs such as ketoconazole (Nizoral) or sertraline (Zoloft) can inhibit or reduce the enzymatic function of CYP3A4. Even with drugs that inhibit CYP3A4, little (if any) evidence indicates that the hepatic enzymes responsible for lidocaine metabolism become saturated (see Chapter 18). Although a drug may inhibit CYP3A4 and slow the rate of lidocaine metabolism, this rate remains a linear function of plasma lidocaine metabolism and rate of hepatic blood flow.

ELIMINATION

After Bolus Infusion. Once again, consider the example of a rapid IV bolus dose of lidocaine. An equilibrium is quickly established between lidocaine in the blood and in the lipids of peripheral tissues. From this point the rate of decreasing plasma lidocaine concentration slows noticeably. During the entire β-phase the slow decrease of the lidocaine concentration is essentially 100% attributable to hepatic metabolism. The half life of lidocaine as a result of this β-phase elimination is 100 to 120 minutes, or about 2 hours.

Lidocaine is rapidly and almost entirely metabolized by the liver. Less than 5% of lidocaine is cleared by the kidneys. For a 70-kg person the clearance (blood volume per minute) of lidocaine is 640 ± 170 ml/min, approximately 700 ml/min/70 kg, or more generally 10 ml/min/kg. This approximates the plasma flow to the liver.[9,10]

The liver is so efficient at metabolizing lidocaine that most of the lidocaine that passes through the hepatic circulation is removed (Figure 19-12). Lidocaine is said to have a hepatic extraction ratio of 0.7, which means that 70% of lidocaine entering the liver exits as metabolite. In other words, for every liter of blood that passes through the liver, 70% of its lidocaine is metabolized, whereas only 30% survives unchanged. More precisely, the hepatic extraction ratio for lidocaine is reported to be 62% to 81%.

After Tumescent Infiltration. Elimination of lidocaine after tumescent delivery is significantly different from the process of elimination after an IV bolus dose. For example, the total amount of lidocaine in a tumescent dose, up to 50 mg/kg, is significantly larger than the typical IV bolus dose of 1 to 2 mg/kg.

The absorption half-life of tumescent lidocaine is much longer (approximately 8 to 12 hours) than the elimination half-life for lidocaine (2 hours). Tumescent lidocaine is absorbed so slowly that much of the drug remains to be absorbed well beyond the T_{max} when C_{max} is reached. At any particular time, most of the infiltrated tumescent lidocaine either is in the tumescent fat waiting to be absorbed or has been eliminated. Little of the total dose is in the systemic circulation, or the volume of distribution, at any given time.

Clearance and Half-life. The systemic clearance (total body clearance) and elimination half-life of lidocaine provide a quantitative measure of the rate of liver metabolism.

In young, healthy male volunteers, mean systemic clearance and elimination half-life of lidocaine after a single IV bolus dose are 15.6 mL/min/kg and 1.6 hours, respectively.

Young female volunteers seem to have an increased clearance and half-life and a larger volume of distribution than young, healthy males. In general, therefore, young females can tolerate larger doses of tumescent lidocaine than young males.

Elderly men and women have reduced clearance and prolonged half-life compared with young adult controls.[11] Thus the recommended maximum dose for tumescent lidocaine should be reduced by 10% to 25% for older patients.

Young obese volunteers have a prolonged half-life and an increased volume of distribution. Again, compared with thin patients, obese patients should be better able to tolerate a higher tumescent dosage of lidocaine.[12]

DRUG BIOAVAILABILITY

Bioavailability of a drug is defined as the fraction of a given dose that ultimately reaches a particular targeted tissue. A dose of a drug might have different degrees of bioavailability for different organ tissues. Thus a large percentage of an oral antifungal drug may reach the liver, lungs, and kidneys, but only a small fraction may penetrate the blood-brain barrier and enter the central nervous system.

The concept of bioavailability is different from that of absorption. Drug absorption involves the fraction absorbed from the site of administration and the rate at which a drug diffuses away from its site of administration and into the body's systemic circulation. Bioavailability involves the fraction of dose that reaches the site of action. A drug's bioavailability depends on both its absorption and its ability to penetrate certain barriers and to avoid metabolism or elimination on its journey to the site of drug action.

Bioavailability depends on the following:
1. Site of administration
2. Extent of absorption from the site of administration
3. Physiologic and pathologic states that affect metabolism
4. Amount of absorbed drug that is eliminated before it can reach the targeted site of action

For example, the bioavailability of a hydrocortisone ointment topically applied to the skin might only be 1%. Thus, if 100 μg of hydrocortisone is applied to the skin dissolved in an ointment base, only 1 μg is ultimately absorbed through the stratum corneum, epidermis, and dermis and then enters the systemic circulation, eventually being metabolized and finally excreted.

For another example, after a 4-mg sedative is taken by mouth, 2 mg is actually absorbed from the GI tract into the portal circulation, of which 1 mg is metabolized by the liver. Thus only 1 mg of the original 4 mg actually enters the systemic circulation and eventually reaches the central

Figure 19-12

Lidocaine is rapidly metabolized in liver. When 1 L of blood passes through liver, approximately 700 ml of blood is completely cleared of all lidocaine by hepatic cytochrome P450 3A4 metabolism. As blood flows through liver, 70% of blood lidocaine content is eliminated.

After tumescent infiltration the process of lidocaine elimination is prolonged by the continuous, slow, systemic absorption of tumescent lidocaine and persists up to 48 hours. Elimination of lidocaine after tumescent infiltration is not much different from the rate of lidocaine absorption from the tumescent fat. In fact, when the rate of lidocaine absorption is exactly equal to the rate of lidocaine elimination, the plasma lidocaine concentration is constant. When lidocaine absorption and elimination are equal, lidocaine concentration as a function of time is a constant plateau (see Figure 19-11).

nervous system. The bioavailability is $(1 \text{ mg})/(4 \text{ mg}) = 0.25$, or 25%.

It is typically an advantage to maximize bioavailability when a drug is targeted at the parenchyma of an internal organ. When a potentially toxic drug is targeted at subcutaneous or external (epidermal or mucosal) body tissue, however, it may be an advantage to minimize systemic bioavailability. Examples include a topical anticandidiasis cream or an antihelminthic drug for intraluminal intestinal parasites (the GI tract's mucosal surface is topologically an external body surface).

TUMESCENT LIDOCAINE

Tumescent liposuction is unusual in that the site of action is the local subcutaneous fat targeted for liposuction. Optimal local bioavailability requires a certain time for the tumescent solution to be dispersed by bulk flow throughout the targeted compartment and for lidocaine to diffuse into sensory nerves. To minimize lidocaine toxicity, one must lessen systemic bioavailability by minimizing systemic absorption.

Lidocaine delivered by the tumescent technique is targeted at localized tissues. It is a therapeutic advantage to maximize the local effects of tumescent lidocaine and to minimize its systemic effects. The safety of tumescent liposuction is the result of (1) reducing the rate of lidocaine absorption (by means of extreme dilution and profound vasoconstriction) and (2) reducing the systemic bioavailability (by open drainage and bimodal compression after liposuction).

Lidocaine toxicity is reduced by minimizing the amount of lidocaine absorbed into the systemic circulation. The goal with tumescent liposuction is to maximize local bioavailability and minimize systemic bioavailability of lidocaine.

Liposuction removes a percentage of lidocaine and thus reduces the systemic bioavailability of lidocaine. Without liposuction the systemic bioavailability of lidocaine after tumescent infiltration would be 100%. Because of the slow rate of tumescent lidocaine absorption, however, high doses of lidocaine are safe even without liposuction. If liposuction cannot be completed after tumescent infiltration, the risk of lidocaine toxicity is minimal if total dosage is below the recommended maximum safe dosage of 50 mg/kg.

With liposuction the margin for safety for tumescent lidocaine is even greater. The systemic bioavailability of lidocaine with tumescent liposuction can be reduced by two distinct processes that physically remove lidocaine from the body. First, liposuction reduces the systemic bioavailability of lidocaine by about 20% simply by aspirating lidocaine along with fat. Second, open drainage with bimodal compression further reduces the amount of systemic lidocaine absorption by increasing the amount of lidocaine that drains out of the body after surgery.

Accelerated drainage of residual tumescent anesthetic solution is accomplished by using *adits* (punch biopsy holes 1.0, 1.5, or 2.0 mm in diameter) instead of incisions. If in-

cisions are used, drainage is maximized by allowing incision sites to remain open (not closing incisions with sutures). Finally, applying a high degree of uniform compression over the treated areas encourages a maximum volume of drainage.

Maximum Safe Dose. After tumescent infiltration has been completed and before liposuction can be initiated, something may force the patient or surgeon to cancel the surgery, resulting in 100% lidocaine bioavailability and an increased risk of systemic toxicity.

Thus any estimate of a maximum safe dose of lidocaine for tumescent liposuction must assume 100% systemic bioavailability. One cannot assume that liposuction will always be accomplished after tumescent infiltration is completed, nor can one assume that the systemic bioavailability will be substantially less than 100%.

SEQUESTERED LIDOCAINE RESERVOIR

Delayed lidocaine absorption is key to the safety and efficacy of very dilute (tumescent) solutions of lidocaine. This delayed absorption seems to result from a reservoir effect; lidocaine is sequestered within the infiltrated adipose tissue and unavailable for immediate absorption in the systemic circulation. The actual site of this reservoir is not critical to the pharmacokinetics of tumescent lidocaine.

With an idealized one compartment model for tumescent lidocaine, no pharmacokinetic distinction exists between lidocaine that is bound or unbound to tissue. The proportion of bound and unbound lidocaine is assumed to be constant. Also, any change in concentration of the unbound lidocaine is instantly reflected in a proportionate change in the bound fraction. As soon as unbound tissue lidocaine diffuses into the systemic circulation, a proportionate amount of the lidocaine bound to subcutaneous tissue instantaneously becomes unbound.

An ideal pharmacokinetic model also assumes that the bound fraction is not displaced from its binding site by anything other than a change in the concentration of the unbound fraction. In other words, the assumption is that no drugs or processes might displace bound lidocaine from its binding sites and change the proportionality between the bound and unbound fractions.

The lidocaine reservoir may be the result of (1) pools of tumescent anesthetic solution loculated within vasoconstricted fatty tissue and (2) binding of dilute lidocaine to adipose tissue in general and to adipocyte lipids in particular. The relative importance of these sites of lidocaine sequestration is not certain.

When lidocaine is added to a mixture of equal volumes of water and lipids, a greater proportion of the lidocaine is dissolved within the lipid fraction. De Jong[3] favors the direct binding of lidocaine to adipose tissue as the source of the reservoir effect for subcutaneous lidocaine. He has proposed that the ratio of unbound/bound lidocaine within adipose tissue

is a function of the concentration of lidocaine in the local anesthetic solution.

It is unlikely that the explanation for slow systemic absorption of tumescent lidocaine is an intense binding of lidocaine to lipids within tumescent fat or the sequestration of lidocaine within the interstitium of tumescent tissue. If the explanation were as simple as that, one would expect more lidocaine to be removed by liposuction.

SUMMARY

Tumescent lidocaine pharmacokinetics is best represented by a one-compartment model. Tumescent absorption is a zero-order process. The rate of lidocaine absorption from tumescent tissue is constant and independent of the amount of lidocaine remaining at the site of absorption. Tumescent lidocaine resembles the absorption characteristics of a slow-release tablet in the GI tract. The rate of hepatic elimination of tumescent lidocaine is proportional to the concurrent plasma lidocaine concentration and is thus a first-order elimination process.

Large doses of tumescent lidocaine in the range of 50 to 55 mg/kg appear to be safe in most patients. Impaired hepatic metabolism of lidocaine can predispose a patient to lidocaine toxicity. The peak plasma concentration typically reaches a plateau within 8 to 12 hours and can persist for more than 24 hours, before diminishing to zero at about 48 hours.

Tumescent pharmacokinetics might have application beyond local anesthesia. The slow rate of absorption and prolonged concentration plateau associated with extreme dilution might prove advantageous for drug delivery in other areas of medicine, such as oncology. Treatment of breast cancer by the local infiltration of a chemotherapeutic agent may allow a prolonged local uptake of the drug by the proximal lymphatics.

THE MATHEMATICS OF PHARMACOKINETICS

The following sections provide more detailed analyses of concepts discussed in this chapter.

DERIVATION OF SURFACE AREA/VOLUME RATIO

The following calculations demonstrate the relationship between the ratios of surface area *(A)* to volume *(V)* for two spheres, where the volume of one sphere is twice a large as the volume of the other. Interestingly, the same relationship between A/V ratios holds for two cubes, where one has twice the volume of the other.

Conjecture. Suppose that volume V_{II} is twice as large as volume V_I, that is, $V_{II}/V_I = 2$. If A_{II} and A_I represent the surface of V_{II} and V_I, respectively, then $A_{II}/A_I \cong 1.6$, and A/V ratios for these two volumes are related by the equation $A_{II}/V_{II} = (0.8)A_I/V_I$.

Proof (Spheres). The volume of a sphere of radius r is $(4/3)\pi r^3$, and its surface area is $4\pi r^2$. Now suppose $V_{II} = 2V_I$, where R is the radius of the larger sphere, and r is the radius of the smaller sphere. Thus $V_{II} = (4/3)\pi R^3$, and $V_I = (4/3)\pi r^3$.

Because $V_{II} = 2V_I$, then $(4/3)\pi R^3 = V_{II} = 2V_I = 2(4/3)\pi r^3$. Solving for R yields $R^3 = 2 r^3$, and therefore $R = (2)^{1/3}r$. From the classic formula for the surface area of a sphere, $A_{II} = 4\pi R^2$, and $A_I = 4\pi r^2$. Substituting $R = (2)^{1/3}r$ in the equation yields the surface area for A_{II}:

$$A_{II} = 4\pi R^2 = 4\pi[(2)^{1/3}r]^2 = (2)^{2/3} 4\pi r^2 = (2)^{2/3} A_I$$

Thus the ratio of the two surface areas is as follows:

$$A_{II}/A_I = (2)^{2/3} = (2^2)^{1/3} = (4)^{1/3} = 1.5874 \cong 1.6$$

By assumption, $V_{II} = 2V_I$, or $V_{II}/V_I = 2$. Therefore, if A_{II}/A_I is divided by V_{II}/V_I:

$$[A_{II}/A_I]/[V_{II}/V_I] \cong (1.6)/2 = 0.8$$

After rearranging the terms, we may conclude the following:

$$A_{II}/V_{II} \cong (0.8) A_I/V_I$$

Proof (Cubes). A similar calculation holds true when the volumes are cubes (cuboid) rather than spheres (spheric). Suppose V_{II} and V_I represent the volume of the two cubes, where the volume of the larger cube is twice the volume of the smaller cube; thus $V_{II} = 2 V_I$. Let E and e represent the length of an edge of the large and small cube, respectively. Then the volumes can be expressed as $V_{II} = E^3$ and $V_I = e^3$. Because $V_{II} = 2V_I$, then $E^3 = V_{II} = 2V_I = 2e^3$. Solving this algebraic equation for E yields $E^3 = 2 e^3$, and therefore $E = (2)^{1/3} e$.

If A_{II} and A_I represent the surface area of the respective cubes, $A_{II} = 6E^2$, and $A_I = 6e^2$. Substituting $E = (2)^{1/3}e$ into $A_{II} = 6E^2$:

$$A_{II} = 6E^2 = 6[(2)^{1/3}e]^2 = 6(2)^{2/3}e^2$$

Thus the ratio of the two surface areas is as follows:

$$A_{II}/A_I = [6(2)^{2/3}e^2]/6e^2 = (2)^{2/3} = (4)^{1/3} = 1.5874 \cong 1.6$$

By assumption, $V_{II} = 2V_I$, or $V_{II}/V_I = 2$. Therefore, if A_{II}/A_I is divided by V_{II}/V_I:

$$[A_{II}/A_I]/[V_{II}/V_I] \cong (1.6)/2 = 0.8$$

After rearranging the terms, we may conclude the following:

$$A_{II}/V_{II} \cong (0.8) A_I/V_I$$

Discussion. Let us assume that a volume *(V)* of tumescent fat is roughly spherical. If the concentration of the tu-

mescent anesthetic solution is constant, the volume of the sphere will proportional to the total dose (milligrams) of lidocaine, and thus:

V is proportional to the total dose of lidocaine.

If we assume the systemic absorption of lidocaine only occurs from the surface of the sphere, the rate of absorption is proportional to the surface area *(A)* of the sphere, and thus:

A is proportional to the rate of lidocaine absorption.

Finally, the *surface area/volume* term is as follows:

A/V is proportional to the rate of lidocaine absorption
per total dose of lidocaine.

This conclusion is derived from elementary geometry and from the assumption that tumescent lidocaine absorption is proportional to the surface area of the mass of tumescent fat. This relation between *A* and *V,* where $A_{II}/V_{II} \cong (0.8) A_I/V_I$, helps to explain why an obese patient tolerates a larger dose of tumescent lidocaine better than a relatively thin patient.

Suppose patient P_{II} weighs 100 kg and patient P_I weighs 50 kg. If each receives the same mg/kg dose of lidocaine, then $V_{II} = 2 V_I$, where V_{II} and V_I represent the volume of tumescent fat in each patient, respectively. The rate of absorption per total dose is less for the obese patient than the thin patient by a factor of 0.8.

ESTIMATING TIME FOR LIDOCAINE CLEARANCE

Using standard values for lidocaine clearance and other clinical values yields calculations consistent with observed pharmacokinetic parameters. For example, consider a 70-kg patient who received a 50-mg/kg dose of tumescent lidocaine. The total dose of lidocaine is 50 mg/kg × 70 kg = 3500 mg. From clinical experience, I know that this dosage will yield an average peak plateau of peak plasma concentration of approximately 2.0 mg/L.

Also, from data published by others, lidocaine clearance in a 70-kg patient is 700 ml/min. In other words, the liver will clear 700 ml of lidocaine per minute. If the blood contains 2.0 mg/L, then 700 ml of blood must contain 1.4 mg. Because the liver clears 700 ml/min, the liver must metabolize or eliminate 1.4 mg/min of lidocaine. By simple multiplication we calculate that the liver will metabolize lidocaine at a rate of 1.4 mg/min = 84 mg/hr. Finally, we can calculate that the number of hours necessary to metabolize 3500 mg of lidocaine is (3500 mg)/(84 mg/hr) = 41.6 hours.

Thus, knowing that a 3500-mg dose of lidocaine will typically yield a peak plasma lidocaine concentration 2.0 mg/L, and using standard average value of 700 ml/min for lidocaine clearance in a healthy patient, we can derive an estimate of the time required to metabolize and eliminate the entire 3500-mg dose of lidocaine: 41.6 hours.

The actual time for complete lidocaine metabolism depends on the validity of several assumptions. For example, because plasma concentrations are not a constant 2.0 mg/L, the actual time for complete clearance may be greater than 41.6 hours. On the other hand, because liposuction will reduce lidocaine bioavailability, not all 3500 mg of the infiltrated lidocaine will be absorbed into the systemic circulation. Thus the time required to metabolize all the tumescent lidocaine is less than 41.6 hours. This time is consistent with the observed values of 36 to 48 hours for complete lidocaine clearance after a tumescent dose of 50 mg/kg for liposuction.

A few simple calculations demonstrate the internal consistency of the estimated values for the various pharmacokinetic parameters, using the previous example. At steady state, rate of elimination $= R_E = R_A =$ rate of tumescent lidocaine absorption. Since $R_E = 1.4$ mg/min $= 84$ mg/hr, we can conclude that $R_A = 84$ mg/hr.

Systemic clearance (Cl) can be viewed as a proportionality constant in the relationship between R_A and steady-state plasma concentration (C_{SS}). Thus $R_A = Cl \cdot C_{SS}$. Substituting the appropriate values:

$$1.4 \text{ mg/min} = (0.7 \text{ L/min})(2.0 \text{ mg/L})$$

MATHEMATICAL DESCRIPTION OF TUMESCENT LIDOCAINE KINETICS

All drugs exhibit undesirable and toxic effects. Clinical pharmacokinetics helps to determine the optimal dosage regimen for any particular drug. This section provides a more rigorous discussion of some basic pharmacokinetic principles as applied to the tumescent technique.

The apparent volume of distribution *(V)* is a theoretic concept that allows one to express the *(total amount of drug in the body)* = *(X)* in terms of the *(concentration of drug in the blood)* = *(C)*. This theoretic V is a tool that simplifies the mathematical modeling of complex pharmacokinetic processes.

When a drug enters the body, it is distributed into various tissues in different concentrations. If the degree of drug-tissue binding is independent of concentration, the ratio of the concentrations in the various tissues is constant. By making this theoretic assumption, one can express the ratio between the (C) and (X) by a simple proportionality equation, $C = (1/V) \cdot X$, where (1/V) can be regarded as a constant of proportionality.

Knowing both X (e.g., total IV dose) and C (measured from a blood sample), one can express concentration (C) as the total amount (X) of drug per apparent volume (V):

$$C = X/V$$
$$X = V \cdot C$$

The theoretic number V represents the hypothetic volume that would be necessary to contain all the drug present in the body at exactly the same concentration as found in the blood.

Lidocaine: Rate of Elimination.   The rate of elimination of lidocaine from the body is known from the change of lidocaine blood levels over time after a simple IV bolus injection. By measuring lidocaine blood levels sequentially over time and plotting these levels on a graph, one can show that the rate of elimination of lidocaine from the body is proportional to the concentration (C) of lidocaine in the body.

A pharmacokinetic elimination process for a given drug is defined as a *first-order process* when the drug's rate of elimination is directly proportional to the drug's plasma concentration. Thus, by definition, lidocaine elimination via hepatic metabolism is a first-order process that is mathematically described by a simple, linear differential equation. This differential equation can be written in different ways, each equivalent to the others:

$$d(C)/dt = -K(C)$$
$$d(X/V)dt = -K(X/V)$$
$$dX/dt \quad -KX$$

where $(C) = (X/V)$, X is amount of drug currently in the body, V is hypothetic apparent volume of distribution, and K is linear elimination rate constant.

This equation can be expressed as follows: the rate of decrease in the amount of lidocaine in the body is directly proportional to the amount in the body. The negative sign (−) indicates that a negative change is occurring, that is, X is decreasing with time. So far we have two proportionality equations: $X = V \cdot C$ and $dX/dt = -KX$. From elementary calculus we can solve the differential equation as follows:

$$dX/X = -K \, dt$$

Taking the integral of each side:

and
$$\int dX/X = \ln X - \ln X_0 = \ln(X/X_0)$$
$$\int -K \, dt = -K \cdot t + K \cdot 0 = -K \cdot t$$

Then equating the results:

$$\ln X - \ln X_0 = -K \cdot t$$

or equivalently:

$$\ln(X) = \ln(X_0) - (K \cdot t)$$

Converting this natural logarithm to an exponential, one obtains an expression of the amount of drug in the body as a function of time:

$$\exp[\ln(X)] = \exp[\ln(X_0) - (K \cdot t)]$$

This is equivalent to the following:

$$X = X_0 \cdot \exp(-Kt) \tag{1}$$

Finally, because $X = V \cdot C$, we can write $V \cdot C = X = (X_0) \exp(-Kt)$. After a rearrangement of terms, we can now have an equation that expresses blood concentration $C(t)$ of lidocaine after IV bolus injection as a function of time:

$$C(t) = (X_0/V)[\exp(-Kt)]$$

Finding Experimental Value of C_0 and V.   By experimentally measuring the plasma concentration C of lidocaine at various times, we can determine experimental estimates for the values of K, the elimination rate constant, and V, the apparent volume of distribution.

Numeric calculations and drawings of graphs are easier using common logarithms to the base of 10 rather than natural logarithms to the base e. By definition:

$$Y = \log_{10} X \tag{2}$$

if and only if:

$$10^Y = X \tag{3}$$

We can express Y in terms of natural logarithm to the base e by taking the natural logarithm of both sides of equation 3:

$$\ln X = \ln 10^Y = Y \ln 10 \tag{4}$$

After rearranging the terms, we have:

$$Y = (\ln X)/(\ln 10) \tag{5}$$

By equating equations 1 and 4, we have:

$$\log_{10} X = (\ln X)/(\ln 10) \tag{6}$$

Because $\ln(10) = 2.303$, or equivalently, $e^{2.303} = 10$, equation 6 can be written as:

$$\log_{10}(X) = \ln(X)/2.303$$

or

$$\ln(X) = (2.303)\log_{10}(X) \tag{7}$$

By taking the natural logarithm of both sides of equation 1, $X = X_0 \cdot \exp(-Kt)$, we have:

$$\ln(X) = \ln(X_0) - (K \cdot t) \tag{8}$$

Substituting equation 7 into equation 8, we have:

$$\log X = (\log X_0) - (K \cdot t/2.303)$$

Because $X = VC$, and $X_0 = VC_0$, we derive:

$$\log C(t) = (\log C_0) - (K/2.303) \cdot t \tag{9}$$

By measuring the plasma lidocaine concentration C(t) at various times and then plotting a graph of the data log C(t), which is the same as plotting C(t) using semilog graph paper, the data should fall along a straight line described by the equation for log C(t), where $-K/2.303$ is the slope of the line. By extrapolating back to time t = 0, we obtain:

$$\log C(0) = \log C_0 - (K \cdot 0/2.303) = \log C_0$$

This is an experimental estimate for the value of C_0.

Now we can estimate for the apparent volume of distribution $V = X_0/C_0$, where X_0 is the IV dose and C_0 has been derived experimentally. For lidocaine, experimental data published by several investigators suggest that a reasonable estimate of the apparent volume of distribution V for a 70-kg person is 77 ($\pm$ 28) liters, or 1.1 L/kg.

Experimental Estimate of K

Method 1. An experimental estimate for the value of K, the apparent first-order elimination rate constant, can be determined from the relationship $C(t) = C_0$ at time t   0, and $C(t_{1/2}) = C_0/2$ at time $t_{1/2}$, where $t_{1/2}$, the half-life of C(t), is the length of time required for C(t) to decrease from C_0 to $(C_0)/2$. We can easily determine $t_{1/2}$ by simply plotting the graph of C(t), the plasma concentration of lidocaine, as a function of time following an IV bolus dose.

Substituting $C(t_{1/2}) = C_0/2$ in equation 9, we have:

$$\log(C_0/2) = \log C_0 - [K \cdot t_{1/2}]/2.303 \qquad \textbf{(10)}$$

After rearranging the terms, we derive:

$$\frac{[\log(C_0/2) - \log C_0]}{t_{1/2}} = -[K]/2.303 \qquad \textbf{(11)}$$

where $-[K]/2.303$ is equal to the slope of the line C(t) between t = 0 and $t = t_{1/2}$. Thus, by estimating C_0 and measuring $C_0/2$ and $t_{1/2}$, one can determine the numeric value of the slope $-[K]/2.303$ and therefore the number K.

Method 2. From equation 1 we have:

$$X = X_0 \cdot \exp(-Kt)$$

If $X = (1/2)X_0$, equation 1 becomes $X_0/2 = X_0 \cdot \exp(-Kt_{1/2})$. Thus, $[1/2] = \exp(-Kt_{1/2})$, or equivalently, $2 = \exp[Kt_{1/2}]$, and $\ln(2) = K \cdot t_{1/2}$, and finally:

$$K = \ln(2)/t_{1/2} = 0.693/t_{1/2} \qquad \textbf{(12)}$$

Thus, by measuring the half-life of *C(t)*, one can calculate the value of K.

Absorption.   The process of drug absorption is a zero-order process when the drug enters the systemic circulation at a constant rate. Thus $dX/dt = k_0$ describes a zero-order process of absorption.

After tumescent infiltration of a large volume of dilute lidocaine and epinephrine into subcutaneous fat, the majority of the lidocaine is sequestered inside the tumescent subcutaneous tissue. Only the lidocaine near the peripheral "surface" of the infiltrated tissue is available for absorption. The profound degree of tumescent vasoconstriction in effect isolates the lidocaine that is contained deep within the tumescent tissue.

Thus, once a given dose X_1 of tumescent lidocaine at a concentration C has been infiltrated, the lidocaine absorption rate k_1 is approximately a constant. When a larger dose of tumescent lidocaine X_2 having the identical concentration C is infiltrated, the rate of absorption will be a constant k_2. However, k_1 and k_2 are not necessarily equal.

Simultaneous Absorption and Elimination.   From the previous discussion, we know that lidocaine is eliminated by a first-order process, and therefore $dX/dt = -KX$.

In reality, after tumescent infiltration of lidocaine, the plasma concentration depends on both the rate of absorption and the rate of elimination. The differential equation that describes the simultaneous absorption and elimination of lidocaine is as follows:

$$dX/dt = k_0 - KX$$

where X is the amount of lidocaine in the body, and k_0 is the constant rate of absorption (units of mg/sec). The solution of this differential equation is as follows:

$$X = (k_0/K)[1 - \exp(-Kt)]$$

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CHAPTER 20

Lidocaine Toxicity and Drug Interactions

Lidocaine toxicity is dosage related and directly proportional to its plasma concentration. Lidocaine for cardiac conditions has a narrow therapeutic index, with only a small difference between therapeutic and potentially toxic concentrations.

When intravenous (IV) lidocaine is given to treat ventricular arrhythmias (dysrhythmias), the therapeutic range for plasma concentrations is 1 to 5 mg/L, or 1 to 5 μg/ml. The potential for lidocaine toxicity is considered to be clinically significant at plasma concentrations greater than 6.0 mg/L. The metabolites of lidocaine have both pharmacologic and potential toxic effects; the threshold concentration for lidocaine-metabolite toxicity has not been established.

The safe use of lidocaine requires knowledge of lidocaine toxicology. This is especially important when using tumescent local anesthesia for large-volume liposuction.

TOXIC EFFECTS AND TREATMENT

Lidocaine toxicity typically occurs in two settings: (1) slow systemic absorption with a slow sustained IV infusion and (2) rapid systemic absorption, such as an excessive IV bolus dose. With slow systemic absorption of lidocaine, the onset of toxic symptoms is progressive. With a toxic IV bolus dose of lidocaine, seizures, loss of consciousness, and rarely cardiovascular collapse may occur without any of the milder central nervous system (CNS) symptoms. Respiratory acidosis and hypoxia exacerbate lidocaine toxicity.

GASTROINTESTINAL

Tumescent lidocaine at 35 mg/kg has proved to be exceedingly safe. In my experience a tumescent dosage of 55 mg/kg is associated with a small (2% or less) incidence of mild lidocaine toxicity manifested by nausea and vomiting. When this nausea has occurred, the corresponding blood lidocaine concentrations have all been less than 3 μg/ml. Above 60 mg/kg the incidence of nausea is 10% or greater. A few liposuction surgeons have reported more than a 30% incidence of nausea or vomiting among patients given 70 to 100 mg/kg of tumescent lidocaine; the corresponding blood levels were not reported.

Occasionally, tumescent liposuction patients report nausea and vomiting at lidocaine plasma concentrations well below the toxic threshold of 6 mg/L. Nausea may also result from antibiotics, however, as well as trauma-induced inflammatory effects of liposuction. Nausea and vomiting might also be caused by narcotic analgesics used in the perioperative period.

It is easier to prevent than to treat nausea and vomiting. Limiting the dosage of tumescent lidocaine to 50 mg/kg or less and avoiding the use of narcotic analgesics is the simplest approach to avoiding gastrointestinal toxicity from lidocaine.

CENTRAL NERVOUS SYSTEM

Lidocaine toxicity develops progressively with increasing plasma concentrations. "Typical" clinical signs and symptoms of lidocaine toxicity, however, may appear at very safe, low therapeutic plasma concentrations. These typical symptoms are also produced by other drugs often used together with tumescent local anesthesia.

Mild drowsiness is a common symptom experienced by nearly all patients who have received tumescent local anesthesia with resulting plasma concentrations of 1 to 3 mg/L, well below the threshold for toxicity. Drowsiness is so common that it cannot be considered a sign of impending toxicity. At high plasma concentrations, however, drowsiness can be expected to precede unconsciousness and coma.

Lightheadedness is less common but not rare. Localized muscle fasciculations typically occur, especially in muscle groups immediately subjacent to the fat infiltrated with tumescent anesthesia. Such CNS and neuromuscular symptoms are more appropriately referred to as *pharmacologic side effects* rather than toxic events.

Early signs of true lidocaine toxicity include nervousness, apprehension, euphoria, confusion, dizziness, and blurred or double vision (see later discussion). These same symptoms are manifestations of benzodiazepine toxicity, which may confuse the situation.

Certain premonitory CNS symptoms, including tinnitus, nausea, vomiting, lightheadedness, and generalized muscle twitching, have been reported to precede lidocaine-induced seizures, unconsciousness, and coma. The onset of various signs and symptoms of CNS toxicity from lidocaine is progressive and sequential. The surgeon must recognize that CNS toxicity occurs before potentially fatal lidocaine-induced cardiovascular collapse.

RESPIRATORY

Respiratory depression and respiratory arrest are definite signs of serious toxicity. Respiratory depression with respiratory acidosis can significantly worsen the toxicity of lidocaine. Respiratory acidosis and hypercarbia cause an exponential increase in lidocaine toxicity.[1]

CARDIOVASCULAR

Cardiovascular lidocaine toxicity is more dangerous than CNS toxicity. The plasma concentration of lidocaine that causes cardiovascular toxicity is several times greater than the threshold for CNS toxicity.

Direct cardiac toxicity of lidocaine causes bradycardia, peripheral vasodilation, hypotension, depressed myocardial contractility, and depressed conduction through the cardiac conduction system, which can lead to cardiovascular collapse and death.

INITIAL TREATMENT MEASURES

Dependable ventilation is necessary to prevent respiratory acidosis, and oxygen should be administered at the first signs of systemic toxicity. Based on animal studies, lidocaine-induced dysrhythmias and cardiac depression are best treated with bretylium.

Although diazepam (Valium) and midazolam (Versed) are the drugs of choice to treat lidocaine-induced seizures, no evidence shows that benzodiazepines can be safely used to prevent seizures in an outpatient setting. The use of diazepam to treat a seizure presumes that the patient has adequate respiratory support. The high doses required to terminate a lidocaine-induced seizure can depress ventilations. When diazepam is administered to treat a grand mal seizure, the physician must be prepared to assist respiration with an Ambu bag or other means of artificial respirations.

If a lidocaine-induced seizure does occur, initial interventions must be to prevent physical injury and to provide hyperventilation and good oxygen delivery.

Midazolam, a water-soluble benzodiazepine, is the drug of choice for treating lidocaine-induced seizures. After an initial bolus of 5 to 7 mg, additional 1-mg to 2-mg increments of midazolam are given until the seizure is controlled.

Postoperative Diazepam Contraindicated. In experimental animals given convulsant doses of a local anesthetic, pretreatment with a benzodiazepine prevents seizures in a dose-related manner.[2-4] Preoperative use of benzodiazepines, such as oral lorazepam or IV midazolam, is reasonable for anxiolysis and sedation. Routine postoperative use of benzodiazepines, however, should be avoided.

Some surgeons have proposed that patients receive diazepam 8 to 10 hours after surgery to prevent lidocaine-induced seizures, which are most likely to occur during peak plasma lidocaine concentrations. Despite the plausibility of this conjecture, I do not recommend preemptive treatment with diazepam for the following reasons:

1. A surgeon should never give so much lidocaine that concern exists about a lidocaine induced seizure. The fact that diazepam will protect against a lidocaine-induced seizure is no reason to administer higher and higher doses of lidocaine.
2. A benzodiazepine such as diazepam may predispose to lidocaine toxicity by causing respiratory depression and respiratory acidosis.
3. Benzodiazepines may slow lidocaine metabolism by inhibiting cytochrome P450 3A4 (CYP3A4), thus increasing plasma lidocaine levels and the risks of nonseizure-related lidocaine toxicity.
4. If the surgeon believes that seizures from tumescent lidocaine are a significant risk, the patient should be admitted to an intensive care unit (ICU) for observation. In an ICU, benzodiazepines are appropriate for seizure prophylaxis but require close patient observation, since the first evidence of toxicity might be cardiac arrest without premonitory seizure activity.
5. It is not appropriate to send a patient home with oral diazepam if the surgeon is concerned about a lidocaine-induced seizure. If seizures are unlikely, however, peremptory benzodiazepines are unnecessary and may cause symptoms such as confusion, nausea, and ataxia, which can be mistaken for early lidocaine toxicity.

Bretylium is preferred to lidocaine for the treatment of ventricular dysrhythmias from high doses of local anesthesia. Plasma lidocaine concentrations resulting from tumescent anesthesia rarely approach the threshold for toxicity. However, giving IV lidocaine to treat ventricular fibrillation in a patient who has already received a high dose of lidocaine might precipitate toxicity.

DIRECT TISSUE EFFECTS

Although muscle toxicity induced by tumescent local anesthetic has not been noted clinically, muscle lysis and ischemic necrosis associated with lidocaine and epinephrine have been reported in experimental models using much higher doses.[5]

High concentrations of lidocaine can have a toxic effect on peripheral nerves. Peripheral nerve toxicity involving the

cauda equina may have been caused by repeated or continuous infusions of 5% lidocaine during spinal anesthesia.[6,7] A solution of 5% lidocaine caused irreversible conduction block in desheathed amphibian nerves.[8]

RAPID ABSORPTION TOXICITY

An excessive IV bolus dose of lidocaine can result from the following:

1. Appropriate dose of lidocaine for a regional nerve block that is inadvertently injected intravascularly.
2. Regional IV anesthesia (Bier's block) that is released too rapidly into the systemic circulation.
3. Excessive IV loading dose of lidocaine for initiating treatment of ventricular tachycardia.

A moderately excessive IV bolus dose of lidocaine produces brief peak plasma concentrations above the toxic threshold. The short duration is the result of the rapid α-phase redistribution of lidocaine out of the vascular space and into the peripheral tissues (see Chapter 19). The lung temporarily binds large amounts of lidocaine on its first pass through the pulmonary circulation. Within 20 seconds of an 0.5-mg/kg IV bolus dose of lidocaine, about 60% is absorbed into lung tissue.[9] This pulmonary reservoir effect is saturable and insignificant in the setting of a prolonged lidocaine infusion.

Therefore, except for massively excessive doses, lidocaine toxicity after an IV bolus dose is brief and self-limited.

SLOW ABSORPTION TOXICITY

Toxicity after a sustained infusion of lidocaine is more prolonged and more ominous. With extended infusion the threshold for toxicity is gradually exceeded after lidocaine has saturated all the peripheral fatty tissues. Rapid redistribution of lidocaine out of the vascular space, as occurs after an IV bolus dose, cannot occur because the peripheral storage sites are already saturated with lidocaine. Instead, plasma lidocaine concentrations decrease only as fast as hepatic metabolism will allow. Thus toxicity associated with sustained infusion or prolonged absorption, such as with tumescent anesthesia, is more long lasting and therefore potentially more dangerous than toxicity after an IV bolus dose.

A typical setting in which a physician might encounter lidocaine toxicity involves the treatment of ventricular ectopy (ectopia) in an intensive cardiac care unit. Toxicity occurs when standard doses are administered to patients with decreased ability to metabolize lidocaine. Examples include patients with decreased hepatic blood flow caused by congestive heart failure, with greatly impaired hepatic function caused by advanced cirrhosis, or with drug interactions caused by lidocaine analogs or other drugs that impair lidocaine metabolism.[10]

PREVENTION: AVOIDING HUMAN ERROR

To my knowledge, no deaths have resulted from lidocaine toxicity with true tumescent liposuction totally by local anesthesia. However, fatal cases of lidocaine overdose have occurred

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BOX 20-1 ORDERS FOR TUMESCENT LOCAL ANESTHESIA

Patient's preoperative weight today: _____ kg
Maximum allowable lidocaine dosage: _____ mg/kg

Bag #_____: Lidocaine _____ mg Epi _____ mg
Bag #_____: Lidocaine _____ mg Epi _____ mg
Bag #_____: Lidocaine _____ mg Epi _____ mg
Bag #_____: Lidocaine _____ mg Epi _____ mg
Bag #_____: Lidocaine _____ mg Epi _____ mg

Epi, Epinephrine.

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in other clinical settings. The increasing popularity and more frequent use of tumescent anesthesia guarantee an increased incidence of adverse pharmacologic and toxic reactions.

The surgeon can minimize the probability of a negligent or careless error by insisting on written operating room (OR) policies and procedures for the use of lidocaine with tumescent anesthesia for liposuction. The most important safeguard against careless or inadvertent errors in lidocaine dosing is a requirement for written lidocaine orders. The surgeon must insist on the most fastidious records of the exact total milligram doses actually administered. Physician and staff must double-check the orders for accuracy. Lidocaine orders must be expressed in terms of total dose in milligrams (mg) and total dosage (mg/kg).

The most likely causes of lidocaine toxicity with tumescent liposuction result from errors by the physician, nurse, or patient. In my experience, preventable mistakes in lidocaine dosage have been associated with the human errors listed next.

1. *Casual or indifferent attitude* regarding the maximum safe lidocaine dosage (mg/kg) proved to be fatal in one case. The surgeon apparently disregarded or was ignorant about the recommended maximum safe dosage of tumescent lidocaine. One cannot assume that tumescent anesthesia is safe at any dosage.

2. *Dosage miscalculations* must be expected to occur, even with the most fastidious attention to detail.[11] Surgeons, nurses, and anesthesiologists should double-check each other's calculations of the total allowable dosage.

3. *Poor communication among staff*, as a result of verbal orders, ambiguous or imprecise written orders, and illegible written orders, has been associated with critical misinterpretation and has had serious consequences. Oral orders are dangerous. Lidocaine orders must be written and signed by the surgeon before a nurse is permitted to prepare the tumescent anesthetic solutions (see Box 20-1).

4. *Inaccurate or nonexistent records* of the cumulative lidocaine dose (mg) and dosage (mg/kg) have been associated with lidocaine toxicity during tumescent liposuction when more than 110 mg/kg was given inadvertently. The result was temporary neurologic toxicity (see Box 20-2).

BOX 20-2 SAMPLE ENTRY FROM FLOW SHEET DOCUMENTING AMOUNT OF INFILTRATED ANESTHETICS

Bag # (drugs + 0.9% NaCl):	1	2	3	etc.	TOTALS
Lidocaine (mg put in bag) [A]:					
ml of bag infiltrated [B]:					
Initial ml in bag [C]:					
Lidocaine mg infiltrated [A × (B/C)]:					
Total mg/kg lidocaine actually infiltrated:					

5. *Inadequately trained staff* is the fault of the surgeon. Poorly trained OR staff resulted in a fatality when lidocaine was mistakenly added to an IV infusion without the clinician's knowledge.[12]

6. *Inadvertent double dose* of lidocaine has occurred when the anesthesia orders were written in terms of "ml" of lidocaine instead of *mg* of lidocaine. A medical assistant used 2% lidocaine when the surgeon had intended 1% lidocaine. No dermatologic surgical procedure requires 2% lidocaine. It may be advisable not to permit 2% lidocaine in an office or surgical facility where tumescent liposuction is performed. Medical assistants are not as well trained as registered nurses for mixing medications.

7. *False or inaccurate clinical history* may result in errors. Patients do lie, and others forget to inform the surgeon of important clinical information. When one patient neglected to inform the surgeon of a preexisting seizure disorder, the result was an unexpected intraoperative seizure, with aspiration, asphyxia, and death. Even with standard "safe" dosages, propofol and lidocaine can lower the seizure threshold.

8. *Use of unreported medications* places patients at risk for unexpected drug interactions. Clinical experience demands the assumption that every patient is taking medication(s) without reporting this to the surgeon. For this reason alone, total lidocaine dosage should be moderate. Pushing lidocaine dosages to their limit to avoid the inconvenience of serial liposuction procedures on separate days does not meet any prudent standard of care.

9. *Unawareness of adverse drug interactions* with lidocaine or epinephrine is always a risk. Although they cannot reasonably expect to have knowledge of every reported or conceivable drug interaction, surgeons should at least know about published accounts of the most dangerous or the most common adverse interactions. The hepatic isoenzyme CYP3A4 is critical for the metabolism of lidocaine. Any physician who uses lidocaine should have an understanding of the role of cytochrome P450 isoenzymes in the occurrence of drug interactions with lidocaine (see Chapter 18).

10. *Expressing lidocaine doses in terms of milliliters per kilogram is dangerous.* It is much safer simply to express lidocaine doses in terms of total milligrams per kilogram (mg/kg) rather than total volume of lidocaine solution times concentration of lidocaine solution per kilogram, (mL) · (mg/ml)/(kg). Expressing lidocaine doses in terms of milliliters of 1% or 2% lidocaine is more susceptible to error and has been associated with at least one death. An order for "100 cc of lidocaine per liter" with the intention of ordering "100 ml of 1% lidocaine placed in a liter of solution" can easily result in the patient receiving 100 ml of 2% lidocaine per liter.

The risk of lidocaine toxicity is known to be closely correlated with mg/kg dosage. Thus it is reasonable to express a lidocaine order in terms of the milligrams of lidocaine. It is easier to calculate the total lidocaine dose (3000 mg) when the order is written as "four liters of solution at 750 mg of lidocaine per liter" versus "four liters of solution, each containing 37.5 ml of 2% lidocaine per liter."

SYMPTOMS OF TRUE TOXICITY

Earliest symptoms of true lidocaine toxicity are not pathognomonic. Symptoms of lidocaine toxicity overlap with signs and symptoms of side effects from other drugs taken by tumescent liposuction patients. For example, lightheadedness, anxiety, confusion, disorientation, tremors, dysarthria, and unsteady gait are early signs of toxicity for both benzodiazepines and lidocaine. Similarly, nausea and vomiting are often associated with antibiotics, benzodiazepines, and elevated lidocaine plasma concentrations.

If a patient has nausea and vomiting as well as the other signs just listed, true lidocaine toxicity might be suspected. Such a situation might justify an examination in an emergency room (ER) and obtaining plasma lidocaine levels. If the lidocaine levels are elevated, observation overnight in a hospital is appropriate.

I have encountered only one patient with true lidocaine toxicity. This obese female patient had a plasma lidocaine concentration of 6.1 mg/L after having received 58 mg/kg of tumescent lidocaine. She was also taking 200 mg of sertraline (Zoloft) daily for an anxiety disorder. Sertraline, as with other selective serotonin reuptake inhibitors (SSRIs), is a competitive inhibitor of CYP3A4, the same enzyme responsible for metabolic elimination of lidocaine. She was taken to a local ER 12 hours after completion of tumescent infiltration, complaining of nausea, vomiting, confusion, memory impairment, and anxiety (see Case Report 18-1).

MILD TOXICITY: CASE EXAMPLES

Virtually all patients who have tumescent anesthesia without sedation experience a mild degree of *somnolence*. Patients typically feel slightly sleepy when reclining and listening to quiet music. They often take a brief nap on returning home or to a hotel room. I estimate that a serum lidocaine concentration less than 1 mg/L (1 µg/ml) is sufficient to produce this subjective sleepiness.

Having treated more than 1000 tumescent liposuction patients with lidocaine doses in the range of 45 to 60 mg/kg without any serious lidocaine toxicity, I am confident that a

dosage of less than 50 mg/kg is safe. Careful questioning postoperatively, however, has revealed an apparent 1% to 2% incidence of mild, transient CNS effects in patients receiving tumescent lidocaine dosages of 50 to 60 mg/kg. Typically the symptoms are noticed within 8 to 16 hours after the infiltration of the tumescent anesthetic. Often the patients have just awakened from a nap when they first notice the symptoms.

Usually the symptoms are minimal, and patients do not bother to inform me by telephone. When I do receive telephone calls about these symptoms, they are typically mild but worrisome to the patient and always have been transient, lasting 1 to 4 hours. Mild nausea is occasionally described. Some patients describe a degree of mild dysarthria, mild confusion, and slight memory impairment.

For example, a patient might have difficulty pronouncing words or have a slightly unsteady gait, as if mildly drunk. One patient had difficulty remembering her telephone and apartment numbers. Another patient, who had taken no sedatives, experienced mild nausea and brief mild dysarthria approximately 8 hours after receiving 51 mg/kg of tumescent lidocaine. One surgeon inappropriately gave more than 70 mg/kg to a patient, who had a similar experience. The onset of symptoms occurred approximately 12 hours after surgery, on awakening from a nap. Serum lidocaine concentrations were not obtained.

On receiving a telephone call from a patient with these symptoms, the surgeon should take a careful history and perform a rapid evaluation. Patients may admit self-medication with a sedative or a codeine-type narcotic analgesic from a prescription written by another physician. One patient admitted taking a "bushel-full" of a health food store version of Ephedra (ephedrine) to "cleanse her system of the lidocaine."

The symptoms listed are known to occur with reactions associated with benzodiazepines or hydrocodone. For some patients the subjective symptoms have been consistent with a hyperventilation syndrome, with perioral and digital tingling and mild to moderate anxiety.

Once the mild nature of the complaint is determined, I speak to the patient by telephone every 1 to 2 hours or until the symptoms improve. I tell the patient that if the symptoms worsen, evaluation in a local ER will be necessary. The symptoms usually begin to improve noticeably within an hour or two. Having the patient drink fluids, relax in a semirecumbent position, watch television as a distraction, or breathe into a paper bag has been helpful.

Ten to 12 hours after tumescent infiltration of almost 60 mg/kg of lidocaine for liposuction, two of my patients awoke after a brief nap with disorientation, memory impairment, slightly slurred speech, and anxiety. They were sufficiently anxious to warrant more than a telephone evaluation. Plasma lidocaine levels, obtained as part of an ER examination, were 2.8 and 3.1 mg/L, well below the 6.0 mg/L threshold for lidocaine toxicity. These patients likely had much lower thresholds for subjective symptoms.

Subjective CNS toxicity is most likely to occur with relatively high doses of tumescent lidocaine. Serious conse-

quences have not been reported. Nevertheless, I rarely allow the lidocaine dosage to exceed 55 mg/kg.

TOXICOLOGY NOTE

It is theoretically impossible to define precisely the maximum safe dose of tumescent lidocaine. A scientific attempt to determine a maximum safe dose of tumescent lidocaine is, at best, a sophisticated process of biostatistical estimation (see Chapters 6 and 21).

As noted elsewhere, a proposal that a higher dosage limit for tumescent liposuction is safe is merely a clinical hypothesis. The surgeon who makes such a proposal has a strong ethical obligation to make a concerted statistical effort to disprove the hypothesis. Presenting an untested hypothesis as if it were an "established, scientifically validated fact" is unethical and dangerous.

In one report, 59.1 mg/kg resulted in a serum lidocaine concentration of 6.1 µg/ml (6 µg/ml = 6 mg/L).[13] In addition, I have been told of two fatalities in liposuction patients who were mistakenly given approximately 105 mg/kg. This information allows one to estimate the level at which toxic and fatal reactions to tumescent lidocaine might occur, 60 mg/kg and 105 mg/kg, respectively.

LOCAL ANESTHETIC ALLERGIC REACTIONS

In the late 1940s and early 1950s, procainamide (Novacaine), now procaine (Novocain), was virtually the only local anesthetic used in the United States. By 1960, lidocaine had become the most widely used local anesthetic because of its superior safety and efficacy and the exceedingly low incidence of allergy. Patients and some clinicians still tend to use "novacaine" as a generic term referring to all local anesthetics.

Procaine is an ester-type local anesthetic that is metabolized in the blood by plasma esterases. Lidocaine is an amide-type local anesthetic that is metabolized by CYP3A4. The general population has a 10% prevalence of allergy to procaine. True allergic reactions to lidocaine are extremely rare, but a history of allergy to any local anesthesia cannot be ignored.

Most patients are not aware of the distinction between *adverse* drug reaction and *allergic* drug reaction. Many dental patients and some dentists use the words "allergic reaction" to describe the alarming tachycardia that is a common sequela of a rapid systemic absorption of epinephrine after injection into the highly vascular buccal mucosa. They make no distinction between an allergic reaction and the predictable pharmacologic event following rapid systemic absorption of epinephrine. Questions during the preliposuction history generally provide enough information to distinguish between a potentially serious anaphylactic or anaphylactoid drug reaction and a benign pharmacologic response.

If a true adverse reaction to a local anesthetic cannot be excluded by the history, or if the patient insists that a reaction was truly allergic, the patient should be referred to a special-

ist for consultation, allergy testing, and a written report documenting the findings and recommendations.

Most "adverse" reactions to local anesthesia are not truly allergic but rather pharmacologic events, anxiety reactions, or vasovagal reactions (syncope). Chemically mediated reactions are most likely related to a preservative such as sodium bisulfite.[14] Preservative-free lidocaine without epinephrine is available in single-use ampules. Epinephrine, 1 mg/ml, containing no bisulfite and no preservatives, is commercially available in 1.0-ml ampules (American Regent Laboratories, Shirley, NY).

ADVERSE DRUG INTERACTIONS

Other local anesthetics have adverse interactions with lidocaine. The pharmacologic or toxic effects of lidocaine and any other local anesthetic are additive.[15] Lidocaine is displaced from plasma binding proteins by bupivacaine at therapeutic doses of each drug.[16]

Drug that share CYP3A4 as the important metabolic enzyme may have adverse interactions with lidocaine.

General anesthesia with halothane plus nitrous oxide causes an elevation in lidocaine plasma concentrations.[17] Systemic anesthesia can have two dangerous effects in the setting of tumescent liposuction, as follows:

1. General anesthesia can lower the maximum safe dose of lidocaine. Such a potentially dangerous drug interaction is likely to result from competition and inhibition of hepatic CYP3A4, as well as decreased hepatic blood flow.
2. General anesthesia can suppress lidocaine-induced seizures, which might otherwise act as premonitory signs of impending cardiac toxicity, including fatal cardiovascular collapse.

Sinus bradycardia was seen in a patient taking the oral antiarrhythmic drug *amiodarone* after being given lidocaine as local anesthesia. Amiodarone competes with lidocaine for binding to CYP3A4.[18] A seizure was reported in a patient given these drugs intravenously.[19]

Dilute bupivacaine and high-dose dilute epinephrine have been associated with a death during liposuction by local anesthesia in a patient taking *phentermine* (Fastin).

Cocaine and lidocaine interact adversely. In a rat study, the overall toxicity of cocaine was significantly increased with simultaneous exposure to lidocaine.[20] At doses of 30 or 40 mg/kg, intraperitoneal lidocaine does not induce seizures or death; the pharmacokinetic absorption characteristics of intraperitoneal injections are similar to IV injections. In animals receiving 35 mg/kg of cocaine alone, the incidence of seizure was 10%, with no deaths. With the addition of 30 and 40 mg/kg of lidocaine, the incidence of seizures increased to 50% and 80%, respectively, with death occurring in 30% and 60%.

At sufficiently high doses, *beta blockers* decrease cardiac output, thus decreasing hepatic blood flow and rate of lidocaine extraction by the liver. *Propranolol,* in moderate therapeutic doses, decreases the systemic clearance of lidocaine by up to 50%.[21,22] Many liposuction patients take beta blockers for treatment of hypertension or migraine headaches. To avoid preoperative hypertension or recurrent severe headaches, patients should continue these drugs during liposuction surgery. By reducing the maximum lidocaine dose to less than 40 mg/kg, no evidence of lidocaine toxicity has been reported during tumescent liposuction.

A study using rat liver microsomes showed that lidocaine 3-hydroxylation and propranolol ring hydroxylations are mediated by the same cytochrome P450 2D isoenzymes.[23]

Phenytoin and lidocaine have been reported to have additive cardiac depressant effects.[24]

Using high-dose lidocaine in patients with seizure disorders probably carries a risk of lowering the seizure threshold.

SURGEON-ANESTHESIOLOGIST COMMUNICATION

Lack of communication between anesthesiologist and surgeon has contributed to deaths of patients not being treated totally by local anesthesia. Both surgeon and anesthesiologist should be aware of the total parenteral (IV and subcutaneous) fluid dosage. If either clinician is unaware of the fluids administered to the patient by the other, a fluid overload is highly probable. Excessive parenteral isotonic fluids can result in hemodilution, leading to disseminated intravascular coagulation (DIC), pulmonary edema, and adult respiratory distress syndrome (ARDS).

Similarly, both the surgeon and the anesthesiologist should constantly know the exact mg/kg dosage of tumescent lidocaine that the patient has received; this is an *absolute* standard of care. A physician must be continually aware of the precise dosage of a potentially toxic anesthetic that is administered to a patient under the physician's supervision. This requirement demands compulsively accurate record keeping, using an efficient intraoperative anesthesia flow sheet that is specifically designed for tumescent anesthesia.

SURGICAL ORDERS AND FLOW SHEETS

I know of two superwet liposuction—related deaths resulting from pulmonary edema and lidocaine toxicity (see Chapter 9). In both cases, no explicit orders were written for lidocaine. Surgeons should know that local anesthetics are toxic and that explicit orders must be written before the preparation or mixture of parenteral medications.

Surgeons and anesthesiologists must be in complete agreement regarding the exact type and dosage of drug and fluids used during liposuction. Besides excessive volumes of liposuction, lack of knowledge about IV fluid toxicity, and careless surgical technique, the greatest risk of surgical mortality with the tumescent technique is lack of precise communication between the surgeon and staff.

The intended total mg/kg dosage of tumescent lidocaine must be written before preparation of the anesthetic solution. Surgeons, anesthesiologists, and OR staff are not accus-

tomed to written orders for local anesthesia, but written orders are an *absolute necessity* for safe tumescent anesthesia. The OR staff should be instructed not to mix any tumescent anesthesia unless explicit written orders have been completed by the surgeon (Box 20-1).

The orders must specify the following:
1. Patient's weight in kilograms
2. Maximum allowable total mg/kg dosage of lidocaine individualized for patient
3. Total milligrams of lidocaine and epinephrine in each liter bag of solution
4. Milliequivalents of sodium bicarbonate in each liter of physiologic saline

The surgeon and staff are responsible for documenting the *true* dose of lidocaine and epinephrine that the patient *actually* has received. This is accomplished by means of a special intraoperative anesthesia flow sheet, which all surgeons performing tumescent techniques are encouraged to use (Box 20-2).

TREATMENT OF LIDOCAINE OVERDOSE

As discussed, human error is the most likely cause of lidocaine overdose and serious toxicity. The goal is to minimize the possibility of error through training of staff and fastidious written policies and procedures; for example, staff should have Advanced Cardiac Life Support (ACLS) training. The person responsible for preparing the tumescent anesthetic solution should be specifically trained in the proper procedure of following written orders specified in terms of "mg of lidocaine per liter of solution." Also, 2% lidocaine should be either eliminated from inventory or stored separately from the lidocaine used for tumescent anesthetic solutions.

If there is a significant risk that a toxic overdose has been given, the patient should not be managed in an outpatient facility. Appropriate clinical observation in an ICU, with cardiac monitoring, secure IV access, and oxygen supplementation, is necessary with a suspected or a recognized overdose of tumescent lidocaine.

A patient who has received too much lidocaine should not be treated for a seizure before it occurs. For example, preemptive treatment with a benzodiazepine such as diazepam may actually impair lidocaine metabolism by inhibiting CYP3A4, thereby increasing the risk of a seizure. By impairing ventilation, benzodiazepines can also increase the risk of seizures. The most prudent approach is to observe the patient closely in the ICU for a potential seizure. Plasma lidocaine concentrations should be obtained every 4 to 6 hours. The patient should be discharged only after two consecutive levels indicate that (1) the peak concentration has been achieved and (2) the subsequent levels are definitely on a downward course.

When a serious lidocaine toxicity is encountered, the principal therapeutic intervention is treating seizures and maintaining adequate ventilation and oxygenation. Treatment with oxygen alone is insufficient to prevent hypoventilation and respiratory acidosis. Good ventilation and protection of the airway are crucial. After initial administration of oxygen by mask, maintaining a patent airway may require endotracheal intubation.

When a lidocaine seizure does occur, the two most important aspects of treatment involve the following:
1. Ensuring adequate ventilation and protecting the airway
2. Treating the seizure with IV antiseizure medications (e.g., midazolam, diazepam, propofol) or an ultrashort-acting barbiturate (e.g., thiopental)

Treatment of hypotension may require IV fluids, a vasopressor drug such as dopamine, or another appropriate sympathomimetic agent. Dialysis is of no significant benefit for overdoses with amide-type local anesthetic agents.

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Maximum Recommended Dosage of Tumescent Lidocaine

This chapter examines the process of estimating the maximum safe dosage of tumescent lidocaine for liposuction. A pragmatic estimate is proposed, followed by review of previously published attempts to define the maximum recommended dose. The chapter examines how pharmaceutical companies and governmental regulatory agencies have determined the maximum safe dose of local anesthetics, then discusses the political aspects of changing the official U.S. Food and Drug Administration (FDA) recommendations.

DOSE-TOXICITY RELATIONSHIP

As noted in earlier chapters, determining the risk of lidocaine toxicity as a function of the dosage of tumescent lidocaine is not a simple task. For humans it is known that the higher the lidocaine concentration in the blood, the greater the incidence of toxicity. Without human experimentation, however, coefficients for a mathematic model cannot be accurately estimated.

Thus, at present, the precise relationship between plasma lidocaine concentration and lidocaine toxicity in humans is not well defined. The little knowledge available is based on clinical anecdotes, not objective clinical experimentation. From using intravenous (IV) lidocaine to treat patients with ventricular arrhythmias (dysrhythmias) and neuropathic pain, however, plasma lidocaine concentrations that exceed 5 to 6 $\mu g/ml$ are probably outside the therapeutic range and approach the realm of toxicity.

An unknown percentage of patients with plasma lidocaine concentrations in the range of 2 to 6 $\mu g/ml$ experience minor unpleasant pharmacologic effects that may be subjective or objective (see Chapter 20). Subjective symptoms include lightheadedness, perioral numbness or paresthesias, and nausea; objective symptoms include confusion, dysarthria, ataxia, shivering, muscle twitching, and vomiting. Lidocaine is not always responsible for these symptoms. Other causes of nausea and vomiting include perioperative medications (e.g., benzodiazepines, narcotic analgesics, antibiotics) and self-medication with prescription or nonprescription drugs. Finally, simple anxiety reactions (e.g., hyperventilation, vasovagal episodes) may account for some cases of mild, early toxicity.

Attempting to define the dose-toxicity relationship for lidocaine based on formal clinical research with significant statistical accuracy would involve an unreasonably large number of "experimental" subjects. In general, however, the *probability* of lidocaine toxicity is a function of the plasma lidocaine concentration, which is a function of the dosage of tumescent lidocaine, its rate of absorption, and the apparent volume of distribution. Because of the complexity of this relationship, the required number of patients needed to ensure statistical significance is difficult to determine.

PRAGMATIC ESTIMATE

A pragmatic determination of the safe maximum dose of tumescent lidocaine requires extensive clinical experience, sound clinical judgment, and enlightened disregard for statistical analysis.

Although the hepatic extraction of lidocaine is high, approximately 70% in a healthy young adult, significant variability can exist in hepatic lidocaine metabolism. Thus predicting the risk of toxicity is unusually complex. Any group of patients has the usual random variability. More impor-

tantly, significant variability also occurs over time within any one patient because of possible drug interactions that alter lidocaine metabolism. Patients are prescribed drugs by other physicians, and patients take drugs without informing their liposuction surgeon. If a drug interaction or disease produces a 50% decrease in the rate of lidocaine metabolism, the peak plasma lidocaine concentration will double. Any estimate of the maximum safe dosage of tumescent lidocaine must consider this clinical fact.

The accuracy of statistical estimation using a random sample technique depends on the size of the sample. In turn, the required size of the sample depends on the population variance of the random variable in question. Because the variance of plasma lidocaine concentration among tumescent liposuction patients is so large, the size of a random sample required to estimate accurately the safe maximum dosage of lidocaine is prohibitively large. No clinical study will probably ever satisfy all the requirements for rigorous quantitative statistical analysis of maximum safe lidocaine dosages for tumescent liposuction.

ETHICAL ISSUES

Defining a safe maximum dose of tumescent lidocaine requires a philosophic (ethical) decision regarding how much safety is desired. One must ask, "What is an acceptable incidence of lidocaine-induced cardiac toxicity that is ethically acceptable?" Clearly a dose that yields one severe cardiac dysrhythmia in every 100 patients or even every 1000 patients is too dangerous. For some, one cardiac emergency or serious toxic event in every 10,000 patients is unacceptable. Is one lidocaine-induced cardiac arrest in every 100,000 patients acceptable? I believe that the "safety" threshold should be one per million.

The choice of the "safe maximum recommended dose" for lidocaine is arbitrary; it relies on subjective medical ethics and objective clinical pharmacology (see Chapter 3).

SENTINEL CASES

For the pragmatist, finding a reasonably safe dose of lidocaine for tumescent liposuction must involve caution and common sense as well as objective statistical logic. Sentinel cases of toxicity are an important consideration.

For example, at least two liposuction-related deaths have occurred in patients who received general anesthesia and lidocaine doses of 95 and 105 mg/kg. Also, a surgeon who used general anesthesia reported that more than 70% of his tumescent liposuction patients experienced nausea and vomiting after lidocaine doses of 80 mg/kg. Another surgeon reported that 30% of patients had nausea and vomiting at average doses of 70 mg/kg.

In my experience, approximately 0.5% of patients have nausea or vomiting at doses less than 50 mg/kg, with at least a 5% incidence at doses of 55 to 60 mg/kg.

From this information, one can expect that the maximum safe dose of tumescent lidocaine is in the range of 50 to 55 mg/kg. For example, in a 70-kg (154-pound) patient, a 50 mg/kg dose would be 3500 mg of lidocaine. Using a 1-g/L (0.1%) tumescent solution, this patient would receive 3.5 L subcutaneously.

Margin of Safety. Lidocaine dosages should not be increased to greater and greater levels merely for convenience and economic efficiency. Safety must outweigh convenience. No fine line divides safe and unsafe maximum dosages of tumescent lidocaine. Equivalent doses in different patients will produce different maximum concentrations of lidocaine in the blood. Because of the imprecise, nondeterministic nature of this situation, a wide margin of safety is necessary.

Case Examples. After 45 mg/kg of tumescent lidocaine, a patient had a peak lidocaine blood level of 3.5 μg/ml and experienced nausea and dysarthria. Another patient received 75 mg/kg with a lidocaine blood level of 2.8 μg/ml and had an uneventful postoperative course. Still another patient received 59.1 mg/kg with a lidocaine blood level of 6.1 μg/ml and had associated nausea and vomiting as well as mild disorientation, resulting from an adverse drug interaction with sertraline (Zoloft).

An 86-kg (190-pound) male received 90 mg/kg of lidocaine by mistake when a nurse used 2% lidocaine instead of 1% lidocaine when mixing 100 ml of lidocaine into 1000 ml of normal saline. Liposuction of the abdomen and flanks was completed without incident. When the mistake was discovered, the patient was admitted for overnight observation. The plasma lidocaine concentration was 2.9 μg/ml at 12 hours and 2.4 μg/ml at 26 hours from when tumescent infiltration was initiated. The patient had no subjective or objective signs of toxicity at any time.

These examples demonstrate that toxicity is not predictable. Variable factors are involved, many of which are not well understood.

Dosage Ranges. Clearly, the traditional dosage limitation of 7 mg/kg for lidocaine with epinephrine at out-of-the-bottle commercial concentrations is far below a reasonable safety limit for very dilute tumescent lidocaine for liposuction. My experience with tumescent liposuction totally by local anesthesia using very dilute lidocaine (approximately 1 g/L = 0.1%) has shown that 35 mg/kg is very safe.

A tumescent lidocaine dosage in the range of 45 to 50 mg/kg is now widely regarded as "safe." Physicians should strive to keep the dosage below 50 mg/kg. In my opinion a dosage greater than 55 mg/kg is associated with a risk of mild but definite lidocaine toxicity.

MEGADOSAGES

As discussed earlier, an obvious conflict of interest exists when a surgeon uses a dose of tumescent lidocaine that exceeds 55 mg/kg merely as a matter of convenience "for the patient"; it is also convenient for the surgeon. If a patient is not

informed that controversy surrounds the safety of such high doses, informed consent might be lacking.

Current ethical standards require that the nonstandard use of huge dosages of a toxic drug be considered experimental. In any experimental trial using potentially toxic doses of a drug such as lidocaine, ethical standards of care require that every human subject (1) sign informed consent before participation, (2) receive intensive postoperative clinical observation, and (3) have sequential determinations of plasma lidocaine concentrations every 4 to 6 hours for at least 24 hours immediately after surgery.

Liposuction surgeons with no practical concept of the pharmacologic definition of safety may use titanic doses of tumescent lidocaine ranging from 70 to 100 mg/kg. One surgeon found that at least 30% of patients given comparable doses of lidocaine experienced nausea or vomiting. These signs of toxicity were attributed to the effects of codeine, antibiotics, or vasovagal events.

Megadoses of a potentially toxic drug such as lidocaine should not be used without the backing of peer-reviewed scientific literature and without approval of a human studies research committee.

The safety of megadosages of lidocaine cannot be proved based on the experience of clinicians who do not personally monitor their patients for 24 hours after liposuction. Anecdotal statements (e.g., "We have treated 50 patients with 70 to 100 mg/kg of lidocaine without any significant complication, and we conclude that 80 mg/kg is safe") are merely conjectures without objective validation. Such "studies" only permit the conclusion, "We believe that the risk of death is less than 1 in 10, or 1 in 20," or, "Whatever toxic effects might have occurred, either we did not notice them or we did not consider them to be significant complications." One cannot conclude that the risk of death is less than 1 in 100 (Case Report 21-1).

It is known that 60 mg/kg of tumescent lidocaine can produce unpleasant gastrointestinal toxicity and objective neurologic symptoms in patients taking drugs that impair the hepatic metabolism of lidocaine.

CASE REPORT 21-1 Lidocaine-Associated Death

A liposuction-related death occurred after a lidocaine dose of 105 mg/kg together with general anesthesia and significant IV fluid supplementation. The coroner found pulmonary edema and a serum lidocaine level of 14 µg/mg. The circulating nurse misinterpreted the surgeon's verbal order for 35 mg/kg of tumescent lidocaine and mixed the anesthetic solution, documenting a dose of 105 mg/kg.

Discussion. A tumescent lidocaine dosage greater than 60 mg/kg is perilous. At this stage of knowledge, I must conclude that a tumescent lidocaine dose of 100 mg/kg or greater is possibly negligent.

EARLY REPORTS AND RECENT STUDIES

FIRST TUMESCENT REPORT

The first description of tumescent liposuction reported the results of treating 26 patients (22 female, four male) with a mean lidocaine dosage of 18.4 mg/kg.[2] The mean serum lidocaine concentration 1 hour after liposuction and 2 hours after infiltration was 0.34 µg/ml, with the highest measured concentration 0.61 µg/ml. This clinical study provided the first documentation that doses of tumescent lidocaine (approximately 0.1% or less) could exceed the traditional dosage limitation of 7 mg/kg by at least three times without clinical evidence of toxicity.

Two subsequent publications also reported that dosages exceeding 7 mg/kg produced low peak plasma lidocaine concentrations. These reports were based on the assumption that peak lidocaine levels are achieved within 1 or 2 hours after subcutaneous infiltration. In 1988 Lillis[3] observed that patients exhibited no signs of toxicity after tumescent lidocaine doses as high as 60 to 90 mg/kg. Since then, surgeons have administered similar doses of tumescent lidocaine. Some of these surgeons, on observing the remarkably high incidence of nausea and vomiting in their patients, attributed the symptoms to postoperative narcotic analgesics.

A 1989 study reported using general anesthesia plus a relatively high concentration of subcutaneous lidocaine (2500 mg/L = 0.25%) and epinephrine (2.5 mg/L = 1:400,000). Six patients received lidocaine dosages ranging from 9.1 to 13.8 mg/kg.[4] Blood samples obtained during the first 3 hours after injection revealed peak plasma concentrations of 0.5 to 0.8 µg/ml.

These values of maximum plasma lidocaine concentrations were probably incorrect. The true peak concentration most likely occurred several hours after the last blood sample was drawn. Before 1990, all the literature assumed that peak lidocaine levels occur within 60 to 120 minutes after a subcutaneous injection. By 1990, researchers realized that a subcutaneous infiltration of dilute lidocaine with epinephrine could produce a peak plasma lidocaine concentration 8 to 14 hours after injection.

THE 35-MG/KG ESTIMATE

The first reasonable estimate of the maximum safe dose of tumescent lidocaine was 35 mg/kg and was published in 1990 in the *Journal of Dermatologic Surgery and Oncology*.[5] The dosage of dilute lidocaine at concentrations of 500 mg/L (0.05%) to 1000 mg/L (0.1%) with dilute epinephrine at (1 mg/L = 1:1 million) ranged from 11.9 to 34.1 mg/kg, with associated peak plasma lidocaine concentrations that ranged from 0.8 to 2.7 µg/ml. This report also showed for the first time that peak plasma lidocaine concentration (C_{max}) for tumescent lidocaine is achieved 12 to 14 hours after initiation of infiltration.

All pretense of statistical analysis was avoided. The method of estimation relied on unsophisticated, simple common sense.

The comfort of a liposuction patient under tumescent local anesthesia and the safety of tumescent hemostasis are so obvious that a formal statistical analysis is unnecessary.

Estimation Process. The 35-mg/kg estimate was derived as follows. First, plasma lidocaine concentrations were repeatedly measured in sequential fashion over more than 24 hours in eight different patients. Five of these patients participated in at least two of these 24-hour studies. In four patients, sequential concentrations were measured on two different days more than a week apart, first without liposuction, then with liposuction after infiltration. This allowed evaluation of liposuction's effect on C_{max}. After plotting the data points on a *concentration-versus-time* graph, a smooth curve was drawn through the points, and the apparent C_{max} was determined by visual assessment (Figure 21-1).

The second step involved plotting a graph of C_{max} *versus-mg/kg dosage* that showed the scatter of data points similar to that seen with a linear regression plot. The corresponding regression line, however, was not determined. A linear regression plot is a graph of the expected value of the dependent variable $Y =$ [peak plasma lidocaine concentration] plotted against the value of the independent variable $X =$ [mg/kg dosage of lidocaine]. Instead, visual "best-fit" line was drawn so that all the data points were below the safety line (Figure 21-2).

Extrapolation extended this safety line to intersect the point corresponding to 6 μg/ml and 50 mg/kg. Thus this subjective analysis suggested that any dosage less than 50 mg/kg of tumescent lidocaine, with or without liposuction, would be expected to produce a plasma lidocaine concentration less than 6 μg/ml, the accepted threshold for significant lidocaine toxicity.
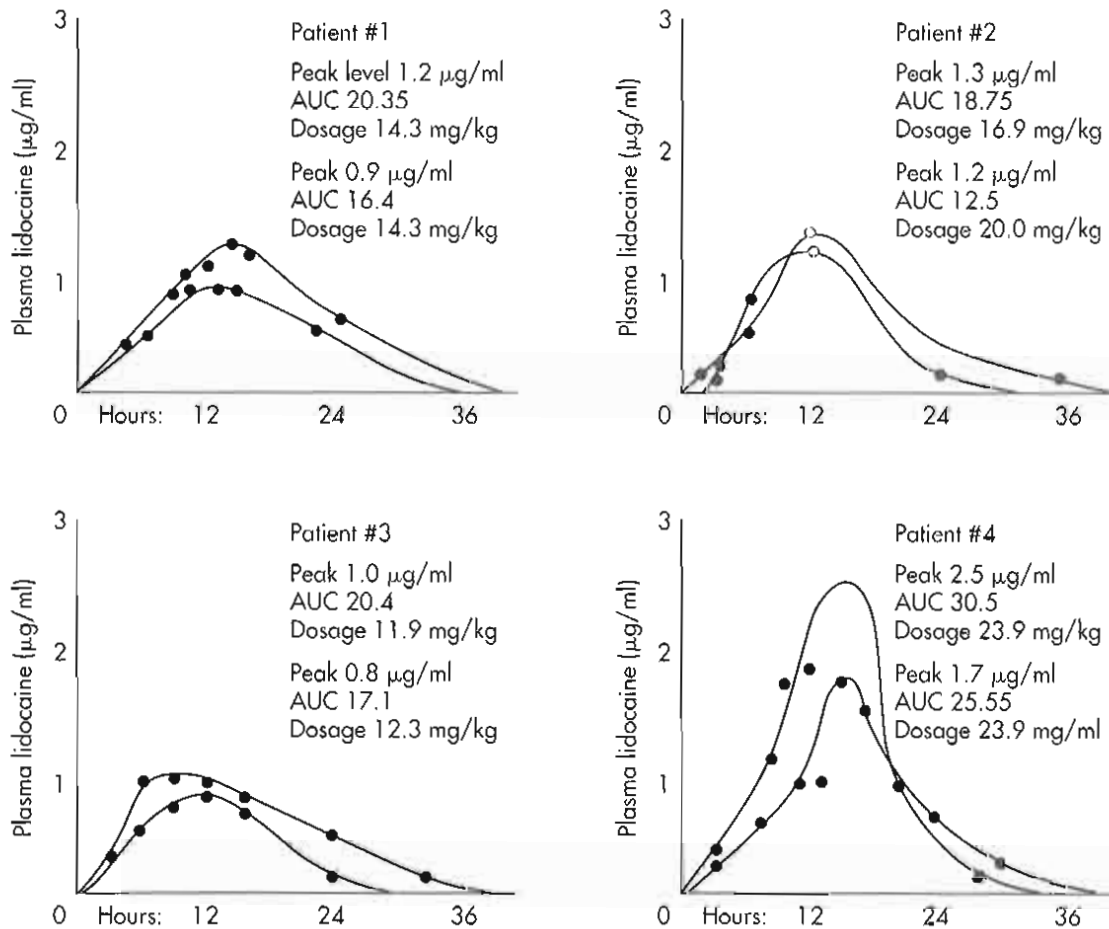
Figure 21-1

Plasma lidocaine levels over time. Area under the curve (AUC) of each group represents total amount of lidocaine systemically absorbed after infiltration into subcutaneous fat using tumescent technique. In each case, curve with larger AUC represents lidocaine absorption as a function of time without liposuction done after infiltration. Curve with smaller AUC documents lidocaine absorption when liposuction was performed immediately after completing infiltration. Liposuction reduced both average amount of lidocaine absorbed systemically and peak plasma lidocaine concentrations to a similar degree. (From Klein J: *J Dermatol Surg Oncol* 16:248-263, 1990.)
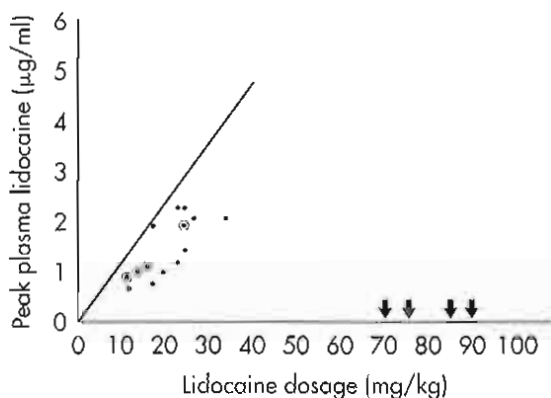
Figure 21-2

Maximum recommended dose of lidocaine is estimated under assumption that peak plasma lidocaine concentration is a linear function of mg/kg dosage of tumescent lidocaine. One data set (○) represents peak plasma lidocaine concentrations when liposuction was not done, whereas other data set (●) consists of peak levels when liposuction was completed immediately after infiltration of local anesthetic solution. Conservative estimate of maximal safe dosage of dilute lidocaine infiltrated into subcutaneous fat is 35 mg/kg. Lillis has reported using much higher dosages (arrows) followed by liposuction without serious toxicity. (From Klein J: *J Dermatol Surg Oncol* 16:248-263, 1990.)

Extending Safety Margin. Even this estimate, however, needed a greater margin for safety. The process of estimating the maximum safe dosage of tumescent lidocaine must account for the worst-case scenario where infiltration cannot be followed by liposuction, for example, because of equipment failure, an acute patient problem, or incapacitation of the surgeon. Liposuction seems to reduce the bioavailability of tumescent lidocaine by 15% to 25%.

Thus the estimate of the maximum safe dosage was cautiously reduced by 30%, from 50 to 35 mg/kg. For this reason, 35 mg/kg was chosen as the first published estimate of a maximum safe dosage for tumescent (very dilute) lidocaine. This dosage was recommended rather than 50 mg/kg.

Subsequent clinical experience has proved the safety of the 35-mg/kg estimate. In fact, 50 mg/kg for tumescent liposuction is probably a more realistic estimate of a maximum safe dosage of tumescent lidocaine, and it is the threshold that I currently recommend. Results of future clinical experiments may justify higher doses, but at present such data do not exist.

When surgery might require more than 50 to 55 mg/kg of lidocaine, either (1) the concentration of lidocaine in the bags of anesthetic solution should be reduced, or (2) the procedures should be divided into two liposuction surgeries, separated by at least 72 hours and preferably 1 month or more.

Lidocaine Metabolism. If a patient is taking a drug that might interfere with the hepatic microsomal enzyme cytochrome P450 3A4 (CYP3A4), which is responsible for the metabolism of lidocaine, the maximum safe dosage of lidocaine must be reduced from 50 mg/kg to less than 35 mg/kg. Preferably, all drugs that inhibit CYP3A4 can be discontinued 1 or 2 weeks before surgery. Unfortunately, although many drugs are known to be metabolized by CYP3A4, surgeons usually do not know which one produces significant inhibition of lidocaine metabolism. This unknown aspect of potential drug interactions between lidocaine and other drugs metabolized by CYP3A4 demands caution when estimating a maximum recommended dosage of tumescent lidocaine.

SPECIFIC TUMESCENT DOSAGES

Surgeons other than dermatologists took serious notice of the tumescent technique after a November 1993 article in the journal *Plastic and Reconstructive Surgery*.[6]

In the 112 patients, all of whom had liposuction of more than 1500 ml of supranatant fat totally by local anesthesia, the mean lidocaine dosage was 33.3 mg/kg (range 11 to 52.1 mg/kg), and the mean volume of supranatant fat was 1945 ml (range 1500 to 3400 ml). For each 1000 ml of fat removed, 9.7 ml of whole blood was aspirated. Patients had no clinical evidence of lidocaine or epinephrine toxicity and no surgical complications.

One 75-kg (165-pound) patient received 35 mg/kg of lidocaine on two separate occasions, first without liposuction, then 25 days later with liposuction. Peak plasma lidocaine concentrations occurred at 14 and 11 hours after beginning the infiltration and were 2.37 and 1.86 µg/ml, respectively (see Chapter 19).[6]

Liposuction removes a portion of the tumescent lidocaine before it can be absorbed into the systemic circulation. This reduces the bioavailability of tumescent lidocaine and results in a lower C_{max}. At the time this study was conducted, sutures were placed in all incision sites.[6] If the incisions had been left open without sutures to encourage postoperative drainage of the blood-tinged anesthetic solution, C_{max} might have been even less than 1.86 µg/ml.

This article also presented evidence that the tumescent technique for liposuction totally by local anesthesia does not require IV fluid supplementation.[6] The volume of tumescent subcutaneous infiltration is sufficient to produce more than 24 hours of hemodilution, with decreased urine specific gravity. As a corollary, IV fluids are usually unnecessary except with an excessive volume of liposuction. Gratuitous IV fluids may precipitate systemic fluid overload and pulmonary edema.

Most surgeons have begun to use the tumescent technique because of its unprecedented hemostasis. On the other hand, many of these same surgeons have not used tumescent local anesthesia to eliminate general anesthesia. Although most surgeons have perceived the tumescent technique as an opportunity to maximize safety by reducing surgical blood loss, a few have used the technique inappropriately to maximize the volume of fat removed during a single surgery.

Anesthesiology. In 1995 a report of brachial plexus blocks with lidocaine (1% to 2%) and epinephrine appeared

in the anesthesiology literature.[7] The authors attempted to evaluate the accuracy of the standard maximum recommended dosage of lidocaine (7 mg/kg) for local anesthesia. The study of 17 patients found that peak plasma lidocaine concentrations occurred at 45 to 60 minutes after injection. The highest plasma lidocaine concentration was 5.6 μg/ml 30 minutes after a dosage of 18 mg/kg of lidocaine.

The authors concluded, "In brachial plexus block, the dose of lignocaine with adrenaline [lidocaine with epinephrine] can be as high as 900 mg without fear of toxic symptoms."[7] They thought the maximum recommended dose of lignocaine should be reevaluated.

Confirmatory Study. In 1994, Samdal et al[8] studied 12 liposuction patients who received 10.5 to 34.4 mg/kg of tumescent lidocaine (1 g/L = 0.1%) and epinephrine (1 mg/L = 1:1 million). The observed peak plasma lidocaine concentrations ranged from 0.9 to 3.6 μg/ml. The experimental design included a sufficient number of plasma samples (taken at 1, 2, 3, 6, 8, 10, 12, 14, 18, and 24 hours) to permit an accurate estimate of C_{max}.

The authors used linear regression analysis to derive a 95% confidence interval for an expected C_{max}, estimated to be 4 μg/ml at a dosage of 35 mg/kg. Linear regression can be used to estimate C_{max}, but the "expected C_{max}" cannot be regarded as being equivalent to maximum recommended (safe) dosage for tumescent lidocaine. The authors avoided any claim that their expected C_{max} was an estimate of the recommended dosage.[8] The appearance of a linear relationship between lidocaine dosage (mg/kg) and C_{max} does not logically justify using linear correlation to establish a maximum safe dosage of tumescent lidocaine.

LINEAR REGRESSION

Misconception About Use. Several studies have used linear regression analysis inappropriately to define the maximum safe dosage of tumescent lidocaine. They provide much useful information, however, and have confirmed the clinical impression that the maximum safe dosage for tumescent lidocaine is 50 mg/kg. The section discusses some of the difficulties in designing a rigorous statistical analysis of this complex clinical situation.

Lidocaine toxicology assumes that high mg/kg dosages of lidocaine are correlated with high plasma lidocaine concentrations, which in turn are correlated with an increased probability of lidocaine toxicity. The goal of tumescent clinical pharmacology is to find a reasonable mathematic model that, given any dosage of lidocaine, will predict the plasma lidocaine concentration.

Linear regression is not the best mathematic model for predicting C_{max} as a function of mg/kg lidocaine dosage. Linear regression is often used incorrectly when predicting maximum safe dosages.

Simple linear regression is a statistical procedure that allows one to summarize the relationship between Y (the dependent variable) and X (the independent variable): $Y = a + bX$. Simple linear regression allows predictions of Y (average

C_{max}) for any given X (specified mg/kg dosage of lidocaine). This application of linear regression, however, provides neither direct information about the probability of tumescent lidocaine toxicity nor an estimate of a maximum safe dosage of lidocaine.

Linear regression is an inappropriate method for estimating the maximum safe dosage of lidocaine for tumescent liposuction for two major reasons. First, linear regression uses a least-square estimation to define a line $Y = a + bX$, which passes through the middle of the data, thus giving information about the "average" predictable C_{max} for any given mg/kg dosage. Any line that predicts the maximum safe dosage, however, should pass above *all* the data points; this line is not derived by least-squares linear regression. Although an obvious linear relationship exists between mg/kg lidocaine dosage and C_{max} for lidocaine, it does not validate the use of linear regression to estimate a "safe" dosage of lidocaine.

Second, one cannot assume that lidocaine toxicity (as a function of mg/kg lidocaine dosage) is approximated by a normal distribution. A basic assumption of linear regression is that the dependent variable in question is normally distributed. As noted, toxicity is a function of C_{max}, which in turn is a function of mg/kg dosage. With so many unpredictable outcomes (e.g., unknown drug interactions) and large statistical outliers among liposuction patients, however, one cannot assume that they all will conform to a gaussian (normal) distribution. The unpredictable patient who manifests extreme deviation from the gaussian distribution disqualifies linear regression as a statistical tool to estimate a maximum safe dose of lidocaine.

From a biostatistical point of view, it is impossible to give an exact and definite "safe" dose limit for any drug. At best, one can only hope to determine an *estimate* of a safe dose, together with an appropriately narrow confidence interval.

Misinterpretation of Results. In a 1996 study of 10 patients, Ostad et al[9] concluded that tumescent anesthesia with a total lidocaine dose of up to 55 mg/kg is safe for use in liposuction. This approximates the 50 mg/kg that I consider a maximum recommended dosage of tumescent lidocaine for liposuction.

After each of 10 patients received different lidocaine dosages, linear regression was used to determine that 55 mg/kg was the average dosage. A sample size of 10 is too small to permit any reliable estimate of the true variance of the plasma lidocaine concentrations at doses of 55 mg/kg.

More importantly, the authors found a significant linear correlation between total lidocaine *dose* (total mg) and C_{max} but found no correlation between mg/kg lidocaine *dosage* and C_{max}. They should have stated the maximum safe dose of lidocaine in terms of total milligrams but concluded, "Tumescent anesthesia with a lidocaine dose of 55 mg/kg is safe for liposuction." This assumes that the total mg/kg dose of lidocaine is correlated with toxicity. The scientific basis of therapeutics relies on the observation that pharmacologic effect is a function of mg/kg dosage and not total mg dose.

This study assumes that a low lidocaine concentration in the infranatant solution implies that liposuction does not remove significant amounts of lidocaine, which in turn implies that liposuction does not reduce the C_{max} of lidocaine. In fact, because of lidocaine lipophilicity, one would expect lidocaine in the supranatant fat, where much of it is rapidly partitioned after infiltration. This is consistent with the observation that liposuction reduces the area under the curve (AUC) of plasma lidocaine concentration versus time (see Chapter 19).

Liposuction reduces the amount of lidocaine that enters the systemic circulation (reduces bioavailability). Therefore liposuction provides an extra margin of safety. Any estimate of a safe dosage of lidocaine must account for the unlikely situation where the surgery must be canceled after the infiltration has been completed and before liposuction surgery has started. The authors' 55-mg/kg estimate does not explicitly account for this possibility.

Although the authors' perceptive clinical insight and good judgment have shown that a reasonable estimate of the maximum safe dosage for tumescent lidocaine is 50 to 55 mg/kg, their statistical analysis did not *prove* it.

Weak Assumptions and Heteroscedasticity.   In linear regression analysis the term *heteroscedasticity* describes the unequal scatter or variation in the variance of the dependent variable Y as a function of the independent variable X. In other words, the variance of C_{max} is unequal at different mg/kg dosages of lidocaine; the confidence interval about any estimate of Y may vary as a function of the value of X. Elementary linear regression analysis requires relatively large numbers of observations to derive any reliable information about the heteroscedasticity of the variable in question.

As an alternative to linear regression, one might choose a fixed dosage and then determine the frequency of toxicity at that dosage. This would allow a much more accurate estimate of the variance of lidocaine concentration at the fixed dosage. This approach is encumbered by the difficulty of giving a unique mg/kg dosage of tumescent lidocaine to different liposuction patients.

In 1996, Pitman et al[10] reported 32 tumescent liposuction patients treated with general anesthesia and tumescent lidocaine at a dilution of 1 g/L (0.1%), with epinephrine at 1 mg/L. This is the most patients to have plasma lidocaine determinations reported in a study. The mean lidocaine dosage was 42.2 mg/kg (range 15.2 to 63.8 mg/kg). The greatest plasma lidocaine concentration was 4.2 μg/ml, in a patient who had received 60.2 mg/kg of tumescent lidocaine. The authors measured plasma lidocaine concentration only at 12 hours after infiltration, assuming the peak level would occur about this time.

Using linear regression analysis, they concluded that 50 mg/kg of lidocaine for tumescent liposuction would produce a peak plasma lidocaine concentration of 2.8 μg/ml ± 0.9 μg/ml SE (standard error of mean) with a 95% confidence interval.[11] In other words, assuming that the response variable $Y = a + bX$ has a normal distribution, a probability of 0.95 exists that the true value of Y (50 mg/kg) will be within the following interval:

$$(2.8 \text{ μg/ml} - 1.96 \text{ SE}, 2.8 \text{ μg/ml} + 1.96 \text{ SE})$$
$$= [(2.8 - 1.8) \text{ μg/ml}, (2.8 + 1.8 \text{ μg/ml})]$$
$$= (1 \text{ μg/ml}, 4.6 \text{ μg/ml})$$

X is the dosage of tumescent lidocaine expressed in mg/kg, and Y is the corresponding plasma concentration of lidocaine expressed in μg/ml. In other words, with 95% confidence, one can expect that 50 mg/kg of lidocaine for tumescent liposuction will result in 2.5 of every 100 patients having a plasma lidocaine concentration at 12 hours after infiltration that is greater than 2.8 + (1.96 × 0.9)   4.6 μg/ml. Also, 2.5 patients will have a plasma lidocaine concentration less than 1 μg/ml.

By the same properties of normal distribution, a 99.73% probability exists that the true value of Y will lie within the following interval:

$$(2.8 - 3 \text{ SE}, 2.8 + 3 \text{ SE}) = (0.1 \text{ μg/ml}, 5.5 \text{ μg/ml})$$

This is equivalent to the expectation that 1 in 800 patients who receive 50 mg/kg will have a plasma lidocaine level in excess of 5.5 μg/ml.

The statistical design of this study assumes that the peak plasma lidocaine concentration (T_{max}) always occurs at 12 hours. The experimental design did not allow for the possibility of an average T_{max} of 9 hours. For example, the true average C_{max} might have occurred at 9 hours and was 3.4 ± 1.4 μg/ml. In this hypothetical case, the 95% confidence interval for estimated C_{max} would be 0.6 μg/ml, 6.0 μg/ml.

The statistical analysis assumes that SE is correct with no heteroscedasticity. With the small sample size, however, variance of Y (plasma lidocaine concentration) cannot be assumed to equal scatter or variances at different X (dosages of tumescent lidocaine).

Furthermore, the analysis does not account for the probability of adverse drug interactions. In essence, the experimental design and statistical analysis relied on implausible assumptions, and the sample size was too small to define a reliable, useful estimate of the maximum safe dose of tumescent lidocaine. Nevertheless, this study's conclusions probably are correct and correspond to the clinical experience of hundreds of surgeons with thousands of patients. This is another example of the superiority of good clinical judgment over elementary statistical analysis.

LIDOCAINE FOR BREAST AUGMENTATION

A 1999 study reported the plasma lidocaine concentrations associated with the use of local anesthesia plus systemic anesthesia for breast augmentation in 10 healthy women.[12] Lidocaine at concentrations of 2 g/L (0.2%) and 5 g/L (0.5%) with epinephrine was injected into the tissue space between the pectoralis muscle and the mammary gland. Dosages of lido-

caine ranged from 16.3 to 21.9 mg/kg (mean 18.2 mg/kg), C_{max} from 0.96 to 3.12 µg/ml (mean 1.49 µg/ml), and T_{max} from 4 to 12 hours (mean 7.3 hours). The length of time during which the dose was injected was not specified. Five patients received general anesthesia; the other five patients were given IV sedation (diazepam and fentanyl), with no apparent differences in C_{max} between the two groups.

The authors correctly avoid any assertion that a specific lidocaine dosage is safe: "These data indicate that a dose of 20 mg/kg of lidocaine with epinephrine is probably safe in breast augmentation when the drug is administered as described in this study."[12]

Statistical Outlier.   In this study a single statistical outlier confounded the rote statistical analysis. It exemplifies the maxim that *statistical significance is not the same as clinical significance*. Although a statistical analysis of a small sample of 10 patients is of dubious significance, presence of this "aberrant" individual illustrates an important principle of predicting drug toxicity. The clinician must always assume a large deviation from the mean in a patient who is far more susceptible to an adverse drug reaction than the average patient.

An estimate of a safe maximum dose for a drug must always assume that the patient population is not homogeneous. Certain individuals defy the common assumption that biologic phenomena have a normal probability density function (gaussian frequency distribution). In other words, an estimate of a *safe* maximum *dose* of lidocaine should not be exclusively based on linear regression, which assumes a normal probability density function.

Lidocaine Absorption.   In this study the graphs depicting lidocaine concentration as a function of time demonstrate that subcutaneous infiltration of relatively dilute lidocaine produces a prolonged plateau of plasma lidocaine concentration. This phenomenon is explained by the following:

1. Rate of systemic absorption of dilute subcutaneous lidocaine is constant.
2. Hepatic elimination of lidocaine is a first-order process that depends on the concentration of plasma lidocaine.

This phenomenon, described by a simple linear differential equation, demonstrates that as long as the rate of lidocaine elimination equals the rate of absorption, the plasma lidocaine concentration must be a constant plateau.

The slow rate of subcutaneous absorption of dilute lidocaine with epinephrine, together with the high hepatic extraction of lidocaine, is the secret of the unprecedented safety of large doses of tumescent lidocaine (see Chapter 19).

THE FDA AND SAFE DOSAGES

Pharmaceutical companies that manufacture and market local anesthetics in the United States must provide the FDA

TABLE 21-1   LIDOCAINE DILUTION AND FATAL TOXICITY IN MICE

Concentration (g/L)	LD$_{50}$ (g/kg)*
0.5	1.07
1.0	0.72
2.0	0.59
4.0	0.42

Data from Gorgh T: *Anaesthesia* 4:4-9, 21, 1949.
*Median lethal dose, after subcutaneous injection.

with a suggested maximum safe dosage limitation and scientific information that documents the safety and validity of such a recommendation. Because of the considerable expense and time involved in conducting the appropriate clinical trials, manufacturers have not specifically investigated or documented the maximum safe dosage for subcutaneous injections of local anesthetics.

Both the dilution and the site of injection are important determinants of lidocaine toxicity. Dilution of lidocaine also reduces subcutaneous toxicity. When lidocaine is injected subcutaneously in mice, the lower the concentration, the higher is the total dosage required to produce a lethal effect[13] (Table 21-1).

The slow absorption of lidocaine after subcutaneous infiltration produces a relatively low C_{max}. In contrast, when an equal dose of lidocaine is used for an epidural or intercostal nerve block, the more rapid systemic absorption is associated with a much greater C_{max}.[14-17] A slower rate of local anesthetic absorption produces a lower C_{max}, which in turn corresponds to a larger maximum safe dosage. Consequently, the maximum safe dosage for a subcutaneous local anesthetic is always larger than the maximum safe dosage for regional nerve blocks.

The maximum dosage of a local anesthetic for regional nerve block also suffices as a safe (although less than maximum) dosage for subcutaneous infiltration. By regarding all routes of administration as equivalent to the route with the most rapid rate of absorption, the manufacturer can save a considerable amount of money in the FDA approval process. This tactic minimizes the number of clinical studies needed to document safety and efficacy. Furthermore, underestimating the maximum safe dosage for subcutaneous infiltration provides an additional margin of safety when local anesthetics are used by practitioners with limited experience; this protects the manufacturer.

The tactic of underestimating the maximum safe dosage of a local anesthetic has been used for each of the local anesthetics approved by the FDA for subcutaneous infiltration, including lidocaine, bupivacaine, chloroprocaine, etidocaine, and ropivacaine. The FDA gave approval for marketing these

local anesthetics without requiring studies specifically designed to determine the maximum safe dosage for subcutaneous infiltration.[18]

The 7-mg/kg dosage limitation for commercial 1% lidocaine with epinephrine is an excessively low estimate of a safe dosage. Surgeons must accept this, however, until a more realistic, higher dosage estimate is established based on objective scientific studies.

Considering the thousands of patients who have safely received 50 mg/kg of tumescent lidocaine for liposuction totally by local anesthesia, it is hoped that the FDA will update its 7-mg/kg dosage restriction for very dilute (1 g/L = 0.1%) subcutaneous lidocaine.

CONSEQUENCES OF MISLEADING LIMITS

One consequence of excessively low "official" dosage limits for subcutaneous lidocaine for local anesthesia, including both commercial 1% lidocaine and very dilute 0.1% lidocaine, is that patients are frequently denied the option of surgery by local anesthesia. The artificial dosage limitation of 7 mg/kg for out-of-the-bottle commercial lidocaine by official government agencies compels the surgeon and anesthesiologist to use systemic anesthesia. This unnecessarily exposes many patients to the dangers and unpleasant side effects of systemic anesthesia. The traditional but excessively low dosage limitation for subcutaneous lidocaine might actually expose patients to more risk through systemic anesthesia than the risks associated with using higher, but scientifically based, dosage limits.

Dosage limits for subcutaneous lidocaine also result in biased training of surgeons and anesthesiologists, inculcating reliance on the use of general anesthesia. Residents in training are denied more extensive training with local anesthesia, which in turn perpetuates use of systemic anesthesia.

Despite the tumescent technique for liposuction being the most popular cosmetic surgical procedure worldwide, the term *tumescent technique* has not appeared in the anesthesiology literature. One might suspect a lack of interest regarding anesthesia that does not require an anesthesiologist. It is possible that real and potential conflicts of interest oppose the increased use of local anesthesia and favor the continued unnecessary use of systemic anesthesia.

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Bupivacaine, Prilocaine, and Ropivacaine

Lidocaine's greater safety and prolonged duration of anesthesia make it the local anesthetic of choice for tumescent liposuction and dermatologic surgery. Because tumescent delivery of lidocaine can provide more than 10 hours of good surgical anesthesia, no justification exists for using longer-acting but more toxic local anesthetics such as bupivacaine.[1]

This chapter discusses the actions and effects of bupivacaine, prilocaine, and ropivacaine compared with lidocaine in local anesthetic solutions used for tumescent technique (Figure 22-1).

BUPIVACAINE

Some liposuction surgeons advocate general anesthesia with subcutaneous infiltration of dilute epinephrine and without local anesthesia during surgery, then the injection of bupivacaine for analgesia after surgery. This approach seems less than optimal for the following two reasons:

1. No controlled comparisons have demonstrated improved analgesia with postliposuction infiltration of local anesthesia.
2. Evidence indicates that preincisional infiltration of a surgical wound with a local anesthetic is a more effective method of providing postoperative analgesia than postincisional infiltration.[2]

Without the vasoconstrictive effects of epinephrine, the local anesthetic action of bupivacaine is longer than lidocaine. With epinephrine in the anesthetic solution, however, the effects of bupivacaine last only 27% longer than lidocaine.[3] For tumescent liposuction, no clinically significant difference exists between local anesthesia that lasts 10 hours or one that lasts 12.7 hours. Lidocaine, however, is significantly less toxic than bupivacaine.

MYOCARDIAL DEPRESSION

Bupivacaine directly depresses the myocardium, lowering both inotropy (contractility) and chronotropy (heart rate). This in turn decreases cardiac output[4] and coronary artery blood flow without producing vasoconstriction. Other factors that impair myocardial function and augment bupivacaine cardiotoxicity include hypoxia, hypercarbia, acidosis, β-adrenergic blockers, and digitalis.[5] Bupivacaine is toxic to muscle after direct injection, causing myonecrosis and rhabdomyolysis.[6]

Mechanisms of Local Anesthesia. Local anesthetics reversibly bind sodium (Na) channels, impair the sodium-potassium (Na-K) pump, and thus block neural impulse conduction. Besides binding to Na channels, local anesthetics also interact with β_2-adrenergic receptors. By inhibiting the binding of ligands to β_2-adrenergic receptors, local anesthetics inhibit intracellular cyclic adenosine monophosphate (cAMP) production. The avidity of binding to β_2-adrenergic receptors of different local anesthetics increases with length of the alkyl chain. The correlation between increased inhibition of β_2-adrenergic receptors and alkyl chain length resembles the correlation between local anesthetic potency for nerve blocks and increased alkyl chain length.[7]

Thus a relationship exists among increasing molecular size, increasing receptor avidity, increasing anesthetic potency, and increasing cardiovascular toxicity. This relationship could explain the greater cardiovascular toxicity of bupivacaine in terms of its relatively potent inhibition of β_2-adrenergic receptors and inhibition of cAMP production.

Blood Pressure. Arterial blood pressure may be a misleading indicator of cardiovascular status during bupivacaine overdose. With acute bupivacaine toxicity an increase in vascular resistance apparently maintains blood pressure but masks severe myocardial depression.[8]

CARDIOTOXICITY

Liposuction. Bupivacaine is unnecessarily dangerous and therefore contraindicated for tumescent liposuction. Bupivacaine cardiac toxicity is subtle and occurs without pre-
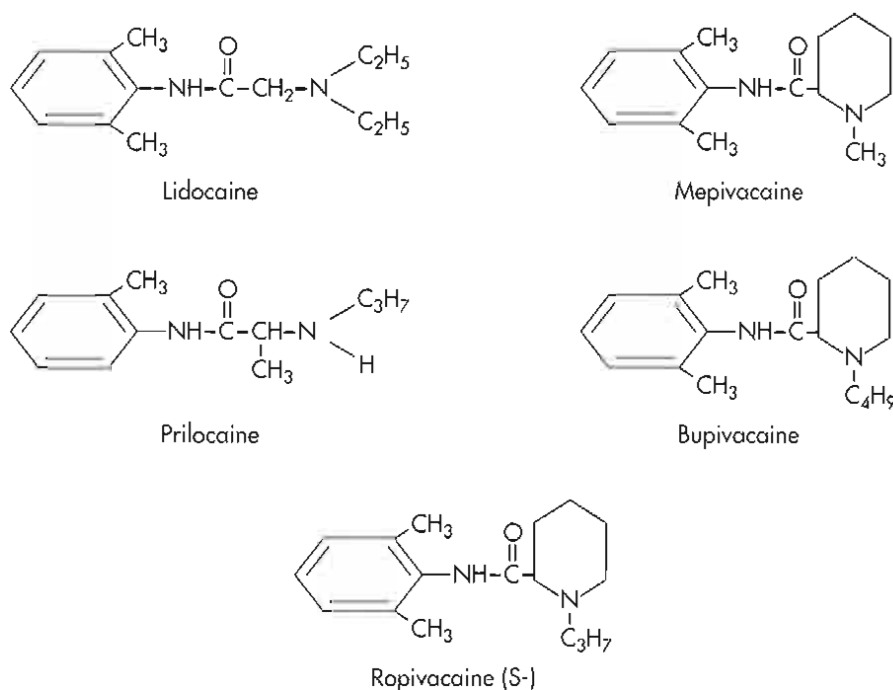
Figure 22-1

Bupivacaine, prilocaine, and ropivacaine compared with two other amide-linked local anesthetics, lidocaine and mepivacaine.

monitory convulsions. Fatal cardiotoxic arrhythmias (dysrhythmias) precede convulsions; in cats, for example, cardiac dysrhythmias occur at only 60% of the convulsant bupivacaine dose.[9] Lidocaine, however, usually gives warning signs of central nervous system (CNS) toxicity (e.g., seizures) before onset of dangerous cardiotoxic events.

The cardiotoxicity of bupivacaine is often unresponsive to resuscitation efforts.[10,11] In cats, successful resuscitation is less likely with bupivacaine than with lidocaine.[12]

Epinephrine. When cardiovascular collapse occurs with bupivacaine, an attempt to resuscitate the patient using epinephrine only worsens the situation. Bupivacaine-induced cardiac collapse therefore presents a therapeutic dilemma.

On the one hand, the American Heart Association recommends epinephrine as the drug of choice for patient resuscitation after sudden onset of ventricular fibrillation. On the other hand, adrenergic agents (e.g., epinephrine) increase the lethality of bupivacaine.[13,14] The tachycardia associated with epinephrine escalates bupivacaine toxicity by increasing myocardial oxygen demand and augmenting the reentry phenomenon.[15]

Bupivacaine demonstrates a *use-dependent toxicity* in which tachycardia increases cardiac toxicity. This phenomenon occurs because charged cationic bupivacaine molecules more easily enter myocardial cells when the transmembrane Na channels are open, which occurs with each myocyte's membrane depolarization-contraction cycle. With a pK_a of 8.10, most bupivacaine molecules are charged cations at

physiologic pH and are less likely to diffuse across the lipid cellular membrane. The respiratory acidosis associated with cardiac arrest only exacerbates this situation.

Lidocaine Comparisons. Long-acting amide local anesthetics such as bupivacaine have a much greater potential for serious cardiac toxicity than lidocaine.[4,16,17] Atrioventricular (AV) heart block and ventricular dysrhythmias are more often associated with bupivacaine than with lidocaine.[18-21]

The dosage (mg/kg) of lidocaine that produces experimental cardiac toxicity (dysrhythmias) must be 16 times greater than the dosage (mg/kg) of bupivacaine that produces the same degree of cardiotoxicity. Thus bupivacaine is 16 times more cardiotoxic than lidocaine, and the ratio for cardiac dysrhythmia with toxicity between bupivacaine and lidocaine is 16:1.[18] The bupivacaine/lidocaine ratio for anesthetic potency is 4:1.

When intravenous (IV) lidocaine (16 mg/kg) was compared with equipotent IV bupivacaine (4 mg/kg), lidocaine produced hemodynamic depression, whereas bupivacaine impaired both electrophysiologic and hemodynamic variables. In anesthetized dogs the lidocaine/bupivacaine ratio of dosages required to produce depressed myocardial contractility was 4.9:1.[22]

In another study, bupivacaine depressed cardiac conduction 70 times more than lidocaine, whereas local anesthetic potency of bupivacaine was only four times that of lidocaine.[23]

In a dog study, lidocaine induced only slight electrophysiologic effects, as manifested by bradycardia, whereas bupivacaine

increased all electrophysiologic variables measured. Bupivacaine facilitated reentrant dysrhythmias and ventricular tachycardia by dramatically slowing ventricular conduction velocity.[24]

All local anesthetics can produce cardiac toxicity with hypotension, AV heart block, ventricular dysrhythmias, and cardiovascular collapse, as well as CNS toxicity. The dose that produces cardiovascular collapse, versus the dose causing CNS toxicity, is lower for bupivacaine and etidocaine than for lidocaine.[25] Ventricular dysrhythmias are common with bupivacaine toxicity but rare with lidocaine.[4,16,17]

When given in doses that cause equivalent CNS toxicity in sheep, bupivacaine produces more serious cardiac toxicity than lidocaine.[26]

Bupivacaine cardiac toxicity is not simply a direct effect on the heart. Evidence indicates that cardiac depression is at least partially mediated by bupivacaine's effect on the CNS.[27,28]

ANESTHETIC MIXTURES

The toxicity of a combination of two amide-type local anesthetics is additive and not independent. In rats the lethal cardiorespiratory toxicity of lidocaine and bupivacaine is additively toxic by both intravenous infusion[29] and subcutaneous infiltration.[30] Similarly, the CNS toxicity of local anesthetics is additive.[31] Bupivacaine and lidocaine lower the seizure threshold in an additive fashion. After administration of the maximum safe dose of one amide-type local anesthetic, it is not safe to administer more of another local anesthetic.

A mixture of different local anesthetics is occasionally indicated for peripheral nerve blocks to achieve rapid onset of action, as provided by lidocaine, and prolonged duration of action, as provided by bupivacaine.[32,33] With tumescent liposuction the local anesthetic effect of lidocaine is sufficiently long, and the addition of bupivacaine is never indicated.

Milligram for milligram, IV bupivacaine is four times more toxic than IV lidocaine, whereas subcutaneous bupivacaine is only twice as toxic as subcutaneous lidocaine.[34,35] This does not mean, however, that a subcutaneous mixture of bupivacaine and lidocaine is safe for cosmetic surgery.[36]

Because the toxic effects of local anesthetics are additive, lidocaine should not be used to treat a bupivacaine-induced cardiac dysrhythmia.

Solubility. Amide local anesthetics are sold commercially in acidic solutions. Lidocaine and bupivacaine are weak bases and therefore more soluble at an acidic pH.

A local anesthetic solution of lidocaine is less painful on cutaneous or subcutaneous infiltration when it has been neutralized to pH near 7.0 by the addition of sodium bicarbonate to the solution. For example, pain is significantly less on infiltration of dilute lidocaine with epinephrine if 10 mEq of bicarbonate is added to each liter of tumescent anesthetic solution. Alkalinization of a local anesthetic solution speeds the onset of anesthesia and enhances the effectiveness of a nerve block.

One of the reasons that bupivacaine without epinephrine has a longer duration of action than lidocaine is that bupivacaine has a greater lipid solubility and is less aqueous than lidocaine. As a result of its decreased solubility in water, bupivacaine depends more on an acid pH for water solubility, and bupivacaine will precipitate more readily than lidocaine when the pH of the solution is increased.

The addition of bicarbonate to an aqueous solution of bupivacaine is dangerous because it can readily cause bupivacaine to precipitate. The intradermal or subcutaneous injection of precipitated bupivacaine can cause tissue necrosis.

PRILOCAINE

Some European surgeons have considered using prilocaine instead of lidocaine in a tumescent local anesthetic solution. The only published information on tumescent prilocaine (35 mg/kg) involved a study in which the plasma concentration of prilocaine was measured in only four liposuction patients; the average peak plasma concentration was 0.91 μg/ml (range 0.44 to 1.27 μg/ml).[37] Without clearly specifying the plasma concentration threshold for prilocaine toxicity and without controls using lidocaine, the authors concluded that prilocaine is safer than lidocaine.

LIDOCAINE AND TOXICITY

Prilocaine is similar to lidocaine in that both are amide-type local anesthetics, and they have approximately equal potency,[7] onset of anesthetic action,[40] and duration of action. They also have equal neurologic and cardiovascular toxicity.[38,39]

Prilocaine is cleared more quickly than lidocaine, however, because of its fast rate of tissue redistribution and its rapid hepatic metabolism.[40] Prilocaine metabolism by hepatic and renal amidases yields o-toluidine and N-propylalanine. Prilocaine is not metabolized by plasma esterases. Although the more rapid clearance of prilocaine may suggest that it might be safer than lidocaine, the metabolites of prilocaine are much more toxic than those of lidocaine. One of the prilocaine metabolites, o-toluidine, has been shown to be carcinogenic in mice and rats and also causes methemoglobinemia. When a metabolite of a drug is toxic, the rapid production of that metabolite may not be desirable.

Safety Factors. To compare the safety of two local anesthetics in the setting of tumescent lidocaine, one needs the following information on each drug:

1. *Plasma concentration thresholds for toxicity.* Although this information is available for lidocaine, I know of no published data on the toxicity threshold for plasma prilocaine.
2. *Peak plasma concentrations* of each drug after tumescent infiltration without and with subsequent liposuction.
3. *Plasma concentration versus time* profile of all potentially toxic metabolites of each drug after tumescent infiltration. The toxicity of the prilocaine metabolite o-toluidine may be a function of total hours of exposure as well as its peak plasma concentration.

4. *Drug metabolism and potential drug interactions.* Prilocaine might prove to be exceedingly toxic in certain clinical situations that increase the toxic effects of *o*-toluidine. Thus prilocaine may be safe in healthy patients but more dangerous in patients with renal impairment.

The assertion that prilocaine is safer than lidocaine simply because prilocaine is metabolized faster than lidocaine is overly simplistic. Rapid clearance might be a positive safety feature when prilocaine is given at relatively low total doses over a short period. When a huge dose of prilocaine is absorbed over an extended time, however, its rapid clearance may produce prolonged exposure to a toxic metabolite. Although prilocaine has a faster total body clearance rate (Cl_T) than lidocaine (2.03 versus 0.85 L/kg/hr), it also has a larger volume of distribution at steady state (V_{dss}) (2.73 versus 1.30 L/kg). Thus a greater volume of prilocaine must be cleared compared with lidocaine. The volume of distribution at steady state V_{dss} is related to Cl_T by the following equation:

$$Cl_T = k(V_{dss})$$

where k is ln $2/t_{1/2}$, and $t_{1/2}$ is plasma half-life. Lidocaine and prilocaine have the same serum half-life of 1.6 hours.[41]

Animal Data. Because a drug's median lethal dose (LD_{50}) varies between species, comparison of the LD_{50} of prilocaine and lidocaine cannot be directly applied to human clinical situations. Furthermore, because of variation among different statistical estimates of LD_{50}, the results of any one study cannot be regarded as conclusive.

For example, one estimate of the LD_{50} of subcutaneous prilocaine in female mice is 550 mg/kg (range 359 to 905 mg/kg).[42] Another estimate is 820 mg/kg, which is 50% greater than 550 mg/kg.[43] Clearly, with such wide variation, physicians must be cautious when using such data to guide clinical decision making about a particular drug's safety.

Large Doses. With no pharmacologic studies of large subcutaneous doses of prilocaine, virtually nothing is known about the clinical toxicity of tumescent prilocaine. I believe, however, that prilocaine and its metabolites are more dangerous than lidocaine and its metabolites.

In the United States, prilocaine does not have Food and Drug Administration (FDA) approval to be marketed as an injectable local anesthetic for dermatologic surgical procedures. It is only available as an injectable dental anesthetic in 1.8-ml "dental cartridges" containing 4% prilocaine and as a component of topical EMLA cream.

The pharmacologic literature does not fully describe the risks of using large doses of subcutaneous prilocaine. Thus any preference for using prilocaine with the tumescent technique is based on conjecture rather than a detailed knowledge of the full range of prilocaine toxicity.

When evaluating the manufacturer's assertion that prilocaine is safer than lidocaine, the physician must be aware of potential financial conflicts of interest. In contrast to lidocaine, no generic equivalents are available for prilocaine. Thus, despite the absence of comparative safety data, a manufacturer might have a financial incentive to promote a drug such as prilocaine over lidocaine.

METHEMOGLOBINEMIA

Methemoglobinemia is a condition similar to carbon monoxide poisoning in which hemoglobin is not capable of binding oxygen. Specifically, the ability of blood to transport oxygen is impaired when oxyhemoglobin (the ferrous form) is oxidized to methemoglobin (the ferric form) by a large dose of prilocaine.[44]

The prilocaine metabolite *o*-toluidine causes oxidation of hemoglobin and can produce methemoglobinemia after systemic doses in excess of 600 mg, or dosages of 7 mg/kg.[45] Patients may show signs of dyspnea and cyanosis and may complain of headache. Pulse oximetry readings are inaccurate and overestimate the true arterial oxygen saturation. The diagnosis of methemoglobinemia is confirmed by laboratory analysis, with 5 ml of blood collected in a tube containing ethylenediaminetetraacetic acid (EDTA).

Patients who are especially susceptible to developing methemoglobinemia include very young children, patients with glucose-6-phosphatase deficiency, and those taking drugs associated with drug-induced methemoglobinemia, such as acetaminophen, antimalarials, sulfonamides, dapsone, nitrites, nitrofurantoin, phenobarbital, phenytoin, and quinine.

Systemic Anesthesia. The risk of prilocaine-associated methemoglobinemia may be increased by concomitant administration of systemic anesthesia.[46] No prospective studies have investigated the possible drug interaction between systemic anesthesia and prilocaine. Using tumescent prilocaine with systemic anesthesia, however, may increase the plasma concentration of *o*-toluidine, thus inducing methemoglobinemia. In two patients, when local anesthesia with prilocaine was supplemented by systemic anesthesia (thiopental, alfentanil, and atracurium), methemoglobin levels increased by 70% and 25% compared with levels before the systemic anesthesia.[46]

Pregnancy. A liposuction patient may not know that she is pregnant, as occurred with one of my patients. One week after tumescent liposuction with lidocaine, she realized that she was approximately 4 weeks' pregnant. The fetus was healthy at birth and was not affected by exposure to lidocaine.

Prilocaine may cause fetal methemoglobinemia and should not be used in a woman who might be pregnant. Whereas toxicity studies in fetal lambs have shown lidocaine to be safe during pregnancy, the same cannot be said for prilocaine or many of the drugs used for general anesthesia.

The effects of fetal methemoglobinemia are not well described. Also, the rate of *o*-toluidine clearance in the fetus and the affinity of fetal hemoglobin for *o*-toluidine are not known. Fetal glucose-6-phosphatase deficiency predisposes the fetus to prilocaine toxicity because of methemoglobinemia.

Methemoglobinemia has been reported in a genetically normal newborn after delivery under pudendal anesthesia with prilocaine.[47,48] Maternal/fetal total concentration ratio for lidocaine is 0.5 and for prilocaine is 1.0.[49] Since the amide-type local anesthetics are weak bases, fetal acidosis will increase the maternal/fetal pH gradient and will result in accumulation of free drug in the fetus and possible fetal side effects.

Treatment.   When a patient who has been given prilocaine becomes dyspneic, first-line treatment of methemoglobinemia is oxygen. Definitive treatment requires a slow IV infusion of methylene blue (1% solution) at 1 to 4 mg/kg over 5 minutes. Extravasation of methylene blue into the subcutaneous tissue can cause tissue necrosis.

Postoperative dyspnea cannot simply be treated with methylene blue. The surgeon must also consider pulmonary edema or pulmonary embolus in the differential diagnosis of acute dyspnea in the immediate postoperative period. Any unnecessary drug that can cause dyspnea in surgical patients should be avoided.

The treatment of choice for pulmonary edema is furosemide (Lasix), a sulfonamide derivative, but sulfonamide-related drugs are contraindicated with methemoglobinemia. Thus, if a patient develops pulmonary edema after liposuction with prilocaine, the use of furosemide may precipitate methemoglobinemia, decrease oxygenation, and worsen cardiopulmonary function.

Tumescent Doses.   The tumescent delivery of large doses of prilocaine might increase the risk of methemoglobinemia. Methemoglobinemia caused by prilocaine is a function of total dose, not rate of systemic absorption. The tumescent delivery of lidocaine or prilocaine slows the rate of systemic absorption and reduces the risk of cardiovascular toxicity associated with amide-type local anesthetics. To the extent that tumescent liposuction might use a total dose of prilocaine that is greater than 600 mg, the tumescent technique might be associated with an increased risk of methemoglobinemia.

PRILOCAINE VERSUS LIDOCAINE

Based on the extensive clinical experience and pharmacologic data available on lidocaine and the relative paucity of information about the pharmacokinetics of prilocaine and o-toluidine, I believe that lidocaine is safer than prilocaine for tumescent liposuction.

ROPIVACAINE

Ropivacaine is a new, long-acting, amide-type local anesthetic and the first local anesthetic on the market as a single isomer.[50] Ropivacaine is the S(-) propyl homolog of bupivacaine and mepivacaine. Human and animal studies show that ropivacaine resembles bupivacaine, with a similar pharmacodynamic and pharmacokinetic profile. Ropivacaine has a pK_a of 8.07 and a protein binding of approximately 94%.

Lipid solubility of ropivacaine, however, is lower than that of bupivacaine.

BUPIVACAINE AND TOXICITY

Extensive animal toxicologic studies have shown a lower propensity for cardiotoxicity with ropivacaine than with bupivacaine. In comparative human studies, ropivacaine and bupivacaine appear to be associated with a similar incidence of comparable adverse effects, except that the incidence of cardiovascular and CNS toxicities is lower with ropivacaine. The adverse effects associated with epidural administration of ropivacaine include hypotension, nausea, bradycardia, transient paresthesia, back pain, urinary retention, and fever.[51]

At equal mg/kg dosages, ropivacaine appears to be safer than bupivacaine. At equipotent doses, however, the two drugs appear to have similar degrees of toxicity. At equal mg/kg dosages, ropivacaine has been shown to be less potent and less toxic. For example, ropivacaine was significantly less potent than bupivacaine for epidural analgesia in the first stage of labor.[52]

Pregnancy.   Subcutaneous bupivacaine and ropivacaine were given to pregnant rats, with the mg/kg dosages in the same range as proposed for humans: bupivacaine, 5.5 to 24 mg/kg; ropivacaine, 5.3 to 26 mg/kg.[53] Deaths from clonic convulsions were occasionally seen in rats receiving 14 mg/kg or more of bupivacaine. The results suggest an increased safety margin before onset of toxic side effects after treatment with ropivacaine compared with bupivacaine.

Studies of pregnant women in labor have shown that ropivacaine and bupivacaine appear to be equally effective in producing epidural sensory block, but motor block seems to be less pronounced with ropivacaine. Equal doses (20 to 30 ml) of ropivacaine 0.5% and bupivacaine 0.5% in epidural anesthesia for cesarean section were equally effective.[54] No adverse side effects and no differences in efficacy were reported with ropivacaine 0.25% or bupivacaine 0.25% when administered epidurally for relief of labor pain.[55]

Central Nervous System.   Acute tolerance of IV infusion (10 mg/min to a maximum dose of 150 to 250 mg) of ropivacaine and bupivacaine was studied in a crossover, randomized, double-blind study in 12 volunteers previously acquainted with the CNS effects of lidocaine. At equal doses the maximum tolerated dose for CNS symptoms was higher with ropivacaine in nine subjects and higher with bupivacaine in three subjects.[56]

Ropivacaine has caused convulsions in humans. After epidural injection, ropivacaine has been reported to cause neurologic toxicity (convulsions), with minimal signs of cardiovascular toxicity.[57,58]

Equipotent Dosages.   Ropivacaine is half as potent as bupivacaine. In equipotent doses ropivacaine has a higher incidence of side effects than bupivacaine. Low-dose hyperbaric spinal ropivacaine does not appear to offer an advantage over bupivacaine for use in outpatient anesthesia.[59]

Ropivacaine 0.5% produces sensory and motor blockade that is similar to that resulting from equal concentrations of bupivacaine after epidural administration in sheep. Peak serum concentrations occurred within 8 minutes after administration, without signs of systemic toxicity. The terminal elimination half-life in serum for ropivacaine was 3½ to 4 hours and for bupivacaine 6 hours.[60]

VASOCONSTRICTION

Ropivacaine has been found to be somewhat vasoconstrictive, unlike other local anesthetics in its class, such as bupivacaine. A statistically significant difference, however, does not necessarily imply a clinically significant difference in vasoconstrictive effects. At least one study has shown that the ropivacaine vasoconstriction is insufficient for reduction mammoplasty, a procedure in which considerable blood loss may occur.[61]

Before breast reduction, each breast of five female patients was infiltrated with 60 ml of 0.9% saline containing either ropivacaine (75 mg) without epinephrine or bupivacaine (75 mg) with epinephrine (0.3 mg) by random allocation. Ropivacaine was associated with much greater intraoperative blood loss than bupivacaine with epinephrine. Vasoconstrictive properties of ropivacaine are not sufficiently great to merit its use as a sole agent for infiltration before reduction mammoplasty.[61]

ROPIVACAINE VERSUS LIDOCAINE AND BUPIVACAINE

When given in equal dosages, lidocaine and ropivacaine are both less potent and less toxic than bupivacaine in animals and humans. Again, ropivacaine is less potent and less toxic than bupivacaine at equal mg/kg dosages, but there is no apparent difference in toxicity at equipotent dosages. Insufficient data are available to allow a reasonable comparison between ropivacaine and lidocaine in terms of safety and efficacy. Lidocaine is less toxic than bupivacaine or ropivacaine, however, and thus remains the drug of choice for tumescent anesthesia.[62]

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Tumescent Formulations

No standard, official, or rigidly prescribed formulation exists for tumescent anesthetic solutions. Concentrations of the lidocaine and epinephrine should depend on the areas treated and the clinical situation.

In this book the word *dosage* implies the total amount of a drug given relative to the patient's weight in kilograms (mg/kg); a *dose* is a quantity of a medicine given at one time and measured in milligrams (mg).

TUMESCENT CAVEATS

Before discussing the formulation of tumescent solutions for local anesthesia, the following concepts and warnings must be emphasized to minimize the risks of lidocaine toxicity.

1. *Understand maximum safe dosage.* The maximum recommended dosage of lidocaine is 45 mg/kg in relatively thin patients and 50 mg/kg in obese patients (see Chapter 21). I avoid using more than 55 mg/kg. At doses less than 55 mg/kg, plasma lidocaine concentrations greater than 6 μg/ml may result from adverse drug interactions mediated by the inhibition of cytochrome P450 3A4 (CYP3A4). Patients occasionally experience nausea and vomiting approximately 12 hours after tumescent infiltration of 50 to 55 mg/kg; in such patients, measured plasma lidocaine concentration has never exceeded 3.5 μg/ml. To minimize this risk, it is preferable not to exceed 45 mg/kg of tumescent lidocaine. These dosage limitations assume no drug interactions and no unimpaired function of hepatic CYP3A4 (see Chapters 18 and 21).

2. *Use signed written orders.* The surgeon must provide explicit written orders for the formulation of the tumescent local anesthetic solution. Standard policy should be that no solutions are mixed unless the surgeon has signed the orders and the orders are in the patient's chart. All orders for tumescent anesthesia should include documentation of the patient's weight (kg), maximum desired dosage (mg/kg), and exact amount of each drug to be included in the tumescent solution expressed in milligrams per liter (mg/L) or milliequivalents per liter (mEq/L).

3. *Know dosage given.* The surgeon, anesthesiologist, and nurses must always know the patient's final *total milligram dose* (mg) and the *milligram per kilogram dosage* (mg/kg). For each patient, the surgeon's orders must also explicitly state the surgeon's determination of the maximum safe dosage of tumescent lidocaine in mg/kg. Surgeons have been charged with criminal negligence (but not convicted) because of apparent errors in lidocaine dosing.

4. *Specify dosage in terms of milligrams.* The orders for formulating the solution of local anesthesia for the tumescent technique should specify the exact total milligrams of lidocaine and epinephrine and the milliequivalents of sodium bicarbonate per liter of tumescent solvent (mg/L and mEq/L). The orders should not be given in terms of milliliters of 1% lidocaine per liter of solution [(ml/L)(10 mg/ml)]; to do so increases the risk of inadvertent dosing errors. It is much easier to determine the mg/kg dose of lidocaine when the concentration of lidocaine in each liter is specified in mg/L.

5. *Use only 1% lidocaine.* Preferably, a surgeon's formulary should stock only commercial vials of 1% lidocaine. The risk of a inadvertent overdose is vastly increased when vials of 2% lidocaine are available. Patients have received double the intended dose of lidocaine when 2% lidocaine was used instead of the intended 1% solution. Although these cases did not result in serious toxicity, each incident of incorrect dosage represents a potential disaster. Epidural anesthesia may require 2% lidocaine, but no dermatologic surgical procedures require more than 1% lidocaine.

6. *Ensure licensed medical personnel prepare solution.* Only well-trained personnel should mix the tumescent solution. Surgical operating room (OR) technicians or medical assistants are usually not licensed to prepare or administer drugs and anesthetics. Unlicensed personnel are more likely to make errors in the interpretation of anesthetic orders or the actual mixture of the tumescent anesthetic solution. Mixing the tumescent local anesthetic solution requires "eyes-on" or hands-on supervision of licensed medical personnel.

7. *Have solution prepared at surgery.* To avoid medication errors, the tumescent anesthetic solution should be prepared in the OR at the time of surgery. Preparing the tumescent

anesthetic solution in large batches and far in advance may increase the risk of unrecognized contamination or inadvertent dosage errors. Concerns about safety outweigh the possible convenience of preparing tumescent solutions for multiple patients.

8. *Save all empty bottles.* All empty vials of lidocaine and epinephrine should be temporarily saved until the surgical procedure is completed. This precautionary strategy allows personnel to double-check the total lidocaine or epinephrine dosage. If a discrepancy exists between an intended dosage and the number of empty vials of lidocaine or epinephrine, all the remaining tumescent anesthetic mixtures must be discarded and new mixtures prepared.

9. *Avoid postoperative sedatives.* Use of diazepam (Valium) 24 hours after tumescent liposuction is relatively contraindicated. Diazepam or other sedatives may increase the risk of lidocaine toxicity by inhibiting CYP3A4 or by impairing ventilation and producing respiratory acidosis.

10. *Use normal saline as preferred tumescent solvent.* As discussed later, normal saline (NS), also known as physiologic saline or 0.9% sodium chloride (NaCl), is the preferred solvent for dilute solutions of local anesthetics using the tumescent technique. When safe and reasonable volumes of tumescent solution are infiltrated, no significant difference exists between NS and lactated Ringer's solution (LR).

11. *Ensure anesthesiologist and surgeon share responsibility.* All physicians, surgeons, and anesthesiologists in the OR are responsible for a surgical patient's safety. When providing systemic anesthesia, the anesthesiologist must be completely informed about and concur with the total dosage of tumescent lidocaine. An anesthesiologist who is not cognizant of the lidocaine dosage (mg/kg) or the volume of subcutaneously infiltrated tumescent fluid may be unable to avoid adverse drug interactions or systemic fluid overload.

Anesthesiologists must be familiar with the pharmacology and pathophysiology of tumescent liposuction to be in compliance with American Society of Anesthesiologists (ASA) standards. For regional anesthesia, the ASA states that "anes-

thesiologists should assume responsibility for all aspects of anesthesia care," including outpatient anesthesia.[1]

SAFETY WARNING

Safe doses of tumescent (very dilute) lidocaine and epinephrine are not the same for "out-of-the-bottle" commercial (considerably more concentrated) lidocaine. Whereas the safe maximum dosage of tumescent lidocaine (with epinephrine) at concentrations of 0.05% to 0.15% is 45 to 50 mg/kg, the traditional dosage limitation for commercial lidocaine (with epinephrine) at concentrations of 0.5%, 1%, or 2% remains valid at 7 mg/kg. All physicians should be extremely careful to recognize this vital distinction.

LIDOCAINE AND EPINEPHRINE CONCENTRATIONS

The concentration of lidocaine and epinephrine in an anesthetic solution should vary according to the clinical requirements. No "correct" or sanctioned concentration of lidocaine or epinephrine exists for tumescent local anesthesia.

This chapter's recommendations for concentration of tumescent lidocaine with liposuction of various body areas have been developed empirically. Years of experience and careful observation have helped define an estimate of the optimal concentrations. The goal is to determine the minimal concentration for each component of the anesthetic solution that consistently permits painless liposuction. Areas that are especially fibrous, such as the upper abdomen, breast, and back, also tend to be associated with increased surgical bleeding. The more fibrous areas tend to require higher concentrations of lidocaine and epinephrine. Less fibrous and less sensitive areas require lower concentrations. Recommended concentrations are simply guidelines and are always subject to modification (Table 23-1).

Use of smaller cannulas is associated with less discomfort and a smaller probability of encountering an area of painful

TABLE 23-1 RECOMMENDED CONCENTRATIONS FOR EFFECTIVE TUMESCENT ANESTHESIA FOR LIPOSUCTION

Areas	Lidocaine (mg/L)	Epinephrine (mg/L)	Sodium Bicarbonate (mEq/L)
Basic/checking	500	0.5	10
Hips; lateral, medial, and anterior thighs; knees	700-750	0.65	10
Back; male flanks; arms	1000	0.65-1.0	10
Female abdomen (medial)	1000-1250	1.0	10
Male abdomen (medial) and male breasts	1250	1.0	10
Abdomen (lateral)	750	0.65	10
Female breasts; chin, cheek, and jowls	1500	1.5	10
Facial resurfacing (CO_2 laser)	600 mg/250 ml	1 mg/250 ml	5 mEq/250 ml

liposuction. Thus smaller cannulas allow the use of lower drug concentrations. Surgical technique that initiates liposuction using the smallest cannulas and then increases cannula size sequentially causes less discomfort than beginning liposuction with relatively large cannulas.

If several areas are treated by liposuction on the same day, the surgeon may need to use the lowest concentrations so as not to exceed the maximum safe dosage limits (mg/kg).

EPINEPHRINE

Epinephrine, a hormone derived from the adrenal medulla, is also known as *adrenaline*. Pharmacologically it acts as both an alpha and a beta agonist, increasing heart rate as well as peripheral vasoconstriction and blood pressure. More importantly for tumescent anesthesia, epinephrine is a potent capillary vasoconstrictor responsible for the dramatic hemostasis and the slow systemic lidocaine absorption associated with the tumescent technique.

Tachycardia. Patients may give a history of some type of adverse reaction to epinephrine. Typically this involved dental anesthesia in which the patient experienced the unpleasant pharmacologic effects of rapid systemic absorption. Injection of a drug into the highly vascular oral (periodontal, gingival, or buccal) mucosa is more likely to produce rapid systemic absorption than injection into less vascular tissue. Rapid absorption is a pharmacologic phenomenon, not an allergic reaction.

Rapid absorption of epinephrine can produce tachycardia, tremors, and anxiety. In my experience, however, patients who have experienced tachycardia from rapid absorption of epinephrine after dental anesthesia do not have a similar reaction with tumescent anesthesia for liposuction.

Liposuction surgeons should be cautious in assessing patients with a confusing history of an adverse reaction to epinephrine. Patients taking pseudoephedrine for nasal decongestion or "health food" supplements that contain ephedrine-like chemicals are predisposed to epinephrine-associated tachycardia. Also, the patient may have an undiagnosed primary cardiac arrhythmia (dysrhythmia), an occult cardiac valvular disease with intermittent tachycardia, or a subclinical metabolic disorder (e.g., hyperthyroidism, carcinoid, pheochromocytoma). When in doubt, the surgeon should consider an internal medicine consultation.

If the patient's history is clearly consistent with rapid absorption of epinephrine and the consequent pharmacologic response with tachycardia, tumescent liposuction probably poses minimal risk. In some patients, especially older persons, it is wise initially to limit the amount of liposuction to relatively small volumes. Once the first procedure has been completed without evidence of tachycardia, tremor, or an anxiety reaction, the surgeon can proceed 1 or 2 months later with a standard dose of epinephrine for tumescent anesthesia.

The routine use of clonidine (0.1 mg) given preoperatively to patients without bradycardia or hypotension has greatly reduced the incidence of intraoperative and postoperative tachycardia with tumescent local anesthesia.

Regional Variation. The physician can vary the concentration of epinephrine depending on the particular area that is being targeted for tumescent liposuction. In areas that tend to be associated with increased intraoperative bleeding, such as upper abdomen, back and flank, and especially fibrous areas of fat, it is reasonable to use 1 mg of epinephrine/L tumescent anesthetic solution. For other areas, 0.65 mg of epinephrine/L is usually sufficient.

SAFETY CHECKS

Basic Solution. A basic, minimally effective solution of tumescent local anesthesia consists of 500 mg of lidocaine, 0.5 mg of epinephrine, and 10 mEq of sodium bicarbonate in 1 L of NS. It is specifically intended for the surgeon who wants to check the completeness of the anesthesia just before beginning liposuction. This may be necessary if someone other than the surgeon, such as a registered nurse or another physician, has done the infiltration.

Checking the completeness of the local anesthesia is intended to detect areas of subcutaneous fat that are not completely anesthetized. This should be done immediately before initiating liposuction. While advancing an infiltrating cannula throughout the tumescent compartment of fat, the surgeon or anesthetist should instruct the patient to indicate any area of incomplete anesthesia by saying the word "there" whenever the cannula causes even a minimally painful sensation. The surgeon can then infiltrate additional anesthetic solution exactly where it is needed.

The minimal concentration of lidocaine in the basic solution is usually sufficient to achieve complete anesthesia and vasoconstriction.

Complete Records. The surgeon must insist that the staff assiduously maintain complete, legible records that document the total milligram dose and concentration of local anesthetic ingredients in each liter of tumescent solution. The important ingredients include lidocaine, epinephrine, and sodium bicarbonate.

Traditionally, physicians have only used relatively small doses of subcutaneous local anesthetics. Few medical students or surgical residents have ever been trained to document or record the exact amount of local anesthetic used. Specific preoperative orders for subcutaneous infiltration of local anesthesia are rarely written. Even now, with increased use of the relatively high doses of lidocaine employed with tumescent anesthesia, many surgeons still have a casual, nonrigorous approach to documentation of local anesthesia dosages.

Poor records are dangerous, below the standard of care, and often associated with malpractice. Careless anesthesia records combined with a patient death may result in a prosecution for criminal negligence. In two such cases the sur-

geon's notes did not accurately document the total dose of lidocaine; both patients died after receiving general anesthesia (inhalational or propofol) plus tumescent local anesthesia, which was not well documented. Although both cases resulted in charges of criminal negligence, neither resulted in a conviction. Criminal negligence is not covered by malpractice insurance, and a conviction can involve time in prison.

Shelf Life of Solution. Manufacturers of 0.9% NaCl and LR state, "When introducing additives, use aseptic techniques. Mix thoroughly. Do not store."

It is safer to prepare the tumescent anesthetic solution on the day of surgery in the OR. Medicolegal considerations favor the use of anesthetic solutions that are freshly prepared in the OR immediately before surgery. It would be difficult to defend the use of a "stale" solution if a complication were attributable to pharmacologic instability or bacterial contamination.

An error in the preparation of the tumescent anesthetic solution is more easily detected if the anesthetic is mixed immediately before or during the surgery. By saving the empty bottles of lidocaine and empty vials of epinephrine, the total dosage of these drugs can be double-checked simply by counting the empty containers. If tumescent anesthetic solution is prepared a day or more in advance or outside of the OR, an inadvertent overdose of lidocaine in one or more bags of saline might not be detected.

The efficacy of a tumescent anesthetic solution is not maximal when mixed several days before surgery. The shelf life varies as a function of pH, temperature, and concentrations of other solutes. In particular, the vasoconstrictive properties of epinephrine are not stable at a pH of 5 or greater. There is a greater risk that lidocaine might precipitate from an older solution or from a solution with a higher pH. If a liter bag of tumescent anesthetic solution has been prepared days in advance, the physician cannot always be certain that it has been properly stored.

Sodium Bicarbonate and Bupivacaine. Bupivacaine is a larger, less water-soluble molecule than lidocaine. Adding 5 mEq of sodium bicarbonate to 50 ml of bupivacaine (0.75%) will result in the immediate precipitation of the bupivacaine. Injecting such a suspension intradermally or subcutaneously has caused full-thickness dermal necrosis.

Therefore the physician should never add sodium bicarbonate to bupivacaine.

Adding 10 mEq/L of sodium bicarbonate to a dilute solution of tumescent lidocaine does not cause the lidocaine to precipitate. It is prudent not to exceed this amount to minimize the risk of lidocaine precipitation.

Triamcinolone. The addition of triamcinolone (10 mg/L) once was considered beneficial in reducing the incidence of focal postliposuction subcutaneous inflammation, or panniculitis.[2] In my early experience with tumescent liposuction, approximately 2% to 4% of patients had focally tender, pink, warm, sterile subcutaneous nodules that did not respond to antibiotics. When postliposuction panniculitis was treated with a course of oral antibiotics and prednisone (10 mg/day), however, the condition improved dramatically within 24 to 48 hours.

It was concluded that including triamcinolone in the anesthetic solution might prevent postliposuction panniculitis. In fact, triamcinolone seemed to reduce the incidence of this focal inflammation.

Careful clinical study, however, showed that the decreased panniculitis resulted from the use of open drainage and bimodal compression. The closure of incisions with suture was eliminated about the same time as triamcinolone was introduced. The simple act of encouraging the rapid drainage of residual tumescent fluid and the inflammatory postsurgical subcutaneous exudate was the true cause for improved healing.

The only advantage of including triamcinolone in the tumescent anesthetic solution is a slight reduction in postoperative soreness, which is apparent 3 to 5 days after surgery. This slight effect is clinically insignificant. On the other hand, the surgeon must be concerned about the possible increased risk of postliposuction infection that might result from steroid-induced impairment of immune function. Thus, it seems prudent to avoid unnecessary use of triamcinolone.

TUMESCENT SOLVENTS AND FLUID HOMEOSTASIS

The choice of solvent, into which the lidocaine and epinephrine are added, is an important aspect of the tumescent technique. The solvent should be isotonic and the pH nearly physiologic. With conservative liposuction, no significant difference probably exists between NS and LR in terms of safety or efficacy. With excessively large-volume liposuction procedures, however, the differences in formulation may be clinically relevant.

First, no studies detail the pharmacokinetics of parenteral (subcutaneous infiltration or intravenous [IV] infusion) administration of more than 6 L of NS or LR in the setting of tumescent liposuction. Most "expert" opinions on fluid and electrolyte homeostasis in liposuction are substantiated only by anecdotal experience or clinical dogma.

Tumescent infiltration of 5 L of solution was closely studied in one patient on two occasions.[2] No liposuction was done after the first infiltration. Two weeks later the second infiltration was followed by liposuction of 1.5 L of supranatant fat. No IV fluids were given during either procedure. The published results showed that, with or without liposuction, urine specific gravity decreased and urine output was greater than 70 ml/hr, indicating no IV fluid deficit (see Figure 19-2, *D* and *E*). Thus IV fluids were not necessary for tumescent liposuction of 1.5 L of supranatant fat.

In my experience, liposuction of up to 4 L of supranatant fat in moderately obese females does not require IV fluids. This assumes that patients are fully alert and can take oral fluids whenever they are thirsty.

TABLE 23-2 ELECTROLYTE CONTENT (MMOL/L) OF ANESTHETIC SOLVENTS AND EXTRACELLULAR FLUID

Solution/Fluid	Na^+ Ions	Cl^- Ions	K^+ Ions	Ca^{++} Ions	Lactate Ions	Osmolality (mOsm/L)
Normal saline (NS), USP	154	154				308
Normal saline (NS), BP	150	150				
Lactated Ringer's solution, USP	130	109	4	1.4	29	273.4
Hartmann's solution, BP	131	111	5	2	29	
Extracellular fluid (ECF)	142	103	4	2.5		290*

USP, United States Pharmacopeia; BP, British Pharmacopoeia.
*Plasma osmolality is largely the sum of osmolalities from plasma electrolytes, glucose, and urea.

NORMAL SALINE

The most common lidocaine solvent for the tumescent technique is isotonic physiologic saline (0.9% NaCl), or NS. As defined by the United States Pharmacopeia (USP), NS contains 154 mEq/L of both sodium and chloride (Table 23-2). Plasma contains 142 mEq Na/L.

Typically, sodium bicarbonate ($NaHCO_3$, 10 mEq/L) is added to the lidocaine solution to neutralize the pH and thus reduce the stinging pain that otherwise occurs when acidic commercial lidocaine is infiltrated subcutaneously in an alert patient. Thus a liter of tumescent solvent will contain 164 mEq of sodium.

RINGER'S SOLUTION WITHOUT LACTATE

Ringer's solution, without lactate, was developed by Sidney Ringer (1834-1910), a professor of medicine at the University of London and one of the first scientific clinical pharmacologists.[3] Ringer is best known for his research on the effects of blood electrolytes on cardiac function.[4-7]

When an assistant mistakenly injected tap water instead of distilled water into a frog heart, Ringer noticed that tap water did not produce the immediate cardiac arrest expected with distilled water. He tied a string around a frog heart and studied the effects of bathing the heart in different solutions, using a tonometer to measure the force of contractions. He showed that a 0.75% NaCl solution profoundly impaired contractions and that adding dried bovine blood to the solution restored normal contractions. Similarly, adding minute doses of potassium salts had the same beneficial effect on cardiac contraction as adding dried bovine blood. Ringer also found that adding $NaHCO_3$ to the saline solution had no beneficial effect on cardiac function.

Ringer concluded that "saline solution, to which is added one ten-thousandth part of potassium chloride, makes an excellent circulating fluid in experiments with the detached heart." The results of Ringer's research were not appreciated for many years.

Other Solvents and Potassium. One application of Ringer's experiments might be in autologous fat transplan-

tation. Ringer's solution might be the preferred solvent for tumescent anesthetic before harvesting donor fat for transplanting into another part of the body. Because of the large quantity of endogenous potassium ion in the extracellular fluid of a healthy human, however, using Ringer's solution or NS as a tumescent solvent would be clinically the same. Furthermore, in vitro potassium requirements may not be the same for heart muscle cells and other cells.

Ringer's solution, LR, and NS are similar when used as solvents for tumescent anesthesia. The dogma that LR is "more physiologic" than NS is only applicable to the patient with severe hypokalemia. Healthy liposuction patients undergoing a safe amount of liposuction have no potassium deficit. The cell lysis associated with liposuction may even increase the local potassium concentration as a result of spilling intracellular potassium into the interstitial space.

HARTMANN'S SOLUTION (LACTATED RINGER'S SOLUTION)

Alexis Frank Hartmann (1898-1964), an American clinical biochemist and pediatrician at Washington University in St. Louis, studied diabetes and diabetic ketoacidosis in children, which led to a search for an optimal isotonic alkalizing solution. He is responsible for putting lactate in Ringer's solution.

Sodium bicarbonate is less than ideal for the treatment of acidosis in children. At therapeutic doses, bicarbonate is highly irritating when given by IV infusion. Solutions of bicarbonate are relatively unstable and cannot be sterilized simply by boiling. If bicarbonate corrects the acidosis too rapidly, it can precipitate a profound and dangerous metabolic alkalosis. Hartmann's research was directed toward finding an alternative to $NaHCO_3$. The treatment of ketoacidosis required an isotonic solution with a moderate alkalizing effect.

Hartmann and a colleague determined that a one-sixth molar solution of sodium lactate is (1) isotonic and can be sterilized by heat without decomposition, (2) metabolized in the liver, (3) safe in patients with renal or hepatic insufficiency, (4) potentially equivalent to 172 mEq of $NaHCO_3$, and (5) equivalent to 600 ml of 5% dextrose in antiketogenic

effect.[8-11] Lactate is used instead of bicarbonate because it is more stable in IV fluids during storage.[12]

Lactate Metabolism.   The lactate in LR is not instantaneously converted to bicarbonate after infusion. Two metabolic pathways, gluconeogenesis and oxidation, are responsible for the conversion of lactate to bicarbonate. Approximately 70% of lactate is metabolized by *gluconeogenesis*, which is initiated by the enzyme pyruvate kinase, principally in the liver but also in the kidneys. *Oxidation* accounts for 30% of the lactate metabolism.

The overall equation for the metabolism of lactate by gluconeogenesis is as follows:

$$2CH_3CHOHCOO^- + 2H^+ \rightleftharpoons C_6H_{12}O_6$$
$$\text{(Lactate)} \qquad\qquad\qquad \text{(Glucose)}$$

The following is the overall equation for the metabolism of lactate by oxidation:

$$2CH_3CHOHCOO^- + H^+ + 3O_2 \rightarrow 3H_2O + 3CO_2$$

With a half-life of approximately 15 minutes in a healthy subject, the complete metabolic conversion of lactate to bicarbonate requires 1 to 2 hours.

Sodium Bicarbonate.   A tumescent anesthetic solution without sodium bicarbonate (10 mEq NaHCO₃/L) is needlessly painful on infiltration in an awake patient. Adding sufficient NaHCO₃ neutralizes the pH of an acidic solution of local anesthetic. When LR or NS is the solvent for a tumescent solution of lidocaine and epinephrine, the addition of NaHCO₃ is necessary for painless infiltration.

Complications.   LR (USP) contains 130 mEq/L of sodium, 109 mEq/L of chloride, 29 mEq/L of lactate, 4 mEq/L of potassium, and 2.7 mEq/L of calcium.

The average adult produces 1200 to 1500 mmol of lactate/day, or approximately 50 to 60 mmol/hr.[13] The liver metabolizes about 60% of this, and the kidney metabolizes or excretes the remaining 40%. The liver and kidney can accommodate large lactate infusions without immediate detriment. Large doses of LR containing 29 mEq/L of lactate produce a delayed iatrogenic metabolic alkalosis.

LR has been associated with perioperative complications. Hemodilution associated with LR during surgery may predispose to deep venous thrombosis.[14]

The administration of sodium lactate in LR can cause alkalosis as well as exacerbate preexisting alkalosis. Lactate is metabolized in the liver faster than the kidneys can excrete sodium. The resulting anion deficiency is compensated by an increased production of HCO₃⁻, and alkalosis occurs.

Alkalosis may cause cardiac dysrhythmias.[15] Alkalosis reduces the effects of vagal stimulation and reduces the level of bradycardia that might result from any given stimulus. Metabolic alkalosis increases oxygen requirements and exacerbates cardiac dysrhythmias caused by hypoxia or hypokalemia. In

alkalotic patients, NS should be used instead of LR for the same indications.

Nerve Compression.   Acute median nerve compression has been described in three patients as the result of significant IV infusion of LR in tumescent liposuction.[16] Each surgical procedure was completed in less than an hour. The patients received a total of 6100 ml, 9000 ml, and 7500 ml of LR, respectively, of which only 2000 to 2500 ml was infiltrated subcutaneously.

From a pharmacokinetic perspective, both LR and NS behave as a drug, for which the rate of absorption, distribution, and elimination can be described in standard mathematic terminology. Systemic absorption of tumescent solvent is insignificant for the first 6 hours after infiltration. Thus all the systemic effects of fluid overload can be attributed to the excessive IV fluid infusion. The systemic fluid overload, as manifested by acute median nerve paralysis, can be avoided by not using IV fluids with tumescent liposuction.

Acidosis and Alkalosis.   As noted, some surgeons prefer to use LR as the solvent for their tumescent lidocaine solutions because of LR's "sodium-sparing effect" or because LR is "more physiologic" than NS. Surgical textbooks provide little information to substantiate this preference.[17]

The lactate in LR is principally intended to produce a gradual reduction of metabolic acidosis. In healthy patients with no acidosis, the excess bicarbonate produces a transient mild metabolic alkalosis, which is promptly corrected by renal bicarbonate excretion. Critically ill patients, however, may be obligate excreters of acidic urine and be unable to excrete the bicarbonate load associated with LR, which in turn may cause metabolic alkalosis and produce renal potassium loss.[18]

Because the body contains a huge supply of intracellular potassium as well as the potassium in the extracellular fluid, the K⁺ in LR is unnecessary, and physiologic saline (NS) is sufficient for the clinical replacement of intravascular fluids with crystalloid solutions.

Transfusion with blood products becomes necessary long before any possible risk of potassium deficit from using 0.9% NaCl instead of LR.

Lactate as Inept Buffer System.   A *buffered solution* resists a change in pH when either hydroxide (OH⁻) ions or protons (H⁺) are added.[19] Blood must be a very efficient buffered solution. Despite the constant metabolic production of acids and bases, the pH of blood must be maintained within a narrow range necessary for cellular viability. *Lactic acid,* a metabolic product of anaerobic metabolism in muscle, is a weak acid with K_a of 1.4×10^{-4} and pK_a of 3.85.

The pK_a of a weak acid used in a buffered solution should be as close as possible to the desired pH of the solution. Because a pK_a of 3.85 is far from the pH of 6.2 of LR and from the pH of 7.4 of plasma, the lactate in LR is not an effective buffer.

Basic chemistry provides the following:

$$HC_3H_5O_3 \rightleftharpoons H^+ + C_3H_5O_3^-$$

and

$$K_a = ([H^+][C_3H_5O_3^-])/[HC_3H_5O_3] = 1.4 \times 10^{-4}$$

where $[C_3H_5O_3^-] = 29$ mmol/L $\cdot$ 2.9×10^{-2} mol/L, which is the standard concentration of lactate ions in LR. Because the pH of commercial LR is approximately 6.2, it follows that $[H^+] = 10^{-6.2}$ 6.3×10^{-7} mol/L. Rearranging the expression for K_a results in the following:

$$
\begin{aligned}
[HC_3H_5O_3] &= [H^+][C_3H_5O_3^-]/[1.4 \times 10^{-4}]\\
&= [6.3 \times 10^{-7}][2.9 \times 10^{-2}]/[1.4 \times 10^{-4}]\\
&= [(6.3)(2.9)/(1.4)][10^{-5}]\\
&= 1.3 \times 10^{-4} = 0.13 \text{ mmol/L}
\end{aligned}
$$

Thus the ratio $[HA]/[A^-] = [HC_3H_5O_3]/[C_3H_5O_3^-] = [0.13 \text{ mmol/L}]/[29 \text{ mmol/L}] = 0.13/29 = 4.5 \times 10^{-3}$, which is far from the ideal buffer, where $[HA]/[A^-] = 1$.

LR has no significant chemical buffering action. LR provides only an indirect source of physiologically active bicarbonate, after lactate has been metabolized by the liver. It is a fallacy to use LR assuming that it provides any significant buffering action. A solution of tumescent lidocaine with epinephrine in LR is acidic, unless it has been neutralized by the addition of sodium bicarbonate. When the tumescent solvent is LR, the anesthetic solution is too acidic and produces significant stinging pain on infiltration of tumescent lidocaine; in contrast, when 10 mEq/L of sodium bicarbonate is added to neutralize the pH of the LR, the pain is virtually eliminated.

CELLULAR DISTRIBUTION

The water in the body is subdivided into different compartments, including intracellular fluid (ICF) and extracellular fluid (ECF). The ECF consists mainly of the intravascular fluid (plasma), or interstitial fluid.

The distribution of water between various compartments within the body is determined by the relative concentration of discrete solute particles, regardless of size or electrical charge. The number of solute particles per unit volume is described in terms of mOsm/L *(osmolarity)* or mOsm/kg H_2O *(osmolality)*.

In clinical medicine, solute particles in body fluids are best quantified of mOsm according to osmolarity (e.g., mOsm/L of plasma). In physiology, osmolality is preferred because it is invariant under changes of temperature and independent of the volume occupied by the solutes in the solution. The osmolality of plasma is 290 mOsm/kg H_2O.

The total body water is 36 L (60% of body weight), with the ECF and ICF containing 12 and 24 L, respectively.

Chloride Load.   Rapid expansion of ECF volume with fluids that do not contain bicarbonate (HCO_3^-) temporarily reduces HCO_3^- concentration in the ECF as a result of excessive Cl^- anions.[20] For example, a rapid infusion of NS produces relatively mild hyperchloremia, which causes a compensatory shift of extracellular HCO_3^- into the intracellular space. This type of normal-anion-gap acidosis is mild and rapidly corrected by respiratory compensation and by the kidneys, which excrete NH_4^+ and Cl^-.

The kidneys filter 4000 mmol of HCO_3^- per day, most of which is resorbed, with 80% in the proximal tubules and 20% in the distal tubules. Because NS is not buffered and does not contain a net excess of H^+ ions, this mild transient hyperchloremic acidosis does not produce systemic acidosis.

Sodium Load.   Sodium ions are excluded from the intracellular space by the Na^+-K^- transmembrane pump. An excessive amount of total body sodium produces an osmotic pressure gradient that pulls water across cell membranes and increases ECF volume. Also, ingested free water is retained in the ECF by the extra sodium.

In progressive degrees, ECF overload is manifested by peripheral dependent interstitial edema, then by intravascular fluid overload with incipient congestive heart failure, and in the extreme, by pulmonary edema.

Based on this observation, some surgeons propose using LR with its lower sodium content (130 mEq/L) instead of NS (154 mEq/L Na) as the solvent for tumescent lidocaine solutions. The use of LR is of no benefit except for tumescent infiltration of greater than 10 to 12 L of anesthetic solution.

Sodium Chloride and Molarity.   The molecular weight of NaCl is 58.5 g/mol and that of Na is 22.9 g/mol. By definition, *one mole* of a substance contains Avogadro's number of units. The weight of one mole of NaCl is its molecular weight.

The *molarity* of a solute is defined as the number of moles of a solute per liter of solvent. A liter of water is approximately 1 kg, depending on the water's temperature. NS consists of a 0.9% solution of NaCl (0.9 g NaCl/100 ml = 9 g NaCl/L). Thus the molarity of NS is as follows:

$$
\begin{aligned}
(9 \text{ g NaCl/L } H_2O)&(\text{mol NaCl}/58.5 \text{ g NaCl})\\
&= 0.154 \text{ mol NaCl/L}\\
&= 154 \text{ mmol NaCl/L}\\
&= 154 \text{ mEq Na}^+/L
\end{aligned}
$$

Thus 1 L of tumescent solvent (NS plus 10 mEq Na/L in the form of $NaHCO_3$) contains approximately 164 mEq Na^+/L.

Saline and Lactate.   A liter of NS with $NaHCO_3$ and a liter of LR differ in sodium content by 34 mEq/L. (164 − 130 mEq/L). This difference is clinically insignificant for routine tumescent infiltration of 5 to 7 L or less of subcutaneous fluid. The time required for systemic absorption of this volume of tumescent fluid is approximately 24 to 36 hours.

However, 5 L of tumescent solvent (NS with 10 mEq $NaHCO_3$) exceeds the amount of sodium in 5 L of LR by 170 mEq Na^+ = 170 mmol NaCl = 0.17 mol NaCl = (0.17 mol) (58.5 g NaCl/mol) = 9.95 g NaCl. To put this in perspective, a 1-pound (450-mg) bag of pretzels contains approximately 9 g of sodium chloride.

Thus LR does have some sodium-sparing effect, but again, this is only significant in the range of dangerously excessive tumescent liposuction that infiltrates more than 10 to 12 L of solution.

The difference between NS and LR should be of little concern for a surgeon who is primarily concerned with patient safety. Problems with fluid overload are easily avoided by not attempting huge-volume liposuction in a single surgical procedure. A large volume of aspirated fat removed by serial liposuctions is much safer than a single surgery.

INTRAVENOUS FLUIDS

BURN ANALOGY

The pathophysiology of liposuction has been compared to that of major thermal trauma. This burn analogy, however, does not hold for the pathophysiology of tumescent liposuction. The fluid resuscitation requirements for tumescent liposuction and burns are distinctly different. Resuscitation after a major burn requires large volumes of IV fluids. In contrast, with tumescent liposuction, IV fluids are unnecessary and contraindicated because of the serious risk of systemic fluid overload.

Severe burns are associated with coagulation necrosis, altered capillary permeability, and large-volume extravasation of plasma into burned tissues. Hypoproteinemia induces edema in remote nonburned tissue, as well as significant intravascular fluid depletion. Because LR has 130 mEq/L of sodium, it is hypotonic with respect to sodium and provides some free water. Surgical textbooks recommend LR as the resuscitation fluid of choice for major burns.[21]

In contrast, tumescent liposuction requires no IV fluids. Tumescent infiltration superhydrates the targeted tissues, and the systemic absorption of tumescent fluid prevents any significant intravascular fluid deficit. Tumescent liposuction produces a net flux of isotonic fluid into the vascular space rather than the intravascular fluid deficit seen with a large burn.

With respect to intravascular fluid homeostasis, tumescent liposuction is more similar to a transurethral resection of the prostate (TURP) than to a burn. To extend the analogy further, with the tumescent technique, as with the TURP syndrome or the operative hysteroscopy intravascular absorption (OHIA) syndrome, the surgeon must guard against intravascular overload and hyponatremia.[22]

EXCESSIVE LIPOSUCTION AND HEMODILUTION

If the volumes of aspirated fat and parenteral fluid administration are so large that sodium overloading is a concern, too much liposuction is being done. Huge volumes of parenteral isotonic fluid and excessive sodium are rarely a concern when tumescent liposuction is limited to safe volumes of supranatant fat (less than 3% to 5% of body weight).

In a healthy patient the maximum safe volume of tumescent infiltration is limited by hemodilution, not by sodium overload. By the time a patient without congestive heart failure has received enough NS to cause concern about sodium overload, the deleterious effects of hypercoagulability associated with hemodilution will have supervened.

Surgeons who perform huge-volume liposuction (supranatant fat volume 5% of body mass or greater) are often compelled to administer IV fluids. IV fluid supplementation in the setting of tumescent liposuction greatly increases the risks of liposuction. Excessive intravascular absorption of LR with simultaneous IV fluid infusion can produce pulmonary edema and a hemodilution-induced hypercoagulable state. Hemodilution with LR use during surgery may predispose to deep venous thrombosis.[14]

With or without liposuction, 5 L of tumescent solution decreases the hematocrit by 10%; this is probably a nonlinear effect. Even greater volumes of tumescent solution may produce an increasing degree of hemodilution, perhaps exponentially.

With tumescent liposuction, IV fluids produce additional hemodilution. Excessive hemodilution predisposes to massive generalized postoperative edema, as well as hypercoagulability and perhaps disseminated intravascular coagulation (DIC). Liposuction under general anesthesia, using 15 L of a subcutaneous tumescent solution plus 18 L of IV LR, has resulted in fatal DIC (see Case Report 14-1).

No persuasive physiologic or pharmacologic rationale exists for using either LR or NS as the solvent for tumescent anesthesia. Massive doses of isotonic solutions should be avoided, however, as should megaliposuction. Supplemental IV infusion in conjunction with tumescent infiltration is an absolute contraindication.

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CHAPTER 24

Ancillary Pharmacology

Intravenous (IV) administration of narcotics and sedatives is the preferred mode of delivery among anesthesiologists, whose priorities are rapid onset, profound effects, ease of titration, and rapid recovery. Dermatologic surgeons have different clinical priorities, including safety in a clinical setting without an anesthesiologist in attendance and prolonged mild effects of the medications. Dermatologists tend to do painless but relatively lengthy outpatient procedures using local anesthesia without an anesthesiologist.

TUMESCENT GUIDELINES

Dermatologists require anxiolytic (antianxiety) drugs, with minimal sedation. For example, the benzodiazepines decrease anxiety at doses below those that produce sedation. Because tumescent local anesthesia is so effective at eliminating pain, anxiolytics need not produce sedation or analgesia.

Oral sedatives such as *lorazepam* or *clonidine* are well suited for surgery totally by local anesthesia. Lorazepam (1 mg) and clonidine (0.1 mg) have clinical onset in 20 to 30 minutes, last for 4 to 6 hours, and are essentially devoid of clinically significant respiratory depressant effects.

By definition, tumescent liposuction totally by local anesthesia does not require parenteral (intramuscular [IM] or IV) sedation or narcotic analgesics. Tumescent liposuction is often performed without sedatives and virtually never requires narcotic analgesics.

Typical preoperative medications for tumescent liposuction patients are given as follows:
1. The night before surgery, patients take lorazepam, 1 mg by mouth, to prevent insomnia and decrease anxiety.
2. On the day of surgery, approximately 20 to 30 minutes before beginning tumescent infiltration, patients usually receive 0.1 mg of clonidine and 1 mg of lorazepam.
3. Clonidine is withheld if the blood pressure is too low (systolic 100 mm Hg or less, diastolic 50 mm Hg or less).
4. Lorazepam is withheld if the patient feels too sedated from the previous day's lorazepam or does not want to take a sedative.
5. No other ancillary sedatives are used routinely.

If a patient has any history of vasovagal near-syncope or fainting, immediately after an IV access is established, a total dose of 0.3 to 0.4 mg of dilute (1 mg/10 ml) atropine is given to prevent a vasovagal event. This prophylactic approach has proved very effective and has not been associated with adverse side effects.

SEDATIVES AND NARCOTICS

To avoid the risks of respiratory depression in office surgery, parenteral sedatives (e.g., benzodiazepines) and narcotic analgesics (e.g., codeine, fentanyl, meperidine) should be avoided whenever possible before, during, and after surgery.

Sedatives and narcotic analgesics are rarely needed after tumescent liposuction and should be avoided for the first 18 to 24 hours after tumescent anesthesia. When properly performed, the prolonged local anesthesia of the tumescent technique usually obviates the need for postoperative analgesics other than acetaminophen.

When sedatives or narcotics are administered with an anesthetic, there is always a risk that an adverse drug interaction will precipitate a toxic reaction. For example, except for lorazepam, the benzodiazepines might inhibit hepatic cytochrome P450 3A4 (CYP3A4) enzymes. This enzymatic inhibition may result in elevated plasma lidocaine concentrations.

Diazepam should not be administered postoperatively to reduce the risk of lidocaine-induced seizure. Postoperative diazepam may actually increase the risk of lidocaine toxicity. Benzodiazepines and lidocaine may impair each other's metabolism by competitive inhibition of CYP3A4. Diazepam can depress respiratory drive, impair ventilation, and result in respiratory acidosis.

Although IV diazepam can be used to treat an acute seizure caused by lidocaine toxicity, respiratory depression may result from excessive plasma concentrations of diazepam. A physician must always be present to ensure adequate respiratory function when diazepam is given to control or prevent a seizure.

Patients should be given explicit instructions not to use sedatives or narcotic analgesics in the immediate postoperative period. Patients who self-medicate or overmedicate with

sedatives or analgesics may develop symptoms that are mistaken for signs of lidocaine toxicity, such as confusion, dysarthria, unsteadiness or ataxic gait, excessive sleepiness, and even nausea or vomiting.

In my earliest days of doing tumescent liposuction, all patients received IM meperidine and IM diazepam. Eventually I realized that these drugs were used merely because of my anxiety that patients would be anxious during surgery. By being more gentle and thorough during tumescent infiltration, the need for systemic analgesics and sedatives can be eliminated.

Most patients are more comfortable when they receive a mild anxiolytic by mouth. The goals of perioperative sedation for tumescent liposuction are to (1) maximize patient comfort and (2) minimize risks of adverse drug reactions.

This chapter describes the perioperative medications used for tumescent liposuction. The drugs most often used include clonidine, lorazepam, and atropine, and less common drugs include midazolam, labetalol, and fentanyl.

ADRENERGIC MEDICATIONS

An understanding of the modern pharmacologic and physiologic effects of the adrenergic agonists epinephrine and clonidine and the adrenergic blockers propranolol and labetalol requires some knowledge about the classification of adrenergic receptors.

The term *adrenergic* (Latin *renes*, kidneys; Greek *erg*, work) is an adjective that refers to (1) the *effects* of chemicals derived from the adrenal gland, (2) the *nerve fibers* that produce adrenaline-like substances, and (3) hormonelike *chemicals* related to adrenaline. Epinephrine and norepinephrine, jointly referred to as *catecholamines,* do not penetrate cell membranes (Figure 24-1).

The words adrenergic and cholinergic were coined in 1934 by Dale[1]: "We seem to need words which will briefly indicate action by two kinds of chemical transmission, due in the one case to some substance like adrenaline, in the other case to a substance like acetylcholine, so that we may distinguish between chemical function and anatomical origin. I suggest the words 'adrenergic' and 'cholinergic' respectively."

Catecholamines affect cell metabolism by first binding to specific receptors on the extracellular surface. This triggers a transmembrane signal transduction via a guanine nucleotide binding (G) protein, which in turn activates a cascade of intracellular reactions that causes the physiologic response. Adrenergic receptors bind to specific G-protein subtypes. The binding of a beta (β) agonist to an adrenergic receptor results in the stimulation of the enzyme adenyl (adenylate, adenylyl) cyclase. In contrast, when an alpha$_2$ (α_2) agonist binds to an adrenergic receptor, it inhibits the G protein, which in turn either inhibits or has no effect on adenylate cyclase.

ALPHA AND BETA DICHOTOMY

The idea of more than one adrenergic receptor was proposed in 1948, when researchers observed that norepinephrine, epinephrine, and isoproterenol have differential effects on smooth muscle.[2] A dichotomy was noted between excitation and inhibition. The Greek letter α (alpha) was chosen to designate receptors on smooth muscle that mediate *excitatory* responses, and β (beta) designated receptors that mediate *inhibitory* adrenergic effects. Pharmacologists were able to rank order adrenergic drugs in terms of their relative α effect and relative β effect.

The potency of α agonists, that is, drugs that have an excitatory effect on smooth muscle contraction, can be rank ordered from the most potent to the least potent: epinephrine $\geq$ norepinephrine > isoproterenol.

The rank order of β agonists, that is, their potency in causing inhibitory effects on smooth muscles, is isoproterenol > epinephrine : norepinephrine.

This classification became widely accepted when it was shown that certain drugs could act as specific adrenergic receptor blockers. For example, phenoxybenzamine was shown to block the α effect of nerve impulses and the pharmacologic effect of α agonists. Similarly, propranolol produced β-receptor blockade.

Nonselective β-adrenergic antagonists include *propranolol* (blocks β_1 and β_2 receptors with equal affinity) and *nadolol* (Corgard). A newer, more useful nonselective adrenergic antagonist is *labetalol* (Trandate), which blocks both α and β receptors (see later discussion).

Beta$_1$ and Beta$_2$ Dichotomy. The β receptors were subdivided in 1967 when researchers found that epinephrine is 10 to 50 times more potent than norepinephrine on smooth
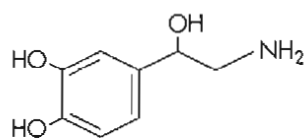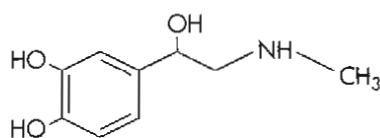
Norepinephrine   Epinephrine

Figure 24-1

Structure of adrenergic agonists. Norepinephrine and epinephrine are endogenous catecholamines that bind to adrenoreceptors.

muscle relaxation, whereas they are equipotent on the myocardial force of contraction and heart rate.[3] Pharmacologists now distinguish between β-adrenergic receptors as follows:

1. The β_1 receptors are equally affected by epinephrine and norepinephrine.
2. The β_2 receptors are affected much more by epinephrine than norepinephrine.

Clinically, β_1-adrenergic receptors are most importantly associated with the myocardium. At present, no selective β_1-adrenergic agonists exist. Selective β_1-adrenergic antagonists include *metoprolol* (Lopressor) and *atenolol* (Tenormin).

Selective β_2-adrenergic agonists include *terbutaline* (Brethine) and *albuterol* (Proventil), which relax bronchiolar smooth muscle in the treatment of asthma and obstructive pulmonary disease. *Pindolol* (Visken) is a relatively selective β_2-adrenergic antagonist with slight β_1-agonist activity used for treating hypertension in patients with mild bradycardia or diminished cardiac reserve.

A third β-adrenergic receptor has been identified; β_3 appears to mediate the adipose tissue responses to adrenergic activation of adenyl cyclase and lipolysis.[4] People with the Trp64Arg mutation of the gene for the β_3-adrenergic receptor may have an increased capacity to gain weight.[5] This allele is associated with increased abdominal obesity and resistance to insulin, and it may contribute to the early onset of non-insulin-dependent diabetes mellitus (NIDDM).[6] Homozygotes for this mutation have an earlier onset of NIDDM.[7]

Alpha$_1$ and Alpha$_2$ Dichotomy. The α-adrenergic receptors are responsible for diverse functions, including pain perception, effects on levels of consciousness, cardiovascular homeostasis, and regulation of metabolism.

Significant similarities exist between α_2-adrenergic agonists and opioids. The α_2-adrenergic receptors and the μ-opioid receptors are found in the same region of the brain and in some cases coexist on the same neuron. Both receptor systems share the same type of G-protein signal transduction system distal to the receptor; thus both α_2-adrenergic receptors and μ-opioid receptors have the same type of molecular pathway.[8]

Different subtypes of α-adrenergic receptors are recognized and classified on the basis of their anatomic location and physiologic and pharmacologic functions. The anatomic location of the vast majority of α_2-adrenergic receptors is presynaptic; α_2-receptor stimulation has an inhibitory effect on the release of norepinephrine from sympathetic nerve terminals. The postsynaptic α_1-adrenergic receptors mediate an augmentation of norepinephrine effects.

Some α_2-adrenergic receptors are also found on the postjunctional surfaces. For example, the surfaces of adipocytes have α_2 receptors that inhibit isoproterenol-induced glycolysis and lipolysis when stimulated by selective α_2 agonists.

The α_2 receptors located postsynaptically in the brain probably mediate the antihypertensive effects of clonidine. Clonidine is an α-adrenergic agonist that has a more potent α_2 effect than α_1 effect. Clonidine has many useful applications in tumescent liposuction surgery.

Stimulation of α_1-adrenergic receptors produces constriction of systemic arteries and veins; it also mediates hepatic gluconeogenesis. Phenylephrine (Neo-Synephrine), a selective α_1 stimulator used as a nasal decongestant, can be given intramuscularly to prevent hypotension associated with spinal anesthesia.

Stimulation of α_2-adrenergic receptors is important for platelet aggregation, smooth muscle contraction, neurotransmitter release, and regulation of sympathetic nerves within the central nervous system (CNS).

EPINEPHRINE

Epinephrine and *adrenaline* are two different names for the same adrenal medullary hormone. Epinephrine is derived from tyrosine in a stepwise biosynthetic process involving three intermediate substances, as follows:

$$\text{Tyrosine} \rightarrow \text{Dopa} \rightarrow \text{Dopamine} \rightarrow \text{Norepinephrine} \rightarrow \text{Epinephrine}$$

The rate-limiting step in the biosynthesis of epinephrine is the hydroxylation of tyrosine, which is subject to negative feedback inhibition by catechol compounds (see Figure 24-1).

The catecholamines epinephrine and norepinephrine are the ultimate mediators of the sympathetic nervous system, which controls cardiovascular homeostasis, states of consciousness, and cellular metabolism. Epinephrine is a circulating hormone derived from the adrenal gland, whereas norepinephrine is released from adrenergic nerve terminals. When combined with a local anesthetic, the α_1-adrenergic receptor stimulation of epinephrine causes capillary vasoconstriction. Epinephrine is responsible for the profound vasoconstriction and consequent hemostasis essential to the tumescent technique.

Adverse Reactions. Simple adverse reactions to therapeutic epinephrine can be caused by either a pharmacologic hypersensitivity or an immune-mediated allergic reaction to an additive. More complex adverse reactions involve drug interactions in which therapeutic doses of epinephrine interact with other agents.

Despite life being impossible without endogenous epinephrine, some patients have a true clinical hypersensitivity to therapeutic doses of epinephrine. In these patients, tachycardia is precipitated by a routine dose of epinephrine, the result of a labile or hypersensitive cardiac sinus pacemaker, sinoatrial node, or myocardial conduction system. Other patients may have an allergic-like hypersensitivity to the bisulfite, an antioxidant often added to pharmacologic preparations containing epinephrine.

The most common adverse reaction to epinephrine is the normal pharmacologic response to the rapid absorption of a therapeutic dose. For example, a rapidly absorbed dental injection of lidocaine with epinephrine may induce a pharmacologic supraventricular tachycardia. Patients may be told incorrectly that a pharmacologic tachycardia is an allergic reaction.

A middle-age woman who stated she had an allergy to epinephrine eventually found a surgeon willing to perform liposuction on her abdomen, hips, outer thighs, inner thighs, and inner knees under general anesthesia. Tumescent hemostasis was attempted with subcutaneous infiltration of 6 L of chilled saline that contained no epinephrine. The preoperative hematocrit was 32%. Liposuction produced 5 L of aspirate; 70% of the aspirate was fat. Also, 4 L of IV fluids was infused.

In the days after surgery the patient complained of dizziness, and on the fourth postoperative day, she developed partial blindness in the left eye. Examination showed a hematocrit of 20%, retinal edema, and a flame-shaped retinal hemorrhage.

Discussion. The vasoconstriction resulting from the tumescent infiltration of chilled saline provides insufficient hemostasis for large-volume liposuction. Dilute epinephrine is indispensable for true tumescent liposuction.

The subcutaneous infiltration of a large volume of chilled saline might produce even more hemorrhage than liposuction using the previous dry technique. Both general anesthesia and subcutaneous infiltration of 6 L of chilled saline can produce hypothermia, which in turn causes hypercoagulability and possible bleeding diathesis.

The combined effects of 4 L of IV saline and 6 L of subcutaneous chilled saline produce hemodilution, which also causes hypercoagulability. Chilled saline injected subcutaneously produces local tissue hypothermia; tissue rewarming leads to a rebound capillary vasodilation with augmented postoperative bleeding.

Even with epinephrine, using a chilled tumescent solution is contraindicated. The resultant hypothermia and hemodilution are unsafe and predispose to a consumptive coagulopathy and increased postoperative bleeding.

The surgeon has two reasonable alternatives for a prospective liposuction patient with a possible allergy to epinephrine, as follows:

1. Refer the patient to an allergist for a formal evaluation of epinephrine or bisulfite allergy; if no evidence of allergy is found, the patient can consider tumescent liposuction.
2. Explain to the patient that the anticipated cosmetic benefits may not warrant the potential health risks of liposuction without tumescent hemostasis (Case Report 24-1).

A third alternative is less reasonable: do liposuction without epinephrine.

Other Interactions. Clinically significant drug interactions with local anesthetics usually involve either lidocaine metabolism via hepatic CYP3A4 or epinephrine–adrenergic agonist effects with other vasoactive drugs. Epinephrine is contraindicated in patients with significant cardiovascular disease, peripheral vascular disease, hyperthyroidism, and pheochromocytoma, as well as in those taking the drugs listed next.

Monoamine oxidase inhibitors (MAOIs), tricyclic antidepressants, butyrophenones such as droperidol (Inapsine), and phenothiazines may interact adversely with epinephrine to produce severe hypotension or hypertension.

Oxytocin-like drugs that induce labor interact with epinephrine-like drugs to produce malignant hypertension and cerebrovascular accidents.

Cocaine, which blocks the reuptake of norepinephrine, interacts adversely with lidocaine, by reducing the seizure threshold, and with epinephrine, by augmenting systemic vasoconstriction and tachycardia.

Hyperthyroidism, induced endogenously, iatrogenically, or by drug abuse, can result in adverse interactions with epinephrine and precipitate supraventricular tachycardia.

Beta Blockers. Epinephrine stimulates both the α-adrenergic and β-adrenergic receptors, whereas propranolol blocks β-adrenergic receptors. When these two drugs are given simultaneously, the net effect may be unopposed α-adrenergic receptor stimulation, which reportedly can lead to peripheral vasoconstriction and severe hypertension. Because this specific drug interaction has been infrequently reported, only certain individuals may be predisposed and susceptible to severe hypertension resulting from an epinephrine-propranolol interaction.

A few cases have been reported of severe hypertension after injection of epinephrine-containing local anesthetics in patients taking propranolol. In my experience, however, no adverse events have occurred when patients receiving propranolol are given tumescent local anesthesia.

Prospective liposuction patients may be taking propranolol for either migraine headaches or hypertension. With relatively large doses of very dilute epinephrine for tumescent anesthesia, no adverse drug interactions have occurred with concomitant use of beta blockers (e.g., propranolol). I do not ask my patients to discontinue propranolol before tumescent liposuction. The amount of lidocaine and epinephrine can be reduced and serial liposuction performed. Although clinical judgment must be used, in general it is not necessary to interrupt propranolol treatment of migraine headaches or hypertension as a prerequisite to tumescent liposuction. Presumably the rate of systemic absorption of epinephrine from tumescent subcutaneous fat is too slow to permit a significant adverse interaction.

Interactions. Interactions between epinephrine and beta blockers can cause toxicity. The determining factor seems to be the rate of epinephrine absorption into the systemic circulation. A rapid absorption of subcutaneous epinephrine is more likely to result in a toxic reaction than when the epinephrine is absorbed much more slowly.

Rapid absorption of an injection of a drug containing epinephrine can occur in at least two clinical settings:

1. A relatively high concentration of epinephrine (1:1000) is injected subcutaneously to treat a suspected allergic reaction.
2. A moderate epinephrine concentration (1:100,000) is injected into highly vascular tissue, such as buccal mucosa for local anesthesia in dentistry, ocular mucosa with blepharoplasty, or for a regional nerve block.

When epinephrine is injected subcutaneously, 5 to 15 minutes pass before the onset of maximum cutaneous blanching and vasoconstriction. Thus, within the first few minutes after subcutaneous injection, significant epinephrine can reach the systemic circulation and precipitate an abrupt hypertensive drug interaction with secondary bradycardia.

In a report of six cases, lidocaine with epinephrine was injected subcutaneously for vasoconstriction before blepharoplasty (eyelid surgery) and resulted in a rapid onset of malignant hypertension and severe bradycardia.[9] Another patient taking propranolol was given 0.3 mg of concentrated epinephrine (1:1000) subcutaneously to treat a suspected allergic reaction and rapidly developed hypertension and bradycardia.[10]

Another report documented chest pain in four patients taking propranolol after subcutaneous injection of 0.4 to 0.5 mg of epinephrine.[11] Severe hypertension has also been reported in patients taking propranolol after IV infusion of epinephrine.[12-14]

In contrast, when epinephrine (1:100,000) is injected subcutaneously into tissue having a relatively low vascularity, absorption is slower, and the incidence of hypertension is greatly reduced or avoided. A prospective study of patients undergoing Mohs' micrographic surgery for skin cancers by local anesthesia with lidocaine and epinephrine compared 10 patients taking propranolol and 10 patients without propranolol. Although neither group had hypertension, the no-propranolol group had a slightly decreased blood pressure compared with the propranolol group.[15]

The route of drug delivery and the rate of drug absorption are decisive factors in determining the relative risk of toxicity. With the slow systemic absorption of epinephrine associated with the tumescent technique, the risk of an adverse interaction (manifested by hypertension) between epinephrine and beta blockers is small. In my patients taking beta blockers, careful blood pressure monitoring has shown no evidence of postoperative hypertension.

As noted, patients being treated with nonselective beta blockers for hypertension or migraine headaches should be maintained on these medications. A cautious approach to such patients is to limit both the number of areas treated and the total dose of epinephrine given during a session of tumescent liposuction.

When using a local anesthetic that contains epinephrine, caution is always necessary. In spontaneously hypertensive rats pretreated with a cardioselective beta blocker, no problem occurred after an intraperitoneal (IP) dose of epinephrine. Pretreatment with a noncardioselective beta blocker and IP epinephrine, however, produced systemic vasoconstriction and pulmonary congestion.[16] Cardioselective beta blockers include metoprolol Lopressor) and atenolol (Tenormin).

LABETALOL

Labetalol (Trandate) represents a relatively new class of drugs that blocks both α_1-adrenergic and β-adrenergic receptors. An IV formulation is available (5 mg/ml). This drug can be useful for treating the epinephrine-associated sinus tachycardia (115 to 130 beats/min) that can occur with relatively large doses of tumescent anesthesia in patients who are especially sensitive to epinephrine.

Orthostatic hypotension is a potential side effect of labetalol. The IV dose of labetalol used to treat perioperative sinus tachycardia is 2 mg by slow push every 10 to 15 minutes. To reduce the heart rate to less than 110 beats/min, 5 mg or less usually suffices.

Significant tachycardia has not occurred and labetalol has not been used since clonidine (0.1 mg) was instituted as a standard preoperative sedative. Clonidine is given orally to liposuction patients whose blood pressure is 105/60 or greater or whose pulse rate is 70/min or greater.

CLONIDINE

Clonidine (Catapres) is a highly selective α_2-adrenergic agonist with several desirable attributes as an oral sedative for surgery by local anesthesia. Clonidine (0.1 mg) in combination with the benzodiazepine lorazepam (1 mg), both given orally, is now the preferred perioperative sedative for tumescent liposuction totally by local anesthesia.

Clonidine was originally synthesized in 1962 for possible use as a nasal decongestant, but this application produced sedation, hypotension, and bradycardia. Although excellent for the treatment of hypertension, clonidine's use was limited by the resulting sedation, which was eventually found to be synergistic with anesthetics and analgesics. No clinically significant respiratory depression occurs, except at extreme overdoses of more than 1000 times a therapeutic dose.

Most surgeons, however, are not familiar with the benefits of clonidine.[17] Also, many anesthesiologists do not routinely use α_2-adrenoceptor agonists, despite the many advantageous perioperative applications, including sedative, anxiolytic, analgesic, anesthetic-sparing, and hemodynamic-stabilizing effects.[18]

Alpha₂ Adrenergic Receptors. The adrenoreceptors are examples of transmembrane G-protein–coupled receptors. *G proteins* are ubiquitous transmembrane signaling mediators.[19] The adrenoreceptors can be classified according to their G proteins' action on adenylate cyclase and sensitivity to ribosylation (i.e., the enzymatic transfer of the ribosyl group from inosine to adenine) by *Bordetella pertussis* toxin.

All the α_2-adrenoceptors are coupled to G proteins that (1) are sensitive to *B. pertussis* toxin and (2) either have no effect on or support inhibition of adenylate cyclase.[20] In contrast, β adrenoceptors are coupled to G proteins that (1) are not pertussis toxin sensitive and (2) stimulate the activation of adenylate cyclase.

Clonidine is an imidazole compound that is highly selective for α_2 adrenoreceptors. Its potency as an α_2 agonist is 200 times greater than an α_1 agonist. An *imidazole* is a heterocyclic compound consisting of the following five-membered ring:

$$N-CH=N-CH=CH$$
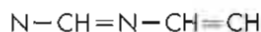
Certain imidazole derivatives have sympathomimetic properties. The imidazole nucleus is also found naturally in the amino acid histidine, as well as in histamine, biotin, and the purines (uric acid, adenine, caffeine, xanthine).

Pharmacokinetics.   Clonidine is a lipid-soluble molecule that is rapidly and completely absorbed after oral administration. Clonidine rapidly crosses the blood-brain barrier. Clinical effects become apparent 20 to 40 minutes after oral administration, and peak plasma concentrations are achieved within 60 to 90 minutes. Clonidine is available in 0.1-mg, 0.2-mg, and 0.3-mg tablets. For outpatient tumescent liposuction surgery, clonidine is given as a single 0.1-mg oral dose; hypotension or bradycardia is rarely a problem at this dose.

Clonidine has a volume of distribution of about 2 L/kg and is 20% bound to plasma proteins. It is less than 50% metabolized by the liver; the rest is largely excreted unchanged via the kidneys, with about 20% excreted in the feces. The elimination half-life is 6 to 20 hours and is prolonged by renal insufficiency. Clonidine clearance is 1.9 to 4.3 ml/min/kg. Sedation can last up to 12 hours.

Antihypertensive Effects.   Clonidine is especially effective for treating severe or malignant hypertension. Many patients with malignant hypertension given 0.1 mg of clonidine in the emergency room respond so well that they do not require IV therapy when admitted to the intensive care unit. Because of its sedative effect, clonidine is usually not acceptable among ambulatory patients for long-term treatment of hypertension.

The exact location and the specific receptors responsible for the central hypotensive effect of α_2-adrenoceptor agonists are not known. The α_2 agonists induce diuresis by inhibiting release of antidiuretic hormone and by increasing glomerular filtration rate.[21,22] Clonidine-induced diuresis helps compensate for the systemic absorption of isotonic fluids associated with tumescent infiltration. Clonidine lowers intraoperative and postoperative hypertensive responses to anesthetics and surgical stress.[23]

Sedative Effects.   Sedation is the most consistent central effect of α_2-adrenergic agonists.[24] Although sedation is an undesirable pharmacologic side effect for an antihypertensive drug, it is a most desirable effect in conjunction with outpatient surgery by local anesthesia. Clonidine synergistically increases the potency of benzodiazepines such as lorazepam and midazolam.[25]

Clinical doses of α_2 adrenoreceptor agonists do not depress respiratory drive and are not associated with hypoxia or hypercapnia. The lack of respiratory depression is one of the principal benefits of clonidine as a sedative.

Anxiolytic Effects.   Clonidine has been shown to have anxiolytic effects independent of its sedative effect.[26] The α_2 agonists reduce anxiety similar to the benzodiazepines.[27]

Clonidine also can suppress panic disorder.[28] Clonidine attenuates the stress response to surgical trauma and decreases sympathoadrenal outflow.[29]

Narcotic Analgesic Effects.   Clonidine both supplements and minimizes the need for narcotic analgesics and thus minimizes the risks of respiratory depression.

Clonidine and other α_2 agonists possess significant analgesic and anesthetic effects.[30] In animals, clonidine produces a more potent analgesic effect than morphine.[31] It decreases the requirements for fentanyl,[32] sufentanil,[33,34] droperidol,[35] and propofol.[36]

The analgesic effect of α_2 agonists synergistically enhances the effect of opioids when administered concomitantly.[37] The α_2 agonists suppress the withdrawal syndrome associated with opioids.[38]

Clonidine pretreatment reduces the morphine requirements in self-administered postoperative analgesia.[39] Intraoperative clonidine enhances postoperative morphine patient-controlled analgesia.[40] Risk of respiratory depression is not increased when clonidine is administered with narcotics such as morphine or alfentanil.[41,42] Clonidine has also proved useful in treating chronic pain syndromes.[43]

Because clonidine might prolong the risk of opioid respiratory depression, fentanyl doses should be reduced when given with clonidine.[44] Respiratory depressant effects of α_2 agonists are minimal.[45] Typical clinical doses of clonidine produce sedation without causing respiratory depression.

Anesthesic Effects.   Clinical observations have shown that clonidine, at approximately 1000-fold lower concentrations than lidocaine, prolongs the action of lidocaine in peripheral nerve blocks. Similar findings have been observed using desheathed rabbit vagus nerve.[46]

Oral clonidine prolongs the effects of spinal local anesthesia.[47-50] Pretreatment with clonidine reduces the systemic toxicity of IV bupivacaine in rats.[51]

Clonidine reduces requirements, such as minimal alveolar concentration (MAC), for halothane and other anesthetics.[52,53]

Bradycardia and Hypotension.   The cardiovascular effects of clonidine include bradycardia, hypotension, and an antidysrhythmic effect, all of which are advantageous in the clinical setting of tumescent liposuction.

By inhibiting the release of norepinephrine from peripheral sympathetic presynaptic nerve endings, α_2 agonists lower the heart rate. Although clonidine's ability to lower pulse rate and blood pressure is desirable, excessive bradycardia and hypotension are potentially dangerous side effects.

Usually, however, bradycardia is a useful side effect of clonidine that counteracts the tachycardic effect of the epinephrine in tumescent anesthetic solutions. Without clonidine, approximately 10% of my patients would experience a sustained heart rate of more than 110 beats/min; less than 2% would have a

tachycardia of 120 to 130 beats/min, requiring IV labetalol to reduce heart rate. Patients have never required labetalol when clonidine is given before tumescent liposuction.

Clonidine is relatively contraindicated if the patient's preoperative pulse is less than 60. The α_2-adrenoceptor agonist may produce bradycardia by a central sympatholytic action that leaves the vagal tone unopposed or perhaps by a presynaptic inhibition of noradrenaline release.[54]

Hypotension is a potential side effect of clonidine, but 0.1 mg of clonidine is rarely associated with clinical hypotension. Nevertheless, clonidine should be used with caution if the preoperative systolic blood pressure is less than 100 mm Hg.

An antidysrhythmic effect is another benefit of α_2 agonists such as clonidine. The α_2 agonists can prevent epinephrine-induced arrhythmias (dysrhythmias).[55]

Miscellaneous Effects.   Evidence indicates that postoperative α_2-adrenergic stimulation attenuates protein catabolism.[56] Clonidine significantly reduces postoperative shivering.[57] In children, premedication with clonidine given orally (4 μg/kg) or rectally (2.5 μg/kg) provides effective preoperative sedation and postoperative analgesia.[58,59] By reducing the salivary flow, α_2 agonists may cause a sensation of dry mouth.

Tumescent Liposuction.   The sedative effects of α_2-adrenoceptor agonists are ideal for tumescent liposuction totally by local anesthesia. Clonidine has significantly reduced the incidence of intraoperative tachycardia that had resulted from epinephrine absorption after tumescent infiltration.

Patients with a history of hypertension may arrive in the operating room with elevated blood pressure despite ongoing treatment for hypertension. Clonidine (0.1 mg) has lowered the blood pressure to acceptable levels, avoiding cancellation of surgery. Clonidine acts synergistically with benzodiazepines to produce excellent sedation and anxiolysis.

For outpatient tumescent liposuction surgery, clonidine is given as a single 0.1-mg oral dose; more than 0.1 mg should be avoided. On the one occasion that a patient was given a second 0.1-mg dose of clonidine, the result was a 3-hour delay before discharge because of a prolonged episode of orthostatic hypotension. If a patient requires additional sedation, it is preferable to give a benzodiazepine such as lorazepam 1 mg by mouth, or alternatively a small dose of IV midazolam in 1-mg to 2-mg increments.

BENZODIAZEPINE SEDATIVES

Discovered in the 1950s, the benzodiazepines' calming effect on test animals became apparent at doses less than those producing sedation or ataxia. This first suggested that benzodiazepines might be useful for anxiolytic effects. Other therapeutic properties of the benzodiazepines include anticonvulsive, muscle relaxation, and sedative-hypnotic effects.

The benzodiazepines' pharmacologic action is associated with gamma-aminobutyric acid (GABA), the principal inhibitory neurotransmitter in the mammalian CNS.[60] The high-affinity benzodiazepine receptor is coupled to GABA receptors in such a way that benzodiazepines enhance GABA effects. *Flumazenil* is a benzodiazepine antagonist with a high affinity for benzodiazepine receptors but little or no interaction with GABA. Flumazenil blocks the agonists' interaction with the receptors.

Benzodiazepines are metabolized by the liver and eliminated in the urine. Any factor that affects liver function, such as age or disease states, can affect benzodiazepine pharmacokinetics. The benzodiazepines, including lorazepam, diazepam, and midazolam, are highly bound to plasma proteins. Benzodiazepines produce reliable anterograde amnesia but no significant retrograde amnesia.

SIDE EFFECTS

The major adverse effect of the benzodiazepines is central respiratory depression. Lorazepam probably causes the least respiratory depression, whereas midazolam appears to have the greatest adverse effect on ventilation. Lorazepam has been reported to attenuate the respiratory depression associated with meperidine.[61] Sedating doses of IV midazolam (0.1 mg/kg) blunt the response to hypoxia by approximately 50% in healthy adults.[62]

An adverse drug interaction may occur with midazolam and fentanyl. IV midazolam (0.05 mg/kg) below the threshold for causing respiratory depression was given with IV fentanyl (2 μg/kg). The incidence of hypoxia increased from 50% with fentanyl alone to more than 90%. Furthermore, the incidence of apnea increased from 0% to 50%.[63]

Patients' tendency to self-medicate with sedatives and narcotic analgesics after tumescent liposuction is especially troubling to surgeons. Self-medication may explain two of my patients' telephone calls the night after surgery to complain about ataxia, confusion, dysarthria, nausea, and vomiting. These symptoms of benzodiazepines are worrisome because they overlap the symptoms of early lidocaine toxicity.

On the two occasions I evaluated patients in the emergency room to rule out lidocaine toxicity, plasma lidocaine concentrations were 3.1 μg/ml or less, well below the toxic threshold of 6.0 μg/ml (Case Report 24-2). When patients are warned explicitly not to self-medicate with sedatives or narcotic analgesics, the incidence of "pseudotoxicity" disappears.

Some dermatologists prescribe sublingual diazepam (Valium) tablets for their surgical patients. The absorption kinetics are not well known, however, and sublingual diazepam has approximately the same rapid systemic absorption as the IV form. These patients require the same level of clinical observation and monitoring as those receiving an equal IV dose.

LORAZEPAM

Based on clinical experience, lorazepam is currently the benzodiazepine of choice for tumescent liposuction. In terms of pharmacologic effect, lorazepam is similar to diazepam, but the two differ significantly in pharmacokinetics. After an IV injection, lorazepam has a short distribution half-life but a rather long elimination half-life of 10 to 20 hours. Thus the effects of lorazepam are of longer duration than those of diazepam.

CASE REPORT 24-2 Suspected Diazepam Interaction with Lidocaine

A 32-year-old, 65-kg (143-pound) female had liposuction of abdomen, hips, and waist, with a tumescent lidocaine dosage of 64.9 mg/kg. She had been prescribed diazepam for sedation. She received another sedative before surgery.

On awakening at 7 PM the evening after surgery, the patient experienced mild nausea, anxiety, mild confusion, unsteady gait, and slurred speech. These symptoms had largely subsided during evaluation in the emergency room. The concentration of plasma lidocaine at 8 PM was 3.1 μg/ml, well below the toxic threshold of 6 μg/ml.

By morning the patient was completely alert and had no symptoms.

Discussion. Nausea associated with a low concentration of plasma lidocaine after tumescent liposuction may be caused by self-medication with benzodiazepines (e.g., diazepam). This results in increased concentrations of plasma lidocaine metabolites. The two principal lidocaine metabolites are monoethylglycine xylidide and glycine xylidide, which may contribute to lidocaine side effects. Any drug interaction that results in delayed elimination of a lidocaine metabolite thus may increase the risk of nausea and vomiting.

After an oral dose, lorazepam's peak plasma concentration occurs in 1 to 1½ hours. Available in 0.5-mg, 1-mg, and 2-mg tablets, lorazepam at 2 mg is equivalent at peak effectiveness to 10 mg of diazepam. A 2-mg to 4 mg oral dose of lorazepam produces anxiolytic, sedative, and anterograde amnesic effects comparable to 10 to 20 mg of diazepam.[64,65]

One milligram of lorazepam appears to provide sufficient perioperative sedation for tumescent liposuction. Patients are instructed to take 1 mg of lorazepam the night before surgery to avoid insomnia but not to take it for 24 hours after surgery.

Lorazepam is the only benzodiazepine not metabolized by cytochrome P450 enzymes and therefore is less susceptible to adverse drug interactions with lidocaine. In its initial metabolic reaction, lorazepam is conjugated to its glucuronide, which has no CNS activity, and is excreted in the urine.

Nausea and vomiting are side effects of high doses of benzodiazepines (e.g., lorazepam) as well as lidocaine. A 2-mg dose of lorazepam produces more nausea than a 1-mg dose. Clonidine in combination with lorazepam provides good anxiolysis while allowing a reduced lorazepam dose, which minimizes the incidence of nausea and vomiting.

After a 4-mg dose of IM lorazepam, amnesia persists for 4 to 6 hours.[65] Lorazepam is the benzodiazepine that provides the most consistent and longest-lasting amnesia.

MIDAZOLAM

Midazolam is widely used perioperatively for its sedative, amnesic, and anxiolytic effects. Fewer than 3% of liposuction patients require IV midazolam during tumescent infiltration to supplement oral doses of clonidine and lorazepam. If the patient is particularly anxious, however, 1 mg of IV midazolam is given and repeated once if necessary.

At a pH of less than 4, midazolam exists in an open-ring form that is highly water soluble. At physiologic pH the ring closes, and the molecule becomes highly lipid soluble and readily crosses the blood-brain barrier. The water solubility of midazolam is unique among the benzodiazepines.

The other benzodiazepines are not soluble in aqueous solution unless propylene glycol is added to the solution to maintain solubility in the bottle. When injected, propylene glycol–containing solutions cause a stinging and burning sensation and possibly a localized venous thrombophlebitis, especially with diazepam. The incidence of thrombophlebitis after IV diazepam administration is 15% to 39%.[66,67] One major advantage of midazolam is its lack of IV irritation.

With short distribution and elimination half-lives, midazolam has a very short duration of action after a single IV dose.[68,69] It has a hepatic extraction ratio of about 50% and is associated with significant first-pass metabolism; thus oral doses of midazolam are not efficient. Typical IM doses for adults are 5 mg, which is reduced to 2 or 3 mg in adults over 60 years old.

Erythromycin. Midazolam and erythromycin utilize CYP3A4 for hepatic metabolism. Erythromycin is a potent inhibitor of CYP3A4 and has been associated with midazolam toxicity when the two drugs are used concomitantly. Elevated plasma midazolam concentrations were associated with unconsciousness after an 8-year-old boy received midazolam (0.5 mg/kg), followed by an IV infusion of erythromycin.[70] Similar effects can be expected from other potent inhibitors of CYP3A4, such as ketoconazole.

Metabolism. Midazolam is metabolized by at least three different cytochrome P450 enzymes.[71] In addition to CYP3A4, the isoenzymes 3A3 and 3A5 are also important in the hydroxylation of midazolam. Whereas 3A3 and 3A4 are hepatic isoenzymes, 3A5 occurs predominantly in the kidney. Knowledge of the specific cytochrome P450 enzymes that metabolize a drug may help the clinician anticipate clinical situations that decrease the rate of drug metabolism, such as drug interactions in combined therapy.

Serum from critically ill patients inhibits the metabolism of midazolam.[72] Serum samples from five critically ill patients were incubated with microsomes prepared from three human livers. The enzymatic activity of CYP3A4 was determined in vitro by adding midazolam to the microsomal preparation and measuring the rate of midazolam metabolism. Compared with serum from normal volunteers, serum from critically ill patients added to the liver microsomal preparation resulted in a significant decrease in the rate of midazolam metabolism.

Patients with extensive trauma, such as excessive liposuction, might be more susceptible to the dose-related effects of midazolam, such as respiratory depression.

Diazepam. Midazolam and diazepam directly depress the myocardium, exerting similar negative chronotropic and inotropic actions.[73] In cardiac myocytes, influx of calcium ions across the sarcolemma via L type Ca^{++} channels is the trigger for Ca^{++} release from the sarcoplasmic reticulum, which activates the myofibrils. Both midazolam and diazepam have a direct myocardial depressant effect at the cellular level, which is mediated by an inhibition of the sarcolemmal L-type Ca^{++} channel.

ATROPINE

VASOVAGAL NEAR-SYNCOPE

A vasovagal near-syncopal episode in a supine patient (e.g., in an operating room) can be a frightening experience. Already supine, the patient usually has a prolonged episode of nausea, diaphoresis, and a feeling of impending doom but no loss of consciousness.

In contrast, a vasovagal attack in a sitting or standing person is usually brief, rapidly progressing from sweating, clamminess, and lightheadedness to loss of consciousness, then recovery.

VASOVAGAL STIMULATION

Atropine is a competitive antagonist of acetylcholine and inhibits postganglionic responses to cholinergic nerve stimulation. Vagal reflex with cardiac slowing or asystole can be eliminated by atropine blocking the vagal influence at the sinoatrial node in the right atrium. Atropine can also facilitate atrioventricular nodal conduction by the same mechanism.

Atropine blocks the effects of excessive vagal stimulation and its subsequent reflex bradycardia. This vagolytic effect is most noticeable in healthy, young and middle-age adults in whom vagal tone is most prominent. In infants and geriatric patients, atropine may not be effective in accelerating heart rate. Atropine can produce innocuous cardiac dysrhythmias without significant symptoms.

PROPHYLACTIC DOSE

As part of the preoperative history and physical examination, all patients are asked if they have ever been extremely lightheaded or have fainted. This question is a good predictor of vasovagal syncope in the operating room during tumescent liposuction in an alert and fully conscious patient. Any history of fainting or lightheadedness is sufficient indication to premedicate the patient with 0.3 to 0.4 mg of atropine.

Before surgery, as soon as the IV access is established, the patient is given IV atropine. An effective protocol consists of preparing a syringe by adding 1 mg of atropine (1 mg/ml) to 9 ml of bacteriostatic saline, which yields atropine at 1 mg/10 ml. A prophylactic dose of IV atropine is typically 0.3 to 0.4 mg.

DRUG ABUSE AND LIPOSUCTION

COCAINE

Cocaine augments the toxicity of lidocaine by lowering the seizure threshold. It also predisposes to epinephrine toxicity by increasing systemic vasoconstriction and possibly tachycardia.

Liposuction surgeons should be aware of the "positive Kleenex sign" associated with cocaine abuse. At least two of my patients wanted to take a box of facial tissue into the operating room because of "allergic rhinitis."

The first patient arrived holding a box of tissue and soon became abusive, demanding narcotics even before the tumescent infiltration. When narcotics were refused, she departed angrily. Later that day she was admitted to a hospital with a diagnosis of cocaine psychosis.

A year later, when a male patient arrived carrying a box of tissue, my suspicions were aroused. Stating that I had not ordered a preoperative urinalysis, I requested a urine sample. The surgery was uneventful, but the urine sample was positive for cocaine metabolites.

THYROID SUPPLEMENTS

Thyroid supplements have a reputation for promoting weight loss. Some patients intentionally ingest excessive doses of levo-thyroxine (Synthroid) to accelerate their weight loss. One such patient showed the difference in clinical response to the slow absorption of epinephrine in a dilute solution compared with its rapid absorption in concentrated commercial preparations (Case Report 24-3).

CASE REPORT 24-3   Thyroxine, Tumescent Anesthesia, and Tachycardia

A middle-age female patient and licensed physician's assistant initially denied taking any medications. Her first surgery involved uncomplicated but extensive tumescent liposuction of her hips and thighs.

She returned 2 months later for a "touch-up" procedure of a small area on her inner thighs. A 250-ml bag of tumescent anesthetic solution was not sufficient to complete the brief procedure as I had estimated. Rather than mix another bag of solution, however, I simply infiltrated the small area with an additional 30 ml of commercial 1% lidocaine with epinephrine 1:100,000.

After surgery the patient developed asymptomatic supraventricular tachycardia. Although the dysrhythmia converted spontaneously to sinus rhythm, she was hospitalized overnight for observation. In the hospital the patient admitted that she was taking self-prescribed excessive doses of L-thyroxine. Her blood levels were three times higher than the upper limit of the therapeutic range for thyroxine.

During the preoperative history, all patients should be asked if they are taking thyroid medications. All patients who are taking thyroid supplements should have triiodothyronine and thyroxine (T_4) levels determined as part of the preoperative laboratory examinations. Approximately 5% of such patients have blood levels that are above the therapeutic range.

There is little risk of an adverse drug interaction between thyroid dosages and tumescent anesthesia as long as T_3 and T_4 levels are within normal limits.

CONSCIOUS SEDATION AND SYSTEMIC ANESTHESIA

Conscious sedation is defined as a medically controlled state of depressed consciousness that (1) allows protective reflexes to be maintained, (2) retains the patient's ability to maintain a patent airway independently and continuously, and (3) permits the patient to respond appropriately to physical stimulation and verbal commands.[74]

Conscious sedation is attained by using a combination of local anesthesia with IV opioids, sedatives, and anesthetics. IV administration of these drugs, however, is not synonymous with conscious sedation. Drugs such as fentanyl, midazolam, and propofol are used routinely to provide IV general anesthesia. Deep sedation and general anesthesia require a higher level of physiologic monitoring than conscious sedation.

The problem with using conscious sedation is that a safe degree of sedation can progress to loss of protective reflexes, airway obstruction, and cardiopulmonary impairment.

The term *systemic anesthesia* encompasses both conscious sedation and general anesthesia. Systemic anesthesia of any kind is more dangerous than simple local anesthesia with the patient fully alert and conversant.

The greatest danger is inadequately monitored conscious sedation. No easily recognizable clinical boundaries exist between light and deep sedation or general anesthesia. Conscious sedation can imperceptibly become deep sedation. Conscious sedation and general anesthesia are equivalent in terms of the risks of hypoxia and the necessity for sophisticated cardiopulmonary monitoring.

Any surgical procedure that is feasible under local anesthesia, such as tumescent liposuction, should not be done routinely under deep sedation or general anesthesia merely for convenience. Tumescent liposuction totally by local anesthesia in an office setting has a long history of safety. On the other hand, virtually every death associated with liposuction has involved the use of systemic anesthesia.

Narcotics such as fentanyl, sedatives such as midazolam, and anesthetics such as propofol are often used for conscious sedation during liposuction. Achieving conscious sedation with such drugs is most appropriately carried out in a sophisticated, fully accredited surgical facility with an anesthesiologist providing patient care. Fentanyl, propofol, and midazolam are usually unnecessary for tumescent liposuction.

FENTANYL

Fentanyl is a narcotic analgesic that is 60 to 80 times more potent than morphine. Although narcotic analgesics are rarely needed for tumescent liposuction, surgeons should be familiar with their pharmacologic effects. According to the records of our state-licensed surgicenter pharmacy, fentanyl is used for tumescent liposuction in less than one in every 500 patients.

Occasionally a patient is not satisfied unless a narcotic is administered. Although patients are told that narcotics are unnecessary and virtually never used, during a procedure a patient may demand a narcotic.

If a patient states, "I think I need 50 micrograms of Sublimaze," the surgeon can either (1) acquiesce, administer some fentanyl, and finish the surgery; or (2) simply refuse and face a hostile, unhappy patient. In these situations, I have acquiesced and given 25 µg of fentanyl.

In less than 0.1% of patients, the initial tumescent infiltration proves to be insufficient, and all efforts to supplement tumescent anesthesia with additional infiltration are unsuccessful. A narcotic analgesic (e.g., fentanyl) then may be administered and the surgery completed.

At low doses, fentanyl (Sublimaze) is the preferred narcotic analgesic because of its low incidence of nausea, vomiting, and orthostatic hypotension. Meperidine (Demerol) is undesirable as an anesthetic agent because of its potent effect as a direct myocardial depressant. Also, as with morphine, meperidine causes the release of histamine, resulting in vasodilation and hypotension. Furthermore, morphine can precipitate a fatal drug interaction if it is given to patients who are taking monoamine oxidase inhibitors (MAOIs).

Respiratory depression is the most dangerous adverse effect of narcotics, with fentanyl and benzodiazepines producing a synergistic effect. Doses of fentanyl and midazolam that have no effect individually can cause apnea in as many as 50% of patients when given together.

Fentanyl is highly lipid soluble, moves rapidly across the blood-brain barrier, and has a rapid onset of action. Because of its rapid redistribution after an IV dose, fentanyl has a relatively short duration of action.

Fentanyl has a large volume of distribution. The body's adipose tissue acts as large reservoir for fentanyl. Attempts to increase the intensity of effect by increasing the dose by tenfold produce an eightfold increase in the time that the plasma concentrations of fentanyl remain above the threshold for respiratory depression. Thus fentanyl is short acting at low doses but becomes long acting at high doses.

The redistribution half-life of fentanyl is so short that a relatively large dose of fentanyl will be completely redistributed before the plasma concentration has decreased to below the threshold for respiratory depression. In this situation, the peripheral stores are highly saturated, and the duration of respiratory depression depends on the slow elimination half-life of fentanyl.

Fentanyl also demonstrates a wide range of variability of its pharmacokinetic parameters from patient to patient. Thus an occasional patient may experience toxicity at a surprisingly low dose. These facts, together with unsuspected drug inter-

actions, explain the occasional unexpected death from apnea after fentanyl administration.

Fentanyl is rapidly and extensively metabolized by CYP3A4. Fentanyl metabolism can be significantly impaired by competitive inhibition of hepatic enzymes with concomitant administration of other drugs. For example, use of alfentanil with erythromycin leads to delayed alfentanil elimination, delayed recovery, and prolonged postoperative respiratory depression because of competitive inhibition of CYP3A4.[75,76] Cimetidine also prolongs fentanyl's effect.

PROPOFOL

Propofol (Diprivan), available since the early 1980s, is an IV general anesthetic. It has gained widespread popularity and a reputation for fast patient recovery, decreased postoperative nausea and vomiting, and a low incidence of complications.[77]

Propofol (2,6-diisopropylphenol) is principally metabolized by the cytochrome P450 isoenzymes 2C9, 2A6, 2C8, 2C18, 2C19, and 1A2.[78] No evidence indicates that propofol is metabolized by CYP3A4, the hepatic microsomal enzyme that is largely responsible for lidocaine metabolism.

A recent systematic analysis of published and unpublished data has shown that propofol carries a significant risk for bradycardia, with potential for major harm despite prophylactic anticholinergics.[79] Sixty-five published and 187 spontaneous reports to drug monitoring centers revealed that propofol had induced 1444 bradycardias, 86 asystoles, and 24 deaths. The risk of asystole is 1 in 660 propofol anesthetics. The risk of death from a propofol-induced bradycardia is an estimated 1 in 112 asystoles. Thus the risk of death from bradycardia is 1.4:100,000 propofol anesthetics.

Propofol might be contraindicated in the presence of an increased risk for bradycardia, such as a history of vasovagal near-syncope, cardiac dysrhythmias, beta blockers, clonidine, laparoscopies, strabismus surgery, and very old or very young patients.

Lidocaine significantly enhances the hypnotic effect of IV propofol in a dose-dependent manner.[80] The dose of propofol necessary to induce hypnosis is reduced by 34% when 3 mg/kg of IM lidocaine is given. When lidocaine is injected into soft tissue before induction of anesthesia by IV propofol, the dose of propofol should be modified.

Propofol can cause significant hypotension. Propofol blood concentrations required to prevent movement after skin incisions in most patients resulted in significant arterial hypotension.[81]

Although propofol can induce seizures, the incidence of this complication is unknown.[82-84] On the other hand, propofol can suppress lidocaine-induced seizures.[85] This suggests that propofol might be useful in treating lidocaine toxicity; however, propofol might mask lidocaine neurotoxicity, which occurs at lower lidocaine blood concentrations than cardiovascular toxicity. Thus, if serious lidocaine toxicity does occur during concomitant use of propofol, the warning signs of seizure activity might not appear, and the first sign of lidocaine toxicity might be cardiac arrest.

Propofol can induce seizures in an epileptic patient. I reviewed the case of an epileptic patient who developed status epilepticus after ultrasonic liposuction under IV propofol and tumescent lidocaine anesthesia.

ANTIINFLAMMATORY DRUGS

The use of pharmacologic antiinflammatory medications should be discouraged for the first 4 days after liposuction surgery. The use of antiinflammatory steroids, such as prednisone, or nonsteroidal antiinflammatory drugs (NSAIDs), such as aspirin or ibuprofen, may delay the diagnosis of necrotizing infections of the soft tissue by reducing manifestations of inflammation.[86]

Because these drugs impair phagocytic function and depress immune response, a minor infection may develop into a fulminant one. Using nonpharmacologic techniques, such as encouraging maximum drainage of blood-tinged anesthetic solution from incision sites that have not been closed by sutures, is much more effective in reducing inflammation than using antiinflammatory drugs.

From 4 to 7 days postoperatively, assuming all the incisions have healed well with no evidence of infection, patients may begin treatment with NSAIDs.

An occasional patient will have a peculiar inflammatory response manifested either by unusual generalized soreness and tenderness or by swelling. This is often an idiopathic phenomenon but may occur when incision sites have healed and closed spontaneously before drainage was complete. After a careful clinical evaluation to rule out infection, an appropriate antibiotic is prescribed for a possible subclinical infection, along with ibuprofen, 400 to 800 mg three times a day, or prednisone, 10 mg daily. The beneficial response can be rapid and gratifying.

DEATHS AND CONSCIOUS IV SEDATION

A 1999 report of five liposuction-related deaths provided epidemiologic evidence that the greatest risk of death associated with liposuction surgery is the use of systemic anesthesia (conscious sedation or general anesthesia).[87] All five patients received systemic anesthesia. There was no evidence of lidocaine toxicity. One patient, a 40-year-old female, died during liposuction under "conscious IV sedation" consisting of midazolam (5 mg), fentanyl (150 μg), methohexital (40 mg), and droperiodol (125 mg). The dosage of subcutaneous dilute lidocaine was 14.3 mg/kg. At 2.3 hours into liposuction and within 30 seconds after rotating the patient from a prone to a supine position, there was an abrupt onset of wide-complex infranodal bradycardia and subsequent unresponsive asystole.

Care must be taken to avoid abrupt changes in posture when using a combination of droperidol and fentanyl because severe hypotension may be precipitated.[88] Midazolam directly depresses the myocardium, exerting similar negative chronotropic and inotropic actions.[73] "Normal" doses of

ultrashort-acting barbituates such as methohexital can cause hypotension, circulatory collapse, and cardiac arrest in the presence of hypotension (e.g., from drug reactions) and hypovolemia (e.g., with use of liposuction).[88]

The association of liposuction deaths with systemic anesthesia is consistent with 95 liposuction-related deaths associated with surgeons who use systemic anesthesia.[89] The greatest contraindication for a drug is a lack of any indication for its use. If systemic anesthetics are not necessary, they should not be used.

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FUNDAMENTAL ASPECTS OF TUMESCENT LIPOSUCTION

Subcutaneous Fat: Anatomy and Histology

The gross anatomy of subcutaneous fat has not been well studied. Anatomists have traditionally regarded subcutaneous tissue as a mere envelope that contains more important structures. Except for an occasional reference to epidural, periorbital, perirenal, buccal, infrapatellar, ischiorectal, and retropubic fat, the gross anatomy of fat is rarely considered. Histology texts describe the individual cellular components of adipose (fat) tissue, but the overall architectural interrelationships among these components are seldom discussed.

ADIPOSE TISSUE

On initial inspection the structure of adipose tissue appears to be a random array of coalescing septa (partitions). A predictable pattern exists, however, and the structure of adipose tissue can be represented by a nested family of subsets, as follows:

Fat cell ⊂ Fat lobule ⊂ Fat pearl ⊂

Fat section ⊂ Fat compartment

In other words, fat cells are contained within fat lobules, which are within fat pearls, which are contained within fat sections, which are within fat compartments (Figure 25-1).

Fat compartments represent the largest collections of subcutaneous fat. A cross section of fat from a female hip would reveal a deep, thick compartment of subcutaneous fat that is divided into sections by tangentially and obliquely oriented, intersecting collagenous sheets of fibrous tissue. Overlying this deep compartment of fat is the superficial mantle layer of fat, with its palisading columnar fatty pearls.

Fat sections subdivide the deep fatty compartment of fat into subunits. Resembling an orange segment, each section of subcutaneous fat is defined by a thin fibrous membrane consisting of intersecting collagenous sheets of fibrous tissue. The paths of the larger blood vessels, lymphatics, and sensory nerves follow the fibrous partitions that subdivide the fat compartments into fat sections.

Fat pearls subdivide the fat section into subunits. Their size varies with anatomic location (Figure 25-2). The size of fatty pearls seems to increase to a limited extent with the degree of obesity.

Fat lobules are the immediate subunits of the fatty pearl. Each fatty lobule is supplied by a neurovascular bundle of arterioles and venules, which in turn are subdivided into terminal capillaries that course by individual fat cells. A fat lobule represents a grouping of fat cells, all of which are enclosed within a small thin membrane and share the same terminal vascular supply.

Fat cells (adipocytes) are the individual cells that are the ultimate target of the liposuction surgeon. Adipocytes store fat, provide insulation, and physically cushion the body (see later discussion).

FUNCTION AND FORM

Adipose tissue in humans is a type of connective tissue containing adipocytes, blood vessels, nerves, and fibrocytes embedded within a three-dimensional collagenous matrix of intersecting septa. Fat, synonymous with adipose tissue, consists predominantly of adipocytes but also contains significant amounts of collagen (type I and III), blood and lymphatic vessels, and nerves. Approximately half the cells in adipose tissue are adipocytes, and half are vascular and connective tissue cells.[1] The triglyceride-filled adipocytes are so much larger than other types of cells, however, that adipocytes represent at least 96% of the adipose tissue mass.
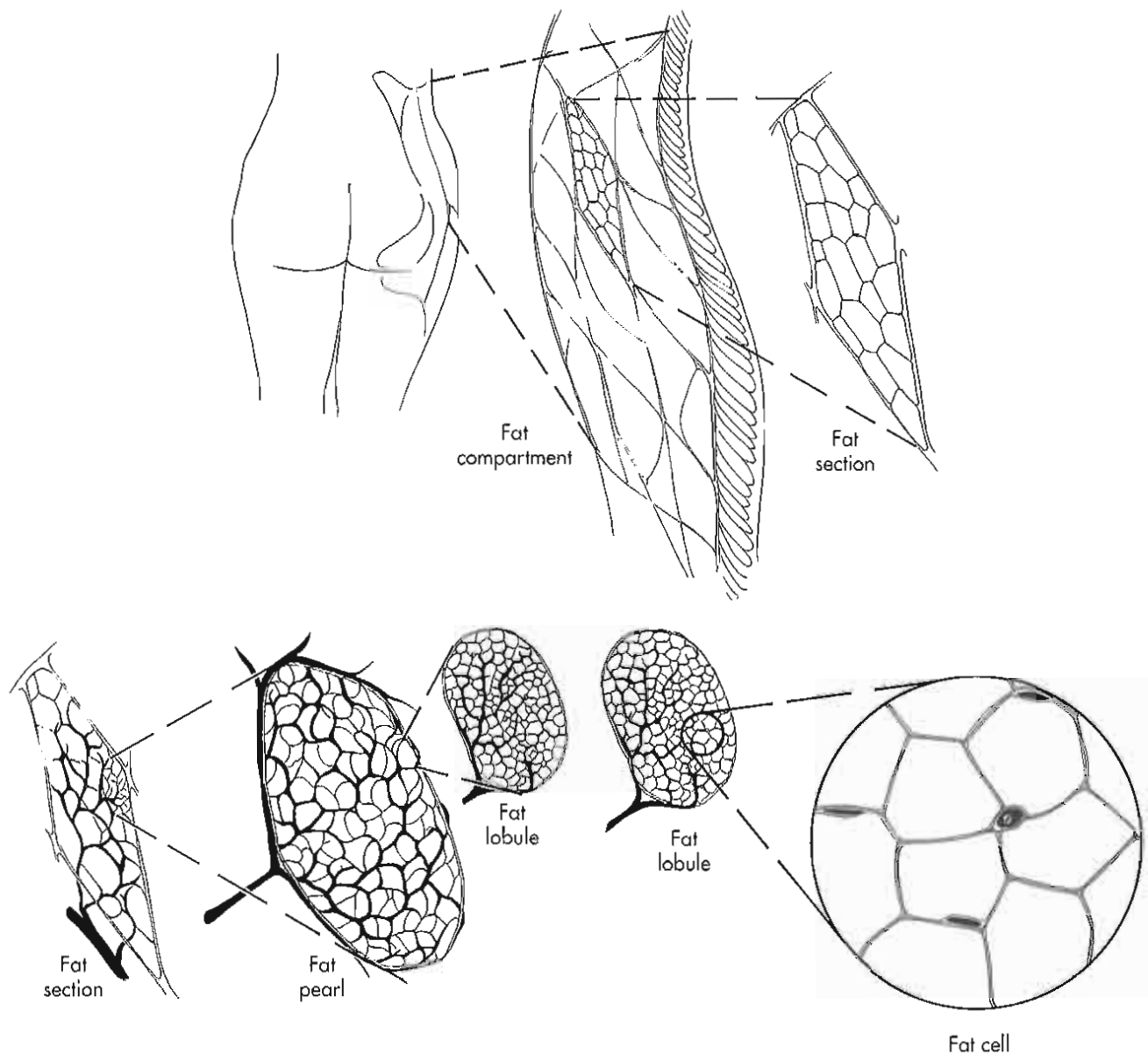
Figure 25-1

Hierarchical structure of subcutaneous fat (see text).

The functions of adipose tissue are as follows:
1. Store energy
2. Provide thermal insulation
3. Act as a physical shock absorber
4. Provide "sex appeal"

The deep subcutaneous fat in humans has a gender-specific distribution. The development and location of individual pads of depot fat are manifestations of sexual dimorphism. Men have more fat in the upper body, whereas women have more fat on the lower extremities.

The idealized male figure has been represented as athletic, showing a maximum of muscle definition and a minimum of fat. In contrast, the idealized female figure has a softer appearance and more alluring curves. From an aesthetic perspective, it is important that liposuction surgeons allow fat to remain in strategic locations.

HISTOLOGY OF ADIPOCYTE

The embryologic appearance of fat cells occurs after 5 months of gestation, when electron microscopy of subcutaneous tissue reveals spindle-shaped, lipid-free precursor cells and young adipocytes with multiple cytoplasmic droplets. Based on in vitro cell culture studies, these forms seem to represent different stages of lipoblast development.

Fat cells are derived from *fibroblasts*, which may originate from perivascular sheath cells or perivascular spindle cells.
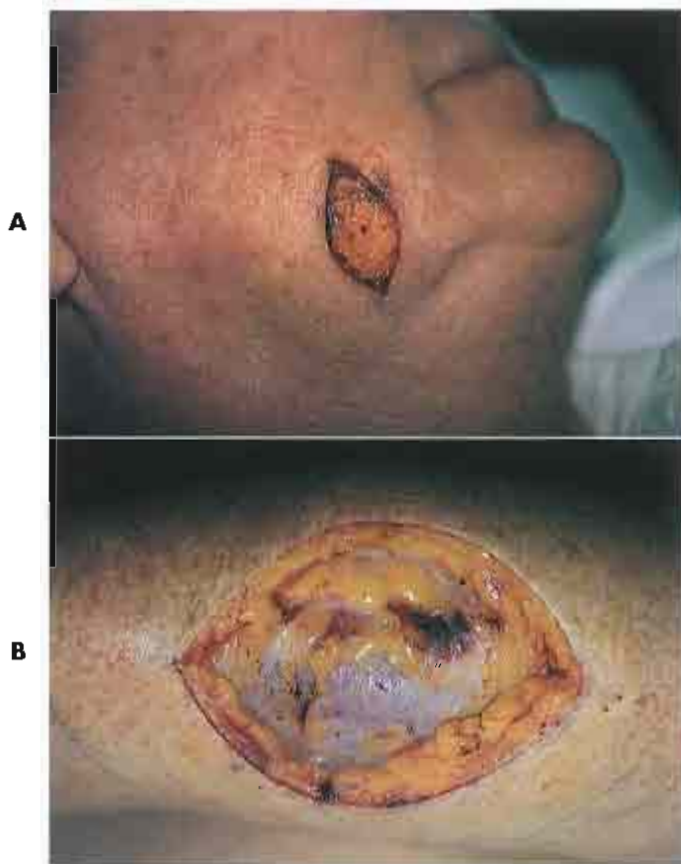
Figure 25-2

Size of fat pearls varies according to anatomic site. **A,** Excision of basal cell carcinoma on male cheek reveals multiple 3-mm to 4-mm fat pearls. **B,** Site of melanoma excision on extensor arm reveals 6-mm to 10-mm fat pearls.

The earliest sign of fat cell differentiation in the adipescent fibroblasts is the appearance of small cytoplasmic vacuoles. The continuing process of lipogenesis causes these vacuoles to expand incrementally and coalesce.

These microscopic vacuoles eventually coalesce into a single, large globule within the mature fat cells with one, large, central lipid droplet and peripheral nucleus.[2] These full, unilocular adipocytes are the body's most efficient long-term depots for storing energy.

When all available fat cells are nearly filled to capacity, the body recruits new fat cells from a population of mesenchymal precursor cells that histologically resemble immature fibroblasts. In the presence of a plethora of dietary fat, excess triglycerides are stored in new adipocytes or lipoblasts.

When an adipocyte becomes depleted of its intracellular fat, the cells become vacuous and again resemble fibroblasts. When a potential patient has lost a considerable amount of weight, the existing fat cells are partially depleted of their triglyceride stores.

Adipocytes have receptors for a number of hormones (cortisol, adrenocorticotropic hormone, thyroxine, glucogon) and cytokines. Lipolysis and capillary dilation are under sympathetic nerve control. Histochemical techniques show an abundance of nerves, typically located perivascularly.

Other types of fat cells include *multilocular* adipocytes, which contain many small lipid droplets, have a foamy appearance, and are present in the fetus and newborn. Their function appears to be intimately associated with heat production, analogous to the "brown fat" of hibernating animals.

VASCULARITY OF FAT

Special stains reveal that each adipocyte is in direct contact with one or more capillaries. When the ratio of capillary surface to the cellular volume of adipocytes is compared to a similar ratio for striated muscle, the capillary bed of adipose tissue appears to be richer than that of muscle.

In several species, including humans, the blood flow in resting adipose tissue, when there is no vasodilation, ranges from 2 to 14 ml/min/100 g of tissue. In maximally dilated adipose tissue the blood flow is 20 to 50 ml/min/100 g of tissue. With the profound vasoconstriction produced by the tumescent technique, the blood flow through tumescent fat must be much less than 1 ml/min/100 g of tissue.

Blood flow expressed per unit of adipose tissue weight is inversely correlated to the size of the fat cells. In rats, for example, blood flow per unit weight of adipose tissue tends to be greater in fasted animals (shrunken adipocytes) and smaller in fed animals (swollen fat cells). The blood flow per adipocyte, however, seems to be independent of fasting or eating.

LAYERS OF SUBCUTANEOUS FAT

Based on my clinical observations and cadaveric dissections, there are three important layers of subcutaneous fat: the apical layer, the mantle layer, and the deep compartment (depot) layer. For the purposes of liposuction surgery, this distinction is a practical way of recognizing and distinguishing the different layers of subcutaneous fat (Figure 25-3).

APICAL LAYER

The apical layer of subcutaneous fat is a very thin layer contiguous with the deepest aspect of the reticular dermis. Apical fat extends upward into the deep reticular dermis as bumpy, culminant colonnades of fat. No intervening substance or structure exists between apical fat and dermis.

Apical fat includes (1) the thecal, or sheathlike, periadnexal fat surrounding sweat glands and hair follicles and (2) the fat that invests the vascular arcade and lymphatic plexus along the interface between fat and dermis. Apical fat is grossly visible as yellow puncta of fat along the cut surface of a deep, split-thickness, tangential excision of dermis.

Nevus Lipomatosus. An unusual example of apical fat is nevus lipomatosus. Clinically, nevus lipomatosus presents as a typical skin-colored, intradermal, cellular nevus or fibroepi-
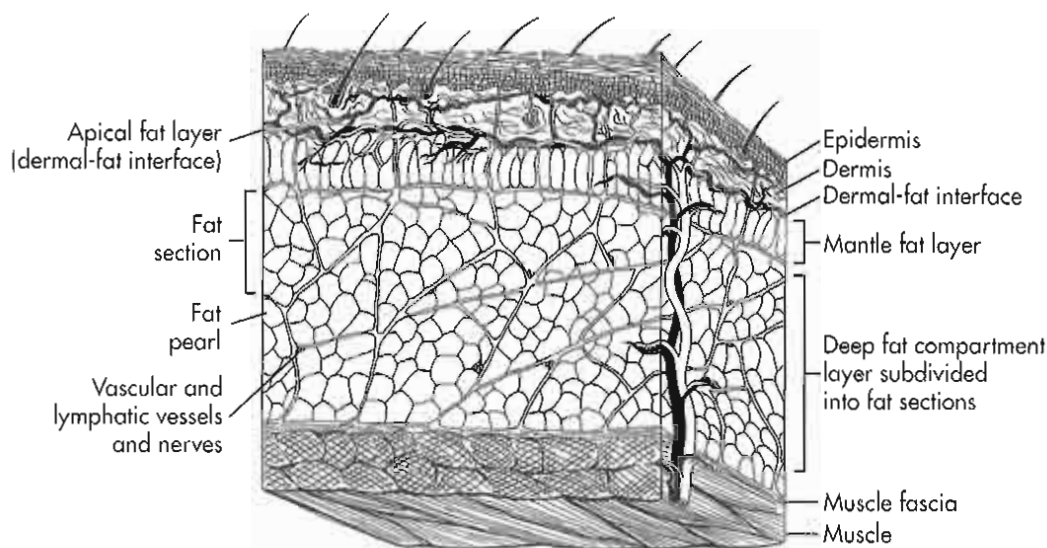
Figure 25-3

Subcutaneous adipose tissue is bounded superficially by collagenous reticular dermis consisting of closely interwoven collagen fibers arranged in netlike or reticular pattern.

thelial polyp. It is a solitary, dome-shaped, soft papule or pedunculated nodule on the trunk or extremities, usually 5 to 10 mm in diameter.

Histologically, nevus lipomatosus is an intradermal nidus of microscopically typical subcutaneous fat located in the middle to upper dermis. It may be loculated and isolated from the subcutaneous fat, or it may be a "fiord"-like extension of fat up into the dermis.

Superficial Liposuction.   Despite its intuitive appeal, liposuction of apical fat with dermal trauma does not produce contraction of the dermis. The predictable result of widespread liposuction-induced trauma to the dermal–apical fat interface is injury to the dermal vasculature and possible dermal necrosis.

Erythema ab liporaspiration is a less extreme but more common consequence of excessively superficial liposuction. It is a permanent reticulated erythema, with a clinical appearance similar to *erythema ab igne* or *livedo reticularis* (see Figure 8-3).

Although the term *superficial liposuction* has gained acceptance in recent years, the procedure of superficial liposuction has not been precisely defined. The ability to produce tumescent hemostasis has permitted the use of relatively small, 2-mm to 3-mm cannulas, which in turn has allowed liposuction that is more superficial than the traditional liposuction that used larger, 8-mm or 10-mm cannulas. Safe superficial liposuction avoids injury to the dermis. Excessive superficial liposuction is dangerous and can easily cause either partial-thickness or full-thickness dermal necrosis.

It is a fallacy that an intentional liposuction of the apical fat and deep reticular dermis will result in an aesthetic contraction or shrinkage of the skin. Aggressive superficial liposuction is counterproductive and dangerous (see Chapter 8).

MANTLE LAYER

The mantle layer of subcutaneous fat is a discrete layer; it is a superficial row of vertically oriented, columnar pearls of fat. Using a cross section of skin and subcutaneous fat, with careful inspection immediately subjacent to the reticular dermis, one can see the distinct blanketlike layer of columnar pearls of fat arranged in a palisading array. The deep margin of the mantle layer consists of a discrete sheet of fascial fibrous tissue.

The mantle layer covers most but not all areas of the body. No significant subcutaneous fat exists in the eyelids (periorbital postseptal fat is not subcutaneous fat), nasal bridge, subungual digits, or penis. The mantle fat layer varies in thickness throughout the body but tends to be uniform over any specific area. It is thicker over areas where it covers deep deposits of subcutaneous fat, such as the hips, thighs, abdomen, and buttocks. Over other areas, such as the leg below the knee, where there are no deep deposits of subcutaneous fat, the mantle layer accounts for nearly all the subcutaneous fat.

Mantle layer fat has the teleologic duty to protect, cushion, and insulate. The individual columnar fat pearls that compose the mantle layer have the structural form of a *gabion* (cylindric wicker basket filled with rocks and earth for use in fortification and engineering). The body's ability to withstand the daily assaults of a physically rough environment partly results from the resilient structural design of the mantle layer. Palisaded gabions of fat are closely packed cushions of fat that function as hydraulic shock absorbers. They allow external pressure to be more evenly distributed and more widely dispersed than if the subcutaneous fat were simply a few large, loosely packed "balloons" of fat.

DEEP COMPARTMENT LAYER

The deep compartment layer is the deepest layer of subcutaneous fat. Although this layer is present in obese infants and children, it is often relatively thin until after puberty. With the onset of puberty and adolescence, accumulations of fat begin to appear.

The development and location of individual compartments of fat are manifestations of sexual dimorphism. The eventual size and individual shapes of these depots are a function of genetic predisposition and the individual's degree of obesity.

The deep fat compartments are capable of enlargement by cell proliferation. Inactivity and a relative abundance of dietary calories tend to augment the size of deep fat compartments, which function as storehouses where excessive dietary energy is saved for later use.

HIERARCHICAL ARCHITECTURE OF FAT

The adipose tissue septa consist of gossamer sheets of fibrous areolar tissue that partition and support an organized series of adipocyte groupings.

The thinnest septa surround fat lobules; they are essentially invisible without magnification. The septa that surround fat pearls are pellucid (translucent) and grossly visible only with great care and attention. The septa that separate fat compartments are thin white sheets; the thinnest are transparent, whereas the thickest (e.g., Scarpa's fascia) are opaque, white, glistening expanses of tenacious connective tissue.

The taxonomy of fat cell aggregates has a hierarchical pattern vaguely reminiscent of the architectural subdivisions of the lung (see Figure 25-1).

FAT CELL

The individual *adipocyte* (fat cell) is the smallest unit within the hierarchy of adipose tissue. Histologically the adipocyte has a signet-ring appearance, with an eccentric nucleus and cytoplasm that is less than 1% of the visible fat cell cross section.

Age, gender, and anatomic location influence fat cell size and number. Within any specified anatomic site, fat cells achieve nearly uniform maximum size. In other words, fat cells do not continue to enlarge indefinitely. The size of a fat cell has an upper limit, and once a large proportion of fat cells are almost their maximum size, new fat cells are recruited.

Adipose tissue proliferates by a process of cell multiplication, in contrast to growth by continuous individual cell expansion. With increasing obesity, humans produce new fat cells. New fat cells are created when multipotential fibroblasts become lipoblasts through an overabundance of dietary calories.

FAT LOBULE

The fat lobule, next in the hierarchy, is a microscopic structure. The fat lobule consists of a packet of adipocytes partitioned off from adjacent lobules by the thinnest of fibrous septa. The smallest terminal capillaries and an occasional autonomic or sensory nerve fiber meander through the lobule.

The smallest lymphatics arise within the interstices between lobules.

The fat lobule is analogous to a compound fruit such as a raspberry, with the adipocyte the smallest individual subsection, or acinus, of the berry.

Fat lobules are easily seen on histologic examination of tissue prepared from a lipoma. When a fatty pearl is sliced open during surgery, fat lobules can be seen as small granules of a yellowish pastelike substance.

Scanning electron micrographs show that each adipocyte is surrounded by a web of collagenous fibers, which are continuous with interlobular septa. With careful inspection, individual fat lobules may be seen without magnification, but the connective tissue membrane that defines a fat lobule is essentially invisible.

FAT PEARL

The fat pearl, encapsulated by a transparent collagenous membrane, is the grossly visible yellow globule of fat that is seen when subcutaneous adipose tissue is transected. The enveloping fibrous membrane gives the fat pearl a shiny, almost pearllike luster. Although somewhat speculative, the fat pearl can be thought of as containing grapelike bunches or clusters of fat lobules.

Although fat pearls are fairly uniform in size within any specific location, they vary in size from one part of the body to another. In the submental chin and cheek areas, fat pearls are about 2 to 3 mm in diameter, whereas in the arms, thighs, and abdomen they may be 1 cm or more in diameter (see Figure 25-2).

Within the same anatomic location, fatty pearls are small in children and larger in adults. Fatty pearls are supplied with small arterioles, venules, and lymphatics. A fat pearl is a *lobulose* structure; that is, it contains many lobules.

FAT SECTION

A fat section contains a conglomeration of many fat pearls, packed together between broad, intersecting, visible, pale-white walls of fibrous connective tissue septa. Along these septa course small blood vessels, lymphatics, and nerves.

The three-dimensional size and shape of a fat section are determined by the intersection of multiple fibrous sheets of connective tissue. The fat sections resemble rhomboidal prisms, packed together in a crystal lattice–like fashion.

FAT COMPARTMENT

A fat compartment is a grouping of multiple fat sections and is the largest entity within the architectural hierarchy of subcutaneous fat. Some fat compartments are so well recognized that they have been given specific names, such as the hip, outer thigh, buttock, inner thigh, anterior thigh, inner knee, breast, upper abdomen, lower abdomen, and extensor arm.

The size and shape of these fat compartments are responsible for the differences in surface anatomy that exist between adult males and females. When an individual becomes aware that his or her fat compartments are "more than the ideal," liposuction becomes an option to improve the situation.

Figure 25-4

Tangential septum of fibrous tissue within midlateral abdominal fat compartment of medium-weight female cadaver. Laminated sheets of diaphanous collagenous tissue form a tangential septum. These laminae can be separated by careful digital dissection.

Figure 25-5

Schematic diagram of tangential and oblique septa within fat compartment.

TANGENTIAL AND OBLIQUE SEPTA

The two types of septal sheets are tangential planes and oblique partitioning walls.

Tangential Planes. These planes of connective tissue are broad, laminated, relatively dense, two-dimensional surfaces that are approximately oriented parallel and tangentially to the subjacent muscle fasciae (see Figure 25-3).

Fascia is the laminated sheet of fibrous tissue that envelops the body beneath the skin. Fasciae also enclose the muscles and groups of muscles and separate their several layers or groups. Subcutaneous fascia is not a functional monolayer of connective tissue; it is a laminate of fibrous sheets, with each lamella a weblike, interwoven film of collagen and fibrocytes. The interfaces between adjacent, loosely adherent lamellae represent potential spaces and become apparent on careful anatomic dissection (Figure 25-4).

These intralamellar potential spaces may be the site of lipoblast formation. A *lipoblast* is a fibroblast that differentiates into a new fat cell. In the process of adipose tissue proliferation, these lamellae separate and become filled with the new adipocytes.

Oblique Planes. These planes are thinner, smaller, less extensive sheets of tissue that intersect the thicker, tangentially oriented septal planes at oblique angles. They partition fat that is contained between adjacent parallel sheets of tangential septa.

The oblique lamellae might simply arise during the process of fat proliferation within a potential space between two lamellae of a single progenitor tangential septum. A previously parallel lamella becomes an undulating oblique septum, attached in alternating areas between parallel sheets of tangential septa. The new oblique lamella functions as a series of
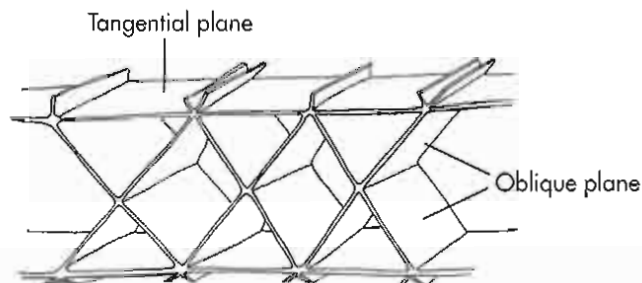
struts that braces and stabilizes the collagenous framework, while concomitantly partitioning and fixing small sections of fat (Figure 25-5).

These sheets of fibrous tissue are intimately attached to both the skin and the deep muscle fasciae, creating a tethering effect on the skin. When the skin and subcutaneous fat of the thigh or buttock are stretched (by gravity or muscle contraction), the resulting irregular distribution of mechanical forces on the tethered skin produces visible dimpling, or cellulite.

CELLULITE

As a medical concept, cellulite is not widely recognized, and its anatomic basis is controversial. Many physicians regard the word cellulite as vague and inaccurate. Every woman, however, knows precisely what the term describes: the unattractive, orange peel (peau d'orange), cottage cheese–like, rippling skin of fat thighs.

The *Oxford English Dictionary* defines *cellulite* as a "special lumpy form of fat supposed to occur in some women, esp. on the hips and thighs, sometimes producing a yellowish puckering of the skin." French liposuction surgeons use the words *cellulite* or *cellulitis* to designate the human surface anatomy associated with dimpled skin on fat thighs. The French word *cellule* is translated in English as "cell." Cellulite is now well established in the English language despite its unscientific origin.

UNPROVEN TREATMENTS

Persons with cellulite despise it and will consider paying for any treatment that promises to remove it. Treatments of dubious value have included acupuncture, exotic diets, special

A   **B**   **C**

Figure 25-6

Posttraumatic pseudolipomas. **A,** Male patient whose right proximal lateral thigh was caught between motorcycle and automobile. **B,** Female patient whose left distal lateral thigh was injured in automobile collision. **C,** Another female patient with posttraumatic pseudolipoma caused by automobile accident.

baths, topical creams, and various external massages. Claims of success using external vacuum-roller devices or topical theophylline creams are unproved.

Claims of efficacy have not been supported by objective, reproducible, scientific evidence. If any treatment truly eliminated cellulite, treating only one thigh on a number of women would provide a statistically powerful, well-controlled test of efficacy. Until objective, reproducible studies are published, all proprietary claims of successful treatment must be regarded with skepticism. Financial motivation and unsubstantiated claims of dramatic medical success always suggest quackery.

Liposuction.   Cellulite cannot be eliminated by liposuction in a predictable manner. Although individual patients might see noticeably improved cellulite, the degree of improvement is usually minimal. An unequivocal elimination of cellulite should not be promised to prospective liposuction patients.

Anatomic Considerations.   Cellulite is probably the result of traction on the skin of subcutaneous fibrous septa. Both tangential and oblique planes can insert into the superficial apical and mantle layer septa and the deep fasciae that cover subjacent muscle.

Any attempt to cut the fibrous attachments between skin and adipose tissue is unlikely to give satisfactory long-term results. It is futile to attempt to disconnect the perpendicular septa of the mantle layer from the reticular dermis with the intention of eliminating cellulite. The mantle layer and its vertical fibrous septa will simply readhere to the dermis by a process of scarring fibrosis. Ultimately, with the resolution of postoperative edema, cellulite reappears (see Figure 25-5).

PSEUDOLIPOMA

A posttraumatic pseudolipoma most often results from a large traumatic tear through one or more tangential septa within a deep fat compartment. In some patients it develops from de novo generation of adipose tissue.

A typical history associated with a lateral thigh posttraumatic pseudolipoma is an automobile collision, with blunt trauma causing a massive hematoma on the lateral thigh (Figure 25-6). After the extensive ecchymosis has resolved, the patient becomes aware of the swelling on the lateral thigh, exactly where the trauma occurred.

It has been postulated that abdominal posttraumatic pseudolipomas are the result of a tear in Scarpa's fascia, resulting in the herniation of deeper fat through Scarpa's layer.[3]

FIBROSIS

Fibrousness of fat, the state or quality of being fibrous, is the degree and spectrum of collagenous fibrous connective tissue within a specific volume of adipose tissue. Fibrousness is a textural quality of fat that is readily appreciated by liposuction surgeons, who encounter a wide spectrum among liposuction patients.

Antitypy is a qualitative word used to describe the degree of difficulty in penetrating a compartment of fat with a cannula. Antitypy describes the resistance of matter to force of penetration, compression, or motion.

CLASSIFICATION

The spectrum of fat fibrousness ranges in degree from soft, easily penetrable fat to extremely fibrous, densely fibrotic, impenetrable fat. Soft fat has a viscous, puddinglike, or doughy consistency and is the easiest type to remove by liposuction. Older and more obese females are those most likely to have soft fat. Fibrotic fat is relatively more difficult to penetrate with an infiltrating needle or a liposuction cannula.

The clinical quality of fat can be classified on a scale of 0 to 4, which rank orders the overall degree of antitypy or fibrousness into five categories (Box 25-1). This type of classification is helpful when describing the liposuction procedure in clinical notes, surgical reports, and clinical presentations. This rank ordering is subjective and depends on the type of cannula, the surgeon's skill and experience, and efficacy of the tumescent infiltration.

Anatomically, fibrosis is the net effect of multiple factors, including location, postinflammatory proliferation of interstitial collagen, septal thickening, and decreased lipocyte size. All these factors contribute to an increased resistance to penetration of adipose tissue by a cannula.

FIBROFACIENTS AND LIPOSUCTION

Fibrosis is the development of excessive fibrous tissue in an organ. A *fibrofacient* is any circumstance or substance that produces fibrosis in fat or is associated with a relative increase in the fibrousness of fat. Various factors determine the degree of fibrosis within any given fat compartment. Fibrofacient

circumstances or substances include inflammation, trauma, the degree of leanness, youthful age, testosterone, and significant weight loss after substantial obesity.

Inflammation is classically defined as any morbid process affecting some organ or part of the body, characterized by excessive heat, swelling, pain, and redness. Inflammation is mediated by inflammatory cytokines. Trauma, infection, chemical irritants, and allergens stimulate the release of a wide range of mediators, the most important of which include prostaglandins.

Testosterone and thus male gender predispose to fibrosis of fat. The male abdomen and flanks are more fibrous than comparable female fat deposits.

Youthfulness helps predict the degree of fibrosis that might be encountered during liposuction. Young patients have more fibrous fat than older patients. Patients in their 20s are more fibrous and therefore more difficult liposuction patients than patients in their 60s. Fibrousness decreases with increasing age.

Leanness also helps predict the fibrousness of fat. Corpulent and obese patients are associated with less fibrousness than thin patients.

Treatment Considerations. Trauma with subcutaneous scarring from a previous surgery or from a contusion-induced hematoma causes significant fibrosis. Prior liposuction without optimal drainage of residual bloody exudates can induce significant fibrosis. Interstitial accumulation of inflammatory mediators precipitates a dense interstitial fibrotic reaction.

Fibrosis after liposuction can be largely prevented by not suturing incisions and encouraging drainage of the blood-tinged anesthetic solution with the use of appropriate postoperative compression pads and garments.

If a patient previously weighed much more than at surgery, liposuction will be more difficult. When a person gains a large amount of weight, the body creates new adipocytes and new supporting fibrous tissue scaffolding in the form of collagenous septa, vessels, and nerves. With subsequent weight loss, existing adipocytes merely lose volume without significantly decreasing in total number. Because the total mass of fibrous tissue decreases minimally, the relative degree of fibrosis is increased as the mass of lipid in the fat compartment shrinks.

Fat in any given patient is rarely homogeneous, with some areas being more fibrous than other areas. Even within a specific area, fibrousness may vary significantly. An extreme example of lumpy fat is a patient who has received months of twice-daily injections of lipid-soluble hormones into the hips for treatment of infertility and has densely fibrous, calcified nodules throughout the superolateral quadrant of her buttocks.

EFFECTS ON TUMESCENT ANESTHESIA

The slow absorption of lidocaine after tumescent delivery is explained by the anatomic structure of subcutaneous adipose tissue. Tumescent anesthesia is not homogeneously distributed and dissolved into fat. The fat septa physically isolate

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BOX 25-1 CLASSIFICATION OF FIBROSIS

0 Minimal antitypy, very soft; no effort required to penetrate fat
1 Mild antitypy, soft fat; penetration requires some effort
2 Moderate antitypy, moderately fibrous; penetration requires average effort
3 Significant antitypy, significantly fibrous; penetration requires great effort
4 Extreme antitypy, extremely fibrous; almost impossible to penetrate

and loculate discrete collections of anesthetic solution within fat compartments and fat pearls. Globular collections of anesthetic solution are partitioned and sequestered by the fibrous septa of the fat pearls and fat sections.

Most of the tumescent anesthetic solution is thus physically remote from intimate contact with capillaries. The isolation of anesthetic from absorptive capillaries and profound capillary vasoconstriction account for the prolonged systemic absorption of lidocaine.

Because the septa between compartments impede bulk flow of large volumes of anesthesia, achieving complete anesthesia requires a compulsive infiltrating technique that delivers anesthesia throughout every fat section. Incomplete infiltration usually results in suboptimal hemostasis and anesthesia.

The anatomy of fat has functional implications for the pharmacokinetics of the tumescent technique and for aesthetic liposuction. The infragluteal crease, inframammary fold, nasolabial crease, and waistline result from identifiable agglomerations of fibrous tissue.

For example, the distinct infragluteal crease results from fibrous septa that attach skin to deep fascia immediately distal to the gluteal muscles. Attempting to create an infragluteal crease by liposuction often produces a deformity that only becomes apparent when the patient bends over at the hip and reveals a deep, unnatural-appearing, transverse lipotrop along the proximal posterior thigh.

PHYSIOLOGY OF FAT

If no postoperative change occurs in dietary energy intake and exercise energy output, a patient's weight will probably return to its preliposuction magnitude. Unfortunately for obese patients, living organisms are obliged to obey the first law of thermodynamics. Thus, when weight is stable, the following is true:

Energy intake = Energy output

This equation cannot predict how weight changes as a result of a change in either energy intake or energy output. The *linear* energy balance equation follows:

Change in energy stores = Energy intake − Energy output

This is a *static* energy balance equation. It seems intuitively valid, but it does not take into account that daily energy expenditure increases with increasing weight. Basal energy expenditure (BEE) is a function of body weight, a relationship described by the Harris-Benedict equation as follows:[4]

Men: BEE (kcal/day) = 66.47 + 13.75W + 5H + 6.76A
Women: BEE (kcal/day) = 655 + 9.56W + 1.25H + 4.68A

where W is body weight (kg), H is height, and A is age in years.

If the linear energy balance equation were valid, a small increase in energy intake, sustained over many years, would re-

sult in a huge weight gain. In reality, after a certain amount of weight gain, a new steady-state equilibrium is attained.

It is more realistic to consider a *dynamic* energy balance equation. Consider the following differential equation:

$$dW/dt = dE_i/dt - dE_o/dt$$

where dW is rate of change in energy stores, dE_i is rate of energy intake, and dE_o is rate of energy output. Energy output E_o at time t is also a function of BEE, which in turn is a function of weight.

When the *rates* of energy intake and output are equal, $dW/dt = 0$. In other words, weight does not change with time.

After liposuction, weight change is equal to the weight of fat removed surgically. As a result, the body's BEE will decrease. If a patient does not change the rate of daily food intake or the rate of daily exercise energy expended, the change in BEE will account for a surplus of calories, leading to a net gain in weight. The weight will eventually rise and form a plateau at the preoperative weight.

Analogy and Weight Reduction. A realistic analogy is a tub of water with an open drain, which is in a state of equilibrium when the rate of water inflow and the rate of drainage are equal. In this situation the water level is constant. The rate of water outflow is a function of the height above the drain. Removing a bucket of water from the tub will only lower the water level and slow the rate of drainage temporarily. With the continued steady inflow, however, the water level will rise to the level where the rates of outflow and inflow are again equal.

This analogy helps explain the futility of relying on liposuction as a means of weight reduction. Patients must understand the necessity of either increased exercise or reduced food consumption to maintain any weight reduction achieved by liposuction.

Thus a surgeon should not imply that liposuction alone is a reasonable treatment of obesity. Megaliposuction, besides being risky and expensive, may also be futile.

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CHAPTER 26

Tumescent Infiltration Technique

Complete tumescent local anesthesia can be achieved in the vast majority of patients without using systemic anesthesia during infiltration or liposuction.

The term *tumescent* describes tissue that is swollen and firm. Infiltration with the tumescent technique implies that such a large volume of dilute local anesthetic solution is infiltrated that the targeted tissues become swollen and firm. The goal of tumescent infiltration is to produce 100% anesthesia and profound vasoconstriction with minimal risk of complications, minimal discomfort, and minimal elapsed time.

Tumescent liposuction can be accomplished either totally by local anesthesia or with simultaneous use of systemic anesthesia. Those who use systemic anesthesia often argue that the choice of anesthesia is based on the personal choice of the patient and surgeon. The patient has a choice, however, only if the surgeon or anesthesiologist is skilled in tumescent infiltration. If the clinician cannot produce complete tumescent local anesthesia, the surgeon is forced to rely on systemic anesthesia.

PRELIMINARY CONSIDERATIONS

The prerequisites for training in tumescent infiltration include the following:
1. Modicum of manual dexterity
2. Basic knowledge of subcutaneous anatomy
3. Understanding of abnormal cardiac rhythms
4. Empathetic attitude regarding patients' anxieties
5. Confidence that complete tumescent local anesthesia should be routine

Continuous monitoring for cardiac rhythm and automatic blood pressure measurements are required. If parenteral sedation or narcotics are given, the patient should be monitored by pulse oximetry.

Registered nurses, surgeons, and anesthesiologists are appropriate candidates for training in the special techniques of tumescent local anesthesia.

EFFECTS OF TUMESCENCE

Tumescent infiltration can achieve at least six clinically useful effects, as follows:
1. Subcutaneous pharmacologic reservoir effect
2. Targeted pharmacologic delivery
3. Hydrodissection
4. Hydraulic elevation of tissue
5. Hydraulic magnification of tissues
6. Hydraulic compression

The subcutaneous reservoir effect on lidocaine effectively slows its systemic absorption, thereby prolonging the local anesthetic effect and decreasing the peak plasma concentration and the risk of toxicity. Targeted pharmacologic delivery of epinephrine produces profound vasoconstriction and surgical hemostasis.

Hydrodissection spreads dense fibrous collagenous tissue and permits easier penetration of a microcannula. Hydraulic elevation of tissue removes the deeper layers of fat away from vulnerable subjacent tissues.

Hydraulic magnification of fat tissues facilitates detection and correction of any fat deposits initially missed during liposuction and promotes smoother liposuction results. Hydraulic compression of blood vessels may promote hemostasis.

ALERT PATIENTS

A patient who is awake and alert can cooperate and help the clinician achieve complete local anesthesia. Once an area has been completely infiltrated, the clinician can determine the degree of anesthesia by gently probing the area with an infiltrating cannula or spinal needle. If an area of incomplete anesthesia is encountered, the alert patient can inform the clinician, and the indicated area can be given additional infiltration. With this methodical technique, the clinician can consistently achieve complete local anesthesia.

Complete local anesthesia can be more difficult to achieve in a sedated patient. With less attentive, more rapid, and

more "time-efficient" infiltration techniques, the ultimate degree of local anesthesia is more likely to be suboptimal. The patient with inadequate local anesthesia will experience surgical pain, will become anxious, and will not tolerate liposuction without significant ancillary sedation and narcotic analgesia or general anesthesia.

Tumescent infiltration under systemic anesthesia tends to be a self-fulfilling process: it often provides incomplete local anesthesia and therefore requires more systemic anesthesia.

INFILTRATION CANNULAS

Based on clinical experience, fibrous septa are associated with more sensory nerve fibers than adipocytes. Reducing the traction on the fibrous septa as a metal tube or probe is passed through subcutaneous fat will reduce the painful stimuli.

Surgeons who rely on systemic anesthesia for liposuction typically use 14-gauge or 12-gauge, blunt-tipped, multiholed infiltrating cannulas to facilitate the maximum rate of tumescent infiltration. In a patient who has received no systemic anesthesia, however, a relatively large blunt-tipped infiltrating cannula causes more pain when passed through fibrous adipose tissue than does a 20-gauge spinal needle. Without systemic anesthesia, it is too painful to use a blunt-tipped cannula to infiltrate the most fibrous areas, such as the back, female and male breasts, male flanks, and epigastric and periumbilical areas of abdomen. In contrast, these areas can be routinely infiltrated without intravenous (IV) sedation or narcotic analgesics by using a spinal needle as the infiltration device.

Infiltrating cannulas with smaller diameters cause less patient discomfort. A 25-gauge pediatric spinal needle causes almost no discomfort when passed through fat and can be used during the initial stages of infiltration if a patient is unusually sensitive or anxious. After using the 25-gauge needle briefly, the tissues are sufficiently anesthetized to permit the use of 20-gauge needle with minimal discomfort.

A 20-gauge spinal needle causes an unpleasant pricking sensation that can be greatly reduced simply by advancing the needle more slowly. Using a 20-gauge spinal needle for the infiltration allows the vast majority of patients to tolerate infiltration easily without parenteral sedation.

The ideal infiltrating cannula slips through the fibrous septa with minimal discomfort to the patient and minimal risk of injury to nerves or blood vessels. A short-bevel spinal needle is designed for puncturing while minimizing the risk of cutting or lacerating tissue. In contrast, a long-bevel hypodermic needle is designed for cutting through the skin and deeper tissues with minimal resistance, but it is more likely to lacerate tissue.

An infiltrating needle that is unnecessarily sharp may lacerate nerves or blood vessels. A cannula tip that is extremely blunt imposes excessive traction on the fibrous tissue as it is pushed through the collagenous septa.

PAIN DURING INFILTRATION

Infiltration need not be uncomfortable and painful if done with gentleness and care. Gentleness is one of the most essential factors in minimizing discomfort with infiltration. Infiltration that is done too vigorously will be painful and require systemic anesthesia.

The most uncomfortable aspect of tumescent liposuction is the infiltration of the local anesthetic solution. With proper technique in tumescent infiltration, however, the patient should not require parenteral analgesia. After the tumescent infiltration has been accomplished, liposuction should cause little, if any, discomfort.

The degree of discomfort associated with tumescent infiltration increases along with the following:

1. Flow rate of anesthetic solution as it is pumped into adipose tissue
2. Speed at which infiltrating cannula is pushed through adipose tissue
3. Outside diameter of infiltration cannula
4. Bluntness of infiltration cannula tip
5. Speed and delivery of infiltration technique
6. Patient's anxiety level
7. Patient's intolerance to discomfort

Those who tolerate the infiltration process most easily are females, older than 40 years of age, and not thin. Mothers seem to be much more tolerant of discomfort than are women who have never given birth.

Body areas that are especially sensitive to the discomfort or pain of infiltration include the periumbilical area, areas near costal margin or overlying ribs, the posterior waist, posterior aspects of lateral thigh, medial knee, and infragluteal crease.

Proper Technique. The mild to moderate pain associated with infiltration can be decreased or eliminated with proper infiltration technique. Less pain results when a spinal needle is pushed through fat while simultaneously infiltrating local anesthetic solution compared with advancing the needle without infiltration. The stream of local anesthetic solution seems to anesthetize the fatty tissue in advance of the needle tip. With experience the clinician can quickly determine the optimal rate for advancing the needle.

Fibrous Tissue. The pain of a metal tube or probe being pushed through fat is associated with the puncturing of the fibrous septa that partition fat. The greater the fibrousness of the adipose tissue, the greater is the degree of discomfort. The upper abdomen, periumbilical area, breasts, upper posterior flanks, and scapular areas are particularly fibrous and therefore may cause discomfort on the initial infiltration.

Medication. With proper technique the vast majority of patients will tolerate tumescent infiltration without parenteral sedation or narcotics. Approximately 96% to 98% of patients should require only minimal oral sedation during infiltration.

Typical preoperative medication consists of oral lorazepam (1 mg) and/or oral clonidine (0.1 mg). Fewer than 3% of patients receive 1 to 2 mg of IV midazolam.

Cannula Insertion. The rapidity with which an infiltrating cannula is pushed through the subcutaneous fat can affect patient comfort. A cannula that is advanced more slowly causes less discomfort. Excessively rapid infiltration or an excessively large cannula requires systemic anesthesia.

Tissue Immobilization. A firm but gentle grip on the target adipose tissue facilitates infiltration. A proper grip immobilizes the collagenous partitions and allows the needle to pass through these sensitive sheets of fibrous tissue with less resistance and less discomfort.

On the other hand, squeezing or pinching the skin and subcutaneous tissue too vigorously can be painful.

Clinical Skills. Tumescent infiltration has two principal goals: complete local anesthesia and profound hemostasis. With systemic anesthesia, any clinician with basic infiltration skills can easily and rapidly achieve sufficient tumescent hemostasis. In contrast, achieving complete local anesthesia without systemic anesthesia requires more advanced skills.

Surgeons who lack training in tumescent infiltration may have difficulty with routine liposuction totally by local anesthesia. Others have stated, "In our experience, the dilute lidocaine used in Klein's wetting solution provided inadequate intraoperative anesthesia for many patients, even those receiving intravenous sedations."[1]

The volume of tumescent anesthetic solution necessary for surgical anesthesia is twice that necessary to produce adequate hemostasis. Thus surgeons who use tumescence only to achieve hemostasis tend to infiltrate an inadequate volume of tumescent solution, which produces inadequate local anesthesia. These surgeons may not be able to achieve adequate local anesthesia with subcutaneous infiltration.[2]

Special Training. Learning to master the technique of painless tumescent infiltration and to achieve profound tumescent local anesthesia is not difficult. It cannot be learned, however, simply by reading a set of instructions or a chapter.

Unskilled infiltration can be painful for the patient and usually requires systemic anesthesia. Surgeons compensate for insufficient training by using systemic anesthesia to achieve local anesthesia.

Skillful infiltration and use of microcannulas are the keys to doing liposuction totally by local anesthesia. The surgeon untrained in these two essential techniques will need to use epidural or systemic anesthesia.

RATE OF INFILTRATION

The following two distinct variations exist for tumescent infiltration:
1. Rapid infiltration under general anesthesia
2. Slow to moderate infiltration under minimal oral sedation or intramuscular (IM) sedation

If a variable-rate peristaltic pump is used to deliver the anesthetic solution into the subcutaneous adipose tissue,

the rate of infiltration can be adjusted. When the peristaltic pump rate is sufficiently slow, the flow of fluid exiting a 20-gauge spinal needle will appear as discrete pulses of water. As the flow rate is increased, the jet of fluid flows more continuously. A first approximation of the optimal flow rate is the rate at which the pulsatile stream exiting the spinal needle becomes a continuous stream.

If the patient is comfortable, the flow rate can be increased further. The flow rate only needs to be reduced in areas that require a more precise infiltration, such as the submental chin, face, neck, or ankle areas.

RAPID VERSUS SLOW APPROACH

The more rapid the rate of tumescent infiltration, the more painful the process becomes and the greater the requirement for parenteral sedation and narcotic analgesia.[3] Other than requiring systemic anesthesia, rapid infiltration of dilute tumescent solutions is generally safe, but the resulting local anesthesia tends to be incomplete and often requires heavy IV sedation or general anesthesia.

If the infiltration is extremely rapid, it tends to be less uniform. Unevenly distributed anesthetic solution might provide adequate hemostasis, but the degree of hemostasis is not optimal. Under general anesthesia the completeness of local anesthesia is not relevant during surgery, but postoperative analgesia may be less complete after rapid infiltration.

Incomplete and "patchy" tumescent infiltration may predispose to liposuction results that are lumpy and uneven.

Rapid infiltration under general anesthesia or heavy IV sedation requires less skill and less time. The convenience of rapid infiltration, however, must be weighed against the risks of the anesthesia and a tendency toward uneven aesthetic results.

Lidocaine Concentration. For commercial out-of-the-bottle concentrations of lidocaine (1% = 10 g/L) and epinephrine (1:100,000 = 10 mg/L), the faster the rate of infiltration, the greater the peak plasma lidocaine levels. In contrast, no evidence indicates that rapid infiltration of dilute tumescent lidocaine will produce significantly higher peak plasma lidocaine concentrations than slow infiltration.

The rate of tumescent infiltration and the maximum tissue pressure during the injection of dilute lidocaine (0.1%) do not affect the rate of lidocaine absorption.[4] The occurrence of peak plasma lidocaine concentration is significantly delayed by the epinephrine in the tumescent anesthetic solution.

Optimal Results. Optimal tumescent anesthesia is synonymous with complete local anesthesia and profound hemostasis. Rapid infiltration typically produces less than optimal tumescent anesthesia. The clinician whose goal is to achieve accurate, painless, and complete tumescent anesthesia will usually achieve superior results compared with one whose priority is speed rather than accuracy and completeness.

Optimal tumescent infiltration into fibrous fat requires deliberate attention to detail. For example, the periumbilical area is more fibrous than the surrounding fat and requires slower infiltration than adjacent areas. In less fibrous areas, slow rates of infiltration are not as necessary.

INITIATION OF INFILTRATION

INTRADERMAL BLEBS

To anesthetize skin sites where the infiltrating spinal needle will be inserted, the tumescent anesthetic solution is injected intradermally in small blebs. This intradermal local anesthesia is exactly the same dilute solution that is injected into fat.

Using a 30-gauge needle on a 6-ml syringe, these intradermal injections are usually the most painful part of the entire tumescent liposuction procedure. The degree of this pain varies for different patients, as well as for different sites on the same patient. Warning patients about increased stinging in certain areas also allays anxiety.

The least painful injection technique stretches the skin taut with two fingers of one hand while the other hand holds the syringe with a sharp 30-gauge needle that is inserted at a 45-degree angle into the superficial dermis. The 30-gauge needle must be replaced when it becomes dull after 15 to 30 injections.

DEEP INFILTRATION

Tumescent infiltration should be initiated in the deepest planes of a targeted fat compartment, not in a superficial layer of fat. Commencing infiltration too superficially creates a superficial plane of firm induration within the fat, which makes it difficult to palpate the interface between the deepest layer of fat and muscle.

Starting the infiltration too superficially also obscures the deeper planes and impedes complete anesthesia. Clinicians tend not to infiltrate more deeply than the initial plane of tumescence. Any uncertainty about the depth of the targeted fat compartment may predispose to inadequate deep anesthesia and may impair optimal liposuction.

By first infiltrating along the deepest layer of fat, the more superficial layers are partially anesthetized. The patient will then experience less pain when the superficial layers are infiltrated later (Figure 26-1).

COMPLETE ANESTHESIA

For painless liposuction totally by local anesthesia, virtually every cubic centimeter of adipose tissue must come into direct physical contact with the anesthetic solution. In contrast, achieving adequate tumescent hemostasis does not require such complete infiltration. When anesthesia for liposuction relies on general anesthesia, and if the tumescent technique is used principally for its hemostatic effect, achieving a maximum degree of tumescence is not essential.[2]

With meticulous infiltration that delivers tumescent anesthesia throughout the fat, surgical blood loss is minimal, with less than 10 ml of whole blood per liter of aspirated supranatant fatty tissue (1% or less).[5] A compulsive, methodical, relatively slow infiltration not only achieves complete anesthesia but also yields an aspirate containing approximately 1% whole blood.

A rapid tumescent infiltration yields an aspirate containing 7% whole blood. For example, in one series of 107 patients who had liposuction under general anesthesia with rapid tumescent infiltration, the estimated blood loss was 73 ml of whole blood per liter of aspirate (supranatant plus infranatant).[6]

Three liters of an aspirate with 1% blood contains 30 ml of whole blood, and an equal volume of an aspirate of 7% whole blood contains 270 ml of whole blood. Neither situation requires a transfusion. Thus, if systemic anesthesia is used without concern about optimal local anesthesia, no significant clinical difference exists between a methodical or a rapid tumescent infiltration.

PATIENT COMFORT

To minimize the discomfort of infiltration, a generous volume is injected in a steady stream of anesthetic solution while the needle is advanced at a slow and uniform rate along the deepest plane within the fat compartment.

If it is the patient's first experience with tumescent infiltration, the first area treated should be a location that is less sensitive (e.g., hips instead of flanks).

Another means of minimizing the discomfort during the initial infiltration is to insert the needle slowly to its full extent, then infiltrate a generous volume while slowly withdrawing the needle.

Infiltration Patterns.   The infiltrating needle is advanced smoothly through the targeted tissues. To avoid leaving nonanesthetized areas in any portion of the targeted fat, it is important to direct the infiltration needle in a specific fanlike pattern radiating from each insertion site. Fanlike patterns of infiltration should overlap like tiles on a roof. Beginning along the deepest plane within the fat, the infiltration needle should follow these patterns within the middle and superficial planes (Figure 26-2).

The number of planes infiltrated depends on the thickness of the targeted compartment of fat. Adjacent fanlike patterns should overlap as they radiate from different intradermally anesthetized blebs. The overlapping fans should cover the entire targeted area.

During infiltration, clinicians should pay close attention to any areas of discomfort. These areas will likely require infiltration of extra anesthetic solution. Superficial areas that are not blanched (not etiolated) might require additional infiltration.

Firm Approach.   A firm grip is required to lift the tissues as the infiltration needle is aimed at the deepest plane. To avoid an inadvertent puncture of tissues that are deep to fat,

Preinfiltration   Early infiltration   Immediately after   Ready for Liposuction:
                                                                   infiltration: tumescent   slightly detumescent
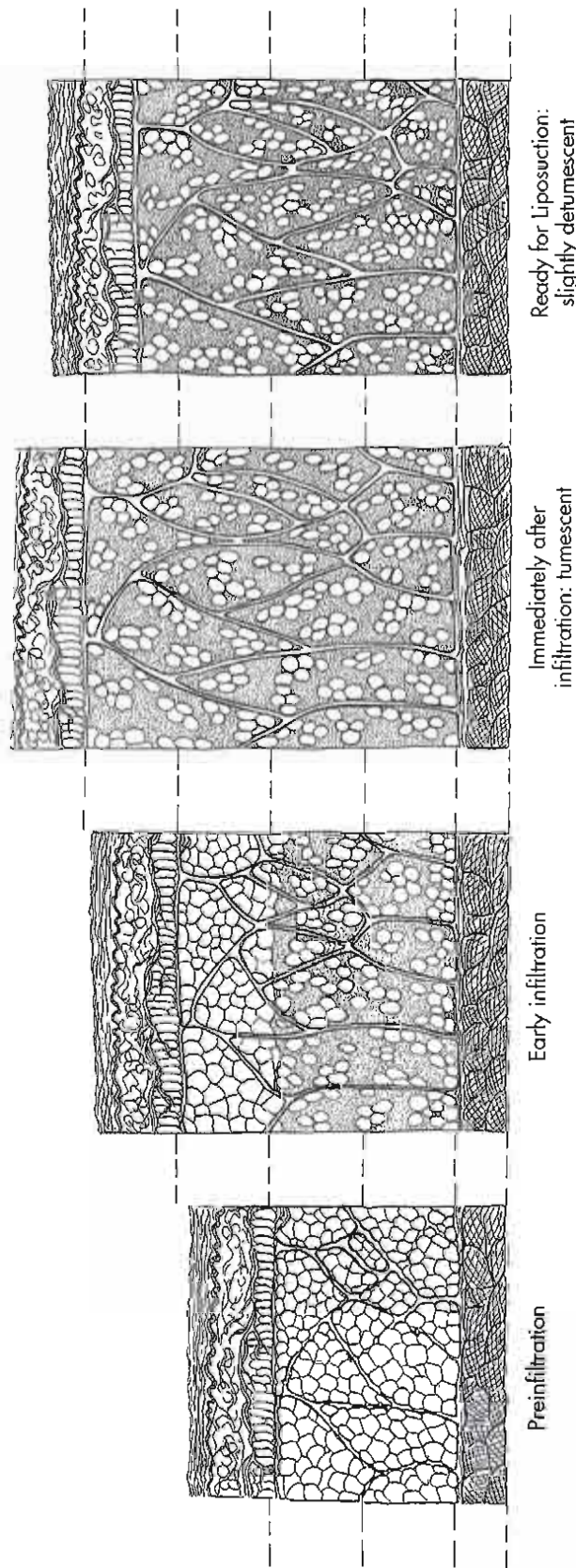
Figure 26-1

Tumescence and detumescence. **A,** Cross section of subcutaneous fat before initiating tumescent infiltration. **B,** Tumescent liposuction is facilitated by directing initial infiltration along deepest plane of subcutaneous fat. If infiltration is initiated too superficially, it becomes difficult to palpate and recognize deeper interface between fat and muscle fascia. Thus subsequent attempts to infiltrate deepest layers of fat are more challenging. **C,** After blocking nerves in deeper layer of fat, subsequent infiltration of more superficial tissue can be accomplished with less discomfort. After infiltrating all fat within a targeted compartment, infiltrating an additional small volume of tumescent fluid into most superficial fat will produce peau d'orange skin. **D,** Partial detumescence of infiltrated fat compartment occurs as tumescent fluid flows through interstitial gel substance into surrounding adipose tissue. Allowing sufficient time (20 to 30 minutes) for detumescence to occur before doing liposuction permits maximal vasoconstriction and local anesthesia. With detumescence, it becomes easier to grip subcutaneous tissue and thus easier to do liposuction.
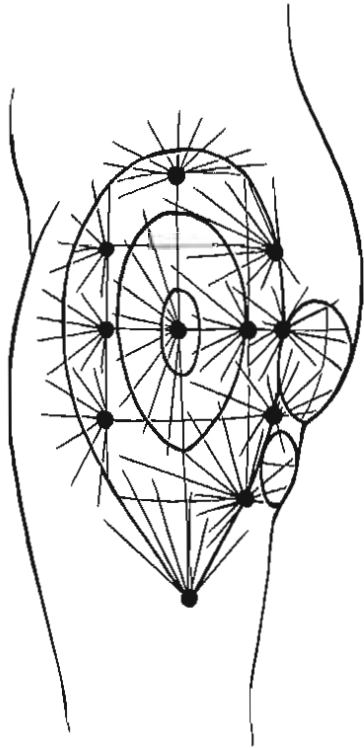
Figure 26-2

Fanlike pattern of tumescent infiltration using spinal needle. Concentric topographic ellipsoid rings accurately indicate relative location and depth of subcutaneous fat. Horizontal and vertical straight lines provide a grid that helps to achieve uniform infiltration. Intersecting lines indicate sites of intradermal injections of local anesthesia through which spinal needle is inserted for tumescent infiltration.

the needle's path should be in a plane that is tangential to the deep muscle fascia.

Short fingernails are required to obtain a firm grip on the deepest fat and lift it away from muscle.

Follow-up Checks. After infiltration from the deep to superficial plane, the clinician can check the completeness of local anesthesia by inserting the needle into the targeted fat and moving it in and out from one side of the targeted area to the other. Random checks are made deeply and superficially for "hot spots" caused by insufficient anesthesia. The patient should inform the physician if sensitive areas are encountered (Box 26-1).

INTRAOPERATIVE INFILTRATION

If the patient experiences tenderness or discomfort during the surgery, additional anesthetic solution should be injected into the affected area. The infiltration technique is modified to compensate for the existence of tunnels created by liposuction. The tissue must be gripped in a firm but gentle manner to occlude the tunnels during infiltration.

BOX 26-1 REASONS FOR INSUFFICIENT LOCAL ANESTHESIA

ANESTHETIC TECHNIQUE
Lack of attention to detail
Insufficient local infiltration into fibrous areas
Incomplete volume of tumescent anesthetic solution
Insufficient concentration of local anesthetic drug
No sodium bicarbonate in tumescent anesthetic solution
Gripping tissue with excessive force

SURGICAL TECHNIQUE
Unnecessarily large diameter of cannulas
Overaggressive approach

PATIENT FACTORS
Anxiety
Previous liposuction
Residual scarring
Fibrosis

After liposuction has been initiated in an area, the preferred infiltration cannula for adding anesthetic solution to an insufficiently anesthetized area is either a 20-gauge spinal needle (8 cm) or a long 18-gauge intradiscal needle (15 cm). A blunt-tip infiltrating cannula is less effective because of its tendency to follow the path of preexisting tunnels.

The concentration of lidocaine used for intraoperative infiltration can vary depending on the clinical situation. Frequently a concentration of 500 mg/L of lidocaine and 0.5 mg/L of epinephrine is sufficient.

VOLUME OF INFILTRATION

The appropriate volume of tumescent anesthetic solution for any given volume of targeted fat is the minimal volume that will achieve complete local anesthesia. The ratio of the optimal volume of tumescent solution to the volume of the entire fat compartment is not a fixed number. Similarly, the ratio of the volume of the tumescent solution to volume of aspirated fat varies widely.

Subcutaneous fat occupies a space that can accommodate an additional volume of fluid that is approximately twice the volume of the subcutaneous fat. Tissue tumescence is therefore typically achieved by infiltrating a volume of fluid that is approximately two times the volume of the targeted subcutaneous fat.

Because it is not the goal of liposuction to remove all the fat from any area, the volume of aspirated fat will be less than the total volume of fat within any targeted compartment. Thus the ratio of the volume of tumescent anesthesia to aspirated fat is often, but not always, in the range of 2:1 or 3:1 (tumescent fluid/aspirated fat). Patients who were very obese and then lost weight are exceptions to this generalization.
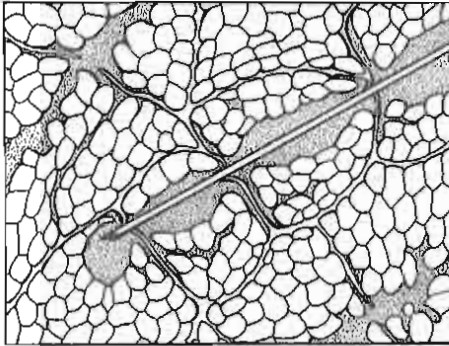
Figure 26-3

Tumescent infiltration initially produces loculations, or small deposits of anesthetic solution, within adipose tissue. As spinal needle is advanced into subcutaneous fat, it punctures adipocytes and perforates fibrous septa while simultaneously injecting anesthetic solution. Subsequently, after spreading by bulk flow through interstitial gel substance, tumescent fluid becomes more homogeneously distributed. Intensity of anesthesia and vasoconstriction increases as greater numbers and lengths of nerves and blood vessels are exposed to tumescent anesthesia.

TABLE 26-1 TUMESCENT INFILTRATION: ESTIMATED TIME (MINUTES) AND VOLUME (MILLILITERS)*

Anatomic Area	Small Patient (min/ml)	Large Patient (min/ml)
Outer thighs	15/600	25/1400
Inferolateral buttocks	4/200	6/400
Inner thighs	15/800	25/1600
Inner knees	5/200	10/400
Hips	15/600	25/1200
Waist	10/300	20/600
Flanks/postaxilla	15/400	25/800
Buttocks	15/400	20/900
Abdomen	30/1400	60/2800
Arms	20/500	30/1000
Male breasts	15/400	30/1000
Male flanks	15/600	25/1000

*Time and volume vary according to patient tolerance. For bilateral symmetric areas, use double the indicated time per side. Physician may prefer to infiltrate chin, cheeks, jowls, and breasts, which require special techniques (see Chapters 35, 37, and 38).

Obesity causes the skin and subcutaneous fascia to be permanently stretched. With subsequent weight loss, the skin and subcutaneous interstitial tissues remain stretched and capacious. On infiltration of tumescent local anesthesia, a greater volume of tumescent solution is required to achieve tumescence.

In patients who weigh much less than their maximum weight, producing complete tumescence is not always necessary to achieve adequate local anesthesia and hemostasis. The clinician should avoid infiltrating unnecessarily large volumes in these patients with "flabby fat."

BULK FLOW OF ANESTHETIC SOLUTION

A sufficient volume of anesthetic solution is important for achieving adequate local anesthesia. A large volume of solution facilitates the spread of local anesthesia by bulk flow throughout the subcutaneous tissue.[7]

Bulk flow is a mechanical process involving hydrodissection and the movement of a volume of liquid en masse throughout the subcutaneous fat compartment. Bulk flow can occur rapidly under elevated hydrostatic pressure produced by an injection pump. It also occurs more slowly from the elastic recoil of the fascial tissues acting on a subcutaneous bolus of injected fluid or from the effects of gravity.

In contrast, *diffusion* is a small-scale chemical process whereby lidocaine molecules move across a relatively short distance after bulk flow has pushed a solution containing lidocaine to within a short distance of a sensory nerve.

Bulk flow is responsible for the delivery of lidocaine on a large scale throughout the entire fat compartment. A solution of local anesthetic spreads through subcutaneous tissue by bulk flow through the interstitial gel substance, dissecting along anatomic planes and along the lamellae of fibrous septa within adipose tissue (Figure 26-3).

Table 26-1 lists approximate volumes of tumescent anesthetic solution required for various body areas.

PEAU D'ORANGE APPEARANCE

Peau d'orange (French, "orange-peel") refers to a characteristic pitted appearance of the skin of an orange. The subcutaneous infiltration of a sufficiently large volume of tumescent local anesthesia produces a fine, dimpled appearance of the skin texture that resembles the skin of an orange.

The peau d'orange appearance is the result of intradermal swelling everywhere except around pilosebaceous hair follicles, which prevent expansion because of their relative inelasticity. Tumescent infiltration can cause peau d'orange skin by extreme hydration of the dermis after superficial subcutaneous injection of a crystalloid solution such as 0.9% normal saline or lactated Ringer's solution.

Although peau d'orange skin is one possible end point of tumescent infiltration, this appearance is not necessary to achieve complete tumescent local anesthesia. Good vasoconstriction and sufficient local anesthesia can be achieved without the tumescent infiltration producing peau d'orange skin. If the infiltration is only superficial, however, the clinician

can produce a peau d'orange appearance without complete local anesthesia. In most patients, provided that the infiltration has been initiated in the deepest plane, tumescent infiltration that produces peau d'orange appearance is usually a reliable sign of complete local anesthesia.

In other words, tumescent infiltration to the point of producing peau d'orange skin is usually sufficient, but not always necessary, to produce complete local anesthesia and profound tumescent vasoconstriction.

AVOIDANCE OF EXCESSIVE VOLUMES

The optimal volume for tumescent anesthesia is not precisely defined. Some care and experience are required to determine the safest and most effective volume of solution. Maximum tumescence is not required to produce profound capillary vasoconstriction. Thorough, uniform tumescence is necessary, however, to optimize the local anesthesia.

Clinicians should avoid infiltrating an excessive volume of tumescent solution. Too much fluid volume in the subcutaneous fat results in tediously inefficient, unnecessarily slow and difficult liposuction. In some patients, excessive subcutaneous infiltration of isotonic fluid can predispose to hemodilution and produce prolonged edema of the lower extremities.

An excessively large volume of tumescent fluid infiltrated into the subcutaneous fat of the abdomen may be uncomfortable for the patient and may impede liposuction. No advantage is gained by infiltrating 5 L of excessively dilute tumescent solution at 500 mg of lidocaine/L when 2 L of 1250 mg of lidocaine/L is more comfortable, is safer, and facilitates more effective abdominal liposuction.

An excessive volume of tumescent isotonic fluid can be dangerous. Subcutaneous tumescent fluid in the abdomen that greatly exceeds the amount necessary to achieve local anesthesia can impair diaphragmatic expansion and limit respiratory ventilation.

Symmetric areas of the body should receive approximately equal volumes of tumescent anesthetic solution. Unless the patient displays obvious asymmetry preoperatively, the goal is to infiltrate equal volumes of anesthetic solution into each side of paired areas, such as both hips or symmetric portions of both thighs.

TECHNIQUE FOR FACIAL RESURFACING

Tumescent infiltration of the entire face can provide excellent anesthesia for full-face carbon dioxide (CO_2) laser resurfacing, without using systemic anesthesia.

Preoperative medications, given at least 15 to 30 minutes before infiltration, include oral lorazepam (2 mg) and clonidine (0.1 mg). Although IV sedation is usually not necessary, an occasional patient will require midazolam (1 to 2 mg) just before infiltration.

The formulation for tumescent anesthetic solution in CO_2 laser resurfacing is 600 mg of lidocaine, 1.0 mg of epineph-

rine, and 5 mEq of bicarbonate in 250 ml of physiologic saline (0.9% NaCl). This anesthetic solution, when appropriately infiltrated, should provide complete anesthesia for the entire face for up to 1 hour of CO_2 laser resurfacing. The infiltration typically requires about 45 minutes (range 35 to 60 minutes).

INFILTRATION SEQUENCE

The superficial subcutaneous infiltration of the central portion of the face, including the periorbital, nasal, and labial areas, is accomplished with the use of hand-held syringes by a well-trained physician or registered nurse. The equipment usually consists of two 6-ml syringes with a 1.25-cm (½-inch) or 2.5-cm (1-inch) 30-gauge needle, depending on the area being infiltrated, and two 12-ml syringes with a 5-cm (2-inch) 25-gauge needle. Having an assistant to refill the syringes is very helpful.

In some patients a peristaltic pump can be used to help infiltrate the lateral portions of the face over the mandible and submental areas. A peristaltic pump should not be used around the eyes, lips, and delicate mid facial structures. After topical anesthesia of the cornea, stainless-steel eye shields are placed before initiating the tumescent infiltration.

An initial ring of tumescent anesthesia is infiltrated from the glabella, across the cheeks, and onto the submental chin. The initial injection is extended over the eyebrows by alternating the injections between left and right. Past the lateral brow, the bead of tumescent infiltration is continued past the lateral canthus, using a 0.5-cm 30-gauge needle on a 6-ml syringe. Next, using a 25-gauge 5-cm needle on a 12-ml syringe, the paths of tumescent infiltration are extended onto the cheeks, past the lateral oral commissure, and over the mandibular margin, meeting on the submental chin.

This initial ring of tumescent anesthesia produces a superciliary nerve block for anesthesia of the entire forehead. The ring also provides a path of anesthetized skin through which needles can be painlessly inserted to anesthetize the lateral and medial portions of the face.

Anatomic Considerations. Anesthetizing the medial cheeks and chin results in some anesthesia of the lips, which subsequently can be infiltrated with less discomfort. The nose is anesthetized with tumescent infiltration extending from the glabella, along the nasal dorsum to the tip and columella, and then laterally.

The upper and lower lids must be anesthetized with special care. The needle must never be held pointing toward the globe. After raising a bleb of tumescent anesthesia at the lateral canthus, the tumescent anesthesia is injected and caused to flow medially by bulk flow, aided by direct pressure from the surgeon's fingers. The anesthesia is extended medially by inserting the needle superficially through the thin skin that is already tumescent.

The left hand should rest on the patient's face, with the right hand holding the syringe and resting on the left hand. By moving the syringe and needle in concert with the pa-

tient's face, this technique minimizes the risk of ocular injury from the needle should the patient suddenly jerk the head.

Infiltration of the eyelids and face demands careful attention to avoid trauma to vulnerable structures. Tumescent infiltration to provide full-face local anesthesia for CO_2 laser resurfacing is best attempted after observing the procedure performed by an expert.

PATIENT ANXIETY

Anxiety greatly influences how the patient perceives discomfort and pain. A skillful clinician can help relieve a patient's anxieties by insightful communication and, when necessary, conservative use of drugs.

Patients vary greatly in their ability to tolerate discomfort. Some patients tolerate the discomfort of rapid tumescent infiltration without complaint. Others complain that the blood pressure cuff is too tight or when anesthetic solution drips and trickles over their skin. Much of this variability is associated with the patient's anxiety.

PREOPERATIVE RELIEF

In most cases a patient's anxiety is mild to moderate and entirely appropriate to a preoperative situation. This type of anxiety is most effectively treated with a confident and empathetic "bedside manner."

The surgeon and staff can allay the normal preoperative anxiety with patience and gentleness. Compassionate interpersonal skills with thoughtfulness and a caring attitude, as well as clinical experience, are indispensable prerequisites in caring for awake patients under local anesthesia. Surgeons who do not cultivate these skills may be unable to accomplish liposuction totally by local anesthesia.

For example, at the time of preoperative laboratory tests, the site of the phlebotomy needle puncture is anesthetized using a 30-gauge needle to inject an intradermal bleb of neutralized lidocaine. Afterward, patients typically comment that it was the least painful "blood test" they ever experienced. They begin to believe that local anesthesia can be painless. On the day of surgery, the IV catheter site is also anesthetized before percutaneous insertion.

Pleasant and relaxing music is another means of comforting and calming a patient before and during surgery.

Modesty. Protecting a patient's modesty is always helpful in reducing anxiety. The surgical staff must address patient concerns about being naked in the operating room.

All female patients are provided with disposable panties. To expose the surgical field fully during liposuction of the lateral hip, the side straps of these panties can be cut and taped to the patient's back and abdomen before scrubbing the area.

Male patients are advised to wear nylon bathing pants rather than white cotton briefs, which absorb unsightly bloody drainage.

ORAL ANXIOLYTIC DRUGS

By decreasing a patient's anxiety, the clinician can decrease the need for narcotics and sedatives. The ideal anxiolytic drug produces a decreased level of anxiety in a patient without the risks of respiratory depression and decreased ventilation associated with benzodiazepine sedatives and narcotics. An anxiolytic should produce its effect without the patient feeling "sedated" or "drugged."

Anxiolytics are not necessary for effective tumescent liposuction, but they improve the quality of the experience for both the patient and the surgical staff without increased risks of drug toxicity.

Clonidine. This alpha$_2$-adrenergic agonist is given orally to treat severe hypertension. Clonidine tends to lower both blood pressure and pulse rate and also provides sedation. Its sedative properties have traditionally been considered an annoying side effect that has limited its use in treating hypertension in ambulatory patients.

For liposuction surgery, however, low-dose clonidine is an excellent anxiolytic that does not impair respiratory function. At a dose of 0.1 mg, clonidine has significant anxiolytic properties without affecting respiration or the protective airway reflexes. It also attenuates intraoperative hypertension, increases the efficacy of local anesthesia, and decreases the incidence of intraoperative sinus tachycardia associated with the subcutaneous infiltration of dilute epinephrine (see Chapter 24).

Lorazepam. The combination of lorazepam and clonidine acts synergistically to achieve anxiolytic effects in most patients with minimal sedative effects and minimal respiratory depression (see Chapter 24). Low doses of lorazepam (1 mg) and clonidine (0.1 mg) have a long history of safe use by outpatients. These drugs are much safer than the medications routinely employed for IV conscious sedation.

This absence of significant risk for respiratory depression is why the use of lorazepam (1 mg) and clonidine (0.1 mg) with the tumescent technique is consistent with the definition of liposuction totally by local anesthesia.

NARCOTICS AND SEDATION

A few patients have a true phobia or clinical anxiety-hysteria complex about the prospect of a surgical procedure and require narcotic and sedative drugs.

Dermatologic surgery has a long tradition of using small doses of IM narcotics, IM midazolam, and sublingual diazepam to supplement local anesthesia for office procedures. These limited doses have not been associated with significant risks of respiratory depression.

Sodium Bicarbonate. Routine use of IM, IV, or sublingual sedatives or narcotics is not necessary for tumescent infiltration. The addition of sodium bicarbonate ($NaHCO_3$) to a local anesthetic solution neutralizes the pH of the solu-

tion and thus eliminates most of the stinging pain associated with infiltration. The use of sodium bicarbonate therefore has also largely eliminated the need for narcotics and sedatives.

Benzodiazepines.   Some surgeons continue to employ IM narcotic analgesics and IM benzodiazepines such as midazolam because they allow more rapid tumescent infiltration.

I believe that patients feel better without these IM drugs, and the nausea associated with narcotics and the other adverse effects of benzodiazepines (e.g., antegrade amnesia) can be avoided. When IM narcotics or benzodiazepines are used routinely in conjunction with tumescent local anesthesia, the tumescent liposuction cannot be said to be done totally by local anesthesia.

SURGEON ANXIETY

Anxiety about surgery can affect the surgeon as well as the patient. A surgeon may be anxious and insecure due to the lack of training in a particular technique and may communicate that anxiety to the patient, whose anxiety will also be increased. The situation especially may be encountered with the tumescent technique, since many surgeons have had no formal training in doing liposuction totally by local anesthesia.

All surgeons become anxious and worried about the possibility of a patient experiencing insufficient local anesthesia. Among surgeons whose training has inculcated the idea that local anesthesia is usually inferior to systemic anesthesia, the thought of relying entirely on local anesthesia for liposuction is especially anxiety provoking.

I suspect that some surgeons routinely give IM narcotics and sedatives during tumescent infiltration and liposuction more to allay their own anxiety than to make the patient more comfortable. Other surgeons overcome this anxiety by seeking specific training in the specialized techniques of tumescent infiltration and liposuction totally by local anesthesia.

INTERPERSONAL SKILLS AND RECOMMENDATIONS

This section offers my personal suggestions to facilitate tumescent infiltration and addresses the responsible physician, nurse, or surgeon directly.

Before beginning infiltration, make an effort to develop a personal rapport with the patient. First, introduce yourself and make good eye contact.

To divert the patient's attention from the infiltration, engage in conversation about another subject, as follows:

1. Inquire about the patient's background and family situation.
2. Focus on topics the patient seems to enjoy.
3. Inquire about recent or future vacations.
4. Ask about the patient's children.
5. Use the patient's name often in conversation.
6. Touch the patient gently.
7. Share some anecdotes about yourself.

TELL PATIENT WHAT TO EXPECT

Before beginning a procedure, tell the patient what is going to be done and what it might feel like. Educate the patient about the infiltration procedure.

Tell the patient about the discomfort and the duration of the infiltration process. Offer to give a detailed explanation for any question the patient may have about the procedure.

ADDRESS INFILTRATION CONCERNS

Encourage the patient to inform you if any *significant* discomfort requires infiltration of additional anesthetic solution. Ask the patient to ignore or endure any trivial or easily tolerated discomfort.

Explain the importance of good communication between the staff and the patient. Emphasize how much the staff relies on information from the patient during the procedure.

Be alert to the patient's facial expressions (e.g., grimace, wince), body language (e.g., flinch, jump, cringe, shudder, subtle foot movement), and sounds (e.g., groan, whimper). Assess the patient's mannerisms and degree of discomfort. Repeatedly ask if the infiltration is being done in a comfortable manner.

OPTIMIZE PATIENT'S PHYSICAL COMFORT

Use a blanket warmer to preheat the anesthetic solution before infiltration. Warm anesthetic solution is less painful and minimizes patient shivering.[8]

Use a water bath to preheat surgical soap and normal saline used to wipe off excess soap. For comfort and modesty, place prewarmed maroon-colored terry cloth towels beneath patients. Warmed towels can also be used to cover the patient and keep the patient comfortable in a cool operating room.

If a patient states the infiltration is uncomfortable, try a slight modification of the technique, as follows:

1. Increase or decrease the rate of pumping the fluid.
2. Use a smaller needle.
3. Approach the tender area from a different direction.
4. Grip the tissues more gently or more firmly.
5. Avoid pinching the tissues with the gripping hand.
6. Inject only a small volume in the painful area, then return to the area later after anesthetic has taken effect.

DEVELOP METHODICAL ROUTINE

Develop a systematic routine for infiltration, and follow it to avoid confusion about which areas have been infiltrated.

Before infiltration, estimate the volume of solution that will be used to infiltrate each area, then calculate the expected

total lidocaine dosage (mg/kg). This allows advance adjustments in the concentration of lidocaine and avoids use of too much lidocaine.

PROMOTE TEAMWORK

Ask other staff members for their opinions on how to infiltrate each patient. This can minimize the discomfort of infiltration. Also, comparing tentative estimates of the volume of anesthetic solution required for each area often improves the accuracy of the final estimate. This openness promotes cooperation among the surgical team.

If it becomes apparent during the infiltration process that the final dosage of tumescent lidocaine will exceed the maximum intended amount, the concentration should be decreased, or the number of areas to be treated should be limited and postponed until subsequent surgery.

To avoid surprises, the circulating nurse responsible for monitoring the patient should periodically inform the infiltrating nurse about the volume of anesthetic solution already infiltrated.

Office and Time Efficiency. When well-trained registered nurses (RNs) do the tumescent infiltration, time is used more efficiently and safety is improved. While one RN monitors the patient and another infiltrates the local anesthesia, the surgeon can see new or follow-up patients in the clinic.

By avoiding the use of significant sedation, patients can be discharged from the office surgical facility within 30 minutes of completing surgery.

Scheduling. Because it is easier to coordinate the schedules of the surgeon and an RN than the schedules of two physicians, there is further time saving efficiency in using an RN to do the infiltration rather than a physician-anesthesiologist. When an anesthesiologist provides systemic anesthesia, time may be wasted if one physician is delayed elsewhere, forcing the second physician to wait.

Microcannulas. The use of microcannulas allows smoother and more complete liposuction results. Thus microcannulas reduce the need for "touch-up" or "redo" procedures and extra team effort, which saves much time and expense.

LOCAL COMPLICATIONS

A number of complications can occur with any type of local anesthesia. Complications may also result from insufficient anesthesia (see Box 26-1).

Necrosis of local tissue and nerve injury resulting from local anesthesia have been reported in dermatologic surgery. To my knowledge, however, no focal necrosis or nerve injury has been associated with infiltration using the tumescent technique.

BLEEDING

Local subcutaneous bleeding is an unusual complication that can occur with tumescent infiltration when a sharp spinal needle punctures a blood vessel. If bleeding from a puncture site is noticed during infiltration, more fluid is infiltrated into and around the probable bleeding site to produce vasoconstriction and vascular compression. The clinician then waits a few minutes for vasoconstriction to occur, temporarily directing the infiltration elsewhere before completing it in the area of bleeding.

If a hematoma occurs, it is generally small and cannot be detected clinically until it is encountered during liposuction and causes some localized bloody aspirate. The most common anatomic locations for these tiny "infiltration hematomas" have been the midabdomen and medial knee. Such hematomas are of little clinical consequence.

NEEDLE BREAK

Needle breakage can occur with any injection, although I am not aware of it occurring during tumescent infiltration. A needle break is more likely with aggressive, crude, or indelicate technique.

The needle should be withdrawn sufficiently to allow a change of needle direction by pivoting about the needle tip. Attempting to change needle direction with the needle deep within the subcutaneous fat can place excessive force on the needle, causing it to bend or snap.

FACIAL NERVE

Paralysis. Inadvertent motor nerve blockage may occur with local anesthesia of the face. Tumescent infiltration in and around the lateral oral commissure often causes localized paralysis persisting for several hours. The motor nerves that innervate the periorbital muscles can also be temporarily paralyzed with local anesthesia.

The terminal branches of the facial nerve that innervate orbicularis oris muscles and the muscles of facial expression are particularly susceptible to tumescent local anesthesia. Paralysis of facial muscles around the mouth is a common, harmless condition that resolves within a few hours. Patients should be warned that local anesthesia around the mouth may cause temporary difficulty in moving the lip muscles.

For the surgeon's peace of mind, one should test for facial nerve paralysis after infiltration and before liposuction. To neglect this simple test, and then to notice a motor nerve paralysis of the face only after the liposuction surgery has been initiated, makes it difficult to distinguish the possibility of cannula-induced facial nerve apraxia.

Injury and Apraxia. Injury to the mandibular branch of the facial nerve, where the nerve exits the masseter muscle's anterior margin at the mandible's inferior margin, may occur as a result of trauma from a liposuction cannula.

The tumescent technique should protect patients from this injury by elevating the subcutaneous fat away from the subjacent neurovascular structures. The mandibular branch of the facial nerve is located deep to the platysma muscle. During infiltration of the lateral cheek, care should always be taken to infiltrate above the platysma muscle.

Although I have never encountered this complication, I have heard reports of other surgeons whose patients had temporary facial nerve apraxia. Liposuction injury to the mandibular branch of the facial nerve may result from the following:

1. Inaccurate tumescent infiltration involving tissue deep to the platysma muscles, thereby increasing the likelihood of liposuction in this area
2. Overaggressive liposuction of the cheek
3. Use of large cannulas with large apertures, with increased risk of collateral damage to local tissues

Microcannulas have small apertures and are less likely to cause inadvertent nerve injury.

MUSCLE PARALYSIS

Periorbital muscle paralysis is a common temporary sequela of local anesthesia for blepharoplasty. It may also occur with tumescent anesthesia for CO_2 laser resurfacing of the face. Patients should be warned of this common effect.

FEMORAL NERVE BLOCK

Motor blockage of the femoral nerve can occur with local nerve block used in inguinal hernia repair or with femoral nerve block for ambulatory phlebectomy. Using tumescent local anesthesia for phlebectomy eliminates the risk of temporary motor nerve paralysis of the femoral nerve.

VISION PROBLEMS

Blindness and temporary double vision have been reported as the result of a high-pressure injection of too much local anesthetic during an infraorbital nerve block.[9] Mild tumescent infiltration provides sufficient anesthesia for either CO_2 laser resurfacing of the eyelids or for blepharoplasty.

Blindness can result from inadvertent injection into the globe of the eye during injection of local anesthetic into an eyelid. Although not always necessary, stainless-steel eye shields may be helpful in protecting the globe in some patients.

Inadvertent corneal injury or intraocular injection can be avoided by a gentle tumescent injection that is initiated lateral to the orbital rim. As the bleb of subcutaneous anesthesia migrates medially, additional injections can be delivered immediately below the elevated dermis, with direct visualization of the needle placement far from the globe.

SYNCOPE

Vasovagal syncope or near-syncope can occur before, during, or after any percutaneous injection. Vasovagal syncope in the setting of tumescent infiltration and liposuction can usually be prevented. Patients with any history of fainting for any reason are predisposed to a vasovagal event during any medical procedure (see Chapter 8).

This reflexogenic neurologic-cardiovascular reaction during tumescent infiltration or liposuction can be prevented by a prophylactic IV injection of atropine (0.3 to 0.4 mg), given immediately after IV access has been established.

INSERTION AND INJECTION PAIN

Needle Insertion. To minimize painful injections, slow technique and a sharp 30-gauge needle are used to anesthetize the injection site. Subsequent injections at this site are virtually painless (see earlier discussion).

Injection of Anesthetic. This pain is minimized by injecting the anesthetic slowly. The pH of 4 to 5 is typical of commercially available solutions of lidocaine for local anesthesia. An acidic solution is painful on intradermal injection. Sodium bicarbonate neutralizes a local anesthetic solution to a pH of 7.0 to 7.4.[10,11] For example, a 50-ml bottle of 1% lidocaine (without epinephrine) can be neutralized with 3 mEq of sodium bicarbonate (8.4% $NaHCO_3$ = 1 mEq/ml).

Whether neutralized or not, lidocaine with epinephrine seems to sting more than lidocaine without epinephrine. A tumescent solution of local anesthesia (500 to 1000 mg of lidocaine, 1 mg of epinephrine, and 10 mEq of $NaHCO_3$ in 1 L of 0.9% NaCl) seems to produce the least stinging of all the local anesthetic solutions on intradermal injection.

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CHAPTER 27

Microcannulas

Microcannulas are liposuction cannulas with an inside diameter (ID) less than or equal to 2.2 mm, which is the ID of a 12-gauge hypodermic needle.

Microcannulas are constructed from standard, fully tempered, stainless-steel hypodermic needle tubing. In contrast, larger cannulas are made of stainless-steel tubing with a wall thickness that is significantly greater than that of microcannulas.

The relatively thin wall of a microcannula significantly limits the shape and size of the apertures in the cannula; this limits the design of the microcannula tip. A tip design appropriate for a cannula with thick-walled stainless-steel tubing may not be safe or practical with hypodermic needle tubing. The thin wall of hypodermic needle tubing imposes structural limitations on the type of aperture patterns than can be used and still maintain sufficient structural integrity.

The qualitative differences between microcannulas and macrocannulas are determined in part by the fibrous stroma within fat. The tenacious fibrous septa of fat compartments and fat pearls resist penetration by larger cannulas but are easily penetrated by microcannulas.

Microcannulas remove small volumes of fat with each stroke, so they can be used to remove superficial layers of fat with less risk of creating irregularities in the skin. Microcannulas require more time to complete a case but, paradoxically, remove greater amounts of fat. Whereas larger cannulas tend to be directed deeply to avoid creating visible furrows or depressions on the skin surface, microcannulas can be used more superficially and thus can remove more fat.

Microcannulas permit the removal of superficial fat layers without disrupting or disconnecting the many fibrous attachments that connect the skin to the muscle below. After tumescent liposuction removes the heavy weight of fat pulling downward on the skin, these fibrous attachments contract, returning the skin to its normal position.

LIPOSUCTION APPLICATION

Cannular diameter is directly correlated with the degree of discomfort associated with liposuction totally by local anesthesia in an awake patient. If tumescent infiltration has been correctly accomplished, tumescent liposuction should be painless even with larger cannulas. If the surgeon encounters a localized area of incomplete anesthesia, a larger cannula will cause even more burning discomfort, whereas a smaller cannula will cause much less pain with continued liposuction.

The use of microcannulas decreases the probability that an awake patient will experience discomfort during tumescent liposuction. This important fact has gone unnoticed by many surgeons with inadequate training in tumescent liposuction. These surgeons may continue to use large cannulas and often cannot accomplish liposuction totally by local anesthesia.

TUMESCENT HEMOSTASIS

The use of microcannulas was not practical or safe before the advent of tumescent vasoconstriction. The extensive use of microcannulas is only feasible with the profound hemostasis provided by the tumescent technique.

Before the tumescent technique, blood loss was a limiting factor in determining how much liposuction could be done safely. As discussed next, microcannulas cause more surgical bleeding than large-diameter cannulas. Without good hemostasis, liposuction surgeons preferred to use larger cannulas. The profound hemostasis of the tumescent technique almost completely eliminates liposuction blood loss and permits the use of microcannulas.

Bleeding Analysis. The following explanation reveals the relation between the diameter of a liposuction cannula and the degree of liposuction-induced intraoperative surgical bleeding.

Theoretically the shape of the wound made by a liposuction cannula within fat is approximately a cylindrical tunnel, with a circular cross section corresponding to the cannula's ID. A cylinder with a circular cross section of radius R and length L has a surface area $A = 2\pi RL$ and volume $V = \pi R^2 L$. For such a cylindrical tunnel the relation of A to V is given by the following equation:

$$A = 2V/R$$
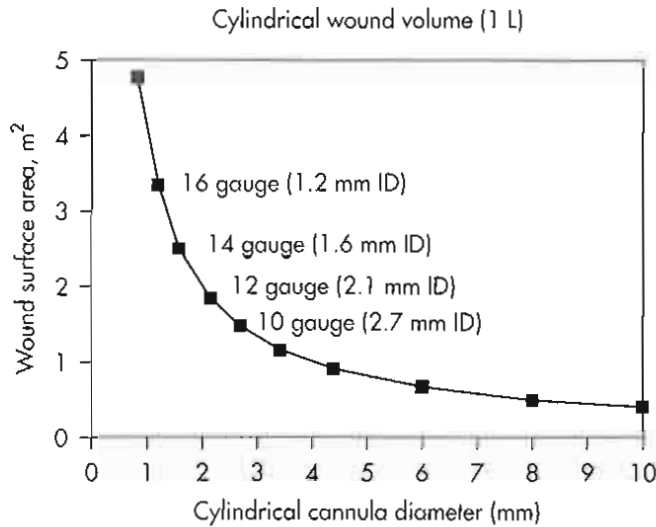
Figure 27-1

Hypothetic liposuction wound surface area. Total surface area of liposuction tunnels within subcutaneous fat varies as a function of inside diameter (ID) of microcannula, where volume of aspirated fat is constant (1L).

Figure 27-2

Typical aperture designs for microcannula tips. **A,** Finesse microcannula. **B,** Capistrano microcannula. *1D,* Diameter of aperture; *4D,* length of oblong slots of Finesse microcannula; *3D,* length of distal oblong slot of Capistrano microcannula; *S,* linear distance (projected onto central axis) between centers of adjacent round apertures of Capistrano microcannula.

In other words, for a fixed volume, the surface area of a cylinder is inversely proportional to its radius. Thus, as the cannula diameter increases, the surface area of the wound decreases (Figure 27-1).

For example, a patient has equal volumes of fat removed by liposuction from each outer thigh, with a small-diameter cannula used on one thigh and a larger cannula on the opposite thigh. For this fixed volume of fat, the small-diameter cannula will have the largest surface area associated with its multiple cylindrical wounds. The larger the surface area of a cylindrical wound within fat, the greater is the number of transected capillaries, and thus the greater the amount of bleeding. Larger cannulas produce a wound with a smaller surface area and fewer transected capillaries.

Before the tumescent technique, large cannulas minimized the bleeding associated with liposuction. Thus the earlier and bloodier liposuction techniques required larger cannulas to minimize bleeding.

Based on this analysis, a 2-mm cannula *theoretically* causes four times the bleeding as an 8-mm cannula. Because bleeding associated with tumescent liposuction is virtually zero, no significantly increased bleeding occurs with tumescent liposuction using microcannulas.

This analysis assumes thorough tumescent infiltration, which is necessary for optimal hemostasis. Incomplete tumescent infiltration will result in proportionately more bleeding.

DESIGNS AND TERMINOLOGY

FINESSE MICROCANNULA

The Finesse microcannula is designed to minimize the risk of injury to the deep surface of the dermis when liposuction is done near the skin. Early cannula designs had one or more oblong apertures or oval slots arranged linearly along the distal end of the cannula. The Finesse microcannula has two in-line oblong slots along one side and a spatula-like tip. This design was motivated by its simplicity and ease of fabrication (Figure 27-2, *A*).

To avoid injury to the superficial vascular plexus on the skin's undersurface when doing superficial liposuction, the apertures of a Finesse microcannula should always be directed away from the dermis. This is achieved by having a "thumb rest" depression machined into the cannula hub. The tube is attached to the hub with the thumb rest facing 180 degrees away from the oblong apertures. This arrangement allows the surgeon to control the direction of the microcannula apertures.

When the cannula is in subcutaneous fat, the cannula is held so that the thumb rest on the hub faces away from the skin. This ensures that the apertures are continuously oriented away from the dermal undersurface.

CAPISTRANO MICROCANNULA

The Capistrano microcannula is designed to maximize liposuction cannula efficiency (volume of fat liposuctioned per
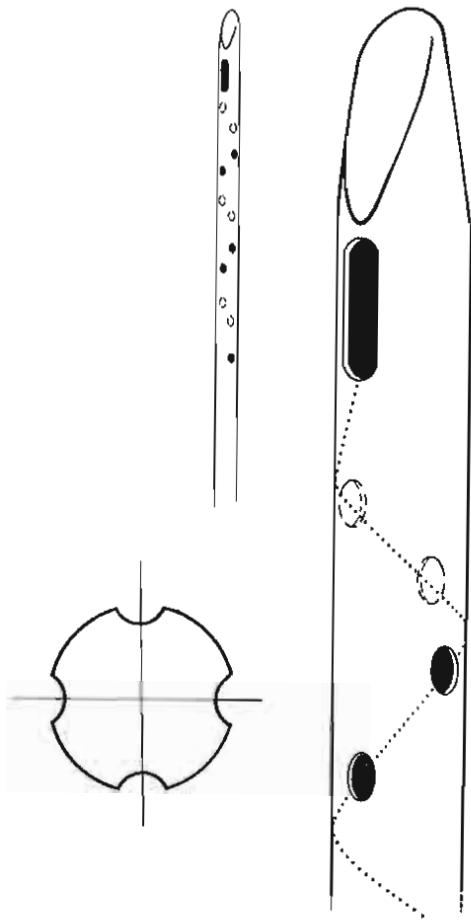
Figure 27-3

Capistrano microcannula is constructed of stainless-steel hypodermic needle tubing with multiple small apertures placed along cannula near distal tip. Distal oblong slot facilitates cleaning and removal of tissue fragments using special brushes inserted through cannula hub (U.S. patent pending).

in-and-out stroke). Because the apertures are arranged around the entire microcannula circumference, some are always directed toward the skin. To prevent dermal injury, Capistrano microcannulas should never approach within one cannula diameter of the dermal undersurface.

The Capistrano microcannula has multiple round apertures arranged in a helical pattern along the distal end of the cannula (Figure 27-2, *B*). It has a single slot located distally to facilitate cleaning and the removal of debris (Figure 27-3).

Because of its size and delicacy, the 16-gauge Capistrano microcannula has only seven round apertures and the one distal slot. Standard 14-gauge and 12-gauge cannulas have 12 round apertures and one distal slot.

Special Capistrano-style cannulas have been designed specifically for reduction mammoplasty by microcannular tumescent liposuction. This design permits efficient liposuction in the fibrous fat and glandular tissue within the female breast.

These microcannulas have smaller holes but also many more holes than a Capistrano microcannula. The small holes minimize the risk of vascular injury.

SPECIFICATIONS

In the early years of liposuction the terminology for specifying the diameter of urinary catheters and abortion cannulas was also used to specify the diameter of the liposuction cannulas. Thus the diameter of a liposuction cannula was specified as being either 8 mm or 24 French. Subsequently, it became common practice to refer to the diameter of cannulas only in terms of approximate millimeter size.

In the engineering of hypodermic needles, where the diameters of progressive sizes vary by fractions of a millimeter, it is traditional to specify tube diameter in terms of wire *gauges* rather than millimeters. The terminology that describes microtubes in terms of gauge has been applied to microcannulas to simplify communication between manufacturers of hypodermic needle tubing, manufacturers of Luer connectors, machinists, and surgeons.

The gauge sizes of the hypodermic needle tube are associated with standard ID, outside diameter (OD), nominal wall thickness, and dimensional tolerances. Because all physicians and surgeons are familiar with the standard needle gauge designations for hypodermic sizes, microcannular size is designated by the corresponding hypodermic needle gauge (Table 27-1).

Table 27-2 lists available microcannulas according to gauge and length specifications.

As with any surgical technique or instrument, the use of microcannulas for liposuction assumes the surgeon has had specific training with regard to the risks, benefits, and indications.

20 Gauge. The 20-gauge Capistrano microcannula is ultrasmall and specifically designed for delicate surgery on the lower face, including the nasolabial cheeks and submental area. It is helpful in removing small, incremental volumes of fat. This extremely fragile instrument will bend easily if it is used roughly or forced through excessively fibrous tissue. Microcannulas such as the 20-gauge Capistrano should never be used near the eyelids.

18 Gauge. The 18-gauge Capistrano microcannula is extrasmall and intended for fine, incremental surgery of the submental area, cheeks, and jowls. When passed through subcutaneous fat of these areas, an 18-gauge microcannula encounters less resistance than microcannulas with larger diameters. An 18-gauge microcannula can be used within the subcutaneous fat of the medial submental area, with or without suction, to define a deep surgical plane immediately above the platysma muscle.

The 20-gauge and 18-gauge microcannulas can be used to create a precise network of fine tunnels through which the larger 16- and 14-gauge microcannulas can subsequently be passed with minimal resistance and improved accuracy.

TABLE 27-1 MANUFACTURER'S SPECIFICATIONS FOR HYPODERMIC NEEDLE GAUGE AND DIMENSIONAL TOLERANCE*

Gauge	Outside Diameter	Outside Diameter Tolerance	Nominal Wall	Wall Tolerance	Approximate Inside Diameter
20	0.0355 (0.9 mm)	0.0005	0.00625	0.0005	0.023 (0.58 mm)
18	0.050 (1.27 mm)	0.0005	0.0085	0.0005	0.033 (0.84 mm)
16	0.065 (1.6 mm)	0.0005	0.009	0.0005	0.047 (1.2 mm)
14	0.083 (2.1 mm)	0.001	0.01	0.001	0.063 (1.6 mm)
12	0.109 (2.75 mm)	0.001	0.012	0.001	0.085 (2.15 mm)
10	0.134 (3.4 mm)	0.001	0.014	0.001	0.106 (2.7 mm)

*Numbers are fractions of an inch.

TABLE 27-2 STANDARD SIZES OF MICROCANNULAS

Gauge	Length: cm (inches)
FINESSE	
16	5 (2), 8 (3)
14	10 (4), 15 (6)
12	10 (4), 15 (6)
10	25 (9)
CAPISTRANO	
20	5 (2)
18	5 (2), 8 (3)
16	5 (2), 8 (3), 12 (4.75), 15 (6)
14	15 (6), 23 (9)
12	15 (6), 23 (9)
BREST (CAPISTRANO DESIGN)	
16 (24 holes)	12 (4.75)
16 (24 holes)	15 (6)
14 (30 holes)	15 (6)
12 (30 holes)	15 (6)

For the most precise control when using 20-, 18-, and 16-gauge microcannulas, many surgeons prefer to attach the microcannula directly to Fine-Touch Aspiration Tubing (modified intravenous tubing) instead of using a microcannula handle and the heavier, standard aspiration tubing. This lightweight tubing allows a delicate three-finger grip of the cannula hub, using the thumb, index, and middle finger to control and maneuver the microcannula.

16 Gauge. The 16-gauge microcannula has an ID of 1.2 mm and OD of 1.6 mm.

A 16-gauge microcannula is useful for liposuction of excessively fibrous fat. Some areas are naturally more fibrous, such as the periumbilical area, back, and breasts; other areas are excessively fibrous because of previous liposuction. In such areas a 16-gauge cannula can penetrate the fibrous septa with minimal force and create multiple fenestrations through the fibrous partitions. After a 16-gauge cannula has prepared an area of fibrous fat, a larger microcannula can be passed through the fenestrations, accomplishing liposuction with minimal resistance, minimal discomfort, and maximal effectiveness.

The 16-gauge microcannula is especially useful for areas that are sensitive or painful during liposuction, such as the medial knees.

These microcannulas allow extremely fine control of the volume of fat that is removed. Thus a 16-gauge cannula is indicated for areas where only minimal fat needs to be removed (e.g., face, neck) or where a small liponot requires minimal liposuction for a smoother result.

14 Gauge. The 14-gauge microcannula (ID 1.6 mm, OD 2.1 mm) is remarkably efficient. It is the most versatile and most frequently used microcannula. The 14-gauge cannula is particularly useful for liposuction of the arms and thighs. These areas often are treated only with 16-gauge and 14-gauge cannulas.

A 14-gauge microcannula fits through a 1.5-mm adit (punch excision) in the skin. Because of the elastic nature of skin, a 1.5-mm punch excision creates a small hole that expands to approximately 2.0 to 2.1 mm in diameter and readily accommodates a 14-gauge microcannula. Thus, in addition to encouraging postoperative drainage, a 1.5-mm adit also provides easy access for both 16-gauge and 14-gauge microcannulas and eventually heals with an imperceptible scar (see later discussion).

As always, to avoid postinflammatory hyperpigmentation, the surgeon must be cautious not to traumatize the cannula access site. Trauma to the dermal-epidermal junction can occur either by allowing the cannula to rub the skin at the site where it passes through the dermis or by allowing the cannula hub to pound the skin repeatedly at the entrance site.

12 Gauge.   The 12-gauge microcannula (ID 2.15 mm, OD 2.75 mm) is used regularly but not necessarily with every case. A 12-gauge microcannula is more efficient than the smaller 16-gauge and 14-gauge cannulas and thus removes fat more rapidly.

Removing fat more rapidly is an advantage as long as the surgeon has the skill and experience to know when and where such an efficient cannula can be used. Inappropriate use of an especially efficient cannula can remove fat too fast and increase the risk of inadvertently creating lipotrops or irregularities within a treated area.

For liposuction of such areas as the abdomen, female hips, and male flanks, the 12-gauge Capistrano microcannula is often employed only after use of a 14-gauge microcannula. For the inner thighs the 12-gauge Finesse microcannula is often the last cannula used, treating the area of maximum depth of medial thigh fat while minimizing the risk of injury to the overlying thin dermis.

10 Gauge.   The largest cannula that I ever use (perhaps once a year) is a 10-gauge Finesse cannula (ID 2.7 mm). Ten-gauge Capistrano microcannulas are not recommended because they can remove fat so rapidly that a large lipotrop can be created without the surgeon's awareness. If a 10-gauge Capistrano cannula is used too superficially, it may cause full-thickness dermal necrosis as a result of obliterating the vascular plexus in the apical fat layer along the skin's undersurface.

16-Gauge and 14-Gauge Brest Microcannulas.   The female breast microcannulas, specialized versions of the Capistrano microcannula, are designed to minimize the risk of trauma to blood vessels and sensory nerves. The distal round holes are more numerous and extend proximally from the cannula tip for a greater distance. The 16-gauge Brest microcannula is used in the initial stages of female breast surgery and typically accounts for 10% to 20% of the supranatant aspirate. The 14-gauge, 15-cm-long Brest microcannula usually accounts for the remainder of the total aspirate.

Tumescent liposuction for female breast reduction is capable of reducing the volume of the breast by as much as 50% without visible scars, without significant mammographic changes postoperatively, and without the prolonged postoperative recovery and delayed return to normal activities typically associated with the traditional excisional breast reduction surgery.

A 1-mm adit is sufficient to accommodate the passage of a 16-gauge or 14-gauge Brest microcannula through the skin of the female breast. Although 12-gauge Brest microcannulas are available, they are not intended for breast liposuction; some surgeons use them for liposuction of the abdomen, hips, and lateral thighs.

Adits

An *adit* is a technical engineering term that describes an extra opening or collateral tunnel by which a mine is entered or drained. An adit used in tumescent liposuction is a small circular hole made by a tiny, skin biopsy punch. Adits facilitate and promote the open drainage of residual blood-tinged anesthetic solution associated with tumescent liposuction.

Round 1.0-mm, 1.5-mm, and 2-mm adits, created by disposable skin biopsy punches, allow better drainage than simple incisions. The edges of a linear slit or microincision made by a scalpel blade may close and heal prematurely, entrapping blood-tinged anesthetic solution in the subcutaneous space.

The round hole of a 1.5-mm adit can easily accommodate a 16-gauge or 14-gauge microcannula with little or no epidermal friction as the microcannula is pushed and pulled through the skin. A 12-gauge microcannula usually requires a 2-mm adit, although a 1.5-mm adit may accommodate a 12-gauge cannula in elastic skin such as the inner thigh.

Small, 2-mm to 3-mm linear incisions can be used for tumescent liposuction of the face and neck, but I prefer to use 1.0-mm adits. Elsewhere, 1.5-mm and 2-mm adits are used almost exclusively for microcannular access into the subcutaneous fat.

Advantages

Microcannulas are necessary for optimal results with tumescent liposuction. They have many advantages over larger cannulas.

Less Pain.   Microcannulas are less painful than larger cannulas. This is an important advantage when doing liposuction totally by local anesthesia.

Better Accuracy.   Microcannulas are more accurate and reduce the risk of liposuction-induced dermal complications. On changing the direction of a cannula, a larger cannula is more likely to follow a path of least resistance and be inadvertently advanced along an existing tunnel. A smaller cannula is more easily advanced through fibrous tissue and thus is less likely to deviate from its intended direction. A microcannula reduces the risk of liposuction along an unintended path.

Greater Finesse.   By removing smaller volumes of fat per stroke, microcannulas provide greater assurance against inadvertently removing too much fat. Proper technique using microcannulas minimizes the risk of skin irregularities after liposuction of areas with less margin for error, such as jowls, cheeks, and nasolabial fat pad; medial and anterior thighs; and buttocks.

Superficial Liposuction.   The superior accuracy in directing the cannula and the more delicate control of fat removal permit more uniform, smoother results. This enables more superficial removal of fat and minimizes risks of irregularities. Superficial liposuction is feasible only with tumescent vasoconstriction and small cannulas.

Excessively superficial liposuction that injures the vascular plexus within the apical fat adjacent to the dermis can cause dermal necrosis.

More Complete Removal. An increased confidence in achieving uniformly smoother results permits more liposuction and removal of larger amounts of fat from any area. Thus more fat can be confidently removed using microcannulas.

The surgeon must always be careful not to remove too much fat. Aesthetic considerations require that the liposuction produce results that look and feel normal; removing all the subcutaneous fat from an area usually does not give natural-appearing results.

Easier Penetration. Microcannulas can penetrate fibrous fatty tissue with minimal force, thus permitting liposuction of areas that are nearly impossible to treat adequately with larger cannulas. Examples of very fibrous areas include the glandular tissue of male or female breasts, the dorsolateral fat just below the bra straps on women, and areas previously treated by liposuction.

Adits and Microincisions. Adits and microincisions permit microcannular access into the subcutaneous fat. An adit is a small, round opening in the skin created by 1.0-mm, 1.5-mm, or 2.0-mm skin biopsy punches. A microincision is an incision so small, usually only 2 to 4 mm long, that it does not require sutures for optimal postoperative healing.

Provided that the cannula does not traumatize the epidermis surrounding an incision, scars from adits and microincisions are rarely perceptible. This permits the use of more incisions, allowing greater accessibility to all subcutaneous fat compartments. Because adits are patulous round holes, unlike linear incisions, they tend to minimize the traumatic friction on the epidermis where the microcannula penetrates the skin. They also promote drainage of fluids after tumescent liposuction.

No Sutures. Adits and microincisions for microcannulas do not require sutures. Although not using sutures to close a surgical wound might seem antithetical to accepted practice, with microincisions the proposition is plausible. Assume that adjacent sutures in a routine surgical closure of a 100-mm incision are usually spaced at least 5 mm apart. Therefore, because the length of a microincision is less than or equal to the distance between adjacent sutures in a larger wound, there is no a priori need to use sutures to close a microincision.

By eliminating the foreign body inflammation and cross-hatch scarring associated with sutures, nonsutured incisions for microcannulas heal better and faster than suture incisions.

Accelerated Healing. Multiple incisions without sutures accelerate drainage, which reduces bruising, swelling, and soreness. Wounds created within fat by microcannulas are narrow tunnels that heal more rapidly than larger tunnels. The greater net surface area of the walls of these "microtun-

nels" promotes more rapid absorption of residual fluid within the subcutaneous space. The net effect is greatly accelerated healing.

Greater Time Efficiency. By eliminating the need for sutures, the use of microcannulas saves the surgical time required to place the sutures. Furthermore, no sutures means no postoperative visit for suture removal.

Nonsutured incisions and appropriate compression optimize drainage of blood-tinged anesthetic solution, which in turn hastens postoperative recovery and return to normal activities. Fewer postoperative problems and less patient anxiety dramatically decrease follow-up visits. The first postoperative visit can be postponed for 4 to 6 weeks.

Microcannulas do not remove as much fat per stroke as do larger cannulas. Thus treating any specific area by liposuction can be completed more rapidly with a large cannula. Larger cannulas are less accurate, however, and more likely to cause skin irregularities that require secondary "touch-up" procedures. Such procedures must be considered when assessing the "total time" required for liposuction. Microcannulas minimize the need for touch-up sessions.

Less Muscle Strength Required. The small cross-sectional area of a microcannula and the flat, semiblunt microcannula tip minimize the resistance encountered when advancing a cannula through the fibrous septa in subcutaneous fat. With the microcannula, no surgeon should be at a disadvantage because of lack of muscle strength.

Similarly, the decreased resistance and decreased force requirement permit more accurate control of the speed and direction of the microcannula tip. This minimizes the risk of an inadvertent penetration of other nontargeted tissues, such as muscle or the peritoneal cavity. To my knowledge, the peritoneal cavity has never been penetrated by a microcannula.

Less Elbow Trauma. The force required to push a cannula through fibrous fatty tissue is minimized by using microcannulas. This is a great advantage in terms of protecting the surgeon's elbow from the chronic stress and trauma of performing thousands of liposuction surgeries.

DISADVANTAGES

Excessive Efficiency. The danger of excessive efficiency is an ever-present concern when using Capistrano microcannulas. The surgeon may not be aware of these cannulas' tendency to remove more fat than is usually removed with other cannulas. Therefore the surgeon may unwittingly remove more fat than intended and produce a disfiguring lipotrop.

Novice liposuction surgeons should use Capistrano microcannulas with great caution. I am aware of two cases in which experienced liposuction surgeons faced litigation be-

cause of inattentive or overaggressive use of Capistrano microcannulas on the medial thighs.

Fragility.   Delicate instruments cannot be used as a pry bar to lift and shift tissue. Using microcannulas requires a straight, in-and-out, pistonlike stroke, similar to the stroke of a billiard cue stick. Microcannulas may bend when used clumsily. Repeated flexion of the thin metal tube will result in metal fatigue and cracking at the point where the tube enters the hub.

Microcannulas are susceptible to being crimped or bent with lateral stress. Flexion can occur when an excessive forceful thrust is stopped by exceptionally dense fibrous tissue.

More Incisions.   Microcannulas require more incisions than was the practice in the past with larger cannulas. Although the incisions are so small that scars are rarely visible, the surgeon must take extra care not to cause prolonged dyschromia by unnecessarily injuring the epidermis.

Dyschromia.   Postoperative dyschromia of the incision site is typically the result of repeated traumatic pounding or friction to the surrounding epidermis. Carefully avoiding injury to the dermal-epidermal junction ensures that scars are virtually invisible. Liposuction with microcannulas should be done with a light touch and finesse.

Postinflammatory hyperpigmentation is a particular risk in individuals who have inherited darkly pigmented skin. The skin of the upper abdomen and the back is especially susceptible to postinflammatory hyperpigmentation or hypopigmentation; the lateral thorax and extremities are less predisposed.

Inspissated Fat in Apertures.   If a small fragment of fat remains in a microcannula aperture and is allowed to dry out, the aperture will become plugged, requiring special cleaning. After using a microcannula or when changing from one microcannula to another, care must be taken to prevent residual fat in the small apertures from becoming desiccated and obstructing the small holes of the cannula tip. When the fat is still moist, the holes can be cleaned out by simply wiping the distal portion of the microcannula with sterile gauze while the vacuum pump is aspirating.

PROPER TECHNIQUE AND FUNCTION

Microcannulas are smaller and more fragile than the rugged, thick-walled steel tubes of large liposuction cannulas. When used correctly, microcannulas are durable, reliable surgical instruments that should last for years. Being more delicate, however, they can be broken more easily if used roughly.

Microcannulas must be advanced with a firm but gentle, pistonlike motion along a linear axis. Repeatedly using

a microcannula aggressively to lift or push the skin and fatty tissue will place repetitive structural stress on the tubing.

FINESSE VERSUS FORCE

A small-diameter stainless-steel tube does not have the strength to endure an excessive force vector applied in a direction that is perpendicular to the tube's long axis. Excessive force may cause the microcannula to bend beyond its limit of flexibility and become permanently damaged. Using a microcannula with inappropriate, aggressive surgical technique will cause the microcannula to fracture at the point of maximum flexion. This point of maximum stress is where the tube enters the cannula hub.

The smaller the diameter, the more flexible is the microcannula. Also, for any given diameter, the longer the microcannula, the greater is its inherent flexibility. Greater flexibility means a microcannula can be more easily bent. Greater care is required to avoid applying excessive force when advancing or pushing more flexible microcannulas through adipose tissue.

Microcannulas must be used with care and finesse. When the surgeon encounters an area of resistance or fibrosis, forceful application of muscle strength is contraindicated. The microcannula should be advanced somewhat tentatively, probing for a path of less resistance. With a gentle technique the cannula can be finessed through fibrous tissue without exerting undue force. Too much force will cause the cannula to buckle and break.

Microcannulas are designed to be effective and efficient. They are not heavy-duty industrial-grade tools, but rather delicate surgical instruments. Microcannulas permit smoother and more accurate results, but they require greater skill and more gentleness than larger, more rugged cannulas.

LOCAL VERSUS SYSTEMIC ANESTHESIA

Microcannulas penetrate the fibrous septa of adipose tissue with minimal resistance. They are less likely to cause painful traction on distant tissues and are most appropriate for liposuction totally by local anesthesia.

Since they require less force to be pushed through adipose tissue, microcannulas permit more surgical finesse and greater surgical precision. They also cause less repetitive trauma to a surgeon's wrist, elbow, and shoulder.

In contrast, large traditional cannulas rely on muscle strength and usually require systemic anesthesia. A large cannula must be rammed through the fibrous tissue partitions of subcutaneous adipose tissue with such force that most awake patients would find it intolerable.

The force required to push a large, blunt cannula through adipose tissue exerts traction on fibrous tissues and transfers the force to distant tissues. Because large cannulas can cause pain beyond the locally traumatized tissue, they are frequently incompatible with local anesthesia.

FAT ANATOMY

Fat is more fragile than most other tissues and is more easily penetrated by a blunt probe. The density and strength of fibrous attachments within fat decrease with decreasing size of the structures in the hierarchy of adipose tissue anatomy (see Chapter 25).

Adipose tissue within a fat pearl generally contains relatively little fibrous tissue and has a jellylike or custard pudding consistency. The tissue within a fat pearl is easily deformed and easily plucked from its weak attachments to the surrounding, denser fibrous stroma. Microcannulas require relatively little force to aspirate the gelatinous mass of fat lobules found inside a fat pearl.

In contrast, large cannulas require considerable force to detach groups of fat pearls from the more fibrous stroma within a fat section. Whereas large liposuction cannulas ingest multiple intact fat pearls and then literally rip large chunks of fat from fibrous attachments, microcannulas remove the fat from within individual fatty pearls.

DESIGN REQUIREMENTS

The desirable qualities in microcannular design include the following:
1. Safety, with minimal risk of injury to nonlipocytic tissues
2. Minimal pain during liposuction in a fully awake and alert patient
3. Optimal efficiency
4. Quality construction that produces durable, easily manufactured cannulas.

The following relationships apply to any cannular design:
1. The smaller the cannula OD, the lower the incidence of pain
2. The smaller the OD, the less the pain caused by pushing the cannula through subcutaneous fat.
3. The smaller the cannula apertures, the less the pain caused by suctioning adipocytes off fibrous septa within adipose tissue

At least two configurations satisfactorily meet these requirements: Finesse and Capistrano. The original microcannular design, now known as the Finesse microcannula, has two distal, in-line oblong openings. For years the Finesse microcannula was the only microcannula designed specifically for tumescent liposuction. Capistrano-style microcannulas, including Brest cannulas, are a more recent design and are more efficient.

Cautious Use. The surgeon must be extra careful when first using the Capistrano microcannula to avoid inadvertent excessive liposuction. The Capistrano microcannula is so efficient than an inattentive surgeon can unintentionally remove more fat than desired.

I recommend that novice surgeons approach tumescent liposuction with caution by first using the Finesse-type microcannula. The Capistrano microcannula is approximately 30% to 50% more efficient than the Finesse microcannula.

THE PHYSICS OF LIPORASPIRATION

This section addresses the following questions:
1. How do liposuction cannulas work?
2. What are the factors that determine the efficiency of a microcannula?
3. Are microcannulas (ID 1.2 to 2.2 mm) qualitatively different from macrocannulas (ID 4 to 8 mm)?

The answers are based on clinical observations rather than published scientific studies.

Hydrodynamics is the branch of physics that studies the forces acting on or exerted by liquids. The mechanical dynamics of a liposuction cannula designed only to suction adipose tissue differ from other systems. The mechanical principles of liposuction cannulas are hydrodynamically distinct from surgical cannulas designed to aspirate liquids such as blood or other body fluids.

A cannula that aspirates blood works on the simple hydrokinetics of pressure gradients. Liposuction involves ripping and tearing of semisolid tissue with the assistance of a pressure gradient. Thus, from the perspective of pure physics, the word liposuction is a misnomer. A lexicologic purist would prefer the term *liporaspiration* (*lipo*, fat; *rasp*, to scrape off or away).

If there is no movement of the cannula relative to the enveloping fat, no fat is removed. In other words, after a cannula is inserted into fat and a vacuum is established within the cannular lumen, no aspiration of fat occurs when the cannula is motionless. If fat were a fluid, an intense vacuum would result in fat being aspirated through a motionless cannula located within subcutaneous adipose tissue. However, adipose tissue consists of fat cells intimately embedded within a fibrous stroma.

Fat is not a fluid, and the physics of liposuction is quite different from the physics of sucking water through a small tubular cannula. Only when the liposuction cannula is in motion, moving to and fro, does fat flow down the tube.

A liposuction cannula works by sucking a discrete morsel of fat into one of its apertures. It then maintains a firm hold on the morsel until it can be ripped away from its attachment by the force of the cannula being pushed and pulled through adipose tissue. Fat enters a cannula through perforations, or apertures, which are located along the cannula's distal 2 to 4 cm.

Because the contents of individual fat pearls are minimally fibrous, the vacuum within a microcannula can pull morsels of puddinglike lobular fat through the cannula apertures. Initially, each fat morsel remains attached by fibrous stroma to the fat outside the cannula lumen. A fat morsel cannot actually be aspirated into the collecting canister until it is sheared off its fibrous attachments by the cannula's pistonlike motion (Figure 27-4).

CANNULA EFFICIENCY

The true efficiency *(e)* of a microcannula design is a theoretic number, defined as the mean volume of fat suctioned per one complete stroke (stroke count, stroke cycle) of the cannula. A
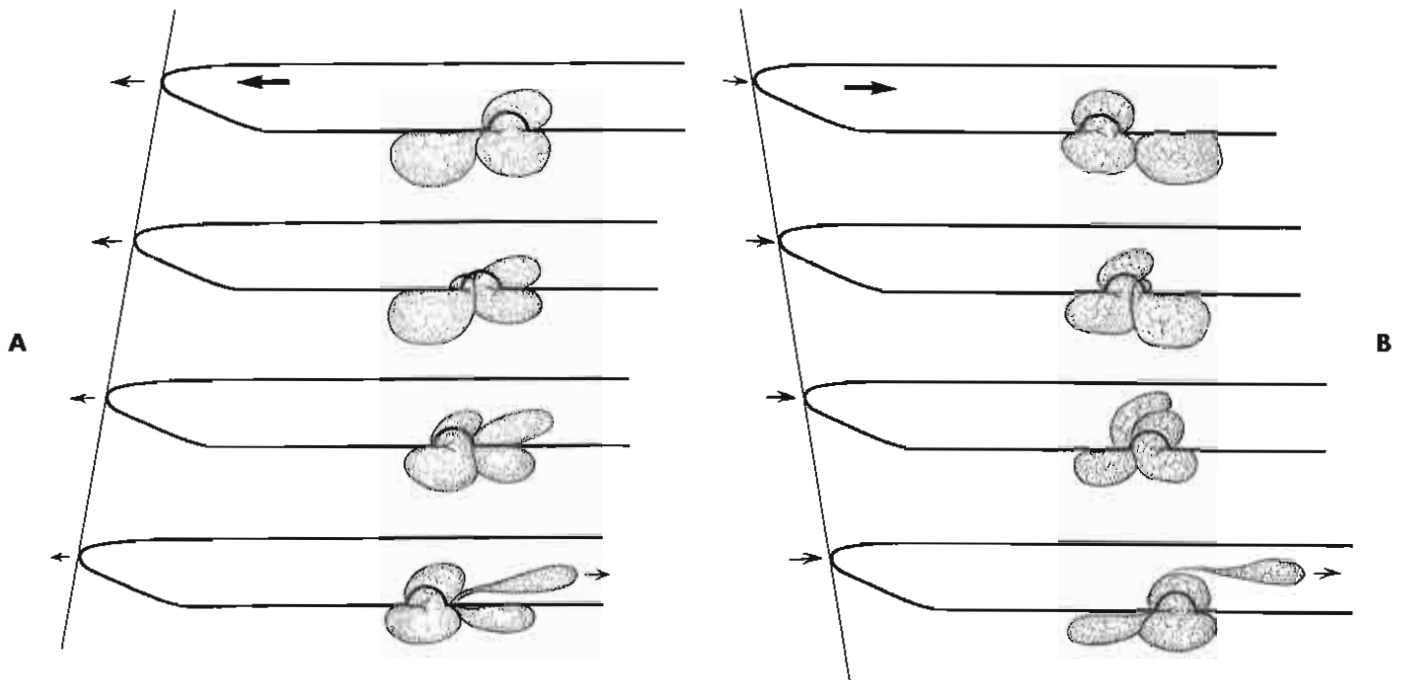
Figure 27-4

Microcannula function is essentially a combination of rasping and aspiration. As small morsels of fat are sucked into mirocannula apertures, pistonlike in-and-out motion of cannula tears delicate strands of connective tissue that hold fat lobules together. Fat removal by liposuction requires both applied suction (vacuum) and longitudinal movement of cannula. Arrows indicate vector direction of cannula motion and detached fat. **A,** Liporaspiration produced by Capistrano microcannula on inward thrust through subcutaneous fat. **B,** Similar liporaspiration effect on retraction of microcannula.

stroke of the cannula consists of the inward thrust and outward pull on a cannula. For any particular cannula, a statistical estimate *(ê)* of the true efficiency of the cannula can be defined as the average

$$\hat{e} = V/n$$

where V is the total volume of supranatant fat aspirated with n strokes of the cannula, and n is an arbitrarily specified number. In actual practice the choice of n depends on several factors, including the gauge of the cannula. Clearly, V increases as n increases.

Testing. From a statistical point of view, n should be large enough to permit the detection of a difference in efficiency between two cannulas when a significant difference truly exists. The number of strokes should be small enough to permit the testing of more than one cannula per area of the body.

Sputum Traps. In practice, if one is using a 60-ml sputum trap to collect and measure the volume of fat per n strokes, n should be chosen to permit all the supranatant fat and in-

franatant anesthetic to be collected in just one 60=ml traps (Figure 27-5).

Two sputum traps are placed in sequence between the collection canister and the microcannula suction tubing. Aspirated fat is trapped in the first sputum trap, where its volume can be measured. The second sputum trap collects any fat that inadvertently "overflows" or splashes out of the first trap. The number n is chosen such that the volume of aspirate will not exceed the volume of the sputum trap for any cannula under consideration.

Volume of Fat. The efficiency of a microcannula is defined as the average volume of fat removed by one complete in-and-out stroke of the microcannula. The volume of fat removed per stroke is a function of the following:

1. Microcannula tip design (size, number, and placement of apertures)
2. Microcannula gauge (ID)
3. Microcannula length
4. Velocity of cannula motion through the fat

When comparing the efficiency of various tip designs, the microcannulas should have the same inside radius and length. They also should be thrust through the fat at approximately the same velocity.

Figure 27-5

Sputum traps for estimating efficiency of microcannula tip designs. (See text.)

Figure 27-6

Relative efficiency of microcannula aperture design. For cannulas of equal radius and length, efficiency of different aperture patterns on cannulas tips can be compared by measuring volume of fat aspirated with each in-and-out stroke.

For example, the efficiency of a 14-gauge cannula 15 cm in length may be estimated as the volume of fat aspirated per 50 in-and-out strokes within fat that has not been previously suctioned. For a 12-gauge cannula, efficiency might be defined as the volume of suctioned fat per 25 strokes (Figure 27-6). The efficiency of a 14-gauge 10-hole Capistrano microcannula, for example, is estimated to be 28 ml/100 strokes, or 0.28 ml/stroke.

Variables. It is important to avoid confounding variables when comparing the efficiency of two or more different cannulas. Each individual trial comparison should use either the same or a contralateral symmetric area of fat to avoid bias caused by different degrees of fibrousness. Similarly, each comparison test should be done by one surgeon. Because this testing procedure cannot be reliably accomplished in a blinded, unbiased fashion, the surgeon can be a source of measurement bias in this estimation process.

For any given cannula, the actual volumes of fat per n strokes will vary as a function of the degree of fibrousness and the surgeon's technique. For any given area of fat, however, the most efficient cannula will tend to harvest the most fat per n strokes.

When two cannulas are compared twice, first using abdominal fat and then using inner thigh fat, both tests should give the same qualitative (nonparametric) or rank-ordered results in terms of which cannula is the most efficient. Similarly, with any surgeon, despite the idiosyncratic nature of surgical technique, the most efficient cannula will aspirate the most fat per number of strokes.

Because of statistical variation, determining which of two cannulas is the most efficient requires repeated testing, then comparison of the mean efficiency measurements using standard statistical techniques.

FACTORS IN MICROCANNULA EFFICIENCY

Along with cannula ID and length, the factors that determine liposuction cannula efficiency include the following (Figure 27-7):
1. Total aperture area
2. Total linear length of distal and proximal edges of apertures
3. Velocity of aperture translocation (speed of the cannula's in-and-out motion)

Aperture Area. The total aperture area is the sum of the cross-sectional areas of all the apertures through which fat is
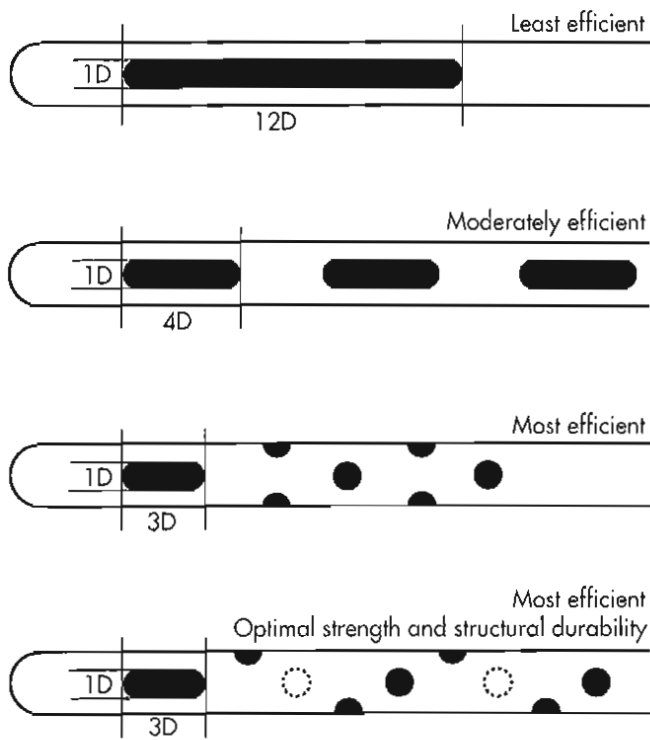
Different microcannula aperture designs. Multiple round apertures are more effective than fewer oval or oblong slots. Aperture's proximal and distal edge is responsible for ripping fat morsels from fibrous stroma. For cannulas with apertures that have equal cross-sectional area, the greater the total length of distal and proximal edges of all apertures, the greater the efficiency of the cannula tip design.

aspirated. If one compares cannulas that have only one round aperture, the efficiency of a cannula is an increasing function of total aperture area. A tiny round aperture will aspirate less fat per stroke than a slightly larger round aperture. The diameter of a round aperture is limited by the cannula's ID.

If the cross-sectional area of an aperture is greater than cross-sectional area of the cannula itself, $\pi[(ID)/2]^2$, the aperture must assume an elongated or oblong shape. If one compares cannulas with a single oblong aperture, the cannula efficiency seems to approach a maximum when the length of the oblong slot is approximately four times its width.

Aperture Edges. The number of distal and proximal edges of the apertures also affects cannula efficiency. The distal (proximal) edge of a round aperture is arbitrarily defined as the portion of the distal (proximal) aperture margin that subtends a 90-degree angle from the center of the aperture. After tiny morsels of fat have been sucked into a microcannula aperture, the distal and proximal edges of the aperture act as foci where the pieces of fat are torn off by the cannula's reciprocating in-and-out motion.

The greater the total length of all proximal and distal aperture edges available to tear off tiny morsels of fat, the greater is the cannula's likely efficiency.

If cannula C_1 has one round hole with an aperture area of A, and if cannula C_2 has two round holes, each with an aperture area of $\frac{1}{2} A$, the cannulas have the same total aperture area. Although each cannula has the same total aperture area, C_2, with two holes, has a greater total aperture circumference and thus a longer total length of proximal and distal aperture edges. Therefore C_2 is more efficient.

Nevertheless, a point of diminishing returns occurs where more and smaller apertures become less efficient.

Aperture Translocation. There is an optimum *velocity* of aperture translocation, that is, the linear or angular velocity of the cannula. As mentioned earlier, if no movement of the apertures occurs relative to the enveloping fat, no fat is aspirated. Again, if a cannula is inserted into fat, and a vacuum is established within the lumen, no fat will be aspirated until the cannula is in motion.

On the other hand, there is probably an upper limit on how rapidly the cannula should be advanced and retracted. The rate of cannular oscillations is limited by concerns about accuracy, the surgeon's endurance, and the patient's safety.

MANUFACTURE AND FABRICATION

Microcannulas are manufactured from standard stainless-steel hypodermic needle tubing that is permanently attached to a stainless-steel hub. At the end of the hub is a helical female Luer connector for attaching the cannula hub to either a cannula handle or a standard Luer syringe.

Press Fitting

The microcannula tube is permanently attached to its hub by a process known as press fitting. This process involves placing one metal part into an excessively small hole in a second metal part.

Press fitting relies on a basic physical property of solid metals. When a metal is chilled, it shrinks; when heated, a metal expands. Thus chilling the cannula tube causes it to shrink. Simultaneously, heating causes the hub to expand in all its dimensions; in particular, the hole in the hub expands. The combined effect of shrinking the tube and expanding the hub allows the relatively large cannula tube to be slipped into the relatively small hole in the hub.

After the cannula has been inserted, the temperatures of the two metal parts equalize. The cannula tube expands while the hole in the hub contracts, causing an exceedingly tight fit.

Special welding techniques can also achieve a strong, durable attachment between a stainless-steel microcannula tube and hub.

HANDLE AND HUB

When a electric-powered vacuum pump is used for liposuction, the microcannula is typically attached to a handle, which in turn is attached to suction tubing leading to the aspirator. This microcannula handle preferably has a thumb-controlled hole or air vent on its side. A vacuum is maintained inside the microcannula while the thumb covers the hole, but the vacuum disappears when the thumb is lifted from the cannula handle (Figure 27-8).

With the thumb lifted and no vacuum in the cannula, the resistance against the cannula is dramatically reduced as it is advanced through subcutaneous fatty tissues. Thus, when the microcannula encounters a seemingly impenetrable fibrous partition within adipose tissue, simply opening the air vent by lifting the thumb is often all that is necessary to advance the cannula. Decreased resistance allows manipulation of the microcannula with more finesse and better control. This fine control is especially helpful for moderating the suction during facial liposuction when advancing through areas where suction is not desired.

The hubs of microcannulas are designed to connect the handles by means of standard connectors. The handle has the advantages just described, but it is not essential for liposuction. The microcannula hubs have an OD that is slightly larger than the ¼-inch ID of the standard, disposable operating room (OR) suction tubing. Thus the microcannula hub can be inserted directly into the OR suction tubing, and liposuction can be accomplished without the microcannula handle.

In certain awkward locations the handle's length may impede the cannula's easy in-and-out motion. Liposuction can be facilitated by attaching the microcannula hub directly to the OR suction tubing.

TUMESCENT PERSPECTIVE

Modern microcannular tumescent liposuction is accomplished totally by local anesthesia, without parenteral sedation or narcotic analgesics, and uses microcannulas, with multiple, small, nonsutured incisions. Drainage of the blood-tinged anesthetic solution is encouraged with the use of postoperative compression garments and absorbent padding.

Since the inception of the tumescent technique in 1985, tumescent liposuction has evolved greatly. In its initial version, tumescent liposuction was accomplished using 4.7-mm ($\frac{3}{16}$-inch)–diameter, lamprey-type liposuction cannulas. The contemporary version of tumescent liposuction uses microcannulas with an ID of 0.6 to 2.2 mm; the incisions are so small that sutures are unnecessary.

Figure 27-8

Microcannula handles are connected to cannulas using standard Luer-lock attachment. Aspiration tubing, connecting handle to liposuction aspirator, can be suction tubing (12 feet in length) with hose-type attachment or special Fine-Touch IV tubing using Luer-lock attachment. Air-vent hole, located in thumb rest of handle, controls vacuum within microcannula. Lifting thumb from air vent prevents or eliminates vacuum.

TABLE 27-3 AUTHOR'S PREFERRED MICROCANNULAS	
Gauge	Length: cm (inches)
BODY LIPOSUCTION *FINESSE*	
14	15 (6)
12	15 (6)
CAPISTRANO	
16	12 (4.75), 15 (6)
14	15 (6), 23 (9)
12	15 (6), 23 (9)
FACIAL LIPOSUCTION *CAPISTRANO*	
20	5 (2)
18	8 (3)
FINESSE	
16	8 (3)
14	10 (4)
FEMALE BREAST LIPOSUCTION *BREST*	
16	12 (4.75)
14	15 (6)

Microcannulas permit liposuction in the most fibrous tissue, with better results and fewer complications than with either ultrasonic liposuction or the larger macrocannulas with 10-mm, 8-mm, and 6-mm diameters.

The average liposuction case does not require every available microcannula. Liposuction of the most frequently treated areas of the body requires a limited number of cannulas. Likewise, liposuction of the face and neck requires only a few select microcannulas (Table 27-3).

Box 27-1 lists steps in the proper cleaning and maintenance of microcannulas.

BOX 27-1 CARE OF MICROCANNULAS

1. *Soak in germicide-detergent.* Immediately after surgery, cannulas, handles, and other instruments are placed in a bactericidal, fungicidal, and virucidal detergent solution (e.g., Control 3*). This is done to prevent desiccation of blood, body fluids, and tissue on the instruments; to minimize presence of pathogens on the instruments; and to reduce risk of exposing staff members to pathogens during initial phases of cleaning.

2. *Rinse in tap water.* All instruments are rinsed thoroughly with warm tap water immediately after removal from germicidal soak.

3. *Flush microcannulas.* A solution of Kleenzyme (1 oz = 30 ml of Kleenzyme in 4 L of tap water) is freshly prepared in a plastic tub or bucket.† With cannula apertures submerged in solution, repeatedly flush this solution through cannula to remove any loose tissue debris, using a 30-ml syringe attached to cannula's Luer connector.

4. *Scour with cleaning brush.* With cannula tip submerged in Kleenzyme solution, push a special nylon brush on twisted stainless-steel wire back and forth through cannulas to dislodge any adherent tissue debris. For each cannula, use brush with largest diameter that will fit inside. Carefully examine cannula holes for adherent tissue.†

5. *Flush microcannulas again.* Repeat step 3, flushing microcannulas with Kleenzyme.

6. *Apply instrument polish.* Scrub instruments with a toothbrush after applying polish, then rinse them under tap water.

7. *Use ultrasonic cleaner.* First, soak instruments in a fresh solution of Kleenzyme and cleaner for ultrasonic instruments for 10 minutes. Next, submerge instruments (e.g., microcannulas, handles) in the ultrasonic cleaner solution and sonicate for 10 to 15 minutes. Then rinse instruments under tap water.

8. *Soak instruments in distilled water.* Soak for at least 1 minute to remove minerals, prevent oxidation or discoloration, and moisten lumen of cannulas. Moistened lumen ensures optimum sterilization on autoclaving.

9. *Wrap and sterilize.* All instruments can then be immediately packaged, pouched, and autoclaved.

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*Maril Products, Tustin, Calif.
†Kleenzyme (enzymatic cleaner) and Hinge-Free (instrument lubricant and rust inhibitor), Merck.
‡Surgical cleaning brushes for 18-, 16-, 14-, and 12-gauge microcannulas.
§Sklar instrument polish, Sklar, Westchester, Pa.

Surgical Technique: Microcannular Tumescent Liposuction

No "orthodox" technique exists for performing tumescent liposuction surgery. Individual surgeons have personal methods of performing their own techniques. In liposuction surgery, personal preferences and variations in a technique may reflect artistic style as much as technical change. In developing an approach to liposuction, a surgeon first observes the methods and strategies of other surgeons, then mimics the helpful aspects and rejects others.

This process of "customizing" a technique to fit the surgeon's personal preferences is a natural part of the evolution and improvement of surgery. Over the years I have made many changes in my own technique, and other surgeons have added their own personal preferences to what is now widely known as tumescent liposuction.

Three criteria can be used to judge any surgeon's tumescent technique: safety, aesthetic results, and ethics. All patients should be able to judge surgeons' aesthetic results. Evaluating safety and ethics can be more elusive. If one surgeon's technique appears to offer greater patient safety than that of another surgeon, the second surgeon's technique must be scrutinized and criticized. If a surgeon intentionally uses "tumescent technique" merely to attract prospective patients but actually performs a relatively antiquated and dangerous procedure, such verbal deception is unethical and deserves criticism.

My preferences and biases regarding the relative safety of various techniques for anesthesia in liposuction are discussed in other chapters. This chapter outlines my step-by-step surgical technique for doing the actual *liposuction*, that is, aspirating adipocytes. I hope surgeons consider the relative merits of this technique and adapt those aspects that seem most helpful.

Microcannulas can be used with either systemic or local anesthesia. Microcannular liposuction has many advantages, especially the remarkably smooth results and fewer secondary touch-up procedures that are required to improve irregularities. The technique of microcannular tumescent liposuction described next has many subtle aspects that are specifically designed to facilitate liposuction totally by local anesthesia. For example, surgeons who do not infiltrate slowly and carefully or who do not use microcannulas will find it impossible to do liposuction totally by local anesthesia.

For optimal cosmetic results of liposuction, *smoothness* is more important than the volume of fat removed. The most common cause of patient dissatisfaction after liposuction is skin irregularities that suggest an unnatural deformity. Successful liposuction requires continuous efforts to maintain a smooth surface in every treated area. A surgeon who is careless, inattentive to details, overconfident, or too aggressive will have many dissatisfied patients. This chapter focuses on techniques that optimize smoothness, symmetry, artistic proportion, efficiency, patient comfort, and patient satisfaction.

In addition to the actual technique for using the cannulas, important aspects of surgical technique include patient selection, patient monitoring, choice of cannulas, vacuum source, preoperative patient markings, and intraoperative positioning. Since it is closely associated with the determination of surgical technique, patient selection is extensively reviewed later in this chapter.

PREOPERATIVE CONSIDERATIONS

TOPOGRAPHIC MARKINGS

On the day of surgery, surface contour lines are drawn on the skin overlying the targeted fat using a felt-tipped pen. These contour lines are the surgeon's shorthand notation for desig-
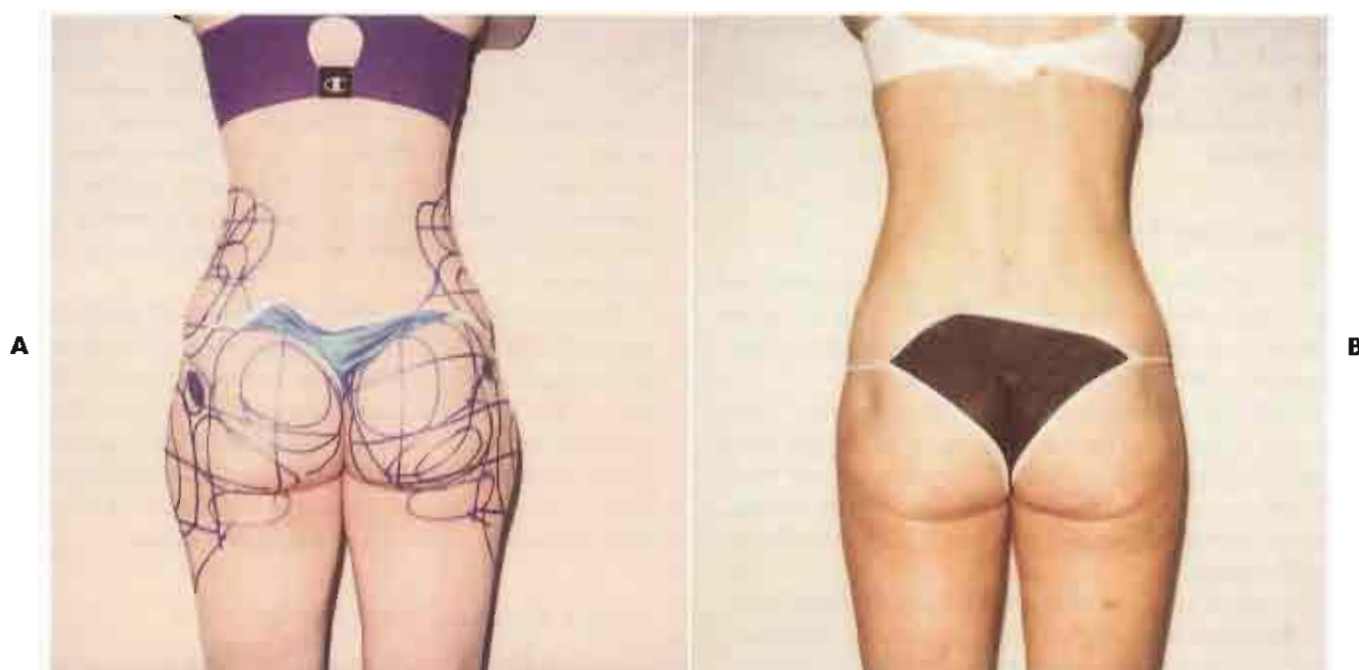
Figure 28-1

A, Preoperative view of contour lines drawn before liposuction of hips, outer thighs, and buttocks. Small bilateral areas of solid color emphasize location and size of common concavities on lateral buttocks between hips and lateral thighs. Surgeon must avoid liposuction in such areas. **B,** Postoperative view reveals persistent bilateral concavities. Without proper preoperative documentation, patient might erroneously assume "defects" were result of liposuction.

nating surgical targets. They are the artistic blueprints for modifying human surface anatomy. The contour lines communicate the planned modifications to the patient, nurses, and other surgeons. Carefully drawn contour lines improve the likelihood of achieving the desired results.

The contour lines typically resemble a topographic map showing the relative altitude of the terrain. The topographic lines appear as a nested or concentric ellipsoids, with the central rings indicating the deepest areas of fat. Individual ellipsoids may be drawn to indicate subtle or isolated bulges within a larger area.

Any preexisting focal depressions or dimples should be marked by drawing an outline of the affected area, then filling the geometric shape with a solid color. Documentary preoperative photographs of the markings are recommended (Figure 28-1).

The preoperative markings on the skin are preferably drawn with the patient standing erect in the anatomic position. The markings are an important means of keeping track of the relative depth of a targeted fat compartment despite subsequent distortions caused by body positioning or tumescent infiltration. The surgeon can compensate for such deformations by paying careful attention to accurate topographic markings.

Such a deformation in shape and depth of a fatty compartment is a *topologic isomorphism*, a reversible one-to-one

mapping from one geometric domain to another. By visualizing the deformation induced by any deviation from the anatomic position, the surgeon can compensate to some degree. Thus, when the patient resumes the standing anatomic position after liposuction, the results will be proportionate and aesthetically pleasing.

After the topographic contour lines are drawn, the patient should examine the drawings and verbally approve the areas to be liposuctioned. Precise preoperative drawings on the patient with good photographic documentation are in the best interests of both the patient and the surgeon.

INFORMED CONSENT

The liposuction surgeon should have a specialized informed-consent form specifically written for liposuction.

After the patient has been given preoperative sedation, the surgeon cannot obtain "reasonable informed consent" for a last-minute addition to the list of areas to be treated. "Doing a little extra liposuction at no charge" is a common pitfall for the well-intentioned but naive liposuction surgeon.

It is inappropriate to liposuction an area without the patient's explicit signed consent clearly documented in the patient's chart. It is only reasonable to extend liposuction into an area not requested by the patient (1) if the area is immediately adjacent to an area where the patient has requested li-

posuction or (2) if doing so is necessary to achieve the cosmetic result desired by the patient.

The surgeon might be accused of battery if liposuction is done in an area that is relatively distant from areas requested by the patient.

LIPOTROPS AND LIPONOTS

An iatrogenic depression of the skin caused by localized excessive liposuction is designated a *lipotrop*. Without careful attention, a lipotrop can occur very quickly, before the surgeon realizes what is happening (see Chapter 8).

A *liponot* is a focal area of insufficient liposuction. Liponots may be caused by focal areas of increased adipose tissue density, such as in the periumbilical region, or may result from uneven removal of fat. Although less common and easier to correct than a lipotrop, a liponot causes considerable patient discontent.

The use of microcannulas and attention to details minimize the risk of lipotrops and liponots. Superior liposuction results require removal of enough fat to achieve significant cosmetic improvement while cautiously avoiding excessive extraction. Careful patient positioning improves the surgeon's confidence in this regard.

SEQUENCE OF AREAS

When planning to do iterative or sequential liposuction over a period of months, the surgeon must not treat an area that will leave the patient looking temporarily distorted. The patient will be unhappy and the surgeon chagrined if the patient decides not to proceed with liposuction of the remaining areas.

GOALS VERSUS PREDICTIONS

The goal of liposuction is to provide an aesthetic improvement in the shape of a patient's body. When the patient looks in the mirror and sees an obvious and pleasing improvement in size and shape, the liposuction should be judged a success.

The surgeon must avoid quantitative predictions about the results of liposuction and should avoid making an estimate of the volume of fat to be aspirated during liposuction. One should not predict how a patient's clothing size will change after liposuction. Little if any reason exists to measure the circumference of a patient's thigh or torso before or after liposuction.

A quantitative prediction is not in the best interest of the patient or the surgeon for the following reasons:
1. If the goal is to remove a specific volume of fat, the surgeon may perform liposuction in excess of the amount required for optimal cosmetic results.
2. Despite excellent cosmetic results, some patients will be disappointed and feel cheated if a quantitative prediction is not realized.

SKILLFUL NURSING

Successful tumescent liposuction is nursing intensive. Liposuction totally by local anesthesia is impossible without excellent nursing. Nurses are responsible for ensuring that the awake patient is comfortable at all times. Nurses often perform tumescent infiltration, thus allowing the surgeon to be more time efficient. Nurses are typically not as "rushed" as a surgeon and therefore are often more patient and precise with infiltration.

Nurses are responsible for taking a thorough history immediately before surgery to verify that the clinical situation has not significantly changed. The nurse who provides effective preoperative education and aftercare instructions will prevent many postoperative problems. With the low incidence of postoperative problems as a result of using open drainage and bimodal compression, nurses may be responsible for most of the postoperative follow-up, primarily by telephone.

PATIENT COMFORT AND MODESTY

Any surgical procedure by local anesthesia is more easily accomplished when the patient is calm and relaxed. If a patient is subjected to unnecessary discomfort, anxiety, fear, and embarrassment, liposuction is more difficult for all concerned. A patient's attitude is more likely to be relaxed and tranquil if the surgical staff is sensitive to the patient's physical and psychologic comfort.

Efforts to maintain the patient's physical comfort and warmth might include covering the patient with drapes or even warm towels that have been kept in a blanket warmer. A water bath can be used to warm the bottles of surgical soap used to scrub the patient and the bottle of sterile saline used to rinse after the scrub. The tumescent local anesthetic solution that will be infiltrated into the subcutaneous fat should be warmer than room temperature and never chilled.

The surgical staff must be aware of patient's feelings of vulnerability and concerns about being undressed and naked. Some patients may feel embarrassed and humiliated by being undressed in an operating room. The surgical team should be protective of the patient's modesty. A female patient should be provided with bra, panties, and gown, when consistent with good surgical technique. Similarly, male patients should be provided with appropriate cover.

STERILE ABSORBENT GAUZE SPONGES

The surgeon should have an ample supply of sterile absorbent gauze sponges always readily available and within easy reach. A large number of sponges are used during tumescent liposuction (Figure 28-2).

Gauze sponges are used to absorb any excessive flow of tumescent anesthetic solution draining from the many adit sites. Gauze sponges frequently are used to wipe the wet skin surface and thereby facilitate a secure, nonslippery grip by the sensory hand during liposuction.

Figure 28-2

Hip and lateral thigh prepared for liposuction, after washing with surgical soap and placement of sterile drape. Preoperative topologic contour markings, including area of solid color that designates focal depression, have been partially washed off. Absorptive cotton gauze sponges are placed on drape and readily available for use during tumescent liposuction.

When fibrous adipose tissue adheres to a microcannula, the cannula can be wiped clean with unsoiled sterile gauze. To minimize the risk of infection, the surgeon should not allow the cannula shaft to contact anything other than clean sterile gauze, subcutaneous fat, or adit sites. The surgeon should avoid touching the microcannula shaft with a surgical glove if the glove has already touched the patient's skin.

INTRAOPERATIVE POSITIONING

In the anatomic position a person stands erect, with the upper and lower extremities slightly abducted. The anatomic position is traditionally used as a frame of reference when describing the relative location of any point on or in the body. The anatomic position is also the most common position for critically evaluating a human figure, especially before and after liposuction.

Distortions of the body during surgery that deviate significantly from the anatomic position can lead to inaccurate intraoperative assessments of results and unintentional aesthetic defects. The optimal intraoperative position minimizes risks of unintentional iatrogenic aesthetic defects. Although large volumes of subcutaneous tumescent anesthetic solution magnify the targeted fat compartment, they should not disproportionately distort the fat compartment.

When the body's position deviates from the anatomic position, the body's fat compartments are stretched, compressed, or twisted to some degree. The risk of inaccurate liposuction is increased when the patient's intraoperative position distorts the targeted fat compartment. Positioning pillows can be used to place liposuction patients in a position that approximates the anatomic position, thus minimizing the risk of liposuction causing skin irregularities. For exam-

ple, the optimal position for liposuction of the thighs is a modified lateral decubitus that approximates the anatomic position (see Chapter 32).

Lipowarp. A lipowarp is a distortion of the subcutaneous fat that is caused by the body assuming a position different from the anatomic position. Lipowarps can be caused by a flexion, extension, or rotation of a body part. For example, when the hip is flexed, the fat compartment of the lateral thigh is distorted; the posterolateral aspect is stretched and the anterolateral aspect compressed. A lipowarp of the lateral thigh can also be caused by the effects of gravity when the patient is lying supine; the lateral thigh is compressed in the anteroposterior direction and bulges in the lateral direction (see Chapters 32 and 34).

Pseudobulge. A pseudobulge is a special case of a lipowarp in which a distortion of subcutaneous fat is caused by the localized protrusion of a skeletal part. The most important example is the *trochanteric pseudobulge* of the lateral thigh. Deviating from the anatomic position by flexing and adducting the hip joint causes the protuberance of the greater trochanter to distend the overlying fat and skin. Failing to compensate for a pseudobulge during liposuction results in excessive localized fat extraction and creation of a lipotrop.

Anesthetic Technique. The method of anesthesia can affect the cosmetic results of liposuction. With liposuction totally by local anesthesia, patients are alert and cooperative in conforming to optimal intraoperative positions (see Chapter 26). Under either intravenous (IV) or inhalation anesthesia, patients are unconscious and cannot cooperate in assuming an optimal position. With endotracheal intubation, considerations of airway management and safety often preclude certain intraoperative positions. Compromises in patient positioning increase the risks of lipotrops and liponots. Attempting to do lateral thigh liposuction with the patient only in the supine position may lead to insufficient and disappointing results (see Chapter 32).

DETUMESCENCE BEFORE LIPOSUCTION

After completing tumescent infiltration of an area, it is best to wait at least 20 to 30 minutes before commencing liposuction of an area (see Chapter 26). Fully tumescent subcutaneous tissue is difficult to grasp. With decreased tumescence the surgeon can more easily grasp the targeted fat, and liposuction becomes easier to accomplish.

Surgeons who rely on systemic anesthesia for tumescent liposuction tend to infiltrate less than the optimum volume of tumescent anesthetic solution, which then allows liposuction to be initiated as soon as the infiltration is completed.

ADITS

A liposuction adit is a 1.0-, 1.5-, or 2.0-mm skin biopsy punch excision. Adits provide access for liposuction cannulas into the

subcutaneous fat and facilitate postoperative drainage of residual blood-tinged anesthetic solution. The optimal choice of location, size, and number of adits or incisions requires an artful skill and experience. The choice must depend on the surgeon's technique, expertise, and artistry (see Chapter 27).

Size. The size of an adit or incision must be sufficiently large to permit easy, almost frictionless passage of the cannula.

Number. The number of tiny adits required for microcannular tumescent liposuction is not fixed or constant. Tumescent liposuction with microcannulas requires more adits or incisions than are typically made when larger cannulas are used. The number of adits should not be excessive. Whereas two to four incisions might be used for traditional liposuction of the lateral thigh using large cannulas (3 to 6 mm), six or eight 1.5-mm adits might be created for microcannular liposuction of the thigh using 14-gauge microcannulas. A large thigh typically requires a few more 1.5-mm adits than a small thigh and perhaps one or more 2-mm adits to accommodate a 12-gauge microcannula.

In general, the number of adits for a particular area is determined by the need to minimize the potential scars and maximize the smoothness and completeness of results. The number of required adits or incisions is often increased when the subcutaneous fatty tissue is excessively fibrous.

Location. When determining the sites for placing adits, the surgeon gives priority to sites that permit optimal access to fat and sites that facilitate and encourage postoperative drainage. The surgeon also must consider that some skin areas are at increased risk of postinflammatory hyperpigmentation (see later discussion).

Placement and number of adits should be equally influenced by (1) the goal of optimizing the smoothness and precision of the liposuction and (2) the need to minimize visibility of scars.

Advantages. Adits are not closed with sutures. Eliminating the use of sutures facilitates postliposuction drainage. This in turn reduces postoperative tenderness, swelling, and edema. With no need to remove sutures, patients usually need not return until 6 weeks for postoperative photographs.

MICROCANNULAS

Surgeons who use large cannulas usually find that tumescent local anesthesia alone is insufficient for most liposuction patients and that the tumescent technique is better tolerated when used in conjunction with either systemic or epidural anesthesia.[1] These surgeons are unaware that consistently painless tumescent liposuction totally by local anesthesia requires the use of microcannulas (see Chapter 27).

Techniques. Microcannulas are made with relatively lightweight hypodermic needle stock and must be used with a cer-

tain degree of finesse. They cannot be used as aggressively as one might use larger cannulas. If a microcannula is used too roughly, it will bend and possibly break. If a large vector of force is exerted perpendicular to the long axis of the cannula, the microcannula may bend.

Microcannulas require a delicate touch and a straight in-and-out, pistonlike motion. The surgeon will find that achieving straight-in, straight-out strokes requires considerable concentration to coordinate the simultaneous motion of the shoulder, elbow, and wrist. With a little practice, achieving this motion becomes second nature.

Advantages. Microcannulas remove more fat per stroke than might be expected and save the surgeon a significant amount of time.

Microcannulas produce smoother results and thus decrease the number of secondary touch-up procedures. Microcannulas also facilitate postoperative care and largely eliminate the need for time-consuming follow-up visits. Fat removal is often more thorough than with larger cannulas.

Types. The choice of cannula is a matter of clinical judgment. No precise formulas tell the surgeon which microcannulas to use at each step of a procedure. The Capistrano microcannula offers maximum efficiency (amount of fat removed per in-and-out stroke cycle of the cannula). The Finesse microcannula allows greater liposuction precision; fat is removed with less risk of excessive fat removal and injury to the dermis. Other microcannula designs are also available for tumescent liposuction.

Sizes. The choice of a cannula should be determined by the smoothness of the liposuction results that it produces. The 12-, 14-, and 16-gauge microcannulas are used for body liposuction. The 14-, 16-, and 18-gauge microcannulas are used for liposuction of the chin, necks, and jowls. The 20-gauge microcannula is specifically intended for precision liposuction of the cheeks.

Handles. Microcannula handles permit the surgeon to change the microcannula easily and rapidly whenever necessary during surgery. A variety of larger aspirating tubes can be attached, as well as IV extension tubing for delicate, small-volume liposuction (Figure 28-3).

By removing the thumb from the hole and opening the air vent in the handle, the vacuum tubing can be cleared of fat without removing the cannula from an incision. Also, by opening the air vent as the cannula tip is retracted toward the incision site, the surgeon can avoid excessive liposuction and minimize the risk of creating a spoke wheel deformity (see later discussion).

FIVE REQUIREMENTS

Successful tumescent liposuction totally by local anesthesia requires a modification of the standard liposuction techniques used with systemic anesthesia. Five absolute require-

Figure 28-3

Close-up and full views of microcannula handle attached to 14-gauge microcannula. Handle attaches to microcannula hub by means of standard Luer-lock connector, which facilitates rapid exchange of microcannulas during surgery. Microcannula handle has air vent within thumb-rest depression; removing thumb from air vent immediately eliminates vacuum inside microcannula. Minuscule 20-gauge microcannula, attached directly to Fine-Touch Aspiration Tubing, is used for delicate liposuction of chin, cheeks, and jowls.

ments for consistently comfortable liposuction by local anesthesia are as follows:

1. Use of microcannulas
2. Highly sophisticated infiltration technique
3. Tumescent anesthetic solutions that vary in concentration according to the area being suctioned
4. Gentle surgical technique
5. Empathetic nursing staff

If any of these five ingredients is missing, liposuction totally by local anesthesia will be difficult, if not impossible, to achieve.

OPERATIVE CONSIDERATIONS

The hands-on surgical technique for microcannular tumescent liposuction is different from traditional liposuction with larger cannulas.

SYNERGISTIC HANDS

The process of liposuction requires that the surgeon's two hands work in concert. One hand is designated the sensory hand (grips the fat) and the other the motor hand (grips the microcannula handle; Figure 28-4).

Sensory Hand. The sensory hand has several functions. By carefully gripping the fatty tissue, it senses the location and relative depth of the cannula tip during the process of liposuction. By maintaining the cannula tip between the thumb and fingers of the sensory hand, the surgeon can ensure that the cannula will not penetrate any tissue that is deep to the adipose tissue (Figure 28-5).

Figure 28-4

Sensory (left) hand grips, immobilizes, elevates, and presents targeted fat to microcannula. Tactile sensitivity of sensory hand is maximized by using volar aspects of thumb and flat volar surface of remaining four fingers to grip targeted fat. This allows surgeon to be constantly aware of location of microcannula tip. Sterile cotton gauze sponges can help surgeon grip slippery skin. Motor (right) hand controls motion of microcannula. When changing direction of microcannula, fulcrum of rotation should coincide precisely with adit.

The sensory hand also gently squeezes and palpates the treated area to follow the progress of the liposuction and to determine when sufficient liposuction has been accomplished. It facilitates the safe and gentle liposuction of the fat located along the deepest plane of the fat compartment. While simultaneously gripping and lifting, the sensory hand can stretch the deeper strata, elevating fat away from the subjacent muscle. By vertically stretching the fat in a direction

Figure 28-5

Conceptual depiction of fat, represented by layers of gauze sponges, illustrates two techniques for immobilizing subcutaneous fat. Using sensory hand to reduce mobility of subcutaneous fat increases amount of fat that can be aspirated per in-and-out stroke of liposuction cannula. **A,** Compressing subcutaneous fat with palm of hand pushes cannula closer to muscle fascia. With this technique, surgeon has difficulty precisely localizing depth of cannula tip within fat. **B,** Squeezing and lifting subcutaneous fat between thumb and flat surface of fingers displaces fat away from muscle fascia. This technique allows liposuction within deepest plane of fat while increasing distance between cannula and muscle. Thus liposuction of deepest fat can be done with minimal risk of inadvertent injury to muscle. In addition, surgeon always knows precise location of cannula tip.

perpendicular to the muscle fascia, fat normally adjacent to the muscle fascia can be suctioned more safely while being elevated away from muscle.

The sensory hand helps maximize the efficiency of liposuction by immobilizing the targeted fat. When a vacuum is applied to a stationary liposuction cannula, fat aspiration does not occur. Similarly, when liposuction is attempted without the sensory hand gripping and immobilizing the fat, relatively little fat is aspirated. Maximally efficient liposuction occurs only when the sensory hand grips the targeted fat and prevents it from oscillating to and fro in unison with the cannula.

Motor Hand.   The motor hand grips the cannula handle and provides the force that moves the microcannula through the targeted subcutaneous fat. The motion is most efficient when the microcannula moves in and out along a straight line.

The motor hand also has some sensory function. The motor hand can detect the rasping sensation that is transmitted from the microcannula tip as fat is detached from the surrounding fat. The motor hand can sense the degree of fibrous resistance to a cannula's progress through fat.

The thumb of the motor hand controls the vacuum applied to the microcannula by either occluding or opening the vent hole located in the thumb depression. Occluding the vent with the thumb permits full suction within the cannula. When the thumb is lifted from the hole, air is vented into the side port, and no suction occurs in the cannula.
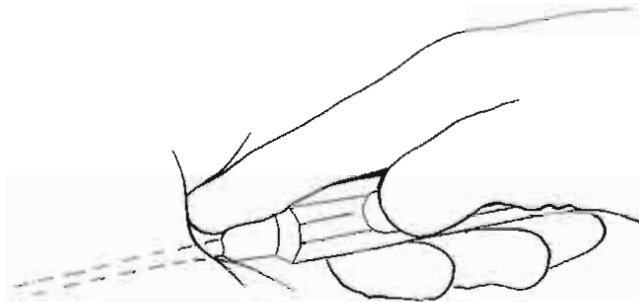
Figure 28-6

Tip of index finger on motor hand extends beyond microcannula hub and acts as cushion to prevent hub from repeatedly traumatizing skin. Each time cannula hub is allowed to bump skin surrounding adit, hub will injure dermal-epidermal junction and produce postinflammatory hyperpigmentation.

Index Finger.   The index finger of the motor hand can be used to cushion the impact of the microcannula hub against the skin. The index finger of the hand gripping the microcannula handle can be extended so that the fingertip just covers the distal portion of the hub, where the cannula tube inserts into the hub. Acting as a cushion, the index finger reduces the risk of mechanical trauma from the hub repeatedly bumping against the adit or incision site (Figure 28-6).

PITCH AND YAW

To minimize trauma to the surrounding skin as the microcannula is pushed and pulled through the subcutaneous fat, the surgeon must move the cannula along a straight-line path through the adit or incision. This minimizes both the friction and the posttraumatic hyperpigmentation.

Coordinating the simultaneous movement of the shoulder, elbow, and wrist to achieve a straight in-and-out motion of the microcannula through an adit requires effort and practice. Inattentive or unsteady guidance will allow the direction of the cannula to deviate temporarily from a straight course, turning either to one side or from side to side as it is advanced. Without experience using microcannulas, the surgeon tends to advance the cannula with slight pitch and yaw.

A cannula is moving with a slight *pitch* if the tip of the cannula does not move along a line that is congruent with its long axis. The cannula is said to *yaw* as it moves through the adit if the cannula rotates about an axis that is perpendicular to its long axis. Both motions cause unnecessary friction to the skin surrounding the adit.

CHANGING DIRECTIONS

Regardless of the technique used to change cannula direction, the surgeon must avoid applying excessive pressure or friction to the skin at the adit or incision site.

When the microcannula direction is altered while it is in the subcutaneous fat, it is turned or rotated about an axis that is perpendicular to its long axis. The point where this axis of rotation and the long axis of the cannula intersect is referred to as the *fulcrum of rotation*. Ideally, the fulcrum of cannula rotation should coincide with the adit, thereby minimizing the trauma and friction applied to the skin surrounding the adit.

In reality, when an experienced surgeon redirects a microcannula, the maneuver involves a coordinated effort of the surgeon's hands. As the sensory hand grips and displaces the targeted fatty tissue, the motor hand directs and propels the cannula in and out of the adit. The pattern of action and motion of the surgeon's hands is typically some combination of at least three different movements, as follows:

1. The cannula is almost completely withdrawn from the subcutaneous tissue, and the cannula is rotated about a fulcrum near the cannula tip. To avoid excessive liposuction at or near the adit, the thumb of the motor hand can be lifted from the side port on the cannula handle, thereby terminating the vacuum within the cannula.
2. While the sensory hand grips, pushes, pulls, and moves the fat laterally or vertically, the motor hand simply continues to reciprocate with a pistonlike motion. The cannula continues to move in and out without changing direction, while the targeted fat is moved from side to side and up or down. The surgeon is careful not to allow the cannula to rub the skin surrounding the adit.
3. Small incremental rotations and slight changes in cannula direction are accomplished with each stroke (thrust and retraction) of the cannula. This maneuver requires a coordinated effort of both hands to change the cannula direction with minimal trauma to the adit and minimal lateral pressure on the cannula shaft.

Excessive lateral forces to the long, flexible tube of the microcannula may bend the cannula. Too much lateral pressure repeatedly applied to the microcannula causes repetitive flexion, metal fatigue, and possible fracture where the cannula inserts into the hub.

FANLIKE PATTERN

Microcannular liposuction, using multiple adits or incisions, is accomplished using a fanlike pattern for directing cannulas. The cannula is repeatedly moved from one incision to another, doing five to 20 strokes in a fanlike pattern of tunnels radiating out from each incision site. The pattern of tunnels that radiate from adjacent incisions are intended to interdigitate, overlap, and intersect. Only a limited volume of fat is removed by liposuction through any one incision before moving to another incision. Using multiple incision sites, adjacent patterns fan out radially and overlap in a shingled configuration and interdigitate on all levels throughout the fat.

The essential goal is to remove fat decrementally in a step-by-step process that removes approximately 10% to 20% of the fat uniformly across the entire targeted fat compartment. This process is repeated several times until the desired amount of liposuction is accomplished. The technique of switching incision sites ensures that fat is removed in relatively small decrements over a large area, yielding smooth results. This repeated shifting from one incision to another makes a liposuction pump somewhat more efficient than a hand-held syringe technique.

MICROCANNULAR TECHNIQUE

Initial Liposuction.   When initiating liposuction, small-gauge microcannulas are preferred over larger microcannulas. Small-diameter cannulas cause less pain than large-diameter cannulas. After first using small-diameter cannulas, large-diameter cannulas subsequently cause much less discomfort when they follow the path made by a small-gauge cannula. The smaller microcannulas are also useful to "check" that all areas are adequately anesthetized.

The surgeon must minimize the degree of lateral force placed on a microcannula shaft. A microcannula cannot be used to lift or move adipose tissue. The force applied to a microcannula is directed along a vector congruent with its long axis.

The longer the cannula, the greater is its relative flexibility. A long, flexible microcannula is more difficult to direct with accuracy as it progresses through the fat. Thus a 16-gauge microcannula that is 12 cm long is often easier to use than one 15 cm (6 inches) long.

The smallest microcannulas can more easily penetrate and perforate fibrous adipose tissue. Thus smaller microcannulas are also useful for initial stages of liposuction of the deep peri-

umbilical fat, the fibrous tissue extending transversely across the midabdomen just superior to the umbilicus, the male breast, the epigastric abdomen near costal margin, the waist, and the back. After first using the smaller microcannulas to tunnel through fibrous fatty tissue, the surgeon can then use a larger microcannula to remove fat more efficiently.

Progressively Larger Microcannulas. Sixteen-gauge microcannulas are ideal for initiating liposuction in a new area. Microcannulas with smaller cross sections encounter resistance as they are advanced through adipose tissue. By using 16-gauge microcannulas, the surgeon can easily and accurately place adjacent cannula paths very close to one another and achieve a uniform extraction of fat.

Next, the existing tiny tunnels can be enlarged incrementally, first using 14-gauge and then 12-gauge microcannulas. This technique of using progressively larger microcannulas is especially useful for the initial stages of liposuction of relatively fibrous areas, such as the medial knees, periumbilical area, breasts, and scapular back.

Determining the appropriate time to switch to a larger cannula depends on clinical judgment and the surgeon's personal style and experience. On accomplishing a sufficient amount of liposuction throughout an area using a microcannula of a particular gauge, the surgeon will notice that the cannula begins to encounter less and less resistance. When little resistance is encountered in a targeted area using a small microcannula, the surgeon might use a microcannula with a greater outside diameter.

Progressing from small to large cannulas differs from the traditional strategy of first using large cannulas to remove fat quickly and then switching to a smaller cannula to smooth out irregularities. The microcannular technique starts with smaller cannulas to prevent irregularities rather than repair them. By first creating a network of narrow, closely spaced tunnels that are later enlarged, the surgeon improves the uniformity of the results.

If a large cannula is used first, it becomes more difficult to direct any cannula along a new path. A large cannula tends to follow the path of least resistance and enter an existing tunnel rather than follow a new direction through intact adipose tissue. Thus, when liposuction is initiated using large cannulas, the surgeon tends to do too much liposuction in discrete or focal locations. After using a large cannula, it is more difficult to remove a small lump of residual fat without exacerbating areas where too much fat has already been removed.

Deep Liposuction. The deepest plane within a compartment of fat should be the first to be liposuctioned. If tumescent liposuction is initiated along a plane that is too superficial, it becomes more difficult to palpate and precisely determine the depth of the residual fat. As with infiltration, once a plane of liposuction has been created, it is difficult to judge by palpation the thickness of deeper layers of fat or to distinguish the interface between deep tumescent fat and muscle fascia. Initiating liposuction along the deepest plane
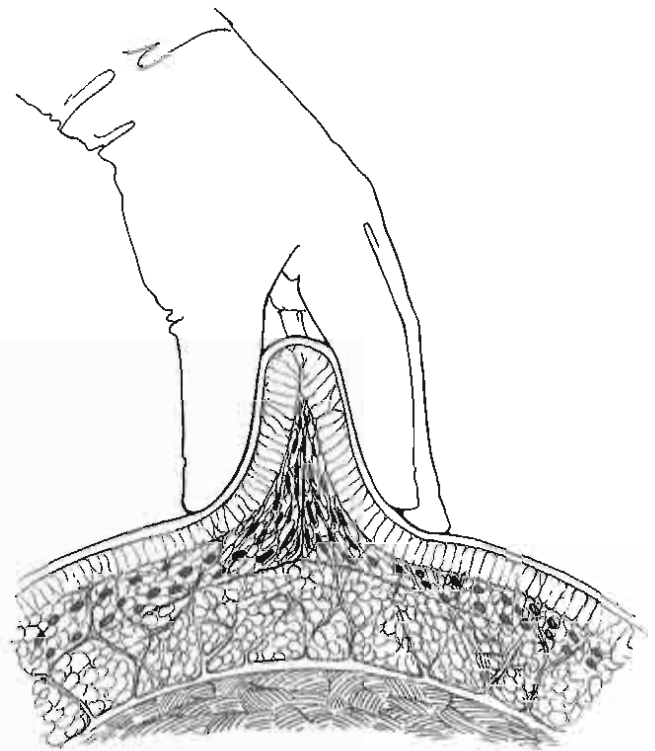
Figure 28-7

If liposuction is initiated too superficially, as shown here, deeper layers of fat probably will not be adequately liposuctioned. Despite thick layer of deep subcutaneous fat, surgeon's hand will grip thin flap of skin and liposuctioned subcutaneous fat, which gives erroneous impression of more complete liposuction.

facilitates a more complete and homogenous removal of fat (Figure 28-7).

As a general rule the surgeon should use a 16-gauge or 14-gauge microcannula to establish the deep plane and then suction the more superficial levels, creating a meshwork of crisscrossing tunnels from different adits. Once the deepest plane of liposuction has been created and a meshwork of tiny paths has been established throughout the fat, larger diameter (14 or 12 gauge) and longer microcannulas can be used with less resistance, less patient discomfort, and greater accuracy. Only a small amount of liposuction in the deepest plane is necessary to establish the deep cleavage plane.

If the initial tunnels are created at the midlevel strata of the fat compartment, this plane tends to act as a natural cleavage plane. Subsequently, as the surgeon attempts to detect the level of the interface between fat and muscle by using the sensory hand to grip, palpate, and stretch the fat, the initial cleavage plane can be mistaken for the deep fat-muscle interface. The fatty tissue at the initial plane of liposuction is easily stretched and elevated away from the residual deep, firm, tumescent fat. As a result, the sensory hand may mistakenly determine that the tumescent fat deep to the cleavage plane is muscle. Thus the initial cleavage plane be-
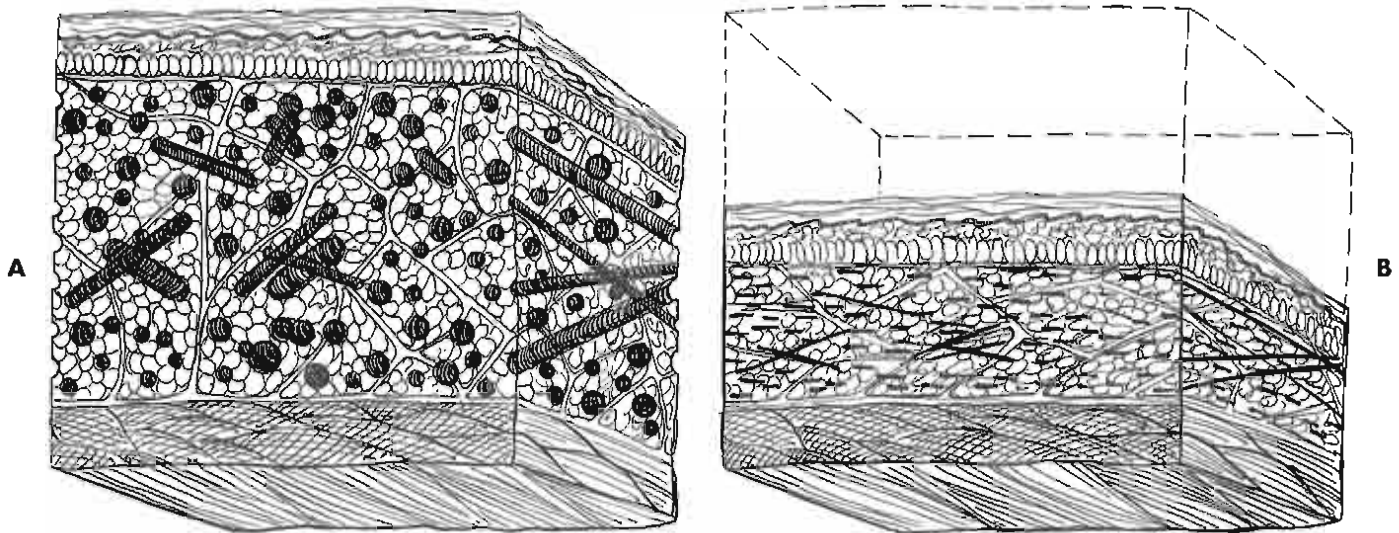
Figure 28-8

A, Tumescent fat showing subtotal liposuction with multiple crisscrossing tunnels resulting from deep and superficial microcannular liposuction. Superficial liposuction does not require injury to dermis or subdermal vascular plexus. Liposuction that leaves thin but smooth layer of intact fat immediately subjacent to dermis increases probability of optimal cosmetic results. **B,** After 24 hours of open drainage and bimodal compression, microcannular tunnels have collapsed, apposed surfaces are in direct contact, and risk of postoperative seromas is virtually eliminated. After liposuction, skin retraction results from normal elastic recoil of dermis and fibrous contraction of subcutaneous fat.

comes a "pseudointerface" between fat and muscle, and the surgeon becomes less confident about attempting liposuction deep to the initial plane of liposuction.

The actual depth of the deepest plane of liposuction is not intended to be precisely at the level of muscle fascia. If too close to muscle, the cannula might puncture muscle and produce significant bleeding. The surgeon can increase the safety of doing liposuction relatively close to muscle fascia by lifting the fat away from deep fascia.

Stretching Deep Fat. The tumescent fat can be elevated away from the deep muscle fascia by using the sensory hand to gently grasp and lift a handful of skin and subjacent tumescent fat. The degree of stretching of the fat at the deepest plane can be augmented by simultaneously elevating the tumescent fat and doing liposuction through the deepest layers of fat. Each new cannula tunnel in the deepest plane incrementally produces laxity of the fat across that plane.

When a microcannula perforates fibrous septa within adipose tissue, the holes in the septa are easily elongated by traction on the adipose tissue. As a consequence, both the septa and the deep fat become more stretchable. This allows the surgeon to accomplish liposuction within the deepest planes of subcutaneous fat while minimizing the risk that the microcannula might encounter and injure a structure deep to fat, such as muscle. Once the deepest plane is established in this manner, the surgeon can more easily and accurately do liposuction throughout the more superficial fat.

Preventing Residual Deep Fat. Initiating liposuction too superficially may result in a deeper layer of undetected fat. The surgeon tends to limit the depth of liposuction to the volume of fat that is superficial to the initial plane of liposuction. The layers of fat that remain deep to the initial plane of liposuction remain tumescent and relatively firm. It becomes difficult to detect, by squeezing and palpation, the depth of the muscle-fat interface (see Figure 28-7).

If liposuction of an area is not initiated at the deepest plane, the surgeon may misjudge the end point of liposuction in that area. When the sensory hand squeezes a mound of subcutaneous fat, the surgeon may grasp only the tissue superficial to the initial plane of liposuction. Because the fat located deep to the initial plane of liposuction is not easily detected by the grasp of the sensory hand, it may not be treated.

By initiating the liposuction too superficially, the surgeon may have a false sense of when liposuction is complete.

Excessive Superficial Liposuction. Conservative superficial liposuction with microcannulas allows the surgeon to remove more fat with fewer irregularities than when using a larger cannula (Figure 28-8).

All liposuction surgeons should know superficial liposuction that is *so* superficial that it damages the undersurface of the dermis is not necessary for optimal contraction of skin. Furthermore, excessive superficial liposuction is associated with a high risk of injuring the subdermal vascular and lymphatic vessels, which can result in either full-thickness der-

mal necrosis or chronic erythema ab liporaspiration (see Chapter 8).

The larger the diameter of the cannula, the greater is the risk that excessively superficial liposuction will cause dermal injury. This is particularly true with Capistrano-style cannulas that are 10 gauge or greater in size.

DECREMENTAL LIPOSUCTION

An ability to achieve consistently the smoothest possible result is the mark of a skillful liposuction surgeon. One means of achieving smooth, natural results involves a technique known as decremental liposuction.

With decremental liposuction the total thickness of a fat compartment is gradually and uniformly reduced in small proportions or small decrements. The goal is to decrease the "thickness" of the targeted fat compartment in repeated steps, each time removing approximately 10% to 20% of the intended result. Throughout this decremental process the surgeon must repeatedly check to ensure the liposuction is producing the desired, uniformly smooth result. Smoothness and uniformity are assessed by vision and by palpation at each step of the decremental process.

Through each adit the surgeon performs a limited number of cannula thrusts, with patterns of cannula paths radiating from the adit. The tunnels or paths created by doing liposuction from one adit should crisscross with other cannula paths that radiate from adjacent adits. After a limited number of cannula strokes through a given adit, the cannula is withdrawn and placed in another incision, and the process is repeated.

At each decremental stage, the entire targeted area is partially liposuctioned using all the adits. Moving from adit to adit, the microcannula is directed each time in a fanning pattern, with strokes from adjacent adits overlapping, crisscrossing, and interdigitating. Little by little, the entire compartment of subcutaneous fat is reduced decrementally.

At each step the surgeon must check the surface for smoothness and shapeliness. Any apparent irregularity is corrected, and the desired smoothness is achieved before continuing with the next decremental stage of the liposuction. This process is repeated several times until the fat compartment has been reduced to the desired thickness.

Using too few incisions or doing too much liposuction through one incision before switching to another incision will predispose to postoperative liposuction irregularities. If the surgeon attempts to treat an area segmentally by suctioning all the fat in one segment of an area before treating the adjacent segment, there is a risk of creating cobblestone-like irregularities or lipotrops. It is difficult to match the thickness of adjacent segments of fat when using the segmental approach to liposuction.

Feathering the Periphery. The technique used to achieve a smooth, imperceptible transition from an area treated by liposuction to an untreated area is called feathering the periphery. The surgeon can produce feathering simply by doing proportionately less liposuction at the periphery of the treated area. Feathering can be accomplished using either microcannulas with the same gauge as those being used for liposuction or smaller microcannulas.

ASSESSMENT OF SYMMETRY

Humans are rarely perfectly symmetric. It is unrealistic for a patient to expect that liposuction will produce perfectly symmetric results. Results that are less symmetric than the preoperative condition, however, are not acceptable. Thus the ability to judge the degree of symmetry during liposuction surgery is important.

Although it is intuitively appealing to analyze the results of liposuction for symmetry with the patient in a standing position, this maneuver is unnecessary and has potential pitfalls. At the conclusion of tumescent liposuction, if the patient has been lying on one side for an extended time, the dependent areas will become compressed by the patient's own weight. This transient compression may distort the treated areas and falsely give the appearance of asymmetry. The surgeon must be careful not to overcompensate for a perceived asymmetry that does not exist.

With tumescent liposuction, assessing symmetry can be easily and accurately accomplished while the patient is recumbent. Areas of residual fat are more easily detected by a careful tactile squeeze than by visual examination. The *tactile squeeze* consists of gently grasping the skin and subcutaneous tissue between the thumb and the flat surface of all four opposed fingers.

The tactile squeeze technique is an accurate means of assessing uniformity of the liposuction. It is important in detecting subtle areas of insufficient liposuction or liponots. Achieving smooth, uniform results on one side and reproducing the same result on the opposite side is an accurate means of attaining symmetry. With experience and attention to detail, uniformity of results consistently leads to symmetric results.

ABDOMINAL SCARS

Linear abdominal scars, even those that are depressed or moderately retracted, can be diminished by careful liposuction of the surrounding fat. Abdominal surgical scars that do not involve direct adherence of the dermis onto muscle fascia can usually be penetrated using microcannulas. The vertical sheet of fibrous scar tissue within fat is punctured and penetrated by the infiltration spinal needle while producing tumescent anesthesia. Then, using a relatively short and less flexible 16-gauge microcannula, the surgeon penetrates the scar along a path that is parallel to the skin and at an angle of incidence to the long axis of the scar that is approximately 45 to 90 degrees.

After fenestrating the scar with this smaller cannula, larger microcannulas can be passed more easily through the scar tissue. To avoid inadvertent penetration of tissue beyond the subcutaneous fat, the surgeon must avoid using too much force when pushing the cannula through a scar.

Dermal scars that are adherent to muscle fascia cannot be eliminated by liposuction. Linear dermal scars that are adherent directly to muscle fascia can be excised as a secondary procedure done months after the liposuction. The surgeon makes a narrow fusiform incision about the scar and de-epithelializes the scar by a tangential excision of the epidermis, allowing the deeper portions of the scar to remain. After undermining the lateral wound margin deeply just above the deep fascia, the wound is closed by suturing the wound margins and burying the residual scar tissue beneath unaffected fat and skin.

VULNERABLE VASCULAR STRUCTURES

If large varicose veins are within an area of subcutaneous fat, the surgeon should consider treating the varicosities before liposuction. The surgeon should know the paths of the larger (named) veins in areas targeted for liposuction.

Significant vascular injury is rarely associated with liposuction, but several major vascular structures are potentially vulnerable to liposuction. In the lower abdomen the anterior superior epigastric veins, the lateral circumflex veins, and the medial neurovascular bundles provide the arterial supply to the midabdominal skin and subcutaneous fat. Other areas with vulnerable venous structures are the breasts and medial thigh (greater saphenous vein).

A liposuction cannula should never enter the popliteal fossa or axilla because of the danger to important neurovascular structures. Similarly, the volar arms should be approached with great caution. Although the important vascular structures in the neck are deep to the platysma muscles, liposuction of the neck region also requires great care.

PREVENTING SURGICAL DEFECTS

Depressed Incision Site. This complication is preventable by minimizing trauma to the skin surrounding the incision or adit. A slit incision produced by a scalpel blade is more susceptible to cannula-induced friction than a round adit hole produced by a skin biopsy punch. If an incision or adit hole is too small, excessive friction from the back-and-forth motion of the cannula will injure the skin, resulting in excessive postsurgical scarring and pigmentation.

Incisions and adit sites must not be too small or unnecessarily large. Excessively long incisions result in scars that are unnecessarily long and therefore more visible.

Spoke Wheel Deformity. This defect is the result of disproportionately excessive liposuction and appears as a focal depression in the area of an incision site. The surgeon can avoid creating a spoke wheel deformity by carefully eliminating the suction when the cannula apertures are near the incision; the suction is eliminated whenever the surgeon's thumb is lifted from the air vent on the cannula handle.

Keloids and Hypertrophic Scars. A liposuction adit or small incision rarely causes these scars. A *hypertrophic scar* is raised above the surrounding skin but is confined within the area of the wound. A *keloid scar* is a special case of a hypertrophic scar that extends beyond the site of the initial wound. Certain individuals have a genetic predisposition for keloid formation.

A hypertrophic scar may be hyperemic and pink or may be hypopigmented. Hypertrophic scars may occur in any patient and are more likely to develop on the chest, neck, shoulders, and deltoid surface of the proximal extensor arm.

A decision to do liposuction on a patient with a history of excessive scarring must consider additional clinical history. Patients with keloid scars or hypertrophic scars may still be good candidates for liposuction. For example, a patient with a keloid scar on the deltoid area of the shoulder but normal scars elsewhere on the body will probably have no problem with keloid formation after liposuction of an area known to be at low risk for keloids, such as the abdomen or thighs.

Patients who have hypertrophic scars must be carefully examined and informed about the risks for scarring.

Erythema Ab Liporaspiration. This chronic reticulated erythema is produced by excessive superficial liposuction, with permanent damage to the subdermal vascular plexus. It is analogous to *erythema ab igne*, the mottled cutaneous vascular pattern that results from chronic thermal injury to the dermis. Liposuction should not be too superficial and should not rasp the dermis. Superficial liposuction must not aggressively involve the dermis. Optimal aesthetic results and rapid healing require at least a thin blanket of atraumatic, uniform residual fat attached to the dermis (see Chapter 8).

INADEQUATE LOCAL ANESTHESIA

Any clinician (surgeon, anesthesiologist, registered nurse) who is well trained and experienced in tumescent infiltration should be able to achieve profound local anesthesia in virtually all patients. In as many as 20% to 30% of patients, however, the surgeon may encounter one or more small areas where anesthesia is less than complete. Surgeons must be able to recognize inadequate local anesthesia and to correct the situation.

When a patient experiences pain during liposuction by local anesthesia, two common solutions exist. One approach is simply to infiltrate additional local anesthetic solution into the affected tissue, using either a 15-cm (6-inch), 18-gauge intradiscal needle or a 9-cm (3½-inch), 20-gauge spinal needle. Alternatively, the surgeon can use a smaller microcannula, which is less painful. Thus, whenever an area of discomfort is encountered, simply reducing the size of the cannula may be sufficient to allow continued suction in that area.

Distinct Types of Pain and Discomfort. Common usage has imparted an imprecise meaning to "local anesthesia." For tumescent local anesthesia, dilute lidocaine produces local analgesia (absence of pain) but not true anesthesia (absence of all sensation).

Adequate tumescent lidocaine can be expected to block sensory nerve fibers that transmit pain and temperature

sensation. Usually, however, it does not block sensory fibers that transmit the sensations of vibration, proprioception, and pressure. Thus nerve fibers associated with the periosteum that transmit vibration, proprioception, and pressure sensation are not completely blocked by lidocaine. An alert patient may feel a "strange" sensation during liposuction over a bony prominence, such as the medial malleolus, iliac crest, and trochanteric tubercle of the outer thigh. Some patients describe the "bizarre" sensation of liposuction as a vague rasping or washboardlike vibration and may perceive it as unpleasant or uncomfortable.

If a patient complains of pain during tumescent liposuction totally by local anesthesia, the clinician must distinguish between true pain and intolerance to vibratory and pressure sensations. *True pain* is typically described as a "sharp," "needlelike," or "burning" sensation and is the result of insufficient local anesthesia. When a patient complains of a sharp or burning pain, more local anesthesia should be given or a smaller microcannula used.

Intolerance to vibratory and pressure sensations is typically described as "dull," "unpleasant," "rasping," or "a heavy pressure." This type of discomfort usually will not diminish with additional tumescent anesthesia. The surgeons can allay much of the patient's anxiety by explaining the cause of the sensation and giving reassurance that muscle or bone is not being traumatized. The surgeon can minimize the "rasping" sensation by using the sensory hand to grip and elevate the subcutaneous tissue away from the deeper tissues while carefully directing the cannula away from the deep fascia.

POSTOPERATIVE CONSIDERATIONS

A number of factors affect the ultimate result of tumescent liposuction. The surgeon must be aware of these factors to achieve the best liposuction results and adequate documentation.

SUPRANATANT FAT VOLUME

Documentation. The volume of supranatant fat and the volume of infranatant blood-tinged anesthetic solution should be documented in every operative report. Recording the total volume of aspirate (supranatant plus infranatant) is less clinically relevant.

Merely recording the total volume of the aspirate provides little relevant information regarding the surgical trauma and the risk of surgical complications. The volume of total aspirate is not a good indicator of surgical trauma. A liposuction that yields 2800 ml of supranatant fat and 200 ml of infranatant blood-tinged anesthetic solution is a greater surgical insult than a liposuction that yields 1500 ml of supranatant and 1500 ml of infranatant fluid.

Infranatant Volumes. For more than 30 minutes after completion of liposuction, the supranatant fat and the infranatant solution continue to settle into two separate layers as a result of the difference in densities.

Supranatant fat floats on the top of the aspirate in the collection canister after tumescent liposuction. Before measuring the volume of supranatant fat, sufficient time must pass for fat and water to separate. Thirty minutes after routine tumescent liposuction the volume of supranatant fat consists of approximately 84% fat and 16% saline. When properly measured and recorded, the supranatant fat provides a general indication of the volume of fat actually aspirated.

Internal ultrasound-assisted liposuction (internal UAL) causes the apparent volume of supranatant fat to increase as a result of the fat emulsification. With internal UAL the fat and water are so thoroughly mixed that they do not separate for more than 24 hours. This volume of supranatant fat does not give a reliable estimate of the amount of fat that was actually removed.

Several other factors help determine the volume of infranatant fluid after surgery. The ratio of supranatant fat to infranatant blood-tinged anesthetic solution will vary as a function of the elapsed time between the completion of infiltration and the initiation of liposuction. If the suction is performed within 10 to 15 minutes after infiltration, the supranatant volume/infranatant volume ratio may be 1:1 to 2:1, but if the elapsed time is more than an hour, the ratio may be 6:1 to 12:1. The greater the time interval between completion of infiltration and initiation of liposuction, the smaller is the volume of infranatant solution.

Furthermore, in patients whose fat is exceptionally fibrous (e.g., males) and in those who were obese and have subsequently lost significant weight, the aspirate will contain more than the usual amount of infranatant solution.

HEMATOCRIT

A 48-hour postoperative hematocrit is generally unnecessary with true tumescent liposuction, especially if the patient is feeling well, with virtually no symptoms referable to anemia or hypovolemia.

Surgeons who do titanic tumescent liposuction (which is not recommended) need to be familiar with the diagnosis and management of severe perioperative blood loss. In these cases, postoperative hematocrits may be required regularly.

SKIN IRREGULARITIES

With proper microcannular technique and the goal of achieving smooth results rather than removing a maximal amount of fat, significant liposuction-induced irregularities should not occur.

A skillful surgeon must nevertheless be able to help patients who have been treated elsewhere and may have been disfigured by significant lipotrops. In my experience a lipotrop is most effectively repaired by cautiously doing liposuction to remove the relative excess fat that surrounds a lipotrop. The strategy of using autologous fat transplanta-

tion is not only inconsistently successful but also supported only by anecdotal reports. A healthy skepticism is justified when contemplating reports about the skillful use of autologous fat transplantation to compensate for unskillful liposuction technique.

Repairing lipotrops and liponots should be done in a careful and conservative manner. The use of 16-gauge Capistrano microcannulas and 14-gauge Finesse microcannulas is often sufficient.

INFLAMMATION AND INFECTION

Significant inflammation or drainage typically persists for no more than 4 days in the immediate postliposuction period. An occasional patient has tumescent drainage that persists for more than a week. Others may experience an unusual, progressive degree of sterile (noninfectious) inflammation with onset several days after liposuction.

With careful observation the surgeon can identify two types of postoperative inflammation associated with tumescent liposuction. Both the frequency and intensity of these types are reduced by using open drainage and bimodal compression.

Soreness. *Prostaglandin-mediated inflammation* is the probable cause of the most common type of postliposuction inflammation. It seems to affect all patients to some degree. Even with open drainage and bimodal compression, an observant patient may notice increased postliposuction inflammation affecting all treated areas, with onset 4 to 5 days after surgery.

This delayed inflammatory response is self-limited and rarely elicits a telephone call to the surgeon. Most patients seem to accept this transient increased soreness as part of the normal healing process. Acetaminophen is sufficient treatment for most patients.

Lesions. *Petite seromas* appear to be the cause of the second type of postliposuction inflammation. Typically with an onset 4 to 7 days after tumescent liposuction, this type of inflammation presents as discrete, focal, erythematous, pink subcutaneous nodules that are firm, tender, and warm to the touch. Often there is only a single lesion. When several lesions are present, they usually become symptomatic and are noticed by the patient within a day or two of each other.

These lesions do not respond to antibiotics alone but do improve quickly when prednisone, 10 mg daily, is added to the antibiotic treatment. On the rare occasions when such a lesion has been opened and drained, all bacterial cultures have had negative results.

The incidence of these petite seromas has fallen precipitously with the use of open drainage and assiduous bimodal compression.

Patient Evaluation. Although fewer than one in every 300 patients returns for examination because of significant local inflammation, all such patients must be carefully evaluated. One approach to the patient who returns for evaluation because of a marked postoperative increase in swelling and pain (inflammation) is as follows:

1. Evaluate for infection, including cellulitis and necrotizing fasciitis (see Chapter 12). Most patients first report the problem and concern by telephone. The clinician usually can establish that the likelihood of an infection is remote by taking a careful history by telephone. If the patient is alert, feels afebrile, has a good appetite, is drinking fluids, is urinating regularly, and is otherwise feeling well and participating in routine activities, a serious infection is less likely. If inflammation and discomfort are symmetric and uniformly distributed over all the areas treated by liposuction, a focal infection is relatively unlikely.

   If an examination is deemed necessary, the clinician should record the patient's body temperature and consider a complete blood count. Any suspicious exudate indicates the need for bacterial culture and sensitivity and possibly a Gram stain. The patient is treated with antibiotics if clinically indicated. If necrotizing fasciitis is suspected, the patient must be admitted to a hospital for emergency evaluation by a general surgeon.

2. Evaluate for a possible deep venous thrombosis (DVT). The probability of a DVT is more likely if lower extremity pain is unilateral and if the lower extremity was not treated by liposuction. If a DVT is suspected, an emergency consultation by an appropriate specialist should be obtained (see Chapter 10).

   After the surgeon has ruled out an obvious infection and DVT, treatment depends on the nature and severity of the symptoms.

3. Evaluate the degree to which the patient's physical activity is impaired as a result of the inflammation. If the patient is able to function without any unusual limitation of activity, treatment with antiinflammatory drugs is less urgent.

4. Evaluate the patient's ability to tolerate discomfort and pain. If the patient has an unusually low threshold for complaining about discomfort, giving the patient reassurance and mild analgesics may be sufficient. If the patient is normally stoic, antiinflammatory drugs may be appropriate.

When treatment of the pain and inflammation is indicated, the clinician should consider the following steps:

1. Empiric treatment with antibiotics for possible infection
2. Administration of prednisone, 10 mg by mouth daily for 2 to 7 days
3. Daily follow-up of the patient's clinical progress, either by telephone or in the surgeon's office

Because antiinflammatory drugs may suppress a patient's immune response to an infection, they should be used with caution in the immediate postoperative period. Both corticosteroids and nonsteroidal antiinflammatory drugs (NSAIDs) suppress leukocyte function and may decrease a patient's resistance to infection. When antiinflammatory drugs are used, concomitant treatment with antibiotics may be indicated.

PERSISTENT DRAINAGE

The problem of persistent drainage that lasts more than a week is unusual and rarely of any serious concern. Persistent drainage tends to be associated with the following:

1. Liposuction of a large area, particularly the thigh or inner thigh/knee areas and abdomen
2. Discontinuation of postliposuction compression garments before all drainage has stopped

The drainage typically appears as a pale-yellow, clear, plasmalike liquid and probably represents a combination of increased lymphatic flow associated with inflammation and ruptured lymphatic vessels resulting from liposuction.

Treatment of persistent drainage includes the three steps listed on p. 261 for treatment of inflammation as well as use of absorptive pads and firm compression of the treated area.

DYSCHROMIA AND HYPERPIGMENTATION

Avoiding hyperpigmented liposuction adits or incisions is a challenge to a surgeon's skill. Inexperience and carelessness increase the risk of inadvertent trauma to the portal of entry for the liposuction cannula.

The more darkly pigmented a patient's natural skin color, the greater is the risk of postinflammatory dyschromia (hyperpigmentation or hypopigmentation) at adit or incision sites. Preventing postinflammatory hyperpigmentation in susceptible patients requires extra care to avoid unnecessary friction and trauma to the skin, particularly the dermal-epidermal (D-E) junction near incisions or adits. Prevention of dyschromia at adit and incision sites is much easier than later treatment. The following strategies have proved useful in minimizing the frequency and degree of postinflammatory pigmentation:

1. *Avoid excessively small adits or incisions* to minimize friction at the portal of entry. Using patulous round adits rather than narrow slit incisions will reduce the friction between skin and cannula. An incision that is too small for a cannula will result in a friction burn and mechanical trauma to the D-E junction, which causes injury to pigment. Melanocytes form at the D-E junction, which leads to postinflammatory localized hyperpigmentation and hypopigmentation. Hyperpigmentation is the result of melanocyte death and disgorgement of melanin granules, with subsequent phagocytosis by junctional and papillary melanophages. *Melanophages* are macrophages or histocytes that have ingested melanin granules or melanosomes.[2]
2. *Minimize friction from the cannula* as it rubs the epidermis within several millimeters of the incision. Lift the skin with the gripping hand so that the cannula enters the adit at an angle, which avoids rubbing the cannula against the periincisional skin.
3. *Do not allow the cannula hub to contuse and bruise the incision site.* With cannulas that are too short, the surgeon tends to advance or push the cannula too far, thus causing the hub to impact the skin around the adit. Gripping the cannula handle with the index finger extended

slightly beyond the cannula hub helps to cushion the hub and minimize skin trauma (see Figure 28-6).

4. *Optimize the number of adits or incisions.* Too few incisions tend to limit the thoroughness and smoothness of liposuction results. Too many unnecessary incisions may result in unnecessary scars. Microcannulas require a few more adits than the minimal number of incisions needed when using larger, traditional cannulas. Multiple adits are usually less visible than a smaller number of larger incisions.
5. *Optimize the placement of incisions.* Minimize the number of incisions or adits placed in sites that are predisposed to dyschromia, such as the epigastrium and the back. Pigmented adit or incision sites tend to be most visible on the back and upper abdomen. When feasible, liposuction of the back should be approached from lateral incisions on the hip and waist.

For liposuction of the upper abdomen, only a few microincisions should be used to allow initial fenestration of the dense subcutaneous fat with the smallest microcannulas. Subsequently, most upper abdominal liposuction can be accomplished from incisions in the lower abdomen. For example, 12-gauge microcannulas can be advanced to the epigastrium from adits located laterally and inferiorly.

Similarly, using 12-gauge microcannulas for liposuction of the subscapular back can be accomplished through incisions placed laterally. Microincisions are preferentially placed where they tend to disappear. In patients of Northern European ancestry, the incisions required for microcannulas usually become invisible on the breasts, arms, thighs, chin and neck, and particularly the inner thighs.

FINAL WARNINGS

All liposuction surgeons must remember the following caveats:

1. It is inappropriate for nurses to do liposuction. Allowing a nurse to do the initial debulking liposuction can be viewed as "partaking in a conspiracy to practice medicine without a license."
2. A surgeon should never allow the administration of systemic anesthesia without adequately trained personnel in attendance.
3. Cold sterilization of liposuction cannulas, other liposuction instrumentation, and tubing is dangerous and below surgical standards of care.
4. Excessive liposuction is unwise and more dangerous than many surgeons realize.

PATIENT SELECTION

Patient selection in cosmetic surgery requires both a precise knowledge of the patient's health status and current medications (prescription and nonprescription) and an insightful awareness of important psychologic factors. Training and skill in careful patient selection are prerequisites for any lipo-

suction surgeon. Patients must be much healthier to qualify as candidates for cosmetic surgery than for therapeutic surgery.

Cosmetic surgery patients should be healthy and at minimal risk for perioperative complications. Candidates for liposuction should have American Society of Anesthesiologists (ASA) class I or II anesthesia risk.[3] Liposuction is ideally suited for healthy patients with localized deposits of fat.

If a potential liposuction patient has an unusual coexisting medical problem with which the surgeon has had little experience, preoperative consultation and medical clearance from an appropriate specialist are recommended.

ETHICAL CONSIDERATIONS

An ethical cosmetic surgeon must be alert to avoid situations that involve real or apparent conflicts of interest. A potential conflict of interest exists for the surgeon making a decision about cosmetic surgery for a patient who is not completely healthy. Against the obligation to fulfill the ethical imperative of "above all, do no harm," the surgeon must weigh (1) the desire to satisfy a patient's request for the cosmetic procedure and (2) the desire to receive a fee for performing the surgery.

When the patient has a potentially serious medical problem that might be exacerbated by liposuction, the surgeon's decision depends on a balance between desire to satisfy a patient's request for surgery and an obligation to avoid significant risks. Concern for such a patient's safety and the surgeon's enlightened self-interest require that the patient's specialists provide a formal letter giving preoperative clearance before liposuction.

The more precarious the patient's health, the more important it is to have the advice and consent of a knowledgeable clinical expert. For example, if a patient has a significant but well-controlled cardiovascular condition, connective tissue disease, endocrine disorder, or psychiatric problem, a preoperative clearance letter should be obtained from the patient's cardiologist, rheumatologist, endocrinologist, or psychiatrist, respectively. If the patient has a history of excessive surgical bleeding or an unusual family history of thrombosis, a hematologist should provide preoperative clearance.

If a patient has a significant medical problem, the surgeon should not do liposuction without the advice of the physician most familiar with the patient's condition. If the patient is ASA class I or II, preoperative clearance is often not necessary.

The cosmetic surgeon must realize that some patients' desire for a cosmetic procedure can overwhelm rationality. Some patients desperate to have liposuction might lie and may be incapable of informed consent. This is sufficient reason for seeking the advice of a physician more familiar with the patient's medical history.

CONCOMITANT GYNECOLOGIC SURGERY

Abdominal liposuction is contraindicated with concomitant gynecologic surgery. Both abdominal liposuction and abdominoplasty after an intraabdominal gynecologic procedure appear to be associated with an exceptionally high incidence of serious perioperative complications. After dehiscence of sutured muscle wall incisions, thromboembolism, perforated abdominal viscus, and herniation of intestines are rare when gynecologic or cosmetic surgical procedures are done alone. The risk of these complications increases dramatically, however, when two such procedures are performed on the same day.

OBESITY

Obesity is not an indication for liposuction. No well-recognized, scientifically documented proof indicates that liposuction has any therapeutic benefit for obesity. On the other hand, an obese patient might be very pleased with the results of localized liposuction. Thus liposuction in an obese patient is not absolutely contraindicated provided that the liposuction is done safely, with every effort to minimize the surgical risks associated with obesity.

Since obesity presents an increased risk for surgical complications, an ethical surgeon does not regard an obese patient's request for liposuction as an indication to do large-volume liposuction.

Patients who exceed their ideal body weight by 30% are obese and at increased risk for perioperative surgical complications, especially respiratory sequelae. Because of the increased risk of postoperative complications, the amount of liposuction performed on any given day should be limited. In other words, obesity is an indication for serial or iterative liposuction procedures rather than one excessively aggressive liposuction procedure accomplished on a single day. The dilemma of choosing megaliposuction or multiple exposures to systemic anesthesia is avoided by doing liposuction totally by local anesthesia.

Morbid Obesity. Morbid obesity is a relatively strong contraindication for liposuction. Because of the increased risk of liposuction-related surgical complications, I will not treat patients with morbid obesity. The incidence of complications is higher because of the increased amount of surgical trauma, which predisposes to seromas, dermal necrosis, and infection. Postoperative hygiene, including drainage and compression, is usually inadequate. Cosmetic results are often disappointing. Little, if any, evidence indicates that liposuction for morbid obesity has any clinically significant therapeutic or lasting cosmetic benefit.

Prior Obesity. Liposuction of a previously obese patient can be more difficult. If two patients currently weigh exactly the same, but one patient was previously much more obese, liposuction of the previously obese patient is typically more difficult. A patient who previously weighed 11 kg (25 pounds) more than at present will have a relatively high proportion of fibrous tissue in subcutaneous fat.

With weight loss, individual adipocytes tend to diminish in volume but not in number. The relative proportion of the collagenous component of adipose tissue is increased in such

patients. Liposuction of fat with a disproportionately large amount of fibrous tissue requires a greater effort.

The ultimate aesthetic results of liposuction in a previously obese patient tend to be less impressive than liposuction in a patient who is at maximum weight.

DIABETES MELLITUS

Insulin-dependent diabetic patients should not be considered for liposuction without significant caution. The risk of complications from anesthesia and surgery is approximately 10 times higher in diabetic patients, who also have a greater risk of dying in the perioperative period than healthy patients.[4]

Before deciding to do liposuction on an insulin-dependent diabetic patient, the surgeon should discuss the proposed surgery with the patient's endocrinologist. Because diabetic patients are at greater risk for infection, especially nosocomial infections, the risk of doing the liposuction in a hospital must be considered. Diabetes mellitus is a predisposing factor for necrotizing fasciitis.

Preoperative laboratory tests should include a determination of hemoglobin A_{1c}, a glycosylated hemoglobin that correlates with long-term diabetic control.

IMMUNOCOMPROMISED PATIENTS

Liposuction on an immunocompromised patient may be associated with a significant risk of perioperative infections. Despite an intense desire to have liposuction, immunocompromised patients may not be good candidates for liposuction.

Not all persons are good candidates for liposuction surgery, but the basis for this decision must be based on fact rather than prejudice. The wisdom of performing cosmetic surgery in immunosuppressed patients is open to question. Certainly, no convincing evidence indicates that liposuction does *not* represent a significant risk for postliposuction infections (see Chapter 12).

Considerable evidence suggests that anesthetic agents adversely affect immune competency. The decision to do any type of surgery must be based on clinical outcomes, with a rational assessment of the relative risks and benefits of the proposed surgery. Although the relative risk of perioperative liposuction infection in a person with human immunodeficiency virus (HIV) infection is not known, the risk cannot be ignored. Until such risks are known, it is reasonable to error on the side of caution.[5]

Some facts are known. All general anesthetic agents, both inhalational and intravenous, depress immune function.[6] Narcotics such as morphine[7] and fentanyl[18] have immunosuppressive effects. Intravenous anesthetic agents, including propofol, methohexital, and thiopental, also depress immune function.[9]

Protease inhibitor drugs are relatively contraindicated for large doses of lidocaine associated with tumescent liposuction because of the potential for inhibiting cytochrome P450 3A4 and interfering with lidocaine metabolism.

All potential liposuction patients should be tested for HIV infection to provide patients with a complete assessment of their risk for perioperative complications. Again, good candidates for liposuction should be healthy ASA class I or II anesthesia-risk patients. Some surgery centers have *written policies* stating that all cosmetic surgery patients must be either ASA class I or II. Patients with HIV infection are typically considered ASA III and are not regarded as ideal candidates for cosmetic procedures.

HEPATITIS C

Hepatitis C virus (HCV) infection is a potentially fatal disease that infects approximately 1% of the population. HCV has several modes of transmission, some of which are not precisely known. The most common form is parenteral exposure or intimate contact with infected body fluids.

Greater than 80% of HCV infections result in chronic viremia. Among all infected patients, 70% to 85% will develop chronic hepatitis. Among patients with hepatitis, 20% to 40% will have cirrhosis. Among patients with cirrhosis, 10% will develop hepatocellular carcinoma.[10] Surgeons and surgical operating room staff are among the risk groups for occupational exposure.[11-13]

The effect of HCV on the metabolism with high dosages of tumescent lidocaine is not known. The effect of lidocaine on the risk of developing chronic hepatitis and cirrhosis also is unknown. Therefore the risks of tumescent liposuction in the setting of HCV infection are not known.

All potential liposuction patients should be tested for evidence of HCV. Some surgeons may classify patients with HCV infection as ASA II or III.

HYPERTENSION

Hypertension, a common condition among overweight patients, must be well controlled before considering liposuction. When significant hypertension is detected at the preoperative examination, the patient should be referred to a primary care physician for appropriate treatment far in advance of surgery. Excessive hypertension on the day of liposuction may respond within 30 minutes to clonidine, 0.1 mg by mouth. If hypertension persists, this is a strong indication to cancel the surgery.

In general, patients should not discontinue antihypertension medications on the day of surgery. Calcium channel blockers and beta blockers, both commonly used to treat hypertension, may interact to some extent with lidocaine and epinephrine. Among patients taking these drugs, the total dosage of lidocaine should be limited to less than 45 mg/kg for liposuction totally by local anesthesia. No drug interactions appear to occur between tumescent epinephrine and beta blockers taken to treat hypertension or prevent migraine headaches (see Chapters 18 and 24).

Hypertensive patients who are subjected to systemic anesthesia are at particular risk for perioperative complications.

AGE

Age is considered a minimal risk factor for liposuction-associated perioperative complications. Advanced age should not be a major factor in the decision to do liposuction. Older patients tend to have fat that is less fibrous and therefore much easier to aspirate. The expectations of older patients tend to be more realistic and less demanding.

Among the most satisfied patients a liposuction surgeon will encounter is the older woman with abdominal subcutaneous obesity that adversely affects physical activity and self-image. Tumescent liposuction of the abdomen in a woman in her 60s or 70s tends to produce dramatic results with relatively rapid and comfortable recovery.

On the other hand, liposuction of very young patients should be approached with considerable caution. A teenager should not have liposuction simply at the parents' request. The admonition that liposuction should not be used to treat obesity is particularly appropriate for teenagers, who must realize that surgery is not the answer to unhealthy dietary habits.

SMOKING

Smoking is a relative contraindication for any cosmetic surgical procedure. Patients who smoke should be encouraged to abstain for at least 8 weeks before surgery. Because most patients are unable to quit smoking, surgeons should limit the amount of liposuction performed at any given time.

CARDIOVASCULAR DISEASE

Patients with significant atherosclerotic coronary artery disease are questionable candidates for liposuction surgery. Exposing such patients to the stress of surgical trauma should be contemplated with great caution. These patients require preoperative clearance from a cardiologist. Epinephrine, and therefore tumescent liposuction, is relatively contraindicated in patients with a history of angina or atherosclerosis.

Mitral valve prolapse (MVP) is usually asymptomatic. Patients who have required medical management of symptomatic MVP because of palpitations, arrhythmias (dysrhythmias), or atypical chest pain may benefit from a preoperative cardiology consultation.

PSYCHIATRIC DISEASE

The cosmetic surgeon must not do liposuction on a patient with a psychiatric problem that prevents reasonable, informed decision making. Liposuction is usually safe in a patient with mild situational depression. For a prospective liposuction patient who is seeing a psychiatrist, either regularly or intermittently, requesting that the psychiatrist provide a preoperative evaluation and letter of approval before scheduling liposuction might be appropriate.

Some antidepressant drugs, including selective serotonin reuptake inhibitors and tricyclic antidepressants, are among those drugs that may interfere with hepatic metabolism of lidocaine. If clinically feasible, these antidepressants may be discontinued at least 7 days before surgery. If they cannot be discontinued, the total dosage of lidocaine should be limited to less than 35 to 45 mg/kg.

HYPOTHYROIDISM AND HYPERTHYROIDISM

Liposuction patients with thyroid disease should be well controlled, with serum thyroid hormone levels within normal limits. If a patient is taking thyroid supplementation, the preoperative laboratory evaluation should include a determination of thyroid hormone to rule out the possibility of over medication and iatrogenic hyperthyroidism.

Hyperthyroidism increases the risk of cardiac dysrhythmias. Some prospective liposuction patients who are somewhat obese will take excessive doses of thyroid supplementation under the assumption that hyperthyroidism will facilitate weight loss.

THROMBOEMBOLIC DISEASE

Patients who have a personal or a family history of unusual thromboembolic events should be evaluated for thrombophilia (see Chapter 10). Unusual venous thromboses include those occurring at a young age; multiple episodes of venous thrombosis or embolism; thrombosis in an unusual anatomic location, such as mesenteric, axillary, or cavernous sinus thrombosis; and spontaneous thrombosis without any known predisposing factors.

MALIGNANT HYPERTHERMIA

Prospective patients who have a personal history of malignant hyperthermia are questionable candidates for liposuction. Prospective patients who have a family history of this condition may be at risk for developing malignant hyperthermia as a reaction to systemic anesthetics. Because significant trauma or excessive physical exercise can precipitate malignant hyperthermia, even liposuction by local anesthesia may be dangerous.

INAPPROPRIATE PATIENTS

One of the most important qualifications for a cosmetic surgeon is the knowledge of when and how to say "no" to inappropriate patients, including the following:

1. Patients who have unrealistic expectations
2. Patients who are unreasonably demanding, inconsiderate, or disrespectful of the office staff
3. Patients who demand a guarantee of flawless results
4. Patients who lie or "neglect" to give complete information about their health or previous surgeries

Poor interpersonal communication between patient and surgeon or a language barrier that cannot be remedied by an interpreter is a contraindication for liposuction.

Patients with a history of serious psychologic problems must have preoperative clearance from a psychiatrist. For medicolegal and ethical reasons, the surgeon should require documentation from the psychiatrist, in the form of a type-written letter on professional letterhead stationery, which is placed in the patient's chart.

"Red Flag" Patients.   Certain categories or stereotyped groups of patients are known to be excessively demanding or unrealistic in their expectations. Patients in these categories are more likely to be impossible to please. This "red flag" status does not automatically exclude these patients from cosmetic surgery, but they should be approached with caution.

The patient who must have liposuction as soon as possible and who demands that the surgeon and nursing staff rearrange their schedules is the most likely patient to cancel surgery at the last minute. Self-important patients who boast of their own fame or wealth may be unusually troublesome. Patients who are "addicted" to cosmetic surgery are often unrealistic. Patients who are disheveled or appear unconcerned about their appearance may be unsuitable for cosmetic surgery.

Patients whose aesthetic judgment differs greatly from that of the surgeon are likely to be difficult to please. For example, the surgeon must be especially alert and judicious when considering the female with large hips who only wants liposuction of her relatively small abdomen.

Some surgeons regard out-of-town cosmetic surgery patients as "high risk" if they are unwilling to stay long for postoperative care.[14] This is reasonable for many cosmetic surgery procedures. In the case of tumescent liposuction, however, with a postoperative care technique that incorporates open drainage and bimodal compression, the patient rarely needs to remain in town more than 24 hours after surgery. Thus the out-of-town liposuction patient who desires an uneventful recovery and a quick return home is not being unrealistic.

Unrealistic Expectations.   The surgeon should not do liposuction on a patient with unrealistic expectations, such as the following examples:
1. A 60-kg (132-pound) woman who expects that liposuction of the lateral thighs and abdomen will allow her to fit into clothes she wore when she weighed 50 kg (110 pounds)
2. A woman who expects liposuction to cure her adulterous husband of his wandering ways
3. A patient who expects liposuction to achieve perfect results

Patients should be told that they are good candidates for liposuction only if they would be satisfied with a 50% improvement. Most patients will achieve much more improvement, but any patient who would not be satisfied with 50% might have unrealistic expectations.

The unrealistic patient who cannot take "no" for an answer is especially troublesome. The patient may return for repeat consultations and attempts to convince the surgeon to do a procedure that is contrary to good judgment. A signed informed-consent form with explicit disclaimers and warnings will not prevent an unrealistic preoperative patient from becoming an unhappy and litigious postoperative patient.

How to Say "No."   The liposuction surgeon must minimize the incidence of dissatisfied patients or patients who are impossible to please. To minimize the risk of gratuitous malpractice litigation, a liposuction surgeon must be skilled at saying "no" to difficult or inappropriate patients.

A surgeon must always be willing to correct a mistaken or inappropriate decision to do liposuction. After having consented to do liposuction on a particular patient, if compelling new evidence of the patient's inappropriate behavior becomes apparent, the surgeon should reverse the decision to do the surgery.

A liposuction surgeon must know how to be diplomatic when rejecting an inappropriate patient. The surgeon must be assertive but polite and considerate. The following statement has proved effective in this regard: "I do not believe I have the skill to achieve the results that you desire, and therefore it would be unethical and inappropriate for me to attempt to do your liposuction surgery." No patient can reasonably expect or demand that a surgeon do something that is unethical.

PHYSICS OF A LIPOSUCTION ASPIRATOR

VACUUM SOURCE

The basic laws of physics state that the effect of a negative pressure applied to a liposuction cannula is independent of whether the negative pressure is created manually by pulling on a syringe or mechanically by using an electric motor. At equal magnitudes of negative pressure, a syringe or an electric aspirator produces equal effects on adipose tissue. In terms of tissue trauma, no difference exists between a syringe or aspirator.

Advantages of syringe liposuction include low initial costs, light weight, and ease of transport. Syringe-assisted liposuction using microcannulas, however, especially the smaller microcannulas, can be extremely tedious.

Using a syringe for liposuction may limit the surgeon's liposuction technique. For example, achieving optimally smooth results, especially on the inner thighs, requires frequently switching liposuction adit (incision) sites and doing only a small amount of liposuction through any one adit before changing to another. This repeatedly causes a loss of negative pressure within the syringe and requires extra time and effort to reestablish the syringe vacuum.

Modern electric liposuction aspirators are more time efficient. Also, by eliminating the need to repeatedly reestablish a vacuum in the syringe, these aspirators may limit the surgeon's exposure to the risk of repetitive-motion injury.

VACUUM-PUMP PARADOX

Misconceptions about the physical principles that govern the function of an electric vacuum-pump aspirator are the source of many paradoxes. For years it was assumed that the most powerful electric vacuum pump was a necessary component for the most effective liposuction aspirator. In fact, this is not the case.

A liposuction aspirator consists of two components: an electric vacuum pump and a liposuction canister (or vacuum reservoir). A vacuum pump is simply an air pump; by pumping the air out of a canister, an air pump creates a vacuum. As a component of a liposuction aspirator, the vacuum canister has two distinct functions: (1) to collect the aspirated fat and (2) to act as a reservoir for storing the potential kinetic energy of the vacuum.

It is an apparent paradox that the liposuction aspirator with "the most powerful electric vacuum pump" is not necessarily the optimal "liposuction aspirator." The statement that "two electric vacuum pumps of different power can produce equally efficient liposuction aspirators" at first seems self-contradictory (see following discussion). With an appreciation of the physics of a vacuum and the functional difference between a liposuction aspirator and its component vacuum pump, the paradox becomes a statement of common sense.

Another misconception leads to an apparent paradox. For liposuction performed at higher elevations, a widely held belief is that optimal efficiency requires a vacuum pump of maximum power. To compensate for the decreased ambient atmospheric pressure, the assumption is that an extra-powerful vacuum pump is necessary. The fallacy of this assumption is revealed by an analysis of the physics of a liposuction aspirator. As presented in the following discussion, the magnitude of the negative pressure contained in the vacuum canister determines the effectiveness of a liposuction aspirator. Provided that a vacuum (air) pump exceeds a certain power threshold, any additional power is essentially superfluous.

CRITERIA FOR OPTIMAL ASPIRATOR

The usefulness of a liposuction aspirator depends more on its ability to aspirate water than its ability to pump air.

An excessively powerful pump is not only unnecessarily expensive, but also unnecessarily heavy and noisy. A smaller aspirator is easier to move from room to room and requires less storage space when not in use. An unnecessarily heavy pump presents a greater risk of a back injury to the surgeon or staff members who might have to move or lift the machine. A lightweight pump minimizes the risk of an occupational back injury and employee disability. Finally, an aspirator with one vacuum pump not only weighs less but is also easier to soundproof than an aspirator with three vacuum pumps.

As discussed next, any vacuum pump that exceeds a minimum threshold of power will allow liposuction at virtually the same rate as more powerful pumps. Excessive power beyond this threshold may be detrimental as well as wasteful. Suppose two aspirators aspirate 1 L of water at identical rates.

The most advantageous aspirator is the quietest (least annoying and least likely to interfere with verbal communication), the most lightweight (least likely to cause back injury), and the least expensive. Thus a less powerful and less expensive aspirator may be more practical and desirable.

THE NATURE OF A VACUUM

The power rating of a vacuum pump and the effectiveness of a vacuum pump as a component of a liposuction aspirator are independent variables. The power of vacuum pumps is rated in terms of the volume of air evacuated per minute. The ability to move large volumes of air per minute has little effect on the volume of water or fat that the pump can aspirate per minute.

If the power of a pump exceeds a certain threshold, the power of a vacuum pump is not an important factor in determining the effectiveness of the pump used as a liposuction aspirator.

A *vacuum* is a space from which the air has been artificially withdrawn. A complete vacuum cannot be produced by mechanical pumps. At best, one can create only a *partial* vacuum, which is almost but not completely devoid of gaseous molecules.

A *torricellian vacuum* is the space left at the top of a barometer by the mercury falling. The height of this column of mercury is a measure of the local atmospheric pressure, and the pressure within the vacuum is the negative value of the local atmospheric pressure. The magnitude of the negative pressure of a torricellian vacuum can never exceed the magnitude of the atmospheric pressure.

Another means of creating a vacuum is by an air pump, or a vacuum pump, which pumps air out of a hollow rigid vessel (e.g., a liposuction canister) to create a space almost empty of air. Commercially available vacuum pumps are either of the rotary vane type or the piston type. A syringe can be made to function as a vacuum pump by forcefully retracting the syringe's piston and creating a space that has negative pressure compared with that of the surrounding atmosphere. Relative to the outside atmospheric pressure at sea level, the relative pressure inside an evacuated vacuum canister is negative, measuring approximately −760 mm Hg, or about −30 inches of mercury.

Atmospheric Pressure.   Expressed in terms of force per unit area, atmospheric pressure is the pressure exerted by the atmosphere on the earth's surface. At sea level the atmospheric pressure is approximately 1 kg per square centimeter, or 14.7 pounds per square inch. The weight of the atmosphere can also be expressed in terms of millimeters of mercury (760 mm Hg) or inches of mercury (30 inches Hg) that the atmosphere can support.

Relative pressure is the measure of pressure relative to the atmospheric pressure. Any pressure greater than the atmosphere is considered positive, and any pressure less is negative.

Vacuum Applied to Fat. Liposuction is accomplished by applying the force provided by a vacuum within a canister directly to the subcutaneous fat. This force can never exceed the negative value of the atmospheric pressure. The vacuum within a canister created by a suction device (e.g., vacuum pump, syringe) forces small globules of gelatinous fat through the cannula apertures and into the vacant space within the liposuction cannula.

If a liposuction cannula does not move relative to the fat, no liposuction will occur. The to-and-fro, in-and-out motion of the cannula acts as a rasp that effectively tears off small fragments of fat. These fat fragments are then sucked into the cannula, flowing into the liposuction tubing and finally into the vacuum canister.

VACUUM CANISTER STORES POTENTIAL ENERGY

To understand how liposuction works, one must recognize that the vacuum within the canister is directly responsible for the work of liposuction, not the vacuum pump. A container (within the earth's atmosphere) that holds a vacuum is a reservoir for potential kinetic energy. The potential energy of a vacuum is converted to kinetic energy, which produces work when the vacuum sucks a fluid up a tube against a resisting force. The potential energy stored in the vacuum canister, not the power of the vacuum pump, determines the rate of liposuction and the relative proficiency of the aspirator.

The magnitude of the potential energy stored in a vacuum depends on the magnitude of the surrounding atmospheric pressure and the volume of the canister. At higher altitudes the pressure difference between the surrounding atmosphere and the inside of a vacuum canister is essentially independent of the size of the vacuum pump that created the vacuum. In other words, for liposuction at higher altitudes, no advantage exists to using an aspirator with an extra-powerful vacuum pump.

UNEQUAL VACUUM PUMPS YIELD EQUAL ASPIRATORS

Energy and *work,* which are equivalent, are defined as the product of force times distance. One joule of energy is equivalent to moving one kilogram of water against the force of gravity for a distance of one meter.

Power is defined as the amount of work that is done per unit of time. One joule per second is a measure of power (equivalent to one watt). The power of a vacuum pump is rated in terms of the volume of air at one atmosphere that can be moved in a unit of time. The power of a liposuction aspirator (vacuum pump plus collection canister containing a vacuum) can be measured in terms of the volume of water that can be moved in a unit of time.

The power produced by a vacuum pump when moving air does not necessarily correlate with the power produced by the pump when it is moving water. One aspirator may have a vacuum pump that is twice as powerful as the vacuum pump of another aspirator, but both aspirators require virtually the same amount of time to suction one liter of water.

The more powerful a vacuum pump, the more rapidly it can create a vacuum. Once the vacuum is established, however, the force necessary to maintain the vacuum does not require a pump of maximum power. Furthermore, the time required to raise one liter of water a distance of one meter is long compared with the short time required to evacuate air out of a liposuction canister. Thus, although two vacuum pumps may evacuate air at slightly different rates, once a vacuum is achieved within two canisters of equal volume, each will move water at equal rates (because equal amounts of potential energy are stored within the vacuum canisters).

LIPOSUCTION CANISTER: RESERVOIR OF POTENTIAL ENERGY

The liposuction canister not only collects fat but also acts as a "vacuum reservoir" that stores the vacuum's potential kinetic energy. The larger the canister, the greater is the amount of work that must be accomplished by the vacuum pump to evacuate the canister air and create a vacuum, and the greater is the potential energy.

The optimal volume of a canister is not excessively large and thus does not require too much time to achieve a vacuum. A canister must be large enough to accommodate a reasonable volume of fat. A canister that has a given wall thickness, however, cannot exceed a certain volume, beyond which the canister will implode. As the volume of a canister increases, the total force exerted on the canister by the atmosphere (the force per unit area of atmospheric pressure multiplied by the canister's total surface area) also increases.

It is not necessary for the power of the vacuum pump to be excessive. Whether generated by a one-horsepower or 100-horsepower vacuum pump, a vacuum is a vacuum, and its magnitude cannot exceed the magnitude of the surrounding atmospheric pressure.

Real Power and "Pseudopower." The real power of a liposuction aspirator is the speed with which it can move a given volume of water. When measured in terms of "the volume of air that can be pumped in one minute," the power rating of a vacuum pump is irrelevant to microcannular liposuction and can be regarded as "pseudopower."

If aspirator III consists of three pumps and can pump three times the volume of air per minute as an aspirator I with one pump, but both aspirators raise one liter of water a distance of one meter in essentially the same time, both aspirators deliver equal liposuction power. The power of an aspirator that contains one or more superfluous pumps is also "pseudopower."

ANALOGY: WATER RESERVOIR

A liposuction aspirator is analogous to water storage tower. When a water pump delivers water to a tank on the top of a high tower, work (force times distance) is converted into potential energy. This potential energy is converted to kinetic energy when the water is released from the reservoir and is al-
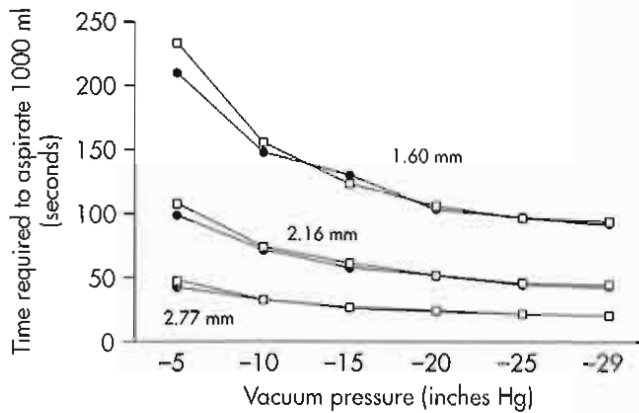
Figure 28-9

Small aspirator powered by single vacuum pump (□) is compared to larger aspirator powered by three vacuum pumps (●) by measuring time required to aspirate 1000 ml of water through tubes with following inside diameters: 14-gauge microcannula, 1.60 mm; 12-gauge microcannula, 2.16 mm; and male connector on microcannula handle, 2.77 mm. Although triple-pump aspirator moves air more rapidly than single-pump aspirator, experiment shows that both aspirators move fluids at nearly equal rates.

Figure 28-10

Rate of aspiration of water (ml/sec) at sea level as function of negative pressure (− inches Hg) is determined for four tubes with following inside diameters: 14-gauge microcannula, 1.60 mm; 12-gauge microcannula, 2.16 mm; male connector on microcannula handle, 2.77 mm; and aspiration hose/tube connector, 6.35 mm. Comparing rate that water is aspirated through 14-gauge and 12-gauge cannulas shows little difference in flow rates between −29 and −20 inches Hg.

lowed to flow downward under the force of gravity. The volume (or mass) of water stored in the reservoir determines the magnitude of the potential energy within the reservoir.

A water reservoir and a vacuum reservoir have similar physical properties and functions. Both store kinetic energy. This analogy will help the liposuction surgeon better understand the requirements for an ideal liposuction pump. Although two air (vacuum) pumps may be different in terms of power (different rates of pumping air), they may be equivalent in their ability to maintain a vacuum reservoir and to suck fat.

Consider a 25-m-tall water tower that is filled with water by an electric pump that pushes the water from ground level up to the storage tank. If the maximum amount of water that can be drained from the tower is 10 liters per minute (L/min), the electric pump that pumps water up to the storage tank at 20 L/min will be sufficient to keep the tank full at all times. A 100-L/min pump is not more useful in storing water than a 20-L/min pump. The more powerful water pump is noisier, more difficult to transport, and less economical.

ESSENTIAL EXPERIMENTS

Two simple experiments reveal the true nature and functional parameters that determine the efficiency of a liposuction aspirator. An understanding of these experiments will help optimize the efficiency of the surgeon's own liposuction technique.

The first experiment compares the function of two liposuction aspirators. One is powered by a single vacuum pump and the other by a combination of three vacuum pumps. Although the triple-pump aspirator moves air more rapidly than the single-pump aspirator, the experiment shows that both aspirators move fluids at equal rates (Figure 28-9).

The second experiment measures the rate of fluid (water) aspiration as a function of negative pressure. Comparing the rate that water is aspirated as a function of negative pressure, only a 10% difference exists in flow rates between −29 and −20 inches Hg. In other words, reducing the magnitude of the negative pressure within the liposuction canister, from −29 to −20 inches Hg, does not substantially alter the rate of liposuction (Figure 28-10).

This fact is also apparent when using a syringe for liposuction. As the syringe fills with aspirated fat, the degree of vacuum decreases in intensity, but the rate of fat aspiration does not decrease significantly.

Reduced negative-pressure liposuction does not improve the results of liposuction, does not minimize trauma to residual subcutaneous adipose tissue, and does not reduce postliposuction recovery time. It may be less stressful to individual aspirated lipocytes, however, and may be preferable for fat transplantation.

CHOICES FOR LIPOSUCTION

Aspirator. When a small, quiet, inexpensive liposuction aspirator performs as well as a heavier, noisier, more expensive aspirator, little advantage exists in buying the larger machine.

Aspirator Tubing. Plastic tubing specifically designed to connect liposuction cannula handles to vacuum canisters of the liposuction aspirator is relatively lightweight, flexible, and easy to use. The wall thickness of disposable suction tubing does not collapse under the force of the vacuum provided by an electric liposuction pump. Current liposuction aspirator tubing is considerably lighter and smaller in diameter than the thick, heavy-duty plastic hose used in the early 1980s.

All liposuction equipment must be steam sterilized in an autoclave before reuse. To minimize the risk of liposuction-associated infections, current aspirator tubing is intended to be single use and disposable. Aspirator tubing is not designed to be autoclaved or reused.

MACHINE-POWERED LIPOSUCTION CANNULAS

Machine-powered (MP) liposuction cannulas have recently been introduced. Prototype MP cannulas use electric or pneumatic engines to provide a form of "automatic" liposuction. Although most MP cannulas are merely modifications of existing orthopedic surgical devices, a few have been designed specifically for liposuction. Rectilinear MP cannulas can be rapid (7000 cpm) vibratory devices or slower (200 to 6000 cpm) reciprocating devices. Rotary MP cannulas might use reciprocating motion or continuous spinning.

Potential problems include noise pollution, which can be physically uncomfortable, psychologically annoying, and perhaps dangerous by impairing communication among the surgeon, staff members, and patient. Prolonged exposure to high-frequency sound may injure the inner ear of the surgeon and staff. Prolonged exposure to vibratory mechanical forces may damage the muscles, nerves, joints, or tendons of the fingers and hands. Blood vessels, nerves, or other tissues of patients may be at increased risk of injury from MP liposuction cannulas.

The risks/benefits and dependability of MP cannulas are unknown. The expense of some devices might outweigh their relative benefits. Preferably, MP cannula devices will accommodate existing cannulas and not require the purchase of new ones.

At this time, liposuction experience with MP cannulas is limited, and important questions remain unanswered. Objective and unbiased studies will be important in defining their eventual role in liposuction surgery.

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Critique of Ultrasonic Liposuction

The term *ultrasonic-assisted liposuction* (UAL), or ultrasound liposuction, refers to any modified liposuction technique that delivers ultrasonic energy to subcutaneous fat to facilitate traditional negative-pressure liposuction. The concept of UAL is intuitively appealing. A piezoelectric crystal converts electric energy to rapid (ultrasonic) vibrations and heat, which are transmitted to a small metal rod or paddle. Ultrasonic energy delivers a combination of vibratory mechanical energy and thermal energy to subcutaneous fat and thus injures living tissue.

At present, any claim that UAL is safe and effective is controversial. One study of 250 consecutive UAL patients concluded that internal UAL is "both safe and effective" despite three cases of dermal necrosis (1.2%), 28 postoperative seromas (11.2%), and 35 patients with Reston foam blisters (14%).[1]

THE SAFETY CONTROVERSY

A 1998 annual scientific meeting dedicated to cosmetic surgery included a symposium on UAL. With no experts on the physics of acoustics, the technical discussions were elementary and featured graphic art illustration supplied by a UAL device manufacturer. The clinical presentations were anecdotal and based on speakers' clinical experience.

No speaker presented data based on personal research projects. All the speakers were enthusiastic about the future of UAL. The symposium gave the overall impression that UAL represented a significant advance for cosmetic surgery.

No speaker mentioned that UAL might prove more dangerous than tumescent negative-pressure liposuction. Apparently no studies have compared the two techniques. Also, no speaker discussed UAL complications. The biologic effects of destructive ultrasonic energy on adipose tissue in vivo have not been well studied, and no in vivo animal studies have defined the safety limits of UAL.

UAL has many enthusiastic advocates among the world's most prominent and well-respected liposuction surgeons. The literature reveals, however, that the incidence of seromas and prolonged postoperative induration is greater with UAL than with tumescent negative-pressure liposuction. Furthermore, the American enthusiasm for UAL is difficult to reconcile when many disappointed European liposuction surgeons have abandoned UAL because of unsatisfactory results.

Objective information is lacking about the safety of UAL. High-profile television interviews of surgeons who are publicly enthusiastic about UAL may provide the public with an unrealistic assessment. Promoting UAL at surgical meetings without a full discussion of its complications may lead surgeons to believe that UAL is relatively safe.

The purpose of this chapter is to point out the need for more objective and scientific studies of UAL. This chapter discusses the ethical and epidemiologic issues associated with UAL safety.

I believe that the enthusiasm about UAL may be based on fallacious reasoning, biased information, and misleading advertising. Ultimately, the benefits of UAL may outweigh its detriments, but this has yet to be established.

BIOPHYSICS OF ULTRASOUND

Named after H.R. Hertz (1857-1894), a German physicist, the *hertz* (Hz) is a unit of frequency equal to one cycle per second. Ultrasound designates high-frequency sound waves exceeding 20 kilohertz (20,000 Hz = 20 kHz), which are not perceptible to the human ear.

The two types of UAL are internal and external. *Internal UAL* delivers ultrasonic energy directly to subcutaneous fat by a metal rod or cannula inserted through a skin incision. *External UAL* delivers ultrasonic energy to subcutaneous fat by applying a paddle-shaped instrument directly to the overlying skin.

BOX 29-1 DEFINITIONS: ACOUSTIC ENERGY AND POWER

Sound waves consist of longitudinal oscillations of pressure within a conducting medium, such as a gas, liquid, or solid. As a sound wave travels through a medium, it is *attenuated;* that is, the sound wave's intensity diminishes as it is absorbed by the medium. A sound wave's ability to penetrate tissue decreases (attenuation increases) as its frequency increases; the higher the frequency, the smaller the depth of sound wave penetration. Ultrasound is an example of transforming electric energy into kinetic acoustic energy, which in turn is transformed into the thermal energy of the conducting medium as the sound wave is attenuated.

Energy, measured in units of *joules* (J), is a scalar quantity associated with a state or condition of one or more objects. The different forms of energy include kinetic energy and heat energy.

Kinetic energy is associated with an object's state of motion. An object that has mass m and velocity v has kinetic energy $K = mv^2$. In the case of kinetic energy:

$$1 \text{ joule} = 1 \text{ J} = 1 \text{ kg} \cdot (m/s)^2$$

where m/s is meters per second. Kinetic energy is never a negative quantity because m and v^2 are always positive. An object's energy changes when an exchange of energy occurs between the object and its environment. A transfer of energy occurs when a force is exerted on the object or heat is exchanged. The process of transferring energy by means of a force is known as doing work.

Work is defined as the amount of energy transferred to or from an object by means of a force acting on the object.

Work is *positive* when work is transferred to the object. Work is *negative* when energy is transferred from the object to its environment. A kinetic frictional force transforms kinetic energy to thermal energy (heat). Thermal energy is associated with the random motions of atoms and molecules within the object.

Power, measured in units of *watts* (W), is the rate of energy transfer. One watt is 1 joule/second (J/s). In the case of kinetic energy:

$$1 \text{ watt} = 1 \text{ W} = 1 \text{ kg} \cdot m^2/s^3$$

Intensity *(I)* of a sound wave at a surface is the average rate per unit area at which energy is transferred by a wave through or onto the surface. Thus:

$$I = P/A = W/m^2$$

where P is the sound wave's rate of energy transfer (power) and A is the area of the surface intercepting the sound.

Heat *(Q)* is the energy that is transferred between a system and its environment because of a temperature difference between them. Before the midnineteenth century, when physicists finally realized that heat was a form of energy (thermal energy), heat was measured in terms of the *calorie* (cal). One calorie of heat was defined as the amount of heat required to raise 1 g of water from 14.5° C to 15.5° C. As with work, heat is transferred energy. Thus:

$$1 \text{ cal} = 4.1860 \text{ J}$$

Data from Halliday D, Resnick R, Walker J: *Fundamentals of physics,* ed 5, New York, 1997, Wiley & Sons.

Diagnostic ultrasound devices used in obstetrics to assess fetal growth and anatomy operate in the range of frequencies between 2 and 4 million Hz, or 2 to 4 megahertz (MHz). External UAL devices typically use 1 to 3 MHz, whereas internal UAL devices operate in the range of 22.5 kHz.

The power of ultrasound, expressed in *watts* (W), refers to the amount of work done through the ultrasound field as it interacts with the medium in which the sound waves are propagating (Box 29-1). Diagnostic ultrasound devices typically operate at 0.1 to 100 milliwatts (mW). Most therapeutic external ultrasound devices (external UAL) operate in the range of 1 to 50 W, and internal UAL devices deliver 150 W. The intensity (output) of an ultrasound device is the amount of energy it delivers per unit area, or watts per square centimeter (W/cm²).

Increased ultrasound frequency (decreasing wavelength) produces increased heating and decreased depth of penetration. Thus the shorter the sound waves, the greater is local heat production and the greater the risk of focal thermal injury. Clinical evidence indicates that thermal injury to the microcirculation causes microvascular thrombosis.[2]

INTERNAL UAL

Internal UAL consists of the delivery of ultrasonic energy directly into subcutaneous fat via a metal rod inserted through a skin incision.

Europeans were the first to embrace internal UAL. After initial enthusiasm for internal UAL, most European liposuction surgeons eventually rejected it because of an unacceptable incidence of complications. Despite this, internal UAL was subsequently introduced into North America.

The following factors have contributed to the initial success of internal UAL in North America:

1. Consumers believe that "high-tech" is synonymous with high quality.
2. News media were eager to showcase UAL because of the widespread interest in liposuction.
3. Many surgeons purchased UAL devices because UAL was "cutting-edge" cosmetic surgical technology and might attract new patients (customers) in a competitive marketplace.

Thus, despite no objective data showing that internal UAL was superior to tumescent liposuction, and despite the

negative European experience, internal UAL acquired an initial marketing success in the United States.

The reality of internal UAL has subsequently become more discernible. Internal UAL is not necessary for the best results; it is more time consuming; UAL equipment is very expensive; and internal UAL is associated with a more prolonged recovery. Most importantly, I believe the risks of UAL complications outweigh any benefits of UAL. The emerging consensus seems to be that microcannular tumescent liposuction is safer and achieves better results than UAL.

MICROCANNULAR LIPOSUCTION

Internal UAL has few indications because of the risks of cutaneous necrosis. Even for treating relatively fibrous fatty tissue, the most common indication for internal UAL, safer and more efficient ways using microcannulas accomplish the same goals. Fibrous areas of fat are efficiently treated by the skillful use of progressively larger microcannulas.

Patients who are not overweight and who require only limited liposuction in well-defined areas are generally not regarded as good candidates for UAL. UAL is unnecessary in these patients, and the prolonged postoperative healing time with internal UAL is unacceptable.

Most surgeons who advocate UAL may have little or no experience with microcannular tumescent liposuction. One comparison of UAL and traditional liposuction did not employ tumescent liposuction and did not use microcannulas.[ ] For any given form of anesthesia, microcannular tumescent liposuction will allow an experienced surgeon to do liposuction more quickly and more completely than with UAL.

HEMOSTASIS

Less bleeding and less bruising occur with UAL compared with the dry technique, wet technique, or superwet technique. It is not the ultrasound that reduces the blood loss, however, but rather the copious tumescent infiltration required for internal UAL.

Liposuction by systemic anesthesia does not demand complete local anesthesia, and therefore the degree of the infiltration and the subsequent degree of hemostasis are rarely maximal. In contrast, internal UAL demands a compulsively high volume of subcutaneous infiltration, which in turn produces profound hemostasis.

Symbolic logic helps explain the spurious correlation between UAL and hemostasis. For example, suppose U is ultrasound liposuction; M, microcannula liposuction, S, syringe liposuction; T, tumescent technique; and B, better results. If $U + T$, $M + T$, and $S + T$ all produce B, but neither U nor M nor S alone produces B, the critically important factor must be T. It would be illogical to conclude that U or M or S is responsible for B.

The same analysis can be applied to superficial liposuction. For example, superficial liposuction would not be possible without the use of small cannulas, which in turn would not be possible without the tumescent technique (see Chapter 27).

THERMAL TRAUMA

Microvascular Thrombosis. Relatively mild temperature elevations of 41° to 43° C (105.8° to 109.4° F) can disturb the delicate intravascular balance between procoagulant and anticoagulant biochemical reactions, which can precipitate thrombosis. Mild hyperthermal stress in humans, such as 3-minute immersion in a 47°-C (116°-F) bath, decreases fibrinolytic capacity and leads to thrombosis.[4] Heat stroke in humans is associated with coagulopathy.[5,6] In one epidemic of heat stroke, 17 of 55 patients had evidence of disseminated intravascular coagulation (DIC).[7]

Elevation of intravascular temperature precipitates intravascular thrombosis and associated tissue necrosis.[8,9] Heating cultured endothelial cells to 42° C (107.6° F) stimulates release of plasmin inhibitor, which is produced by the endothelial cells, and may contribute to postburn vascular occlusion, leading to secondary progressive tissue necrosis.[10]

Platelet thromboembolism appears to be the major factor causing this progression of postburn dermal ischemia.[11] Thermal trauma causes acute thrombosis and occlusion of vessels in the dermis that is directly injured by thermal energy. A vascular response also occurs in the uninjured dermis bordering the site of injury. Diminished blood flow leads to progressive ischemia and necrosis in the dermis beneath and surrounding the burn.[12] Thermal trauma induces hypercoagulability and hyperfibrinolysis related to organ failure.[13]

Early liposuction surgeons said that liposuction creates a large subcutaneous wound that affects the patient in a manner analogous to a thermal burn. Internal UAL literally creates a large area of subcutaneous microvascular thermal trauma.

Pathophysiology. According to manufacturers' claims, UAL devices simply deliver mechanical (acoustic) energy in a way that lyses adipose tissue cells and thus facilitates the aspiration of the resultant detritus. The amount of heat produced by UAL is not discussed, suggesting that manufacturers believe it is unimportant.

Clearly the risk of thermal trauma is a direct function of (1) the amount of acoustic energy delivered per unit of time (energy intensity) and (2) the amount of energy per unit volume per unit time (energy density). Thus using internal UAL at a low energy per unit time is safer than when UAL delivers a higher energy per unit time; in other words, the less ultrasonic energy, the safer the liposuction. UAL delivers significantly more energy (thermal and acoustic) to subcutaneous fat than microcannular tumescent liposuction.

The relative amount of mechanical energy versus thermal energy delivered to the fat is a function of wavelength. Internal UAL and external UAL operate at different wavelengths. Thus, when internal and external UAL devices are adjusted to deliver the same amount of acoustic energy per unit time, they will not deliver the same amount of heat per unit time.

Based on the fundamental laws of thermodynamics (e.g., conservation of energy, heat flows from hot to cold), the excess energy delivered by ultrasonic liposuction must augment the risk of unwanted tissue damage and surgical complica-

Figure 29-1

A, Multiple areas of full-thickness dermal necrosis after internal ultrasonic-assisted liposuction (UAL). **B,** Results of surgical debridement of necrotic skin. **C,** Appearance of wound contractures after excision sites had healed by secondary intention.

tions. Studies estimate that the temperature of a given fat compartment (e.g., thigh, flank, abdomen) infused with 1 L of tumescent fluid rises 1° F for each minute of ultrasonic energy.[14] Tissue temperatures after internal UAL therefore may correlate with incidence of complications.

In a study of tissue temperatures during UAL the maximum subcutaneous temperature in one of 55 patients was 41° C. The authors state, "The heat generated is a byproduct of the energy transfer, and no heat emanates from the probe tip itself."[15] Analagously, one could state that the heat generated from a carbon dioxide (CO_2) laser is the product of energy transfer, and that no heat emanates from the laser handpiece itself. In either case the ultimate consequence of too much heat is tissue necrosis.

Potential Mutagenicity. High-intensity ultrasonic energy generates high-energy chemical reactions that may have adverse long-term effects on living tissue. The destructive mechanical effects of UAL should be differentiated from the potentially mutagenic chemical effects of free radicals generated by ultrasound. The true oncogenic risk of prolonged exposure to high-intensity ultrasonic energy associated with the use of UAL is not known.[16]

Thermal Relaxation Time. UAL and the CO_2 laser interact with biologic tissue in similar ways. Both are capable of a focused delivery of energy that produces an intense spike in local tissue temperature. The UAL cannula focuses the delivery of its electromechanical energy with 1 to

2 mm of the cannula tip. The CO_2 laser beam focuses the delivery of its electromagnetic energy within a 1-mm to 2-mm spot.

In both cases the concept of thermal relaxation time explains the risk of thermal trauma if the energy is delivered over a prolonged time. Either form of energy can produce a thermal burn or small vessel coagulation.

With either internal UAL or external UAL, the probe that delivers the ultrasonic energy to the subcutaneous fat must not be allowed to linger too long in one location. The probe must be kept in constant motion. The transfer of energy to a local area of tissue over a prolonged interval will lead to thermal trauma and tissue damage.

Burns and Necrosis. Appropriate training and experience are prerequisites for safe internal UAL. Clearly, however, unknown factors increase the risk for UAL-associated skin necrosis. For example, in the patient with a clinically undetected hypercoagulable state, focal areas of excessive UAL-induced high temperatures may precipitate focal vascular compromise and local full-thickness skin necrosis. Among such patients, no amount of UAL training can eliminate increased the risks of a "UAL burn."

The incidence of burns and skin necrosis from thermal trauma or vascular compromise has been reported to be as high as 4%.[17] Advocates of UAL state that temperature increases are negligible if the technique is performed correctly.[18] Training and experience, however, do not always guarantee proper technique (Figures 29-1 and 29-2).
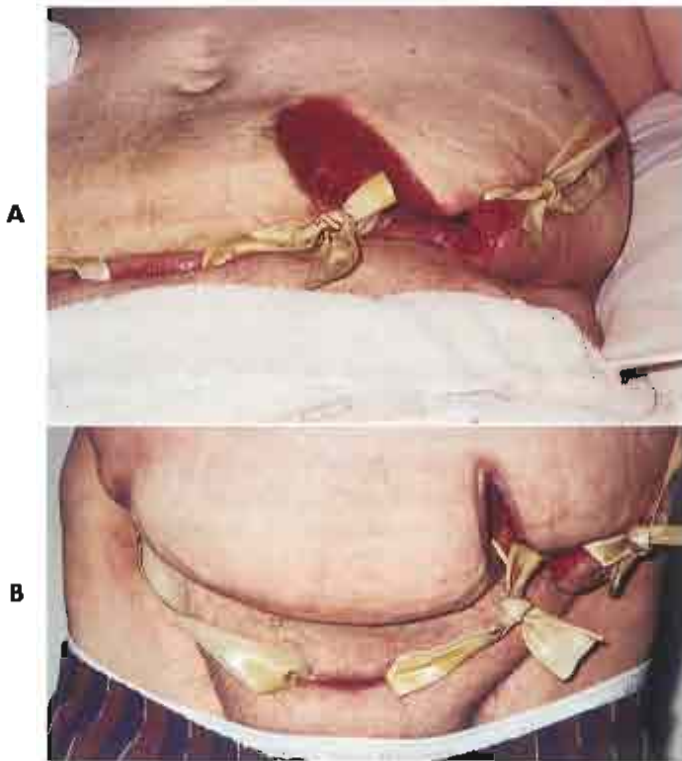
Figure 29-2

Necrotizing fasciitis in 138-kg (304-pound) male after internal UAL of abdomen. Postoperative course was complicated by polymicrobial infection. **A,** Left lower abdomen and pubic areas with drains soon after surgical debridement of necrotic and infected subcutaneous tissue. **B,** Approximately 3 weeks after surgical debridement. Wide excision of multiple areas of skin and subcutaneous tissue was followed by prolonged hospitalization.

Mechanical Versus Thermal.   Traditional liposuction involves the use of a vacuum inside a hollow cannula to aspirate fat. The mechanical trauma of microcannular liposuction is essentially localized to tissue in direct contact with the cannula. In contrast, UAL delivers mechanical (ultrasonic) and thermal (heat) energy that literally radiates beyond the fatty tissue in direct contact with the ultrasonic cannula.

UAL causes thermal damage to cells beyond the range of mechanical trauma. This thermal trauma is not "harmless" and may be associated with delayed healing, excessive inflammation, seromas, prolonged induration, and full-thickness dermal necrosis.

Marketing Conflict.   In general, manufacturers of UAL devices do not provide graphic illustrations of the biologic effects of thermal energy that emanates from a UAL cannula. Deemphasizing the deleterious effects of the heat generated by UAL presents an unrealistic picture.

An uninformed audience might confuse marketing hyperbole with scientific fact. I believe that the surgeon who gives a lecture with illustrations provided by a manufacturer is essentially acting as that manufacturer's spokesperson. This situation could represent a potential conflict of interest. The

conflict of interest is real unless the lecturer makes an effort to provide evidence of the potentially harmful effects of UAL (see later discussion).

SEROMAS

Experts have stated that UAL has a 15% to 70% incidence of seromas. Experience has shown that advancing the internal UAL cannula too slowly or delivering too much ultrasonic energy can result in an unacceptable degree of collateral tissue damage and a high incidence of seromas.

In response to this unprecedented incidence of seromas, one manufacturer has modified its recommendations. The manufacturer has "solved the problem" by recommending that surgeons reduce the amount of internal ultrasonic energy that is delivered to subcutaneous fat. In other words, do less ultrasonic liposuction to reduce the incidence of problems.

EXTERNAL UAL

External UAL is a sequential process involving the following:
1. Infiltration of tumescent local anesthesia
2. Percutaneous delivery of ultrasound energy to subcutaneous fat
3. Traditional negative-pressure liposuction

External UAL is the topical application of ultrasound to the skin under the assumption that the transmission of ultrasonic energy into the subcutaneous fat will improve liposuction.

No convincing data show that external ultrasound provides any clinical benefit. If using external UAL is ineffective, however, at least it is less dangerous than internal UAL.

The external ultrasound machine is essentially the same type of device that has been used for years in rehabilitation medicine and physical therapy. Many surgeons became interested in external UAL after becoming disillusioned with internal UAL.

Typically, external ultrasound is applied after infiltrating the tumescent local anesthetic and immediately before beginning liposuction of an area. For each area treated, applying external ultrasound typically consumes about 10 minutes. Thus, if external UAL on two hips and two outer thighs is planned, an additional 40 minutes of surgical time is necessary for the application of external ultrasound.

UNSUBSTANTIATED BENEFITS

No objective studies support claims that external ultrasound makes liposuction safer, better, or easier. Unsubstantiated claims include that external UAL (1) allows easier penetration of larger liposuction cannulas, (2) promotes dispersion of the tumescent anesthetic solution throughout the targeted fat, (3) is associated with less intraoperative bleeding, and (4) reduces postoperative pain.

All information in favor of external UAL has been anecdotal, with no publication of well-designed, unbiased clinical studies. Presentations at cosmetic surgery meetings consist mainly of enthusiastic testimonials, such as "I've tried this and I'm convinced it is easier" or "it seems that patients like it better."

External ultrasound has also been promoted for postoperative use. Some claim that postoperative applications of external ultrasound, when used repeatedly over several weeks, can decrease postoperative edema and soreness. No unbiased studies, however, have compared the effects of postoperative treatment with external UAL on one side of the body with a sham treatment on the contralateral side.

MANUFACTURER'S WARNINGS

The external UAL device is the same ultrasound apparatus traditionally used by physical therapists. These ultrasound machines are associated with definite risks and dangers. For example, allowing the device to linger over one area of skin can produce a second-degree burn. Also, if the device is applied for too long over a bone, it can blister the periosteum. Surgeons who promote external UAL from the podium at national surgical meetings rarely discuss these risks.

The manufacturers of external ultrasound devices provide instructions that state these devices should not be used over the heart, ovaries, or large arteries (e.g., carotid). Thus manufacturers' warnings would seem to preclude the use of external ultrasound for liposuction of the male chest, the female abdomen, or the submental chin area. If these warnings were followed, external ultrasound would have few applications for liposuction. A surgeon who uses external UAL on the female abdomen probably does not include the manufacturer's warnings when providing the patient with informed consent.

No evidence indicates that external UAL is of any benefit for liposuction of the submental chin and neck. On the other hand, the risk of a carotid embolism after thermal trauma from a local application of external ultrasound is unknown. Is any risk justified with no evidence of objective benefit?

Ethics and Placebo Effect. Without objective evidence that external ultrasound is beneficial, one must assume that it is no more than a placebo. Therefore promoting external UAL may be an unethical conflict of interest. In a elective situation such as cosmetic surgery, deriving financial benefit and profits from promoting a placebo would seem to indicate a financial conflict of interest.

A placebo would also be unethical if its potential complications were not fully disclosed.

OBJECTIVE EVALUATION

An objective evaluation of the external UAL demands an unbiased experimental design in which all participants are unaware of the treatment dose. Thus the patient, the surgeon, and the person who applies the external ultrasound should not know the amount of ultrasound energy applied to any specific area.

In such a "triple-blind" study involving 11 patients, we tested the hypothesis that external UAL has no significant clinical benefit compared with routine microcannular tumescent liposuction. After completion of liposuction, the following information was elicited:

1. The patient indicated which of two treated sides was the most uncomfortable during liposuction.

2. The surgeon indicated the side where liposuction was easiest to perform.
3. The nurse who applied the ultrasound made a visual assessment of the supranatant fat and decided which of two containers of aspirated fat had the greatest amount of blood.

Each patient had ultrasound applied to one symmetric pair of areas, such as both hips or both lateral thighs. Treatments were randomly allocated to either the left or the right side and consisted of 10-minute applications of an external ultrasound device.

One side received a relatively high dose (30 W/cm²) and the opposite side a very low dose (5 W/cm²) of ultrasound. This differential protocol was used to prevent the participants from guessing which side received the significant dosage. If one side received ultrasound and the other did not, the nurse or patient might detect a difference in sensation from the ultrasound.

Results.   Two of 11 patients said the high dose of ultrasound was associated with more pain on liposuction than the low dose. Nine patients indicated no difference.

The surgeon judged liposuction to be easier in two areas treated with high-dose ultrasound and in one with low-dose ultrasound, with no difference in eight patients.

On visual assessment of supranatant fat for evidence of unequal surgical bleeding, the side that received the high dose of topical ultrasound was darker (contained more blood) in one patient. No difference was seen in the remaining patients.

Burn Complication.   Our study of external UAL was terminated when a patient encountered a second-degree burn 2.5 cm in diameter on her hip (Figure 29-3). This burn resolved without significant dyschromia.

Figure 29-3

Second-degree burn after external ultrasound application on right hip of patient who received 3 watts/cm² with 10-cm² paddle (30 watts) after tumescent infiltration and before liposuction. The resulting 2.5-cm lesion resolved without significant postinflammatory hyperpigmentation.

Although this burn might have been avoided with a more fastidious technique, a burn is an obvious risk that should not be ignored. With no objective evidence that external UAL provides any benefit, it was concluded that the risk of an inadvertent second-degree cutaneous burn outweighs any possible benefit of external UAL.

ASSESSMENT

With inadequate or suboptimal tumescent infiltration, external UAL might accelerate the diffusion of the local anesthesia. The increased tissue temperatures might facilitate diffusion. However, this might also increase the rate of systemic absorption.

Tumescent anesthesia is complete with proper infiltration, and thus external UAL would be unnecessary. External UAL provides no significant benefit for liposuction.

COMPLICATIONS AND CONFLICTS

Cosmetic surgeons should be obligated to test the hypothesis that the benefits of UAL outweigh its risks. In principle, establishing that UAL has more risks than tumescent liposuction totally by local anesthesia should be rather straightforward. With the excellent safety record of tumescent liposuction, several reports of significant UAL complications should suffice. I believe, however, that advocates of UAL tend to avoid disclosure of UAL complications.

REASONS FOR UNDERREPORTING

No reliable system exists for reporting adverse events and complications associated with cosmetic surgical procedures (see Chapter 6). Surgeons should be highly skeptical about claims that a UAL device is "safe." UAL complications might not be reported to government agencies or in surgical journals for various reasons (Box 29-2).

BOX 29-2 DISINCENTIVES TO REPORTING COMPLICATIONS OF ULTRASONIC-ASSISTED LIPOSUCTION (UAL)

1. Surgeons and manufacturers want to maintain their reputations.
2. Reports of complications may cause the U.S. Food and Drug Administration (FDA) to restrict sales.
3. If the only significant complication is a death, all other complications are insignificant and need not be reported.
4. Only written accounts of complications must be reported to the FDA.
5. Manufacturers do not survey customers and surgical societies do not monitor members about UAL complications.
6. Reports to the FDA are confidential and are not necessarily made public.
7. Laws prevent voluntary reports of complications.
8. The peer review process is secret.
9. Malpractice settlements are often sealed.

Reputation. Possible harm to one's reputation and exposure to litigation are obvious reasons for surgeons and manufacturers of UAL devices to avoid voluntarily reporting significant surgical complications. This self-protection might be a strong deterrent for candid reporting of UAL complications. Also, as occurred in Europe, if UAL produces too many complications, it will be rejected. To protect the reputation of UAL, manufacturers might downplay reports of UAL complications.

Investigation. The U.S. Food and Drug Administration (FDA) regulates the manufacturers of medical devices and equipment. If a manufacturer has FDA approval to market a surgical device and receives a written report of a serious surgical complication associated with the device, law requires the manufacturer to notify the FDA.

This may result in a time-consuming FDA investigation, a reassessment of the device's safety, and a restriction in sales. Thus a self-serving UAL device manufacturer might attempt to avoid any knowledge of reports about UAL complications.

Definition. To justify not reporting UAL complications, a manufacturer could adopt a policy that (1) a UAL complication need not be reported unless it is "truly significant," and (2) death is the only truly significant UAL complication.

With such definitions, if a complication is not associated with a fatality, it does not qualify as a reportable complication. A manufacturer can plausibly deny knowledge of any "reported UAL complications."

Notification. If the event is not officially reported in writing, it may be regarded as hearsay. Thus, if a manufacturer never receives written notification but merely "hears" about complications from its UAL device, these cases might not be reported to the FDA.

No Surveys. Manufacturers of UAL devices are not required to *actively seek* data on adverse outcomes involving their products.

A manufacturer usually has a list of all surgeons who have bought its UAL device. To my knowledge, however, no manufacturer of UAL devices has conducted a survey of customers seeking information about UAL complications. If a complication is not voluntarily reported to the manufacturer, it may never be reported to the FDA.

No Reporting Requirements. Even if a manufacturer does report a UAL complication to the FDA, the manufacturer is not required to disclose the complication to the public or medical community. The FDA can require public notification, but only under exceptional circumstances. The public remains ignorant about many complications.

Litigation. When a significant UAL complication has occurred, the case will likely be in litigation. Legal constraints thus prevent the surgeon from reporting the event.

Recently, a patient of a nationally prominent advocate of internal UAL developed multiple areas of full-thickness dermal necrosis as a result of UAL. Pending litigation prevented the surgeon from informing his colleagues of this significant UAL complication (see Figure 29-1).

This discrepancy between enthusiastic advocacy of UAL and the underreporting of severe UAL complications highlights the need for caution when judging the safety of UAL.

Results. Even if a surgeon or surgical society wanted to alert the public about surgical complications associated with UAL, the information is simply not available. Based on the previous discussion, surgeons have ample reason to be skeptical when evaluating the safety of UAL.

ANECDOTAL DATA

Case reports of successful applications of UAL are of little statistical value in establishing the procedure's merits and safety relative to other liposuction techniques. A report of one clinician's experience with UAL proves nothing about its long-term safety. In contrast, a few anecdotal reports of severe UAL complications may be sufficient to condemn the procedure.

Reporting Bias. Because of reporting bias, a surgeon's report of no UAL complications is never sufficient to prove that UAL is safe.

Suppose that 10 surgeons have each performed 300 cases of UAL and that one enthusiastic surgeon has had "no serious complications" with UAL. The remaining nine surgeons have discontinued using UAL because of disappointing results, such as local areas of skin necrosis or a higher frequency of seromas, prolonged indurations, or painful recoveries.

The enthusiastic surgeon would likely publish a paper on the benefits and safety of UAL. The nine disillusioned colleagues would want to forget about UAL. Few surgeons are motivated to report their poor results in a journal article.

Thus, without organized epidemiologic surveillance, anecdotal reports may yield an overenthusiastic impression about UAL safety. An unrealistically optimistic view of UAL safety based on insufficient data is not in the best interest of patients.

Cautious Approach. Most evidence presented in favor of UAL is anecdotal in nature. By definition, anecdotal data are statistically biased. In evaluating UAL, these data may be unreliable and susceptible to economic influences.

When the results of a scientific study conflict with an influential group's self-interest, anecdotal data can be used to obscure the facts. If a group's economic interests depend on the successful marketing of UAL, the group might have difficulty being candid about UAL safety.

Thus, again, the surgeon should be cautious in considering anecdotal data in decisions that affect patient safety.

Lack of Studies. The popularity of UAL in the United States is extraordinary, but this is based on marketing rather than objective scientific data. No prospective studies have compared risks and benefits. Instead, the driving force for UAL popularity is media hyperbole and the public's passion for anything "high tech." Rather than relying on convincing scientific data, many surgeons offer UAL merely because patients ask for it.

At cosmetic surgery meetings, discussions are biased. The theoretic effects of cavitation waves on adipose tissue are presented as established fact, whereas comprehensive discussions of the serious complications associated with UAL are usually nonexistent. Complications are dismissed as the result of inexperience and poor training rather than the expected traumatic effects of acoustic and thermal energy.

Typically, after developing a new medical device, the manufacturer provides clinical studies to support the product's safety. Published results of multicenter studies define the types and incidence of complications. This information should allow a physician to decide if the product is safe and effective. In the case of UAL, manufacturers have not presented such information.

SALESPERSON VERSUS SCIENTIST

Whenever the person providing information about the safety and efficacy of UAL is also in a position to profit from the successful marketing of UAL, the profit motive may bias the information. A potential conflict of interest does not rule out that a presenter may provide well-balanced and accurate information. Surgeons must be skeptical, however, and critically examine information about UAL for potential sources of conflicts of interest.

An objective presentation about UAL ought to provide a thorough discussion of its pros and cons. A lecturer who is a salesman would devote most time to enthusiastic support of the product. A lecturer who is a scientist would devote much of any general discussion about UAL to the subject of complications. An audience of liposuction surgeons listening to a lecture about UAL can judge the speaker's objectivity by comparing the amount of time devoted to the benefits and to the risks of UAL.

Any discussion of UAL mechanisms using the applied physics of advanced acoustics must also present information about the thermodynamic inefficiency of ultrasound transmission and its natural conversion to heat energy. A salesperson might attribute the effects of UAL to ultrasonic cavitation and never mention the first law of thermodynamics. A scientist might demonstrate how UAL produces enough thermal energy to cause necrosis.

Because surgeons and manufacturers are naturally reluctant to disclose their complications voluntarily, the scientist must aggressively seek information about UAL complications. The salesperson might avoid a balanced discussion of UAL complications with the statement that UAL complications can be avoided with adequate training and experience.

Potential Conflicts of Interest. As mentioned, in financial aspects of patient care, unethical conflict of interest

might arise when profit motives are allowed to outweigh concerns about patient safety.

Manufacturers of UAL devices do not always have FDA approval to market ultrasonic machines for liposuction.[19] It may be contrary to FDA regulations for a manufacturer or its paid representatives to market UAL machines specifically for liposuction, but it is not illegal for one physician to talk to another physician about the UAL machine.

I believe that many surgeons who promote UAL from the lecture podium or teach UAL courses are intentionally or unintentionally acting as surrogates for the manufacturers in promoting the sale of UAL machines. It is ethical for a physician to act as a spokesperson for a manufacturer provided that (1) all financial incentives are disclosed and (2) patient well-being is given precedence over the profit motive.

A surgeon who has a reputation as an expert or innovator in UAL and travels internationally to surgical meetings as a featured speaker is unlikely to criticize the safety of UAL. If such an influential surgeon downplays the risks of UAL, a professional conflict of interest becomes evident.

If lecturers advocate UAL but avoid a detailed discussion of UAL complications, the audience may receive distorted and prejudicial information that indicates UAL is a relatively benign procedure. Unless equal emphasis is given to the advantages and disadvantages of UAL, the information might create a conflict of interest regarding patient safety.

If money is spent on advertising and promoting UAL, without budgeting for research into the safety of UAL, a financial conflict of interest may result. Surgical societies charging tuition for UAL instructional courses have an obligation to provide prospective epidemiologic data about UAL safety.

It is hoped that UAL will be shown to provide benefits that far outweigh its risks. Unfortunately, no data support this hope at present.

ETHICAL CONSIDERATIONS

The ethics of promoting UAL in North America is open to discussion, especially since UAL has previously been rejected by many European liposuction surgeons. UAL may or may not be more dangerous than traditional liposuction.

Is it ethical to promote UAL as a significant innovation without making an effort to document the safety of UAL relative to liposuction without ultrasound?

Many surgeons have embraced UAL without sufficient knowledge to make an informed decision about its safety. As noted, those who extol its benefits rely on plausible but unsubstantiated arguments.

An internal UAL cannula inserted through a small skin incision delivers enough acoustic and thermal energy to subcutaneous fat that it can cause widespread damage to blood and lymphatic vessels, nerves, and collagenous stroma, as well as adipocytes. An external UAL paddle applied to skin can readily cause a second-degree burn. If the paddle is applied to skin overlying a bony prominence, blistering of the periosteum may occur.

Clearly, external UAL and internal UAL are not entirely benign. The ethical promotion of UAL demands a complete discussion of UAL complications.

AUTHOR'S CONCLUSION

The European experience has shown that internal UAL is less safe than tumescent liposuction. The present state of the art of UAL may not offer sufficient clinical benefits to warrant the significant risks of thermal trauma, seromas, and prolonged healing. Even in the hands of experienced surgeons, serious complications may be associated with UAL and cannot be ignored.

A consensus gentium is a consensus of the people. The consensus gentium fallacy is concluding that a proposition must be true simply because so many people believe it is true (see Chapter 7). Many cosmetic surgeons are enthusiastic about the benefits of ultrasonic UAL. This does not prove that UAL is safe, however, or that UAL is more effective than microcannular liposuction. The liposuction surgeon should remain skeptical until objective evidence confirms the safety of UAL.

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Postliposuction Care: Open Drainage and Bimodal Compression

The goal of postliposuction care is to minimize edema, bruising, and patient discomfort. The postoperative pain and edema resulting from sutured incisions and prolonged postliposuction compression are unnecessary traditions from the days before the tumescent technique.

Early liposuction was so bloody that patients often had to donate and bank their own blood before surgery and receive a transfusion after surgery. Because of this significant bleeding, providing hemostasis and preventing hematomas or seromas were the primary goals of postliposuction external compression. Prolonged high grade compression was thought to be necessary to prevent or diminish the size of hematomas and seromas.

With the advent of the tumescent technique, with its profound vasoconstriction and surgical hemostasis, the imperatives of postliposuction care have changed. Some surgeons, however, are still unfamiliar with the technique of open drainage and bimodal compression.

This chapter explores techniques that minimize postliposuction discomfort and accelerate the patient's return to normal activities. The reader is encouraged to evaluate the suggested procedures by performing simple clinical comparisons between the newer methods of open drainage and traditional methods of sutured incisions.

TRADITIONAL APPROACH

Liposuction causes subcutaneous bleeding and damage to subcutaneous lymphatic capillaries (see Chapter 11). The combination of subcutaneous bleeding and impaired lymphatic drainage entraps large, osmotically active molecules, resulting in prolonged osmotic edema. Any technique for postlipo-

suction care that contributes to this osmotic edema will increase the degree of postliposuction edema, pain, and bruising.

Traditional liposuction and postliposuction techniques often produce an unnecessary degree of prolonged healing and edema, as follows:

1. Incomplete tumescent infiltration leads to subcutaneous bleeding, encourages postoperative subcutaneous inflammation, and augments postoperative edema. The superwet technique is an example of suboptimal tumescent infiltration.
2. Sutured liposuction incisions prevent percutaneous drainage of residual blood-tinged anesthetic solution and encourage subcutaneous edema.
3. Long-term use of high-compression, postliposuction elastic garments compresses and impairs subcutaneous lymphatic capillaries and further blocks lymphatic uptake of large, osmotically active molecules.

A more efficient and effective method is available for postliposuction care.

PREVENTIVE APPROACH

The ideal method for postliposuction care prevents problems before they occur. Prolonged edema, excessive bruising, and persistent inflammation are the most bothersome and most common undesirable sequelae of liposuction. These problems largely can be avoided with a rational, scientific approach to postliposuction care.

One successful method of postliposuction care utilizes open drainage, special superabsorbent pads that provide distributive compression, and bimodal compression.
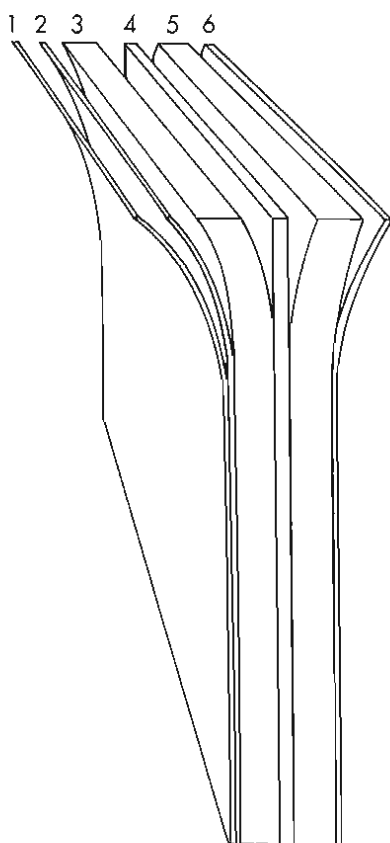
Six layers of compression sponge. *1*, Absorptive layer of non-woven mesh fabric is placed in direct contact with skin. *2*, Dispersion layer consists of meshed fibers that transport fluids laterally. *3*, First sponge layer of cellulose (plant fiber). *4*, Layer of superabsorbent powder (SAP) becomes a gel as it absorbs large volume of water. *5*, Second sponge layer of cellulose (plant fiber). *6*, Impermeable plastic sheet provides waterproof barrier to prevent leakage of liquid onto clothing and beyond.

OPEN DRAINAGE

Open drainage after tumescent liposuction refers to the technique for maximizing the drainage of blood-tinged anesthetic solution through the following:

1. Using adits or minuscule punch excisions to facilitate postoperative drainage
2. Placing adits in strategic locations to encourage gravity-assisted drainage
3. Allowing incisions to remain open instead of being closed with sutures

Open drainage requires the use of superabsorbent, high-capacity, and comfortable absorptive pads.

Compression.   Compression sponges are a combination of superabsorptive sponges and compression pads (Figures 30-1 and 30-2).

Absorptive sponges are required for containment of postoperative blood-tinged drainage. Containing the drainage avoids alarming the patient and prevents staining of clothing
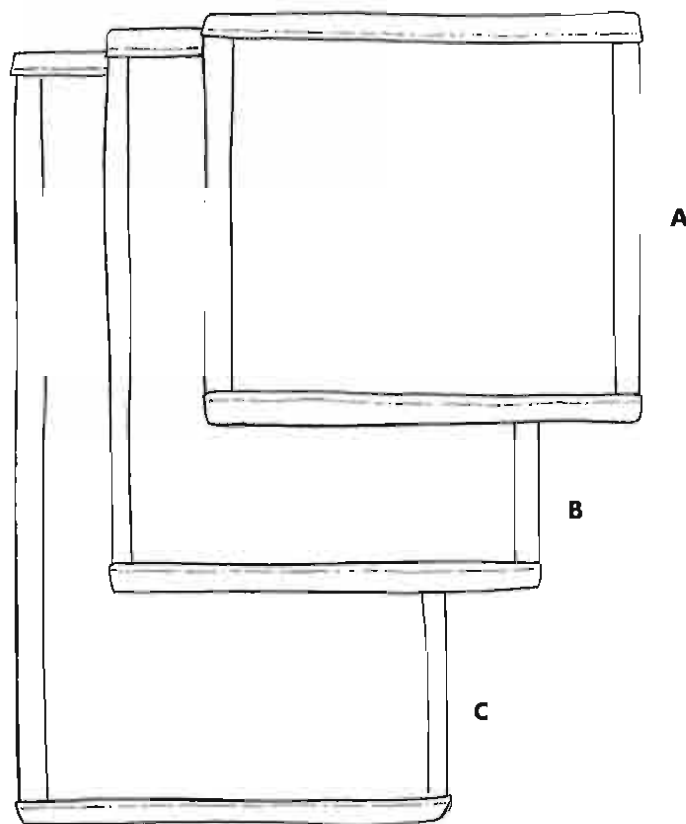
Figure 30-2

Compression sponges of various sizes are available. **A,** 25 × 25 cm; **B,** 25 × 37.5 cm; **C,** 25 × 50 cm. Impermeable plastic sheet backing is wrapped around edges of pad to prevent leakage caused by gravitational forces when patient is upright.

and furniture. Complete absorption and containment of the drainage allows the patient to be mobile and sociable.

The copious drainage after tumescent liposuction requires absorptive pads with a special design. Compared with disposable paper diapers, the post–tumescent liposuction absorptive pads have twice the thickness of absorptive paper pulp and twice the amount of superabsorbent powder (SAP) to provide maximum absorptive capacity (see later discussion).

Compression pads are postoperative cushions placed over liposuctioned areas to distribute the compression provided by an elastic garment in a smooth and uniform manner. Uniform, gentle compression of subcutaneous tissue after liposuction compresses or shrinks the gaps within the interstitial collagen of the dermis. Thus dermal compression prevents bruising by blocking the percolation of red blood cells toward the epidermis.

Technique.   An effective, practical means of applying the compression-absorption pads over the targeted areas is to use a combination of few strips of paper tape and elastic tube netting, similar to the method of applying dressings over burn wounds. After the compression-absorption pads are well positioned, one can apply the elastic compression garment. The optimal garment in this regard must be able to

Figure 30-3

Technique for application of compression sponges and garments. **A,** Immediately after liposuction of abdomen, with patient supine, compression sponges are placed over treated area. Applying paper tape along edges reduces leaking. **B,** Elastic tube netting is applied over compression sponges. **C,** Elastic garment is donned; Velcro strips prevent binders from slipping out of place. **D,** Two elastic binders are placed around torso in overlapping fashion and tightened to degree patient can comfortably tolerate.

accommodate bulk of the pads, and the pads must be easy for the patient to doff and don without assistance (Figure 30-3).

BIMODAL COMPRESSION

Bimodal compression refers to the sequential use of two degrees of postliposuction compression as follows:

1. A high degree of compression is maintained while drainage persists and for 24 hours after drainage has ceased.
2. Mild compression is sufficient beyond the 24 hours after all drainage has ceased.

CLINICAL COMPARISON

Improved postliposuction care using open drainage, distributive compression, and bimodal compression is the result of uncomplicated clinical research. It was developed by comparing different clinical techniques in terms of postoperative edema, bruising, tenderness, comfort, convenience, personal hygiene, and patient preference. The clinical advantages of using open drainage and bimodal compression instead of prolonged high compression and sutured incisions become apparent and make a formal statistical test unnecessary.

Risk Reduction. With early liposuction, cannulas were large and required large incisions, which in turn required sutures for proper healing. With the tumescent technique and microcannulas, incisions are minuscule, and postliposuction healing is better when incisions are not closed with sutures.

Using sutures to close an incision was seen as necessary to prevent infections. Since the advent of nearly bloodless tumescent liposuction, many of the problems that necessitated closure of incisions with sutures no longer exist. Without tumescent vasoconstriction there was a relatively high incidence of hematomas and seromas, which provide an avascular medium for bacterial growth and infection. An open incision was believed to be a portal of entry for an infection.

BOX 30-1 CLINICAL EXPERIMENT: OPEN DRAINAGE VERSUS SUTURES

Every liposuction surgeon must test the assertion that maximizing postoperative external drainage of blood-tinged anesthetic solution will minimize postliposuction edema, pain, and disability. Bilateral liposuction of the outer thighs provides an excellent opportunity for a simple and objective comparison of techniques for postliposuction care.

PROCEDURE

1. On the left outer thigh, after doing routine liposuction, place sutures in all incisions. This will minimize postoperative drainage.
2. On the right outer thigh, place one or more 1.5-mm punch excisions (adits) or routine slit incisions for cannula access. At least one adit should be located distally at the most dependent part of the treated area. To facilitate drainage, liposuction should be done through each adit. For maximal drainage, these adits should remain open without sutures. If such large cannulas are used that all incisions require sutures for proper healing, a few more adits should be placed specifically to facilitate drainage and strategically to maximize drainage.
3. Place superabsorbent pads over the treated area to manage the drainage and prevent leakage onto clothing and furniture.
4. Use an elastic garment to maintain a comfortably high degree of compression until all drainage has ceased (approximately 24 to 48 hours).
5. For the purposes of this clinical comparison, maintain external compression bilaterally for as long as you believe it is necessary.

a. Optimal prevention of edema on the thigh with the adits appears to require bimodal compression: high compression until all drainage has ceased, then mild compression. This mild compression comforts the patient and reduces the prolonged edema.
b. The ultimate cosmetic results are not affected by whether or not compression is maintained after all drainage has ceased.

6. Note that an excessively high degree of compression that is continued even after all drainage has ceased may be counterproductive. Prolonged high compression can impair the lymphatic uptake of edema fluid by compressing the lymphatic capillaries. Excessive postoperative edema of the lower extremities may predispose to deep venous thrombosis.
7. When using open drainage and bimodal compression, continued use of compression garments after drainage is recommended for comfort but is not required.

EVALUATION

To evaluate the two methods of postoperative care (open drainage and closure with sutures), examine the patient twice during the week immediately after liposuction. You can expect to see an obvious difference in edema, ecchymosis, and tenderness. Analogous to the tumescent technique's dramatic reduction of surgical bleeding, open drainage dramatically reduces postoperative edema, bruising, and tenderness. The clinical difference is apparent, and statistical analysis is unnecessary to decide which is the superior technique.

With the tumescent technique, hematomas are rare, and the incidence of seromas is virtually eliminated by open drainage and good compression. Tumescent lidocaine further reduces the risks of infection because residual interstitial lidocaine is bactericidal.

Thus, the tumescent technique has reduced the risk factors for infection, and open drainage further reduces the risks.

Box 30-1 describes an exercise for a bilateral comparison of open drainage and sutures.

POSTTRAUMATIC EDEMA

PATHOPHYSIOLOGY

The trauma associated with tumescent liposuction differs from other types of trauma. The discriminating trauma of tumescent liposuction is controlled and precisely limited to adipose tissue. The superjacent dermis and subjacent muscle are not traumatized.

In contrast, the nondiscriminating trauma of crush injuries or the thermal trauma of burn injuries is typically associated with the third-spacing phenomenon. *Third spacing* results from the massive fluid shift from the intravascular space and interstitial space into the third space of a wound.

The high interstitial hydrostatic pressure and the intense vasoconstriction produced by tumescent technique preclude the occurrence of third spacing. Consequently, no intravenous (IV) fluid replacement is necessary with tumescent liposuction.

The tumescent technique's profound vasoconstriction minimizes trauma-induced hemorrhage, inflammation, and edema. The most significant factors producing edema and inflammation after tumescent liposuction are as follows:

1. Residual blood-tinged anesthetic solution, which contains trauma-induced inflammatory mediators and whole blood (approximately 1% to 2% by volume)
2. Residual traumatized or necrotic adipose tissue

After tumescent liposuction the residual subcutaneous blood-tinged anesthetic fluid contains an excess of osmotically active macromolecules. After the widespread disruption of subcutaneous lymphatic capillaries by liposuction, these macromolecules cannot be resorbed and remain within the subcutaneous wound. The resulting osmotic gradient slowly produces net diffusion of fluid out of the intravascular space and into the subcutaneous wound. The clinical effect of this persistent subcutaneous hypertonic fluid is an insidious, protracted lymphatic edema (Figure 30-4).
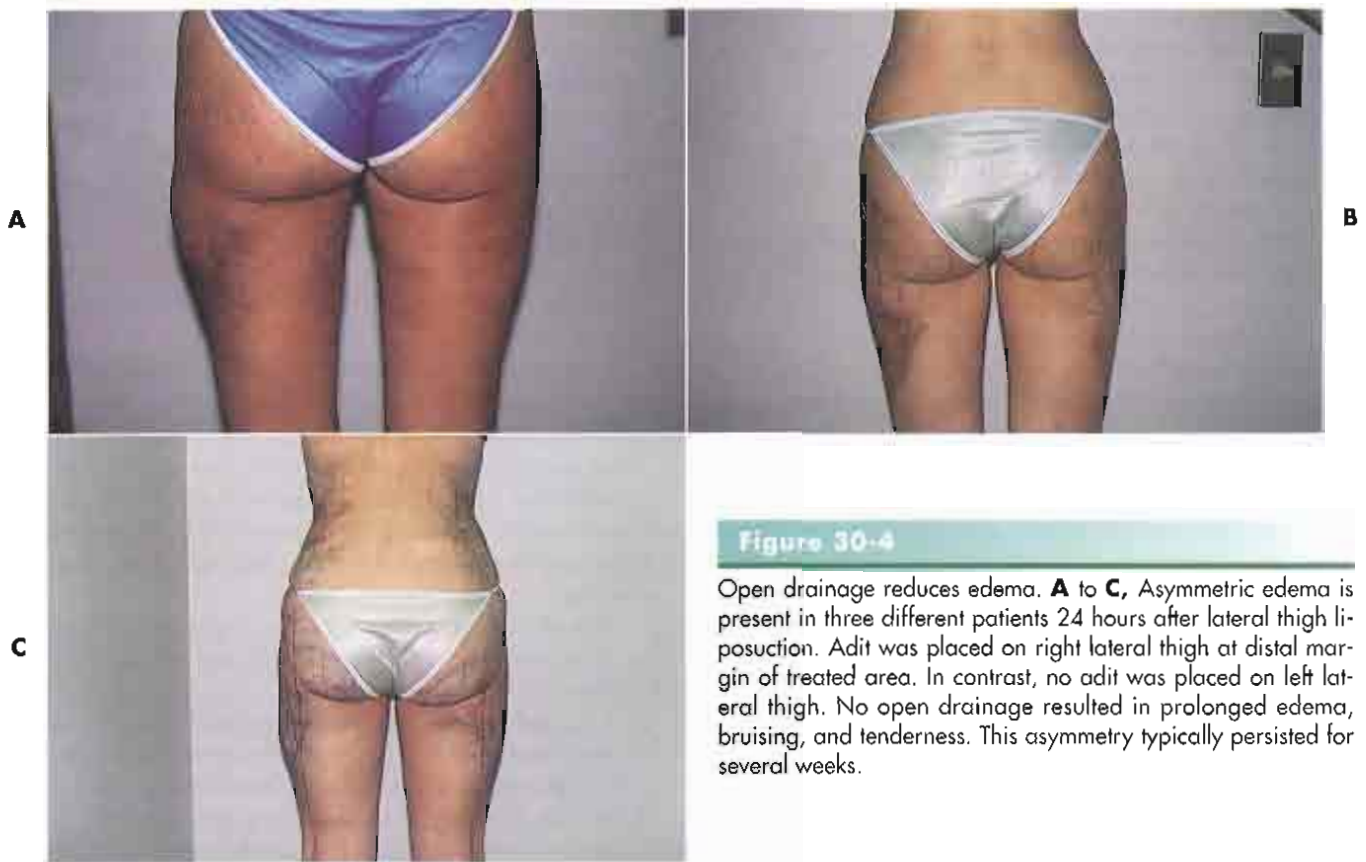
Figure 30-4

Open drainage reduces edema. **A** to **C,** Asymmetric edema is present in three different patients 24 hours after lateral thigh liposuction. Adit was placed on right lateral thigh at distal margin of treated area. In contrast, no adit was placed on left lateral thigh. No open drainage resulted in prolonged edema, bruising, and tenderness. This asymmetry typically persisted for several weeks.

To prevent this posttumescent liposuction edema, the surgeon actively promotes the rapid drainage of the inflammatory hyperosmotic fluid by using adits, leaving the incisions open (without sutures), and using bimodal compression.

PREVENTION OR TREATMENT

Once postliposuction edema has occurred, little can be done to facilitate its resolution safely. Chronic lymphostasis may improve with mild intermittent compression, which augments lymphatic drainage.

For acute postliposuction edema, little evidence supports the assertion that therapeutic maneuvers such as massage therapy, intermittent external compression, or external ultrasound help resolve swelling. The temporary lymphostasis associated with routine tumescent liposuction rarely requires any therapeutic intervention other than early ambulation and physical activity. Postliposuction massage therapy may provide some short-term improvement, but no evidence indicates long-term beneficial effects.

The best approach to dealing with edema is to prevent its occurrence in any way possible. Open drainage and bimodal compression make a dramatic difference by decreasing the immediate postliposuction edema, bruising, and pain.

Even with open drainage, mild edema has its onset after drainage has ceased (Figure 30-5). With or without contin-

Figure 30-5

Prolonged localized pitting edema is common sequela of impaired lymphatic capillary function after trauma caused by liposuction cannula. This type of edema occurs with or without use of open drainage and decreases progressively over 2 to 4 months.

ued compression, this prolonged low-grade edema gradually decreases over several weeks. Because mild compression provides additional comfort during the initial weeks after surgery, some patients continue to wear a mild-compression garment for several days or weeks. Other patients, especially males, find the hassles of wearing an elastic compression garment outweigh its benefits.

Optimal postliposuction healing requires rapid and maximal drainage of blood-tinged tumescent anesthetic solution. This is best achieved by the following:

1. Adits and open incisions (nonsutured)
2. Superabsorbent compression sponges
3. Optimal bimodal elastic compression garments

Adits. A microadit used in tumescent liposuction is a minuscule circular hole made by a tiny (1.0-mm, 1.5-mm, or 2-mm) skin biopsy punch. Adits facilitate and promote the open drainage of residual blood-tinged anesthetic solution associated with tumescent liposuction (see Chapters 27 and 28).

These small skin biopsy punches leave virtually no scars. Thus these punch excisions can be placed over any liposuction area with minimal risk of scarring. Adits are especially helpful over areas such as the thighs and the abdomen, where postoperative edema and bruising can be more pronounced than in other areas.

A 16-gauge or 14-gauge microcannula can easily pass through a 1.5-mm adit. In the thin elastic skin of the female breast, a 1.0-mm adit will accommodate both 16-gauge and 14-gauge microcannulas. Almost no epidermal friction occurs as the microcannula is pushed and pulled through the skin. A 12-gauge microcannula often requires a 2-mm adit. With careful liposuction technique, especially in an area of thin skin such as the inner thigh, a 1.5-mm adit can accommodate a 12-gauge microcannula with minimal epidermal trauma (see Chapter 27).

For the outer thigh the best site for an adit is the most dependent margin of the targeted area. A 16-gauge or 14-gauge microcannula is inserted through the tiny hole to create multiple liposuction tunnels to funnel the postoperative drainage to the adit opening.

The most important advantage to using round adits is that round holes remain patent for a longer period than a slit incision. Round 1.5-mm and 2-mm adits allow better drainage than simple incisions. The edges of a microincision may close and heal before the blood-tinged anesthetic has been completely drained, thus entrapping blood-tinged anesthetic solution in the subcutaneous space.

Several 2-mm punch excisions placed along the lower margin of the abdomen, above the pubic area, allow more drainage than tiny slit incisions. These adits and firm, uniform compression eliminate postliposuction ecchymosis and seromas and dramatically reduce postoperative swelling and tenderness (Figures 30-6 and 30-7).

Even with a large cannula and closure of incisions with sutures, the judicious use of adits provides all the advantages of open drainage. Their strategic use (1) improves the rate of recovery by decreasing the duration of postoperative bruising, swelling, and tenderness and (2) reduces the incidence of seromas and hematomas.

Elimination of Sutures. The most significant advantage of placing adits or eliminating sutures is the dramatic acceleration of recovery and reduction of postliposuction edema. Closing incisions with sutures contrasts greatly with allowing adits or incisions to remain open (Figure 30-8).

Using sutures has few advantages. Closing a relatively long incision with sutures may reduce scar formation. Nevertheless, sutures do not benefit a 4-mm microincision. Some surgeons close incisions with sutures because of a concern that the profuse drainage will alarm the patient and necessitate increased nursing care.[1] With superabsorptive compression pads, however, drainage is no longer a concern.

The advantages of not using sutures include the following:
1. More complete drainage results in less edema, less tenderness, and less ecchymosis.
2. Adits and microincisions (5 mm or less) heal better without sutures because no suture-induced inflammation, foreign body reactions, or cross-hatch scars develop.
3. Patients do not need to return for suture removal.

Patients become less apprehensive about the disconcerting appearance of blood-tinged drainage once it has been explained that the greater the drainage, the less the postliposuction bruising, swelling, and soreness.

Compression Sponges. Compression sponges or pads have two distinct functions. First, they completely absorb the copious tumescent drainage and thus improve patient comfort and hygiene. Containing SAP and cellulose, a 25 × 50-cm (10 × 20-inch) compression sponge can absorb up to 1000 ml of watery fluid.

Second, as noted earlier, these compression sponges or pads distribute the compressive force of an elastic garment over the treated area in a smooth, uniform manner. By uniformly compressing the dermal interstitial collagen, the interstices between the dermal collagen bundles are narrowed, and red blood cells are prevented from moving toward the skin surface. Thus bruising is prevented (Figure 30-9).

Superabsorbent compression sponges eliminate postoperative bruising in a way similar to adhesive-backed, closed-cell foam (e.g, Reston) when applied postoperatively over an area treated by liposuction. Compression pads are superior to foam, however, since adhesive foam must remain on the skin for several days, which precludes showering daily. The compression sponges are replaced once or twice daily, allowing patients to shower. Foam only reduces bruising; compression pads reduce (1) bruising by compression and (2) osmotic edema by facilitating open drainage.
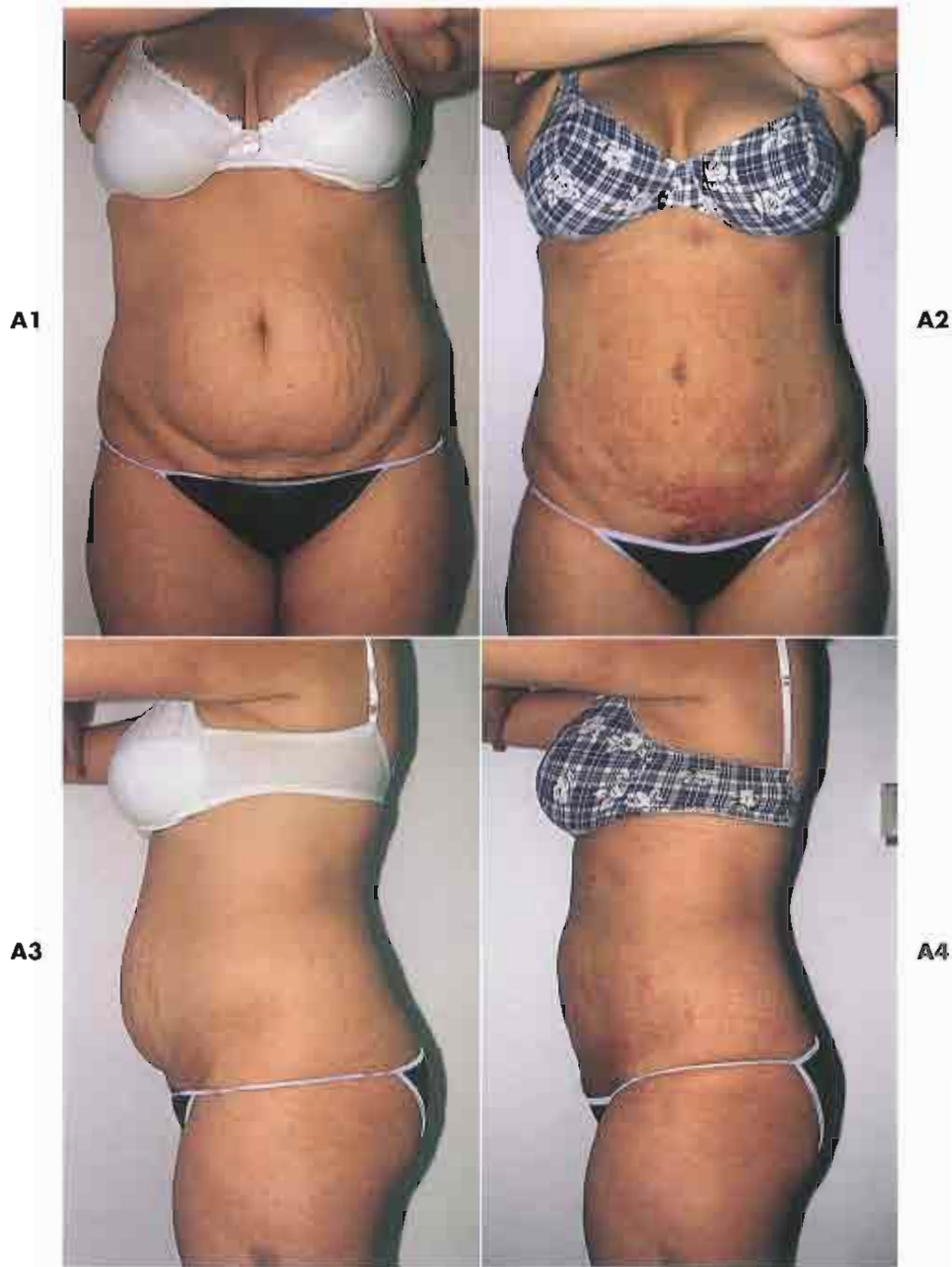
Figure 30-6

Female abdomens. Anterior and lateral views of two female patients before abdominal liposuction and 48 hours after surgery. **A1** to **A4,** First patient.

Continued
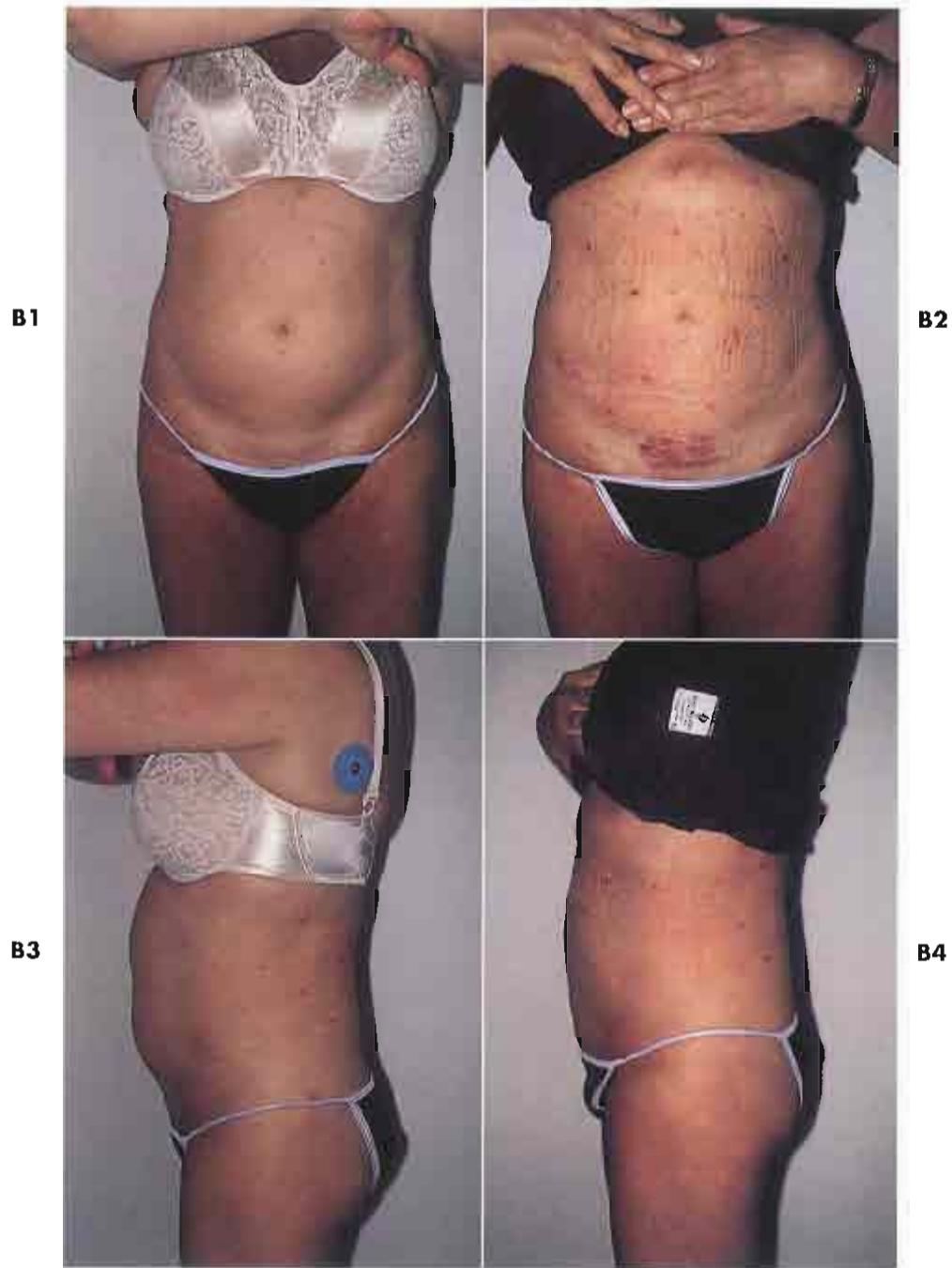
Figure 30-6, cont'd

B1 to **B4,** Second patient. Areas covered by compression sponges show minimal bruising or swelling. Bruising is apparent only on areas not covered by superabsorbent compression pads.

A   **B**   **C**

Figure 30-7

Male abdomen. **A,** Before tumescent liposuction. **B,** Compression sponges, adjustable torso garment, and binders in place immediately after liposuction of 950 ml of supranatant fat. **C,** Use of adits, open drainage, and bimodal compression 48 hours after surgery. Bruising or swelling is minimal except in areas where compression was minimal.

A   **B**

Figure 30-8

Sutures versus open drainage. After liposuction of both lateral thighs, sutures were placed in incisions on left side. Incisions on right side were left open to encourage drainage. **A,** Intense and extensive bruising results from closing incisions with sutures. **B,** Open drainage after liposuction of right lateral thigh results in minimal bruising.

Figure 30-9

Uniform compression prevents bruising. Wherever compression is insufficient, accentuated ecchymosis is more likely. This photograph demonstrates effects from embossed pattern on absorptive surface of old-style absorbent pad. Wherever embossed pattern on sponge's absorptive surface impairs direct contact between sponge and skin, a corresponding pattern of bruising is seen. Ideally, compression sponge provides a uniformly smooth contact surface with skin and resists wrinkling.

POSTLIPOSUCTION COMPRESSION

The tradition of long-term use of high-compression garments after liposuction is a vestige of the earliest days of liposuction during the late 1970s and early 1980s.

HISTORY

Before the tumescent technique, liposuction created a proteinaceous mélange of clotted blood, inflammatory cytokines, prostaglandins, and fragmented adipose tissue. By closing incisions with sutures, this inflammatory detritus was trapped within the subcutaneous wound. Patients were required to endure weeks of being wrapped mummylike in special elastic adhesive "French" tape. Taking a normal shower or bath was not an option. Removing the tape could be so painful that some patients required systemic narcotic analgesia.

Eventually surgeons replaced the use of French tape with high-compression elastic garments. Either type of compression (graduated or uniform) resulted in a high rate of seroma formation, massive bruising, prolonged swelling, and tenderness. The patient's return to normal activity was significantly delayed.

Tumescent liposuction, with its profound vasoconstriction, surgical hemostasis, and use of microcannulas, accelerated postoperative healing and virtually eliminated hematomas. Postoperative care, however, still needed improvement.

MISCONCEPTION OF HIGH COMPRESSION

Chronic venous edema and acute postliposuction edema are different pathophysiologic processes. Leg edema due to venous disease is best treated and prevented by providing *graduated* leg compression beginning at 15 mm Hg, to more than 30 mm Hg distally, and decreasing proximally. In contrast, local edema due to tumescent liposuction can be largely prevented by open drainage and *uniform* (nongraduated) bimodal compression.

It is a misconception that the pathophysiology of acute postliposuction leg edema resembles chronic postphlebitic venous disease. Chronic venous insufficiency is caused by venous valvular incompetence, which leads to venous hypertension and a hydrostatic pressure gradient that favors chronic leakage of intravascular fluid into the interstitial tissues. Acute postliposuction edema is caused by posttraumatic hemorrhage, inflammation, and an osmotic pressure gradient.

This misconception has prompted many surgeons to assume, by analogy, that preventing edema after liposuction requires relatively prolonged, graduated high compression. In fact, high compression may exacerbate postliposuction edema by (1) compressing lymphatic vessels to the point of obstruction and (2) preventing the lymphatic clearance of large molecular and hyperosmolar exudates.

Effects of Excessive Compression. Prolonged high compression is only necessary when drainage is impeded by closing incisions with sutures. With traditional liposuction the subcutaneous voids and tunnels were filled with blood, clot, or hematoma. When traumatic exudate of liposuction is trapped within the subcutaneous space, high compression is unlikely to prevent development of a seroma, although it might impede enlargement of a seroma.

Constant external compression does not increase lymphatic pumping action or facilitate lymph flow. Constant compression applied externally to the skin tends to squeeze the delicate subcutaneous lymphatic capillary, causing the lumen to collapse on itself and preventing interstitial fluid from entering. Thus excessive, continuous external compression may impede lymphatic drainage and exacerbate postoperative edema. Without open drainage the compression delivered by traditional postliposuction garments could be detrimental.

When the interstitial pressure relative to atmospheric pressure is greater than 1 mm Hg, the rate of lymph fluid flow is maximal. Additional external pressure will not increase the rate of lymphatic fluid flow above the plateau value achieved at 1 mm Hg.[2] An external compression garment producing 15 to 30 mm Hg, for example, will not increase the rate of lymph flow.

High compression without open drainage after liposuction may be harmful. In my experience, prolonged high compression that is continued after cessation of all drainage is unnecessary.

GRADUATED VERSUS BIMODAL COMPRESSION

Therapeutic compression after liposuction differs from the type of compression used to treat leg vein disease. Varicose vein treatment requires compression to overcome venous hypertension. Prevention of perioperative deep venous thrombosis (DVT) requires compression to prevent the venostasis associated with the general anesthesia–induced loss of sympathetic vascular tone.

In contrast, compression after tumescent liposuction is used to expel the subcutaneous fluid containing the mixture of blood, fragmented adipocytes, and trauma–induced inflammatory exudate.

Lower extremity venous stasis is treated by a graduated compression garment. Graduated compression is necessary to counter the hydrostatic (gravitational) forces inside veins with incompetent valves.[3] Because the hydrostatic force exerted by a vertical column of fluid increases as a function of the column's length, venous pressure in leg veins with incompetent valves increases distally when the patient is upright. Graduated compression is necessary to counteract the progressive increase in physical forces exerted by fluid contained within the "closed" hydraulic system of the lower extremity.

After tumescent liposuction with open drainage, the goal is simply to maximize drainage. It is not necessary to combat intravascular hydrostatic pressure gradients. Graduated compression is not necessary after tumescent liposuction. For expelling blood-tinged anesthetic solution, open drainage and bimodal compression are more efficient and more comfortable. Bimodal compression garments are easier to apply and remove than graduated compression garments.

Bimodal Technique. Proper postoperative compression after tumescent liposuction requires two degrees of compression applied sequentially. That is, the compression after tumescent liposuction is bimodal. Bimodal compression involves two therapeutic phases: drainage and postdrainage.

Drainage Phase. During the drainage phase, high compression is applied immediately after liposuction to encourage drainage from adits and open microincisions. Uniform high compression maximizes drainage from the suctioned subcutaneous adipose tissue onto the absorptive dressings and minimizes postliposuction edema. With open drainage and high compression the tumescent drainage usually ceases in 24 to 72 hours. After liposuction of an unusually large abdomen or thigh, drainage may persist for several days.

Once all the drainage has ceased, external compression is no longer essential. The ultimate cosmetic result does not depend on continued compression after tumescent drainage has stopped.

Postdrainage Phase. During the postdrainage phase, after all the blood-tinged anesthetic solution has ceased draining, only a mild degree of compression is needed. After external drainage, lymphatic uptake is the only means of clearing the subcutaneous tissue of protein-laden edema fluid.

The function of mild compression is to augment interstitial fluid hydrostatic pressure just enough to counterbalance the increased interstitial fluid osmotic pressure and thereby slow the transudation rate of intravascular water. Mild compression also provides a sense of security during physical activity. For many patients, mild compression offers analgesia and comfort.

TRIMODAL BREAST COMPRESSION

Most areas of the body do not require an exceptionally high degree of compression after liposuction. The breasts are an exception and require extra compression for the first 12 to 18 hours after tumescent liposuction.

This extra compression is necessary for optimal hemostasis. Without adequate external compression immediately after breast liposuction, there is an increased risk of postoperative bleeding, excessive ecchymosis, or hematoma. If the compression is too tight, the patient may experience pain or difficulty breathing.

The solution is to use an adjustable compression garment and apply maximal compression as tolerated. An adjustable compression garment is essential so that the patient can vary the tightness at any time. Special postoperative breast garments are available that allow the patient to adjust the degree of high compression to tolerance (see following physics section).

Immediately after liposuction of the female breasts, the degree of compression should be as tight as the patient can tolerate; this will optimize postoperative hemostasis.

After 12 hours of this extrafirm compression the immediate risk of hematoma and severe bruising is significantly less. Thus the day after surgery, if drainage is still occurring, the compression may be adjusted to a more moderate level.

Ultimately, after all drainage has ceased, the compression is again adjusted to a minimal level that is still sufficient to provide comfort and support.

NEED FOR IMPROVEMENT

The history of liposuction is marked by a lack of objective research directed toward improving postliposuction care. The standard technique consists of first closing all liposuction incisions with suture and then instructing the patient to wear a high-compression garment for 2 weeks or more. I know of no objective clinical evidence to support or justify this form of postoperative treatment.

A strongly held belief in the benefits of closing incision sites with suture and prolonged use of a high-compression garment is not a substitute for objective documentation. Advocates of a specific wound treatment tend to confuse

conjecture with fact and to equate strong conviction with certainty.

Surgeons have an obligation to question ingrained dogma. Every therapy is imperfect and can be improved incrementally. With standard or traditional methods for postliposuction care, "common-sense" beliefs must be validated by the scientific method and improved accordingly.

PHYSICS OF COMPRESSION GARMENTS

Understanding the forces of compression can help surgeons (1) evaluate techniques for postliposuction care and (2) appreciate the benefits of open drainage and bimodal compression after liposuction.

The physical forces acting on a stretched rubber band are the same as those affecting a cross section of a cylindrical compression garment. The analysis of a postliposuction compression garment can be simplified by considering the two-dimensional forces acting on a stretched rubber band.

Definitions

Stretch, or *deformation,* is the fractional or percentage change in the length of a specimen. In mathematic symbolism, stretch $- \Delta L/L$, where L is a unit of length.

In a static system, the elastic force vector *(F)* produced by a stretched rubber band is exactly countered by the force vector necessary to maintain the degree of stretching. The *elastic force* of a rubber band is defined as a force that is equal but opposite to the external force causing a deformation.

Within the range of useful applications, elastic force and stretch are proportional to each other. The constant of proportionality is called a modulus of elasticity *(E)*, resulting in the following equation:

$$\text{Elastic force} = \text{Modulus} \times \text{Stretch}$$
$$F = E\,(\Delta L/L)$$

where $\Delta L/L$ is a dimensionless quantity, and E has the same dimension as force. Within a certain range the elastic force is a linear function of stretch.

If the force or stretch is increased beyond a certain limit, the *yield strength,* a rubber band quickly loses its ability to stretch and becomes permanently deformed. With an additional increment of applied force, the rubber band exceeds its *ultimate strength* and snaps.

Elastic Compression and Applications

Now suppose a rubber band is stretched around a cylindrical body. The magnitude of the force vectors is a direct function of the length of stretch.

In this static equilibrium situation, we know that the vector sum of all the external forces acting on the cylinder must be zero. Also, the vector sum of all the external torques that act on the cylindrical body, as measured at any point, must be

zero. An elastic force vector is the vector sum of a tangential force vector and the perpendicular compression vector. Because the tangential vectors are equal in magnitude but opposite in direction, their vector sum must be zero, and the effect of the two opposed tangential vector forces can be ignored.

We only need to consider the net effect of the *elastic compression vector,* which is equal in magnitude but opposite in direction to the outward force exerted by the cylinder on the elastic garment. It is the compression vector that has true therapeutic significance when an elastic garment is applied to a cylindrical body.

Three interesting consequences of elastic compression have important applications to the use of compression garments.

1. **Compression Sponges Increase Compression.** When a circular elastic band is stretched around any circular cylinder without exceeding the range of elasticity, the greater the radius of the cylinder, the greater is the magnitude of radial (perpendicular) compression. In other words, the magnitude of radial compression at any point on the cylindrical circumference is directly proportional to the elastic force being applied by a stretched elastic garment (the tighter the garment is stretched in a tangential direction, the greater the degree of perpendicular compression).

Thus, for any given garment, the greater the circumference of the cylinder over which it is stretched, the greater is the degree of stretching, and thus the higher the degree of therapeutic compression. The effect of placing bulky compression sponges beneath a garment is to increase the stretch of the garment and increase the effective compression delivered to the patient's body.

2. **Two Garments Are Better Than One.** The effect of two compression garments is additive. Consider two ribbons of elastic fabric A and B having identical length *(L)* and width. If the force required to stretch fabric A over a distance ΔL is half the force required to stretch fabric B over the same distance, A has an elastic modulus with a magnitude half that of B. If two well-fitting compression garments, each having an elastic modulus of 1, are worn simultaneously, their combined compression will be equivalent to a single garment with an elastic modulus of 2.

It is often easier for a patient to don or doff two garments with a low elastic modulus than one garment with a high modulus. Furthermore, when these two garments have a combined modulus that is greater than the single garment, their combined compression is better than the single high-compression garment. Using two garments, each with a modulus of 1.25, is therefore easier and provides more compression than a single compression garment with an elastic modulus of 2.

An elastic fabric with a high degree of resistance to stretching does not necessarily deliver the most effective therapeutic compression.

3. **Degree of Curvature Affects Compression.** The greater the degree (radius) of curvature at a point on a non-

circular cylindrical body, the smaller is the compression vector (at that point) delivered by an elastic band under constant stretch. In other words, the compression vector is inversely proportional to the radius of curvature at any point on a noncircular cylindrical surface. Therefore, for any given cylindrical body at an area of abrupt surface curvature, a small radius of curvature exists, and the garment will produce a relatively high degree of compression. On another area of the same cylindrical body where the surface is flat, the radius of curvature is essentially infinite, and the degree of compression is negligible.

This observation has some useful clinical applications. By effectively decreasing the local radius of curvature, a bulky pad placed over a wound will accentuate the relative degree of compression beneath the pad.

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TUMESCENT LIPOSUCTION BY AREA

CHAPTER 31

Abdomen

The abdomen is the area of the body treated most often by liposuction. It is a high-priority area for both men and women. In terms of surgical anatomy, cosmetic results, patient comfort during and after liposuction, and potential complications, the abdomen is also one of the most challenging of all the areas treated by tumescent liposuction.

The clinical anatomic definition of abdomen is the body's lower cavity, from the diaphragm downward, which contains the stomach, bowels, and other organs of nutrition; sometimes this includes the pelvic cavity. Abdomen may also refer to the belly's outer surface.

ANATOMIC CONSIDERATIONS

Several ways to categorize abdominal fat are relevant to liposuction. For example, the surface anatomy of the abdominal wall can be subdivided into the following areas:

1. Upper abdomen, or epigastric area
2. Lower abdomen
3. Periumbilical area
4. Midabdomen, or waist area

The last area includes the periumbilical area and the area lateral to the umbilicus that overlaps the area between the upper and lower abdomen.

The gross anatomy of subcutaneous abdominal fat can be subdivided into volumes of adipose tissue, such as fascia of Camper (Camper's fascia), sub-Scarpa's fat, and periumbilical fat. Abdominal fat is either *subcutaneous* (located deep to skin and superficial to abdominal wall musculature) or *visceral* (located on the intestines and the omentum).

In very lean individuals the subcutaneous *fascia* is essentially a layered sheet of fibrous tissue containing minimal amounts of fat. With increasing adiposity, yellow fat begins to appear and accumulate within the lamellar connective tissue sheets of the fascia.

In some persons, visceral or omental fat may be relatively more voluminous than the subcutaneous fat. The proportion of visceral fat relative to subcutaneous fat tends to increase with age. This is an important distinction when evaluating a patient for possible abdominal liposuction. Even with substantial fat liposuctioned from an older woman's abdomen, she may be dissatisfied with the results if she has a protuberant lower abdomen due to muscle laxity and visceral fat.

On the other hand, a "beer-bellied" male may have much more subcutaneous fat than suspected after an initial cursory examination. A taut abdomen, apparently of omental fat, may reveal significant subcutaneous lower abdominal fat when the patient is examined in a supine position with the back and hips slightly flexed.

The rectus abdominis muscles underlie the midabdominal fat. The anterior portion of the external oblique muscles underlies the lateral abdomen.

SURFACE ANATOMY

As noted, the surface of the abdomen can be subdivided into lower abdomen and upper abdomen *(epigastrium)*. Occasionally the surgeon must refer to the *midabdomen*, the area encompassing the breadth of the abdomen and a few centimeters above and below the umbilicus. Some patients who have little fat in the upper epigastrium may require liposuction of only the lower abdomen and midabdomen. Other patients, such as women with previous abdominoplasty, may require liposuction of only the midabdomen and upper abdomen.

The surface anatomy of the lower abdomen is dominated by the rounded abdominal "belly." In thin females the skin and subcutaneous tissues of the belly generally are soft and supple to the touch. The visible curvature of a lean female abdomen is gently convex or flattened, essentially reflecting the subjacent musculature of the anterior lower abdominal wall.

Waistline Features. In some relatively obese females the upper and lower abdominal areas are separated by the *waistline sulcus.* This transverse furrow between the upper and the lower abdominal fat pads extends across the abdomen at or just above the umbilical level. Although not usually seen on thin persons, this valley of surfeit is a common superficial anatomic feature of the gourmand (Figures 31-1 and 31-2).

Figure 31-1

A, Various features of abdominal superficial anatomy are highlighted by topographic contour drawings. Upper abdominal fat compartment consists of *1,* supracostal abdominal fat pads; *2,* epigastric fat pad; *3,* lower abdominal fat compartment, which is bounded above by waistline sulcus and below by pubic area; and *4,* inguinal fat pad, which is proximal to inguinal crease. **B,** Preoperative view. **C,** After microcannular tumescent liposuction.

The waistline sulcus coincides with localized increased fibrousness of the adipose tissue. This area of excess fibrousness, present in virtually all patients, is referred to as the *waistline fibrosis* (Figures 31-3 and 31-4). Congruent with the proximal extent of Scarpa's fascia, the waistline fibrosis is a dense combination of collagenous septa and fibrous bands adherent superficially to skin and deeply to the linea alba, anterior rectus muscle sheath, and external oblique muscle.

The extent and density of this transverse abdominal area of fibrosis vary from patient to patient. This fibrotic area requires extra effort to achieve an adequate degree of liposuction.

Upper Abdomen. The *upper abdominal fat compartment* consists of *epigastric fat pads* as well as the more proximal fat overlying the costal margin, the *supracostal abdominal fat pads.* In the obese patient the location of specific large creases and rolls of fat is predictable. The supracostal fat and the more distal epigastric fat may appear as two prominent transverse rolls and furrows.

The fibrous septa of the upper abdomen are more numerous, thicker, and more resistant to penetration than septa and collagenous tissue of the lower abdomen. The upper abdomen is uniformly more fibrous and more sensitive to pain than the lower abdomen. It is also more prone to a permanent postliposuction appearance of irregular lumpiness. Smooth results after liposuction of the epigastrium are more easily achieved using microcannulas than larger cannulas.

Rugosity. With resolution of postoperative edema after liposuction of the upper abdomen, the epigastric skin tends to appear rugose, crepelike, or crinkled. In older patients with decreased skin elasticity, this "crepiness" (rugosity) seems to be the predictable consequence of deflating the upper abdominal subcutaneous fat compartment. Interestingly, lower abdominal skin does not seem to be susceptible to this postliposuction rugosity.

This epigastric rugosity may partly result from the different degrees of flexibility in the thoracic and lumbar spines. The greater flexibility of the thoracic spine allows compression of the upper abdominal skin, whereas the relative inflexibility of the lumbar spine inhibits compression of the lower abdominal skin. The elasticity of Scarpa's fascia might prevent rugosity after liposuction of the lower abdomen.

Pregnancy. Previous pregnancy predisposes to *diastasis recti abdominis,* a condition in which the muscles of the anterior abdominal wall become stretched. This imparts a greater degree of roundness and protuberance to the lower abdomen.

Pannus. A large abdominal panniculus (pannus) usually retracts greatly after adequate tumescent liposuction. Retraction of an excessively large panniculus, however, may be limited or inadequate. *Panniculus adiposus,* a term used to designate subcutaneous fat, is the adipose tissue between the skin and the enveloping aponeurosis. A pannus of abdomi-

Waistline sulcus is most visible in obese patients and is a manifestation of focal subcutaneous fibrosis. **A,** Waistline sulcus is transverse furrow that extends across abdomen at or above umbilical level. **B,** In some patients, waistline sulcus extends around entire torso. **C,** Similar appearance of mother and daughter suggests that abdominal surface anatomy is inherited. **D,** Patient demonstrates that not everyone has waistline sulcus.

nal fat usually refers to an apron of sagging skin and fat on the lower abdomen.

Treatment Considerations. The traditional surgical approach to eliminating an apron of abdominal fat was abdominoplasty (dermolipectomy). The modern approach is first to treat the area using microcannular tumescent liposuction.

In most instances of abdominal obesity, tumescent liposuction provides acceptable or superior aesthetic results, with fewer risks than the traditional "tummy tuck." If a subsequent dermolipectomy with rectus muscle sheath plication is required, it can be accomplished several months later as a delayed secondary procedure totally by local anesthesia. The surgical risk, recovery time, and postoperative disability are significantly reduced by dividing one abdominoplasty, often requiring general anesthesia, into two procedures, both accomplished totally by local anesthesia.

Abdominal liposuction is not ideal for every patient. Liposuction may not provide significant cosmetic improvement for a prospective patient whose principal concern is the elimination of abdominal stretch marks. Similarly, liposuction results may be inadequate for a patient with excessive skin laxity and little subcutaneous fat.
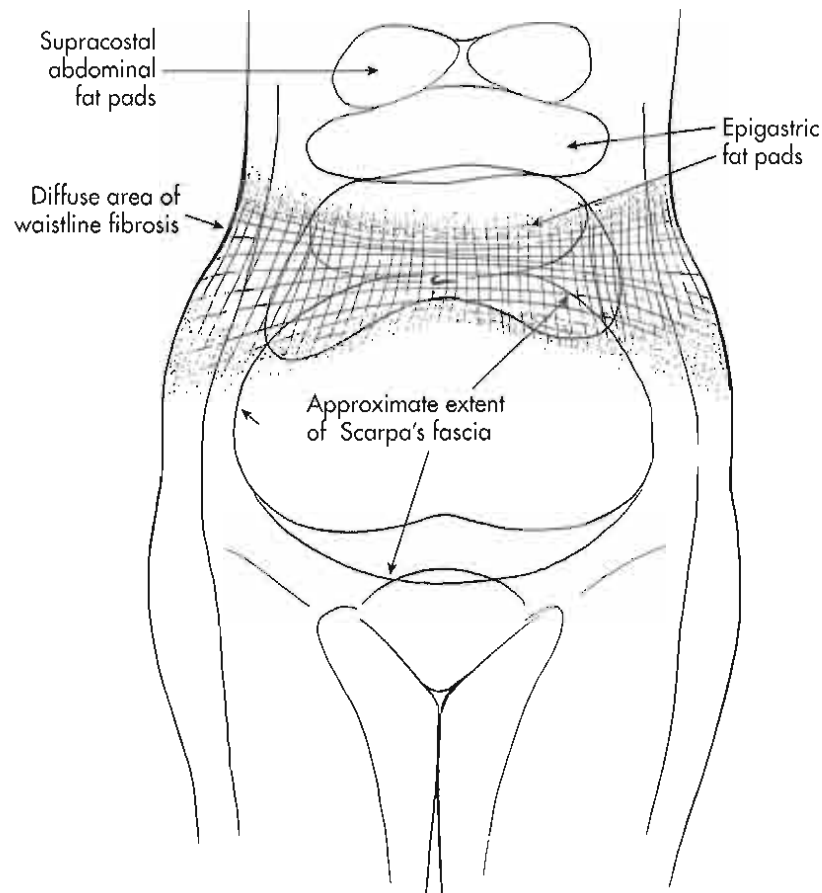
Figure 31-3

Waistline fibrosis is transverse band of fibrous subcutaneous fat that extends across abdomen of most persons. In some obese patients, waistline fibrosis is associated with visible waistline sulcus. Scarpa's fascia is oval-shaped sheet of fibrous tissue that extends across lower abdomen; its proximal extent seems to merge with waistline fibrosis.

GROSS ANATOMY OF SUBCUTANEOUS FAT

The depth of subcutaneous abdominal fat is subdivided into three layers in the upper abdomen and four layers in the lower abdomen. As in most areas of the body treated by liposuction, three layers of fat extend over the entire abdominal expanse: the apical layer, the mantle layer, and the deep fat compartment layer (see Chapter 25).

Apical fat is the most superficial layer of fat. Intimately attached to the deep surface of the reticular dermis, the apical layer of dermal fat contains vascular and lymphatic networks important to the skin's normal appearance and physiologic function. Using a liposuction cannula to rasp the apical fat can cause irreparable injury and inflammation to the subdermal vascular plexus, resulting in erythema ab liporaspiration or dermal necrosis (see Chapter 8).

Mantle fat is a layer of vertically oriented palisading columnar fat pearls that form a blanket of fat attached to the dermis. Dissection or magnetic resonance imaging (MRI) often reveals a thin fibrous sheet of collagenous tissue that separates the mantle layer from the deeper compartment of subcutaneous fat.

An excessively large *deep fat compartment layer* is responsible for the cosmetically unattractive area of focal fat excesses. This compartment is the site of the greatest accumulation of fat in cosmetic lipodystrophy and in obesity. Most of the fat removed by liposuction is derived from the deep compartment of fat.

Camper's fascia is formally defined as the superficial layer of the superficial fascia of the abdomen. For the purposes of liposuction, a more useful definition is the subcutaneous abdominal fat having the following boundaries:

1. The superficial boundary is the apical fat.
2. The deep boundary in the lower abdomen is Scarpa's fascia.
3. The deep boundary in the upper abdomen is the aponeurosis of the abdominal wall muscles.

Camper's fascia extends over the entire area of the abdomen. In the epigastrium, Camper's fascia consists of the mantle layer and deep fat compartment layer. In the lower abdomen, however, an additional layer of subcutaneous fat is located deep to Camper's fascia. This layer is separated from Camper's fascia by a discrete sheet of fibrous tissue known as Scarpa's fascia.
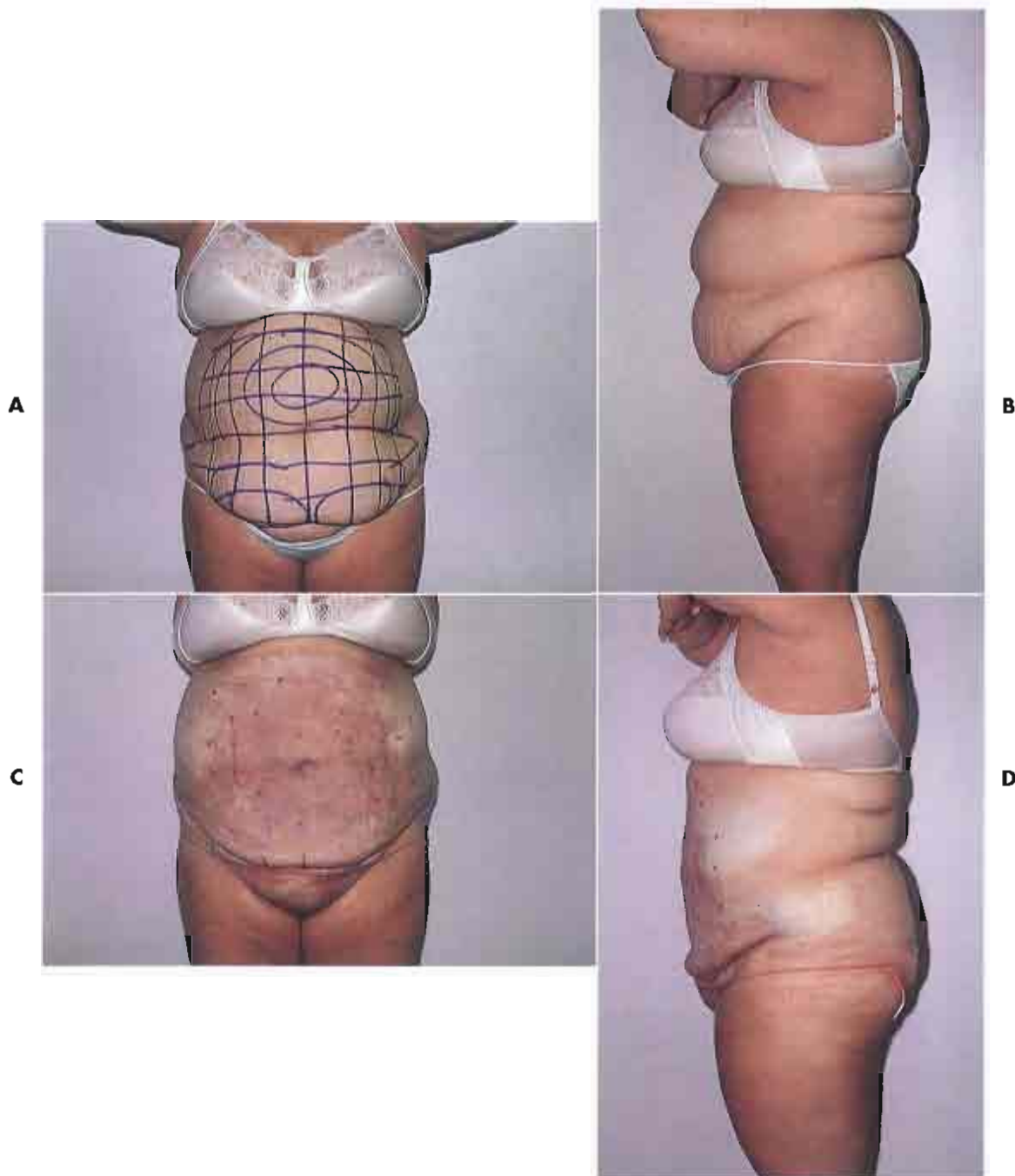
Figure 31-4

Microcannular tumescent liposuction of abdomen can eliminate transverse waistline sulcus. **A** and **B,** Preoperative views of obese patient with prominent waistline sulcus and pendulous lower abdomen. **C** and **D,** Immediately after microcannular tumescent liposuction totally by local anesthesia, waistline sulcus and pendulous lower abdomen are less visible.

Sub-Scarpa's fat is the deepest layer or compartment of fat in the lower abdomen. Sub-Scarpa's fat is separated from Camper's fascia by Scarpa's fascia (Figure 31-5).

Fasciae. The traditional definitions of the subcutaneous fasciae of the abdomen are imprecise and somewhat confusing. Camper's fascia contains fibrous tissue septa, all the deep compartment fat of the upper abdomen, and all the deep fat of the lower abdomen that is superficial to Scarpa's fascia.

Scarpa's fascia extends over the entire lower abdomen and only exists in the lower abdomen. Thin patients have little if any fat between Scarpa's fascia and the aponeurosis of the abdominal wall muscles. Obese patients, however, have a sig-
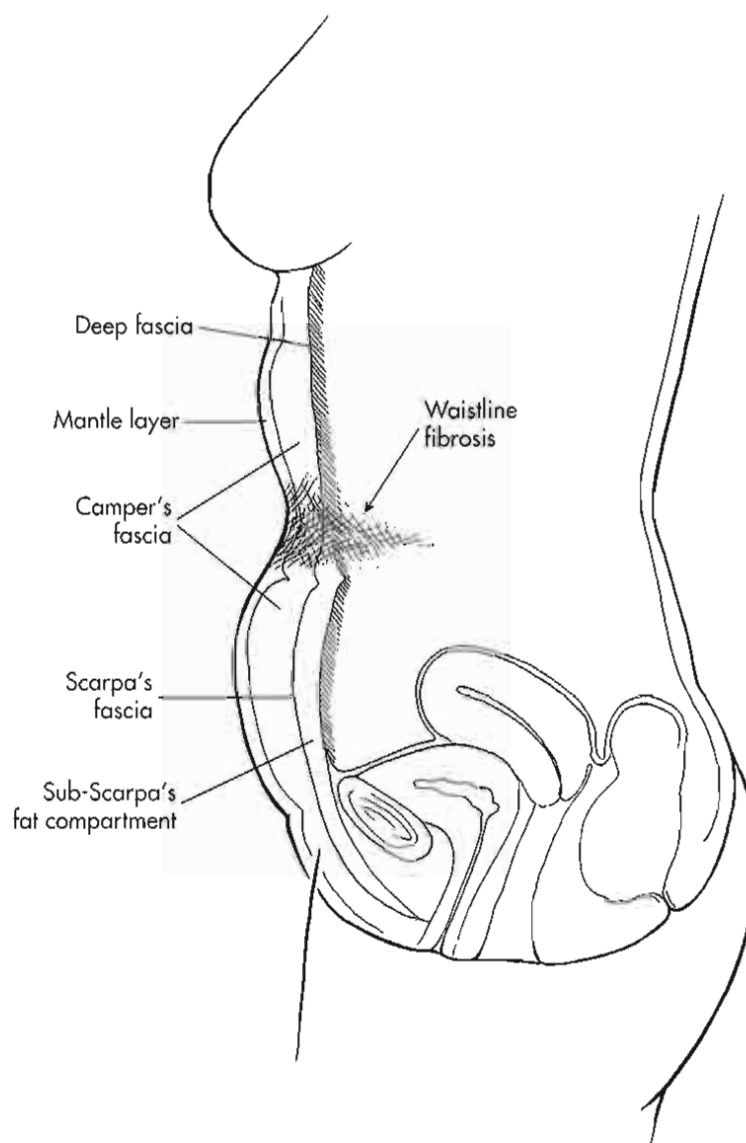
Figure 31-5

Sagittal section through abdomen illustrating important aspects of subcutaneous abdominal adipose tissue (see text).

nificant collection of subcutaneous fat located deep to the plane of Scarpa's fascia (Figure 31-6).

Anatomically, fascia (Latin *fascis,* bundle) is used in several different contexts. *Subcutaneous fascia* designates sheets of fibrous tissue that envelop the body beneath the skin. It includes subcutaneous fat; subcutaneous adipocytes seem to be derived from perivascular fibroblasts of the fascia. Subcutaneous fascia is essentially the layer of subcutaneous adipose tissue (including the collagenous fibrous septa, vasculature, and adipocytes) bounded above by the dermis and below by muscle fascia.

Muscle fascia or *deep fascia* refers to a visibly discrete layer of collagenous fibrous tissue that encapsulates muscles. Muscle fascia, which generally does not contain a significant amount of fat, is distinct from subcutaneous fascia.

SCARPA'S FASCIA

Scarpa's fascia is a fibrous sheet of dense membranous connective tissue within the deeper portion of the lower abdominal subcutaneous fat and is tangentially parallel to the abdominal muscle wall. Scarpa's fascia can be identified on MRI as a thin line within the deep subcutaneous fat, extending across the lower abdomen.

The cephalad (proximal) portion of Scarpa's fascia seems to diverge into the dense fibers of waistline fibrosis just proximal to the umbilicus. The insertion of the proximal extent of Scarpa's fascia actually coincides with the dense waistline fibrosis. Laterally, Scarpa's fascia inserts into the iliac crest and the anteroinferior iliac spine.

The distal fate of Scarpa's fascia has clinical interest for the liposuction surgeon. As Scarpa's fascia crosses the inguinal

Deep fascia of rectus muscle

Anterosuperior epigastric vein
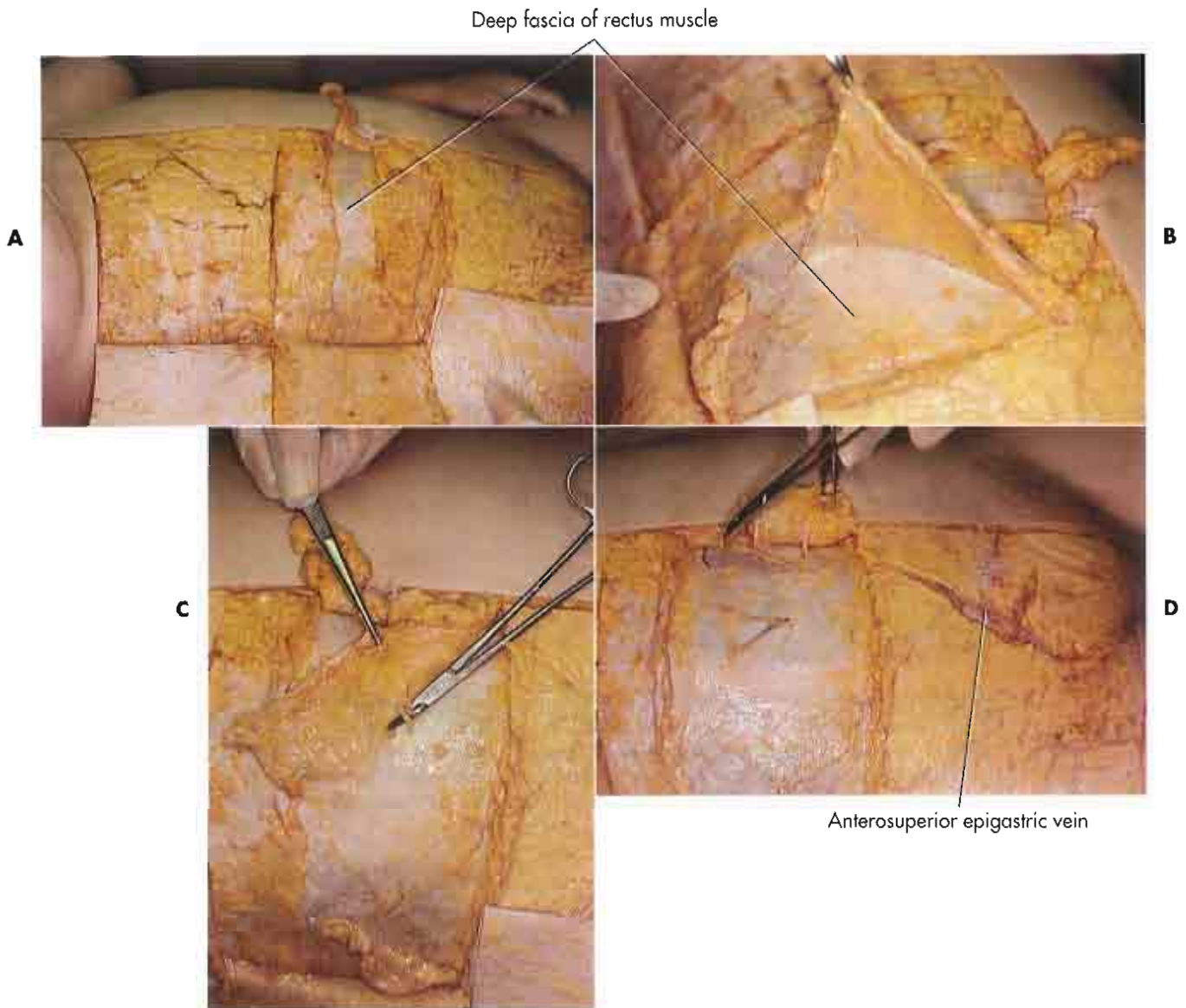
Figure 31·6

Cadaver dissection of subcutaneous abdominal fat. **A,** Subcutaneous abdominal fat is shown divided into three areas. In upper and lower abdomen, skin has been dissected from subcutaneous fat. In midabdomen, dissection has followed a fibrous tissue plane, which is superficial in midline and becomes more deeply located as plane of dissection extends laterally. Deeper dissection through remaining midabdominal subcutaneous fat reveals fascia of abdominal rectus muscle. **B,** Digital dissection along plane at interface between midabdominal fat and fascia of rectus muscle. This plane of dissection is deep to Scarpa's fascia and sub-Scarpa's fat compartment. **C,** Dissection along deep surface of midabdominal subcutaneous fat reveals parasagittal neurovascular bundles. Arterial component of bundles originates deep to rectus muscle from epigastric artery and perforates muscle to supply cutaneous and subcutaneous tissues of medial abdomen. **D,** Further dissection reveals additional arterial perforators. In lower abdomen, anterosuperior epigastric vein originates near saphenofemoral junction and courses superficially to Scarpa's fascia. *Continued*
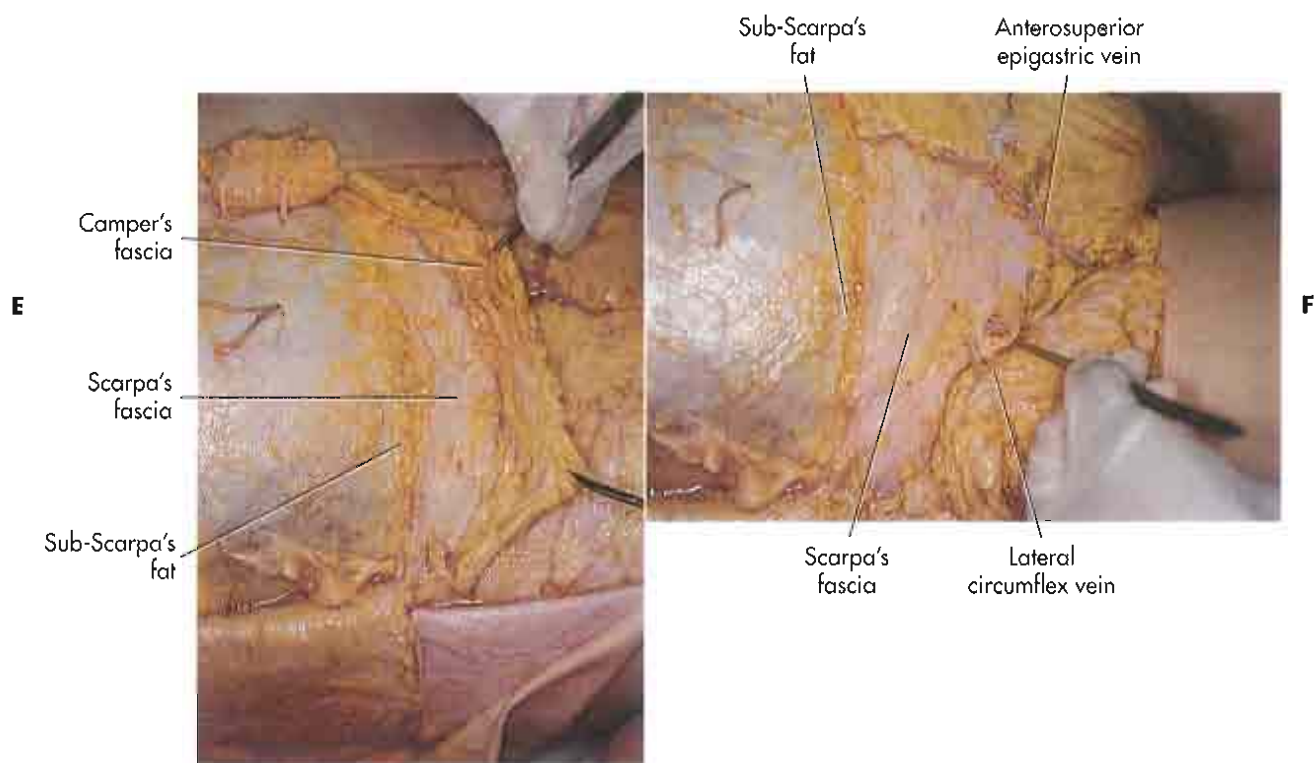
E, Scarpa's fascia extends across entire lower abdomen. **F,** Lateral circumflex vein originates near saphenofemoral junction near origin of anterosuperior epigastric vein. It is shown here as it penetrates Scarpa's fascia midway on its course toward subcutaneous fat near anterior iliac crest.

ligament and extends distally, it merges with the ligament and the deep fascia of the proximal thigh, where it forms a dense attachment. The insertion of Scarpa's fascia 1 to 2 cm beyond the inguinal ligament forms a tightly sealed barrier that prevents distal migration of fluid.

Distally and medially, however, Scarpa's fascia inserts into the deep perineum (Colles' and Buck's fasciae), extending over and enveloping the genitalia. A distal midline condensation of a portion of Scarpa's fascia is said to become the fundiform ligament of the penis.

One purpose of Scarpa's fascia may be the additional weight-bearing function that this elastic sheet provides in supporting the pregnant uterus.

Edema. The location of the fibrous attachments of Scarpa's fascia explains the occasional ecchymosis and edema of the labia or the scrotum and proximal penis after abdominal liposuction. Under the influence of gravity, residual blood-tinged anesthetic solution tends to percolate and seep distally from the abdominal fat deep to Scarpa's fascia, causing more bruising in the midline pubic area than laterally over the anterior thighs.

This bruising is not clinically significant but can be a concern if the patient is not forewarned. To some extent this distal bruising can be prevented by (1) placing several adits or incisions along the inferior margin of the abdominal liposuc-

tion area and (2) establishing multiple drainage pathways through liposuction tunnels not closed with sutures.

The extent of Scarpa's fascia can be identified in the patient with a pelvic fracture and rupture of the membranous urethra. Within hours, leakage of urine into the space deep to Scarpa's fascia will fill and distend the sub-Scarpa's fat compartment with extravasated urine. Clinical examination reveals a distended expanse of the lower abdomen extending from the level of the umbilicus into the perineum, with associated scrotal or labial edema.

Pseudolipoma. A thin patient has little or no fat between Scarpa's fascia and the deeper linea alba, the anterior rectus muscle sheath, and the external oblique muscle fascia. Obese patients always have a layer of fat deep to Scarpa's fascia. The relative amount of fat in the sub-Scarpa's fat compartment tends to be greatest medially and gradually diminishes laterally and distally. Abdominal posttraumatic pseudolipomas may result from a traumatic tear in Scarpa's fascia, with herniation of deeper fat through Scarpa's layer.[1]

Penetration. Liposuction surgeons may have difficulty penetrating Scarpa's fascia with larger cannulas. By squeezing or gripping and tenting the lower abdominal skin and fat with the sensory hand, sub-Scarpa's fat is easily accessible with a microcannula, which readily penetrates fascia.

Figure 31-7

Pseudolipoma on lower abdomen resulting from Pfannenstiel's incision. This common transverse incision, approximately 2 cm above symphysis pubis, provides excellent access to pelvic contents.

Pfannenstiel's Incision.   Scarpa's fascia does have cosmetic significance. Pfannenstiel's incision refers to the transverse lower abdominal incision typically used for cesarean sections and abdominal hysterectomies. The surgeon advances the incision down through the external sheath of the recti muscles, then splits or separates the muscles in the direction of the fibers. The peritoneum is opened at the sagittal midline.

A common complication of Pfannenstiel's incision is a persistent focal transverse bulge of subcutaneous fat proximal to the incision. Although liposuction can repair this annoying but harmless deformity, it might be preventable. The pseudolipoma may result partly from traction on the skin when the incision is made and partly from not approximating and suturing the transverse incision through Scarpa's fascia when repairing a surgical wound. The elastic recoil of the fascia produces a cephalad migration of subcutaneous fat.

Layered closure of the subcutaneous fat at the level of Scarpa's fascia may reduce the incidence of this iatrogenic pseudolipoma (Figure 31-7).

ABDOMINAL BLOOD VESSELS

Blood vessels located within abdominal subcutaneous fat may be traumatized by liposuction (Figure 31-8).

The *anterosuperior epigastric veins* originate near the junction of the respective saphenous and femoral veins and course through the medial lower abdomen. The veins are bilateral, travel in a cephalad and medial direction toward the umbilicus, and are located above Scarpa's fascia (Figure 31-6, *D*).

The *lateral circumflex veins* are also bilateral and originate near the saphenofemoral junction. They travel in a cephalad and lateral direction, extending toward the superior and lateral aspect of the iliac crest. The lateral circumflex vein penetrates Scarpa's fascia at a point approximately half the distance between the pubis and the anterior iliac crest and terminates in the superficial subcutaneous abdominal fat (Figure 31-6, *F*).

The other important vascular structures are the *paramedian neurovascular bundles* that penetrate the rectus muscle of the median abdominal wall near the lateral extent of the linea alba. These arteries supply the skin and fat of a transverse rectus abdominis myocutaneous (TRAM) flap used for breast reconstruction after mastectomy. With the use of microcannulas, these vessels rarely are traumatized by liposuction.

Bleeding and Hematoma.   The anterosuperior epigastric or lateral circumflex veins may be either punctured during tumescent infiltration with spinal needles or lacerated by a liposuction cannula. Bleeding from these veins during tumescent liposuction seems to cause no significant problem.

Infiltration with a spinal needle in the region of these veins rarely causes minor bleeding from a cutaneous entrance site. To stem this slight amount of bleeding, the clinician simply infiltrates an additional volume of tumescent anesthetic solution into and around the immediate area.

Similarly, focal bleeding during liposuction may be evidenced by increased redness of the aspirate. If an unusual degree of bleeding occurs during liposuction of a localized area of fat, the surgeon simply ceases further liposuction in that area. Occasionally, brief application of direct pressure might be required. If additional liposuction in the area is needed, it can be accomplished on another day.

Two of my patients had clinical evidence of a hematoma after liposuction. In both the bleeding probably resulted from a cannula-induced injury either to a small artery associated with one of the paramedian neurovascular bundles or to the rectus muscle.

In an obese male with adult-onset, non-insulin-dependent diabetes mellitus, I noticed the bleeding during surgery and terminated the procedure before completion. Preoperatively the patient denied taking aspirin; postoperatively he admitted taking "baby" aspirin. The bleeding stopped with direct pressure. After surgical consultation the patient was monitored overnight. Although not evident immediately, the patient eventually developed a small area of necrosis in the left lower periumbilical area (see Chapter 8).

Case Report 31-1 describes my second bleeding case.

Neither patient required direct surgical intervention for hemostasis. Both were managed conservatively, and surgical consultation was obtained. Bleeding was controlled by direct manual pressure over the apparent site of bleeding for approximately 1 hour. Then, for another 24 to 36 hours, continuous firm pressure was applied to the affected area by absorption-compression pads and abdominal binders.
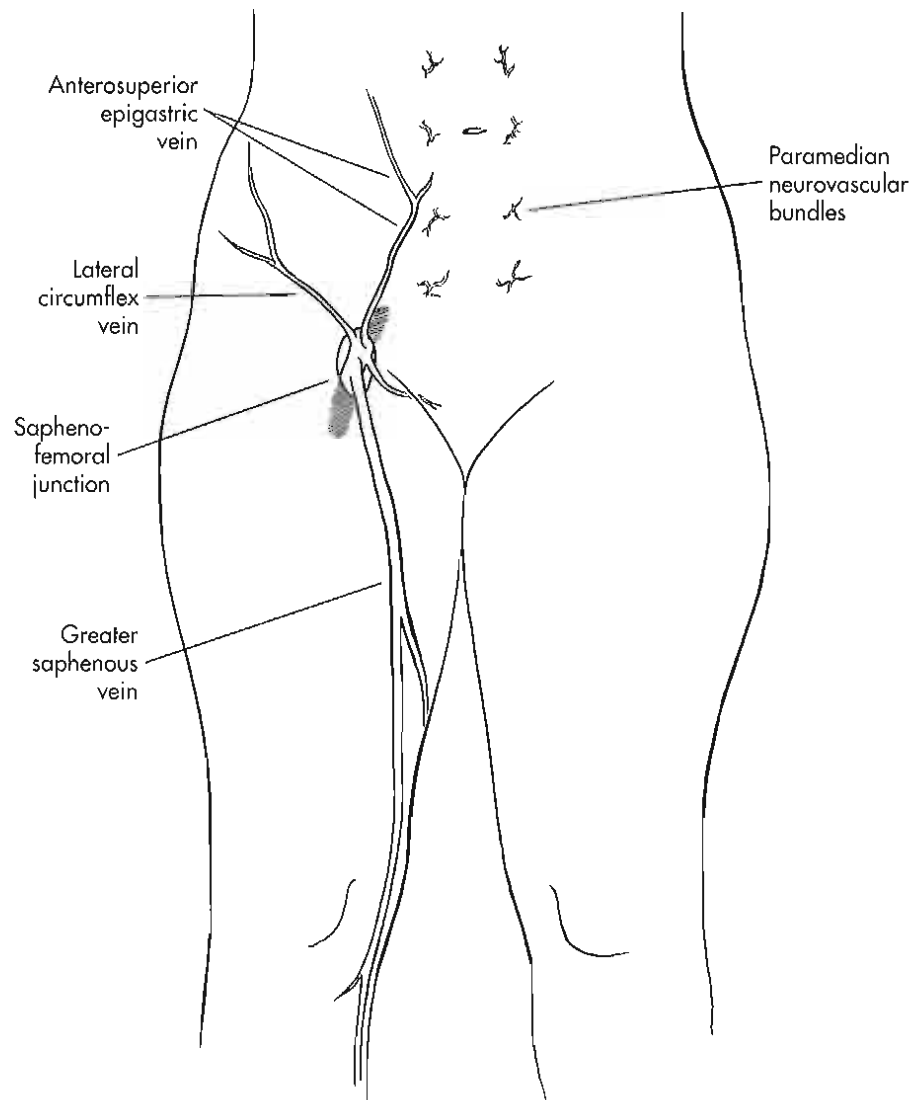
Figure 31-8

Abdominal blood vessels of clinical importance for liposuction surgery include anterosuperior epigastric veins, lateral circumflex veins, and paramedian neurovascular bundles.

CASE REPORT 31-1   Bleeding Associated with Abdominal Liposuction

I had done abdominal liposuction for this female patient years earlier with very good results. On several occasions I denied her requests for additional abdominal liposuction simply because there was little room for improvement. Ultimately, I acquiesced, thinking that the risks were minimal.

The repeat liposuction was notable only for an unusual degree of fibrosis around the umbilicus. I noticed no bleeding during surgery. Immediately after surgery, however, bleeding from several adits became evident. I noted a small hematoma approximately 5 cm lateral and distal to the umbilicus. Eventually the bleeding stopped after direct manual pressure and

application of firm abdominal compression with pads and abdominal binders.

After surgical consultation the patient was admitted to the hospital for observation and discharged home the next day. After surgery I learned of her severe periumbilical infection as a newborn; the degree to which this caused excessive fibrosis and contributed to the bleeding is uncertain. In retrospect, my decision to do more liposuction was inappropriate.

Discussion. See text.

Figure 31-9

Umbilical hernia of significant size represents increased risk of liposuction injury to intraabdominal viscera and should be repaired by a general surgeon at least 8 weeks before liposuction. **A,** Cadaver dissection reveals umbilical hernia and demonstrates small distance between subcutaneous fat and intraperitoneal extension of hernia. **B,** Subtle bulge of umbilical hernia is visible within this patient's umbilicus.

PREOPERATIVE EVALUATION

The preoperative evaluation for patients contemplating abdominal liposuction must include an assessment for the following:

1. Diastasis recti abdominis
2. Umbilical, periumbilical, and ventral hernias
3. Prior obesity and subsequent weight loss
4. Degree of intraabdominal, visceral, or omental fat
5. Previous abdominal surgeries
6. Any history of abdominal liposuction
7. Breast augmentation with prosthesis or by injection of silicone into tissues

The consequences and relevance of these findings must be thoroughly documented and discussed with the patient.

The preoperative physical examination should always document the presence or absence of a periumbilical or ventral hernia. A hernia may increase the risk of inadvertent penetration of the peritoneal cavity during liposuction.

An abdominal hernia may require repair by a general surgeon at least 8 weeks before abdominal liposuction (Figure 31-9). Typically a ventral hernia repair is a simple procedure accomplished under local anesthesia.

The curvature of the abdominal wall musculature largely determines the "flatness" of the abdomen after liposuction. Separation of the abdominal rectus muscles as a result of pregnancy limits the degree of improvement. Nevertheless, the vast majority of patients with diastasis recti abdominis are ultimately very satisfied with results obtained by liposuction alone. Most patients, including those with some diastasis, do not "need" an abdominoplasty to achieve a gratifying cosmetic improvement.

The prospective patient should be questioned about prior abdominal surgery, including laparoscopic procedures. The location and extent of scars from prior surgery should be noted.

Prior abdominal liposuction using inadequate tumescent vasoconstriction and sutured incisions increases postoperative inflammation, causing interstitial fibrosis within the treated fat.[2] Subsequent liposuction will be more difficult because of this excessive fibrosis.

ABDOMINOPLASTY

Tumescent liposuction with microcannulas has proved to be so effective that abdominoplasty is now rarely indicated. After an abdominal liposuction, very few patients require or desire abdominoplasty, even those who have had 2 L or more of supranatant fat suctioned from the abdomen. In the vast majority of patients who have a pendulous lower abdominal panniculus, tumescent liposuction provides a better and more natural cosmetic result than an abdominoplasty.

Indications for abdominoplasty are subjective. A surgeon might recommend an abdominoplasty for the following three reasons:

1. Extensive diastasis or spreading of the abdominal rectus muscles as a result of pregnancy
2. Excessive striae or stretch marks
3. Surgeon's unawareness of the excellent results from liposuction without abdominoplasty

Liposuction alone will not always provide complete satisfaction. Ultimately the patient's opinion of the cosmetic results depends on multiple factors, including (1) the patient's expectations, (2) the patient's preoperative cosmetic deficien-

cies, and (3) the surgeon's technical skills and technique. Thus the results are never completely predictable.

TWO-STAGE PROCEDURE

When an abdominoplasty is indicated, it is safer to separate the traditional surgery into a two-stage procedure. In many patients a two-stage tumescent abdominoplasty can be accomplished totally by local anesthesia.

The first stage is tumescent liposuction. Several months later the patient is reevaluated. The relative merits of abdominal skin resection and rectus muscle plication are discussed. When indicated, the second stage of abdominoplasty can usually be performed totally by local anesthesia using the tumescent technique. General anesthesia is only necessary for the most challenging cases.

The surprising aspect of using this two-stage approach to abdominoplasty is the high degree of satisfaction that patients find from liposuction alone. The vast majority of patients decide not to pursue the second-stage skin resection.

Abdominoplasty is becoming an anachronism.

OPTION: TUMESCENT TECHNIQUE

"Only a tummy tuck will do justice to a patient with a pendulous apron of abdominal fat."

This dogma is obsolete. Microcannular tumescent liposuction has largely eliminated the need for routine abdominoplasty. For many patients with a pendulous apron of abdominal fat, tumescent liposuction offers better cosmetic results, a quicker recovery, and fewer risks compared with traditional abdominoplasty under general anesthesia (Figures 31-10 and 31-11).

For patients with moderate abdominal obesity and good abdominal muscle tone, tumescent liposuction is a better choice than abdominoplasty (Figures 31-12 to 31-14).

A thin female may require an abdominoplasty only when rectus muscle laxity is excessive or when stretch marks are the major cosmetic concern. Abdominal liposuction is almost always a better option (Figure 31-15).

Liposuction of the male abdomen yields excellent results. Male patients rarely require an abdominoplasty (Figure 31-16).

Patients should be informed an option now exists to the traditional abdominoplasty that is safer and often yields better cosmetic results. Compared with microcannular tumescent liposuction, tummy tucks are associated with a relatively higher risk of dermal necrosis, fat embolism, pulmonary thromboembolism, and other serious complications of major surgery. A large, unsightly scar is often a consequence of abdominoplasty (Figure 31-17).

INTRAOPERATIVE POSITIONING

For patient comfort and ease of access to the targeted abdominal fat, the patient is ideally placed in a reclining posi-

tion, with the abdomen slightly flexed. In this supine cernuous (bowing downward) position the patient is lying on the back, bent slightly at the hips and knees, in such a way that the torso is slightly inclined forward relative to long axis of the thighs (Figure 31-18).

A flat supine position causes the patient's lower abdominal skin and subcutaneous fat compartments to become taut, making it difficult to grip the tumescent abdominal fat. When the abdominal fat is firm and taut, it is more difficult to palpate the interface accurately between the abdominal fat and abdominal muscles, decreasing the likelihood of adequate liposuction for the deeper abdominal fat.

On the other hand, if the patient's abdomen is flexed too much, the position of the thighs will obstruct the cannula's in-and-out motion. Furthermore, excessive abdominal flexion compresses the subcutaneous fat, making the tissues difficult to grip and impeding accurate assessment of the uniformity of the liposuction process.

I prefer to have the patient's abdomen slightly flexed during the initial phase of the procedure, when the cannulas are directed transversely or diagonally across the abdomen, using 16-gauge and 14-gauge Capistrano microcannulas.

Toward the end of the procedure, 14-gauge and 12-gauge microcannulas are used. At this stage the patient is placed in a flat supine position to facilitate strokes of the cannula that are parallel with the long axis of the body and to avoid interference from the thighs.

With an alert and fully awake patient, it is advisable to gently restrain the patient's hands to prevent inadvertent contamination of the surgical field. A preferred method is to drape a towel over each side of the table and then have the patient recline on top of the towels. With the patient's arms at the side, the towel is brought up over the arms and tucked under the patient's hips. Patients should not feel too confined because the arms are readily extricated from this position by simply raising the hips and thus loosening the towel.

ANESTHETIC INFILTRATION

The abdomen can be one of the most difficult areas of the body to infiltrate. The abdomen is sensitive, and awake patients feel more vulnerable and anxious. The periumbilical area especially requires proper infiltration technique, since this tissue tends to be more fibrous and more sensitive. Adequate liposuction demands additional effort, and insufficient anesthesia may lead to inadequate liposuction of the periumbilical area.

It is more difficult to infiltrate the abdomen adequately in a patient who has previously lost considerable weight, such as 25 pounds (11 kg) or more. After significant weight loss, residual fat compartments are potentially more capacious than might be predicted based on present physical size. Compared with a patient whose weight is at a lifetime maximum level, a patient who has lost substantial weight has flabbier skin and can accommodate larger volumes of tumescent

Figure 31-10

A, Total of 2500 ml of supranatant abdominal fat was removed from patient's abdomen using microcannular tumescent liposuction totally by local anesthesia. Largest cannula used was 12-gauge Capistrano microcannula. **B** and **C,** Preoperative views. **D** and **E,** After tumescent liposuction. Abdominoplasty was unnecessary.

Figure 31-11

This patient had been told that abdominoplasty under general anesthesia was only option for removing pendulous apron of fat from her abdomen. After tumescent liposuction totally by local anesthesia, patient decided that skin excision was unnecessary. **A** and **B,** Preoperative views. **C** and **D,** Two months after tumescent liposuction.

Figure 31-12

After tumescent liposuction of abdomen, this patient decided further surgery was unnecessary. Residual laxity of skin was insufficient to warrant skin excision, even though secondary excision and rectus muscle plication could be accomplished totally by local anesthesia. **A** and **B,** Preoperative views. **C** and **D,** Six weeks after tumescent liposuction.
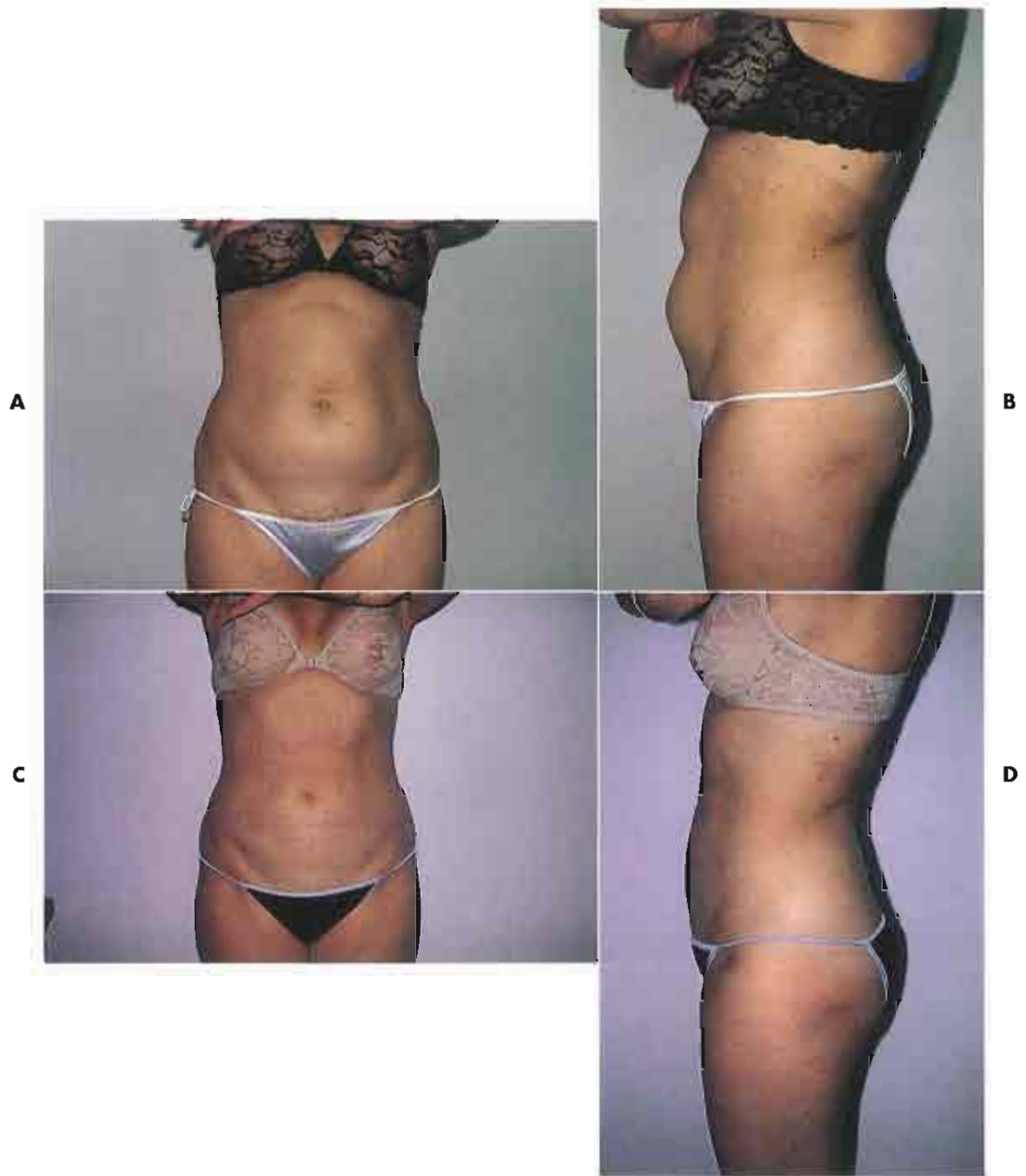
Figure 31-13

Liposuction can be accomplished with minimal scars. **A** and **B,** Preoperative views. **C** and **D,** Two months after tumescent liposuction.
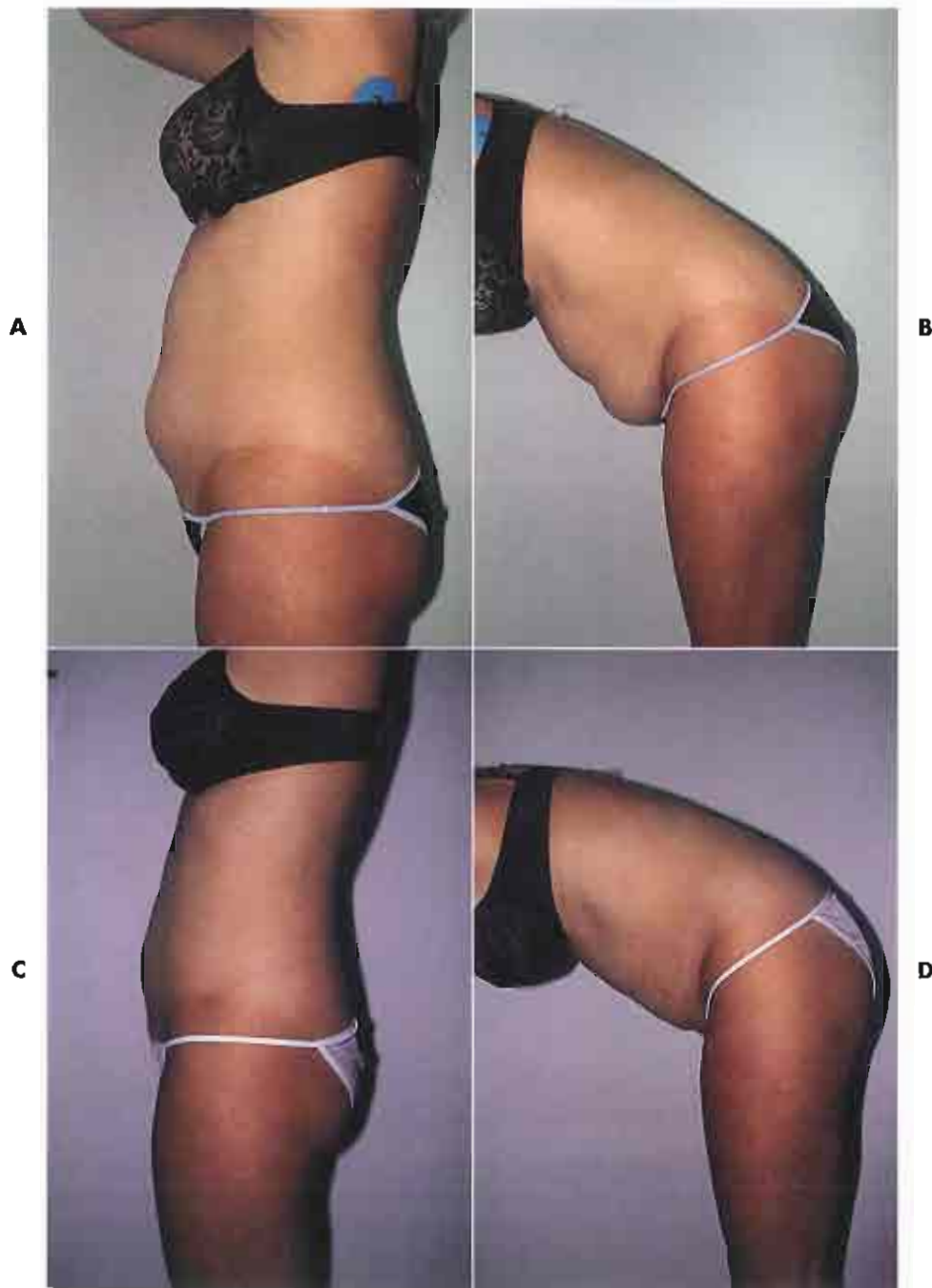
Figure 31-14

Tumescent liposuction for moderate abdominal obesity can be accomplished entirely with 14-gauge Capistrano microcannula, as in this patient. **A** and **B,** Preoperative views. **C** and **D,** Four months after tumescent liposuction.
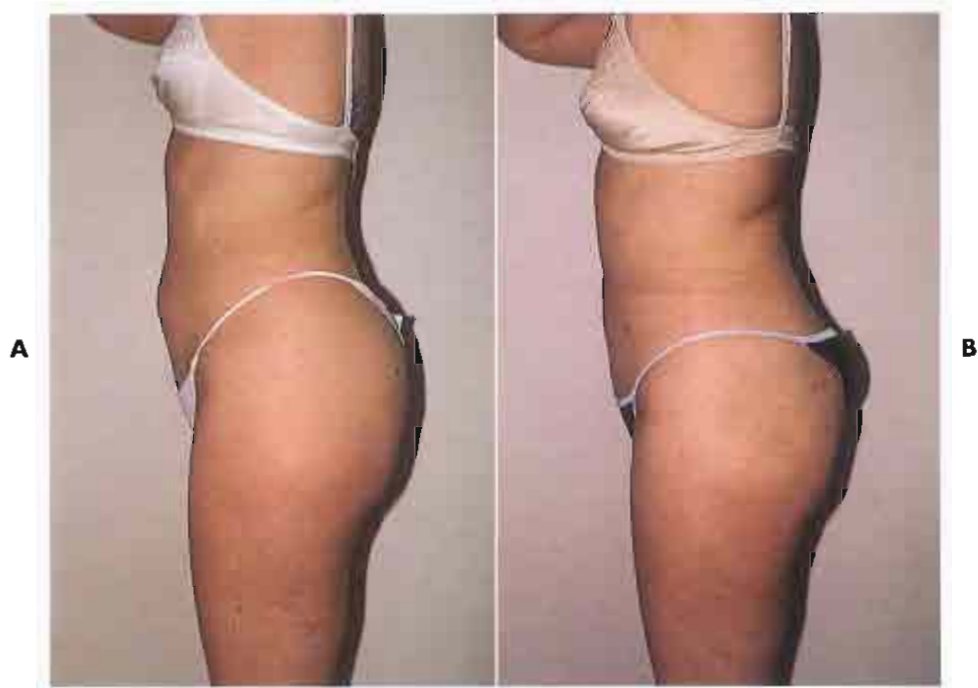
Figure 31-15

Tumescent liposuction for mild abdominal obesity. **A,** Preoperative view. **B,** After tumescent liposuction.
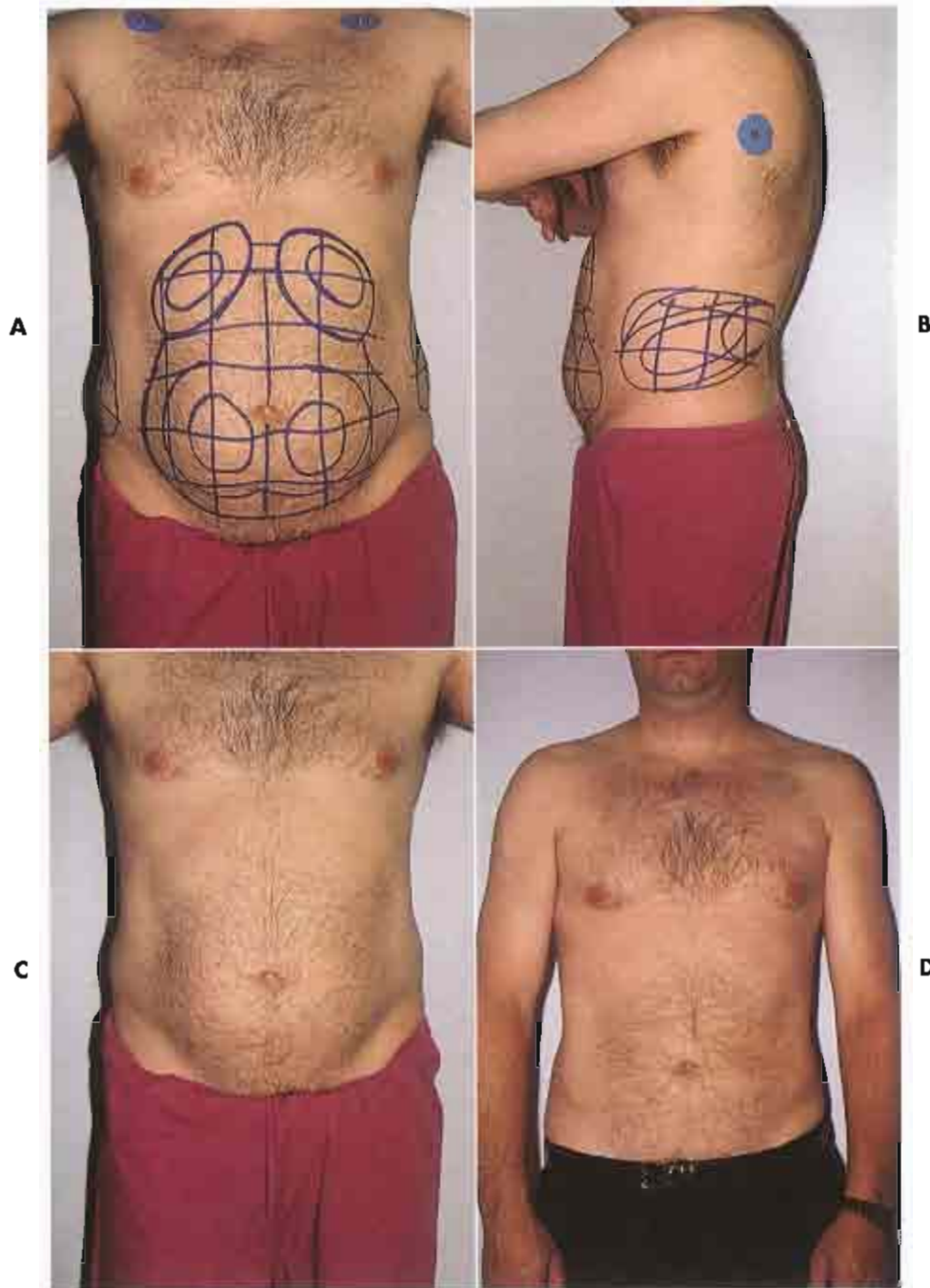
Figure 31-16

Tumescent liposuction procedures for male abdomen and flanks were accomplished on same day, and patient returned to work within 2 days. In males who have a much greater degree of obesity, liposuction of abdomen alone is sufficient challenge. In a large patient it is often prudent to avoid doing liposuction of both abdomen and other areas on same day. **A** and **B,** Preoperative topographic contour markings. **C** and **D,** Anterior views before and after liposuction.

Figure 31-16, cont'd

E and **F,** Lateral views before and after liposuction. **G** and **H,** Posterior views before and after liposuction.

Figure 31-17

A and **B,** Scars provide evidence of prior cosmetic abdominoplasty. With microcannular tumescent liposuction, such scars usually are no longer necessary.
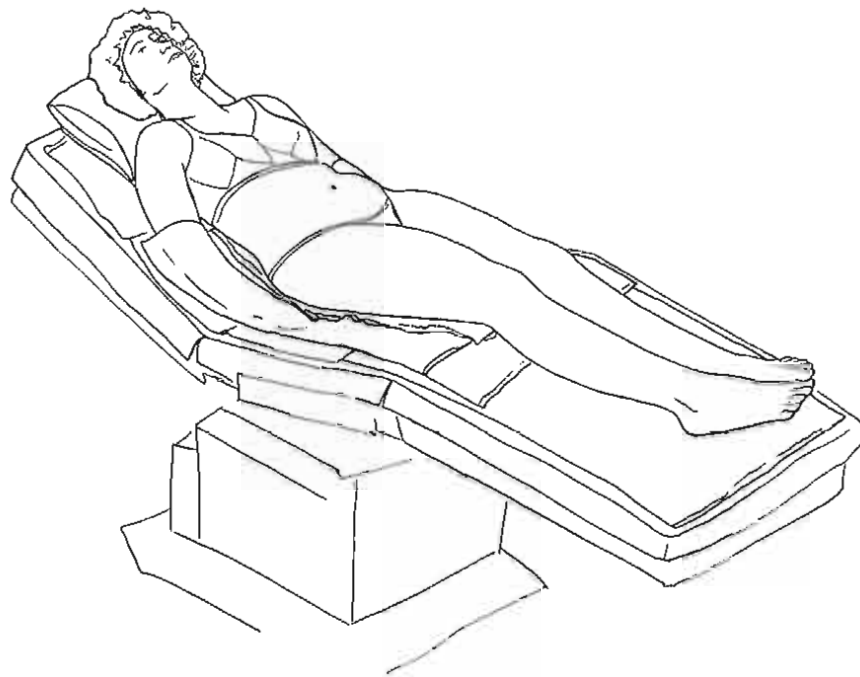
Figure 31-18

Position for liposuction of abdomen and anterior thighs should be comfortable. Patient's arms can be "politely" restrained by wrapping each in towel and then tucking towels under patient. Patient remains in complete control and can remove restraints simply by elevating back and extracting arms. This type of restraint reminds patient not to move arms or hands unconsciously across surgical field, gesture while talking, or scratch nose.

anesthetic solution. Nevertheless, adequate anesthesia can usually be obtained without infiltrating to the point of maximum tumescence.

To ensure optimal anesthesia and vasoconstriction, the surgeon should wait at least 30 minutes after completion of tumescent anesthetic infiltration before commencing liposuction of the abdomen.

SURGICAL TECHNIQUE

Accurate preoperative topographic contour drawings are an important prerequisite to obtaining a uniformly smooth result after tumescent liposuction (Figure 31-19).

Scarpa's fascia can be relatively more resistant to penetration by large cannulas. Larger cannulas require greater force and thus produce greater discomfort. Microcannulas can penetrate Scarpa's fascia without excessive force, resulting in minimal discomfort. Microcannulas thus facilitate more complete liposuction of the relatively inaccessible sub-Scarpa's fat compartment.

Preferably, liposuction deep to Scarpa's fascia is initiated with a 16-gauge microcannula to minimize the force necessary to penetrate the fascia. After establishing multiple tunnels through Scarpa's fascia, larger, 14-gauge and 12-gauge cannulas can be used with greater accuracy and less patient discomfort.

The more fibrous periumbilical fat is more resistant to liposuction than fat located 4 cm or more from the umbilicus. The surgeon must direct extra efforts toward this resistant deposit, or residual fat will result in the appearance of a periumbilical "donut."

Epigastric fat is especially fibrous, and the overlying skin is less elastic than that of the lower abdomen. To maximize
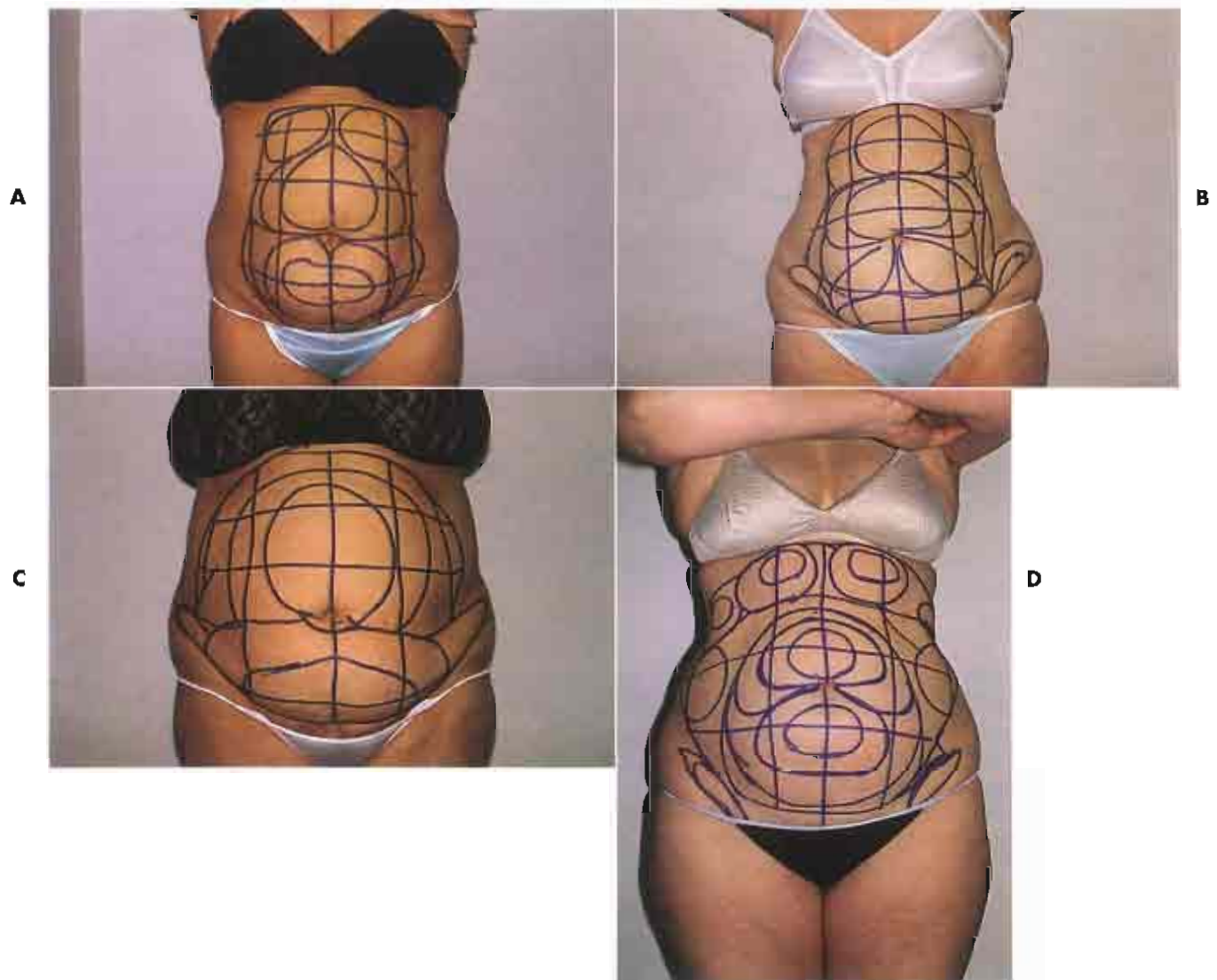
Figure 31-19

A to D, Examples of abdominal topographic contour drawings on different patients.

the probability of a smooth result, the surgeon can use microcannulas in crisscrossing radial patterns. The patient, especially an older patient, should be told that a postoperative crepelike or wrinkled appearance is possible.

Incisions should be placed in a somewhat random pattern to avoid the appearance of a regular or symmetric distribution. Placing three to five 2-mm adits along the inferior margin of the abdomen, followed by doing liposuction through these adits, establishes a drainage pathway, helps prevent bruising, and hastens the resolution of postoperative edema.

When incisions are limited to the suprapubic or umbilical area, liposuction of the epigastric area is usually insufficient. I prefer to place several 1.5-mm adits in the upper abdomen to permit transverse and oblique liposuction with 16-gauge (1.2-mm internal diameter [ID]) or 14-gauge (1.8-mm ID) cannulas. This tunneling with microcannulas reduces the resistance of the highly fibrous upper abdominal fat. Subsequently, liposuction with larger cannulas, using 2.0-mm adits in the lower or upper abdomen, is more effective, more complete, and more comfortable.

Care must be taken to avoid a forceful thrust of the cannula through the epigastric fat that is directed toward the costal margin. Otherwise, the momentum from sudden penetration of a resistant fibrous partition might risk penetration of the diaphragm or pleural space. Typically, during the initial stages of epigastric liposuction, the microcannulas are directed transversely or distally, away from the costal margin. Only after the fibrous partitions of the epigastric fat have been sufficiently fenestrated using 16-gauge and 14-gauge microcannulas should a larger, 12-gauge cannula be used in the lower abdomen or the upper abdomen. Rarely, when treating a large abdomen, a 10-gauge Finesse cannula may be used.

Incisions or adits above the umbilicus should be limited in number and should not be so small that cannular friction can cause epidermal burn and eventual postinflammatory dyschromia. In the vast majority of patients the 1.5-mm adits or microincisions for a 14-gauge cannula become virtually invisible.

Although dyschromia at the site of an adit or microincision is uncommon, an occasional patient will experience some long-lasting hyperpigmentation. Factors that increase the risk of dyschromia include racial or genetic predisposition and the effects of trauma-induced inflammation to the incision. For example, a history of abdominal liposuction is associated with increased fibrosis within the targeted fat. This scarring fibrosis of fat necessitates more vigorous liposuction efforts, resulting in more friction trauma to the adit or incisions and predisposing to incision site dyschromia (see Chapter 8).

UPPER ABDOMINAL LIPOSUCTION

Liposuction of upper abdominal fat is more challenging than that of lower abdominal fat because the upper abdomen is so fibrous. Compared with the easy skin retraction and smooth results routinely achieved for the lower abdomen, liposuction of the upper abdomen is more difficult, and the results may not be as smooth.

Excessive fibrousness often limits the thoroughness and smoothness that can be achieved by liposuction. With traditional liposuction using larger cannulas and only two or three incisions in the lower abdomen, upper abdominal liposuction was often incomplete.

Both weight loss and liposuction of the epigastric fat may produce rugosity or transverse pleats of the upper abdominal skin. This uneven appearance results from the following factors:
1. The removal of fat that once distended the overlying epigastric skin, along with incomplete dermal elastic contraction, results in fine wrinkles or dimpling.
2. The relative fibrousness of the upper abdominal fat is a result of a dense network of fibers and collagenous sheets that tether the skin to the deep muscle fascia. After weight loss or liposuction, these fibrous tethers remain. When the patient is standing upright, gravity stretches the upper abdominal tissue while the fibrous tethers pull the skin in the opposite direction and produce pleats. When the patient is supine, however, and the effects of gravity are mitigated, these folds or plications usually disappear.
3. Liposuction in the fibrous upper abdomen may predispose to uneven results. The visible effects of uneven liposuction will become more prominent with subsequent weight gain, with focal areas of excess residual fat becoming more noticeable than adjacent areas.

In most patients of average weight, only three to five 1.5-mm adits or microincisions are needed in the upper abdomen to fenestrate the fibrous subcutaneous fat with tunnels created by 16-gauge and 14-gauge microcannulas. Subsequently, most of the upper abdominal liposuction can be accomplished with 14-gauge and 12-gauge microcannulas from very few 2-mm adits.

Another explanation exists for the smoother results of liposuction of the lower abdomen compared with the upper abdomen. As a result of Scarpa's fascia, direct fibrous connections may not exist between skin and muscle fasciae in the lower abdomen. Thus Scarpa's fascia may cushion or mitigate the tethering effects of fibrous tissue attachments to the dermis.

END POINT FOR ABDOMINAL LIPOSUCTION

The surgeon should avoid overaggressive liposuction of the abdomen; the end point should be somewhat conservative. The goal is to reduce the deep fat compartment of the abdomen, with the residual layer of fat being uniform in thickness. The shape of the abdomen after liposuction should approximate the shape of the underlying abdominal musculature. The best aesthetic results, however, require that a thin layer of intact fat remain attached to the skin.

The goal is to achieve a result that looks and feels normal. An attempt to remove every possible lobule of subcutaneous abdominal fat often results in patient dissatisfaction. Excessive abdominal liposuction can cause full-thickness dermal necrosis, erythema ab liporaspiration, or an incongruous appearance that feels or looks abnormal. Smooth and natural-appearing results are more important to cosmetic surgery than extreme results.

RESTON FOAM CONTRAINDICATED

In the past, some surgeons have applied Reston foam to the skin overlying areas treated by liposuction to reduce postoperative bruising. This open-cell plastic foamlike sponge has an adhesive backing that adheres to the skin. Although Reston foam minimizes the appearance of ecchymoses, it has no long-term benefits.

No studies have investigated the safety of applying Reston foam after liposuction. A risk of focal skin necrosis and prolonged postinflammatory hyperpigmentation is associated with the foam. The manufacturer of Reston foam has advised against its use after liposuction.

Reston foam causes uniform distribution of the pressure from an overlying postoperative compression garment, thereby preventing extravasated subcutaneous blood from percolating to the skin's surface. Reston foam only prevents the visible manifestation of bruising. It does not reduce the degree of subcutaneous edema or prevent the osmotic pressure gradient resulting from extravasated blood in the subcutaneous space.

Any gentle, uniform compression of the skin will constrict the interstices within the collagen bundles of the dermis and restrict the oozing or trickling of red blood cells through the fine porous openings within the interstitial spaces. Although blood can still flow through dermal capillaries, sufficiently uniform compression of the skin will close the minute apertures between dermal collagen bundles, resulting in a filter-like effect that prevents visible bruising. This mechanism is the basis for scientifically designed, superabsorptive postoperative compression pads that are now recommended for postliposuction care.

The application of Reston foam precludes the patient from taking a shower. Also, when an allergic contact dermatitis occurs under occlusion, bullae or blister formation is likely, which can cause persistent and cosmetically disfiguring postinflammatory hyperpigmentation.

The two most worrisome complications are cellulitis and dermal necrosis. When Reston blisters rupture under occlusion, the risk of infectious cellulitis increases; because the skin is covered and cannot be directly examined, the diagnosis of cellulitis is often delayed. Cutaneous necrosis can occur when the patient sits or bends, causing the skin to fold and the Reston foam to become crimped. After a patient has slept for many hours, with the Reston foam crimping the superficial cutaneous blood supply, the result can be areas of focal avascular skin necrosis.

POSTOPERATIVE CARE

The immediate postoperative course after abdominal liposuction is similar to that after liposuction of other areas.

Because tumescent anesthesia has a long duration, patients do not require analgesics other than acetaminophen. Patients usually experience the most discomfort or soreness 36 to 72 hours after surgery. There is no restriction on gentle postoperative physical activity. Patients are advised not to remain in bed, but rather to walk inside their home or take a short walk outside on the evening of surgery.

The patient is expected to shower at least once or twice daily beginning the morning after surgery. The day after surgery, as a result of open drainage and significant compression, the degree of cosmetic improvement is usually dramatic. Over the next several days, after drainage has ceased and as the inflammatory healing process progresses, there is a gradual onset of swelling. This subcutaneous abdominal swelling can restrict bending forward; for example, tying shoes becomes a minor challenge.

The edema that occurs after liposuction of the abdomen typically takes longer to resolve than edema in other treated areas. A certain degree of lumpiness, detectable by palpation, is normally present for 4 to 12 weeks. Some degree of firm subcutaneous pitting edema usually persists for 3 to 4 months.

Oral nonsteroidal antiinflammatory drugs (NSAIDs) are generally not necessary or routinely recommended. Patients may begin cautiously taking NSAIDs 72 hours after surgery, however, to reduce the degree of tenderness and discomfort. NSAIDs affect leukocyte function and may decrease resistance to infection.

OPEN DRAINAGE AND BIMODAL COMPRESSION

The degree of postoperative bruising depends on the individual patient as well as surgical technique and postoperative care. Multiple 1.5-mm or 2-mm adits (nonsutured incisions) and appropriate postoperative compression promote rapid resolution of swelling, soreness, tenderness, and bruising. Bruising is the least important of these common postoperative sequelae. Whereas swelling and pain will impede a patient's rapid return to normal activities, bruising is merely a cosmetic concern.

Open drainage and bimodal compression minimize postoperative bruising, edema, and pain in the treated areas. This scientific approach to postoperative care allows patients to return to normal activities within days of surgery (see Chapter 30).

Both male and female patients use a postoperative tumescent liposuction compression system specifically designed for abdominal liposuction and breast liposuction.* The system consists of (1) superabsorbent compression pads and (2) a postoperative elastic compression garment and binders.

ABSORPTIVE COMPRESSION PADS

Superabsorbent compression pads (HK Pads) have two purposes. The first function is to absorb the copious postoperative blood-tinged tumescent anesthetic solution associated with open drainage that occurs when adits or incisions are not closed with sutures.

HK Pads are designed and manufactured specifically for liposuction. The pads contain more than twice the amount of absorptive material per unit area than any other absorbent pads. Superabsorbent powder (SAP) is included in the absorptive material. When properly applied using appropriate compression garments, the pads eliminate the inconvenience and messiness of postoperative tumescent drainage.

*HK breast/torso garments (www.hksurgical.com).

The second function of the pads is to distribute uniformly the compressive force delivered to the dermis by the overlying elastic garments. As SAP absorbs a large volume of water, it becomes a gelatinous mass that behaves according to the basic law of physics that describes the uniform distribution of pressure in liquids. A small increment of pressure delivered to one portion of a confined liquid is uniformly transmitted throughout the liquid container.

By uniformly distributing the compression of elastic garments, the pads eliminate most postoperative bruising. The pads minimize postoperative bruising similar to Reston foam. As SAP within the pads becomes swollen with absorbed drainage fluid, the force of the elastic compression garment is hydrostatically distributed evenly over the entire subjacent dermal surface. By preventing the upward migration of blood through the compressed interstices within the dermal collagen, the pads prevent bruising.

Unlike Reston foam, however, HK Pads are not fastened to the skin by an adhesive. Thus the pads eliminate the postliposuction risk associated with using Reston foam, which can fold on itself and crimp dermal blood vessels, resulting in cutaneous necrosis.

ELASTIC COMPRESSION GARMENTS

In addition to absorptive compression pads, the postoperative elastic compression system consists of a spandex breast/torso garment and elastic binders that provide bimodal compression.

The garment has a pair of Velcro strips 2.5 cm (1 inch) wide sewn onto the anterolateral portion of the garment, extending from above the breasts down to the lower abdomen. The Velcro fastens to the woven surface of torso binders, which are 15 or 23.5 cm (6 or 9 inches) wide. These are also known as abdominal binders or rib belts. The Velcro attaches directly to the binders and prevents the binders from slipping out of their intended position relative to the treated areas. A large abdomen may require three overlapping belts, whereas a small abdomen requires only two binders.

The actual placement of the pads, garment, and binders can be easily accomplished using elastic tube netting and paper tape (Figure 31-20).

The purpose of the garment is to deliver a compressive force to the subcutaneous interstitial space and expel the residual blood-tinged tumescent anesthetic solution. Removing this solution dramatically reduces postoperative edema and tenderness.

Figure 31-20

Sequential steps for placing absorptive compression pads and elastic compression garments after abdominal liposuction. **A,** Appearance of abdomen immediately after tumescent liposuction. **B,** Absorptive compression pads are first placed on upper abdomen, then lower abdomen. **C,** Elastic tube netting is pulled up and over thighs. **D,** Tube netting is stretched over torso.

Continued

Figure 31-20, cont'd

E, To facilitate application of elastic garment, absorptive compression pads are held in place by tube netting. **F,** Elastic compression garment is pulled up over legs. **G,** Garment is pulled onto torso, with arms inserted through openings. **H,** Torso binder is placed on lower abdomen, overlapping garment's Velcro strips. **I,** One or two torso binders are placed over lower abdomen; additional binder is used to cover epigastric area. Bruising tends to occur with insufficient padding and compression.

As the patient moves about, the overlying pads and the elastic garments and torso binders enable the patient's skin to move in an incremental manner that is independent of the pads. Besides providing continuous, evenly distributed compression over the treated areas, this combination of pads, garments, and binders also avoids the risks and inconveniences of adhesive foam.

Abdominal and Thigh Liposuction. A breast/torso garment is specifically designed for postoperative compression of the torso, which includes the abdomen, breast, and back. Such a garment will not provide compression of the thighs.

The use of an "overall"-type garment is indicated when a patient's abdomen and thighs are suctioned on the same day.

This type of garment provides compression to the abdomen, thighs, and knees. Bimodal compression is provided by using two garments simultaneously for compression of the thighs plus binders for the abdomen.

To provide additional compression during continued open drainage, two garments are applied. The first garment put on the patient is a size larger than the second garment; the larger garment is easier to pull on over the bulky absorptive compression pads. The second, smaller garment then is easily donned, sliding over the smooth surface of the first garment.

The additive effects of the two garments provide so much compression that patients need to be warned about decompression-orthostatic dizziness, which can occur when the garments are removed the following morning before

showering. About 24 hours after the drainage of blood-tinged anesthetic solution has ceased, only the smaller of the two garments is worn, and the absorptive compression pads are no longer necessary.

Finding that a compression garment provides postoperative comfort and security, patients often continue to wear the garments for many days after all the drainage has stopped.

PITFALLS AND SPECIAL CONSIDERATIONS

Doing liposuction with another surgical procedure increases the risk of an adverse outcome. Any surgery that requires postoperative bed rest increases the risk of pulmonary thromboembolism and should be avoided with liposuction.

PERITONEOSCOPY

Abdominal liposuction and intraabdominal surgery should not be performed concomitantly. Also, liposuction is contraindicated when an intraabdominal procedure is performed on the same day. Peritoneoscopy creates a pathway directly into the peritoneal cavity and increases the risk of a liposuction cannula entering the abdominal cavity and injuring intraabdominal viscera[3,4] (Case Report 31-2).

A periumbilical hernia also presents an increased risk of an intraabdominal penetration with a liposuction cannula. A periumbilical hernia is a relative contraindication for abdominal liposuction; it can usually be repaired by a general surgeon using local anesthesia.

ABDOMINAL PERFORATION

With liposuction under general anesthesia, diagnosis of inadvertent penetration of the abdominal cavity with intestinal laceration will probably be delayed. If a liposuction cannula causes a bowel perforation under general anesthesia, it might not be immediately appreciated. When the patient awakes after general anesthesia, any complaint of abdominal pain may be dismissed as the expected consequence of abdominal liposuction. If the delay extends beyond 18 to 24 hours, there is a serious risk of peritonitis, sepsis, or necrotizing fasciitis.

Liposuction totally by local anesthesia eliminates the possibility of missing the proper diagnosis after a traumatic bowel perforation. A high suspicion of an intestinal perforation should be followed immediately with evaluation by a general surgeon. Prompt diagnosis and surgical intervention greatly reduce the risk of life-threatening complications.

GENITAL EDEMA AND ECCHYMOSIS

An occasional abdominal liposuction patient will experience transient postoperative ecchymosis and edema of the external genitalia. This is simply the effect of gravity on incomplete postoperative drainage of blood-tinged anesthetic solution. The onset is usually on the second or third postoperative day. This gravitational edema is benign and of no clinical

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CASE REPORT 31-2 Concomitant Hysterectomy and Liposuction

In a hospital operating room, under general anesthesia, a 53-year-old woman had an endoscopic hysterectomy by a gynecologist followed by an abdominal liposuction by a surgeon of a different specialty. After the procedures the surgeons did not realize that a small incision through the rectus muscle used for the endoscopic procedure had dehisced, allowing a segment of small bowel to herniate into the subcutaneous space created by liposuction. Assuming that the mass represented a hematoma, the surgeon attempted to aspirate subcutaneous fluid by inserting a large hypodermic needle into it.

Over the next 10 days the patient's condition deteriorated. When a general surgeon performed emergency exploratory surgery, the subcutaneous mass was found to consist of an abscess and mass of necrotic small intestine. After a partial small bowel resection the patient recovered.

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consequence; it resolves spontaneously within a few days after onset. No treatment is necessary, and the patient should be cautioned not to apply ice or attempt other maneuvers that could damage tissues.

Informing patients before abdominal liposuction about the possibility of scrotal or labial edema avoids unnecessary worry and anxious telephone calls to the surgeon. The risk of genital edema can be minimized by avoiding excessive volumes of tumescent anesthesia and by placing 2-mm adits along the inferior margin of the abdomen to facilitate open drainage. Placing sutures in abdominal incisions increases the incidence of edema in dependent parts.

MISCELLANEOUS CAVEATS

Excess Compression. After an abdominal liposuction, excessive postoperative compression can impair breathing by increasing intraabdominal pressure and impeding the excursion of the diaphragm. Reduced ventilation can precipitate respiratory insufficiency. Nonadjustable, high-compression postoperative garments are especially dangerous after systemic anesthesia with administration of respiratory depressant drugs.

Excess Infiltration. Too much tumescent fluid may be infiltrated into the abdominal subcutaneous fat. An excessive volume of anesthetic solution can impinge on the abdominal cavity. This can cause the abdominal viscera to press upward against the diaphragm, impairing ventilation by limiting the respiratory excursion of the lungs.

For a large female abdomen, one usually does not need to infiltrate more than twice the anticipated volume of aspirated supranatant fat. Liposuction of a very large abdomen can be done as staged procedures separated by a month or more.

Fat Distribution.   There is proportionately less upper abdominal fat than lower abdominal fat. Consequently, upper abdominal fat is aesthetically less objectionable than lower abdominal fat. Thinner patients are often unaware of or unconcerned about upper abdominal fat. If the upper abdominal fat is not suctioned or inadequately suctioned, however, subsequent weight gain will enlarge the upper abdomen and create a midriff.

In some patients, suctioning only the lower abdomen may result in a disproportionately prominent epigastric fat pad. When the patient stands upright, the weight of residual epigastric fat causes the upper abdominal skin to sag. This "sad-face" result can be avoided by unweighting the upper abdominal skin by extending the liposuction into upper abdominal fat.

An "inverted-smile" appearance can be treated by carefully reducing the gross weight pulling downward on the epigastric skin, using careful liposuction and microcannulas (Figure 31-21).

Figure 31-21

Sagging abdomen with "inverted-smile" appearance of umbilical area results from thorough liposuction of lower abdomen and insufficient liposuction of upper abdomen.

Excess Liposuction.   Removing too much abdominal fat may lead to unpleasant results for the patient. The goal is not to remove as much fat as possible, but rather to produce a result that will be most pleasing to the patient.

Many women desire as lean an abdomen as possible. For a woman who is somewhat plump, a lean abdomen might appear and feel unnatural. One should never assume that all women want the maximum amount of fat possible removed from the abdomen.

Mons Pubis.   Liposuction of the mons pubis should be approached with caution. Excessive liposuction of the mons pubis may result in the area being so deficient in fat that normal sexual intercourse becomes painful.

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Lateral Thighs

Fat tends to accumulate preferentially on the female thigh. Despite vigorous exercise and physical conditioning, the lack of visible improvement in the shape or size can be discouraging. Disproportionately large thighs often necessitate clothing of two different sizes to accommodate both the upper and the lower body. For this and other reasons, women with this "two-body syndrome" may choose liposuction.

Opinions regarding the ideal proportions of the female figure have varied widely through time and across cultures. In the current era the aesthetic appeal of long legs seems to transcend culture. Artists portray long legs as attractive and refined. Many prospective liposuction patients want this "look" (Figure 32-1).

ANATOMIC CONSIDERATIONS

The English language lacks a word to designate the entire aesthetic unit of subcutaneous fat that includes the outer thigh, inferior lateral buttock, and proximal posterior thigh. For the purposes of liposuction, the usual designations of "outer thigh" and "trochanteric area" are not sufficiently inclusive.

The outer thigh, without the rest of its cosmetic unit, has an obovate (inverted-egg) shape. When liposuction is restricted to just the outer thigh, the result may be disproportionate and aesthetically displeasing. Liposuction that leaves excessive fat in the inferolateral buttock and banana-form fold of the proximal posterior thigh appears artless and amateurish.

GROSS ANATOMY OF SUBCUTANEOUS FAT

The term *lateral thigh aggregate* describes a combined area of subcutaneous fat composed of the lateral trochanteric area, the inferolateral buttock, and the banana-form fold of the proximal posterior thigh. The approximate shape of the lateral thigh aggregate is somewhat cordiform or cordate (heart shaped). This grouping of smaller areas into a larger combined aesthetic unit has true-to-life artistic relevance (Figure 32-2).

The gross anatomy of the lateral thigh's subcutaneous fat is notable for the lack of elasticity of the buttock ligaments.

The inferolateral buttock tends to bulge and sag with advancing years. Slight liposuction of this area can give the patient a rounder, more proportionate appearance.

SURFACE ANATOMY

The shape of the buttock changes with age, probably because of increased gluteal weight and loss of tissue elasticity. The *suspensory ligaments of Jacque* are gluteal ligaments that traverse the fat of the buttock in a manner analogous to Cooper's ligaments of the breast. As with the breasts, the effects of gravity eventually overcome the elasticity of the ligaments. With advancing age the suspensory ligaments of Jacque degenerate and the inferolateral buttock tends to sag.

Immediately subjacent to the subcutaneous fat pad of the lateral thigh is the tensor fascia lata and, more posteriorly, muscles of the buttocks and thigh. The sciatic nerve, located approximately 2 cm deep to the surface of gluteus muscle, is outside the surgical field, even during liposuction of the inferolateral buttock or the posterior thigh.

Malposition of the patient during liposuction increases the risk of significant aesthetic defects and patient dissatisfaction. For the lateral thighs, two aspects of surgical malposition are the topologic lipowarp and the trochanteric pseudobulge. The double infragluteal crease, the lipotrop, and the liponot are other undesirable consequences of artless liposuction.

Lipowarp. A lipowarp of the lateral thigh is a topologic distortion of the thigh's subcutaneous fat compartments caused by a deviation of the body from the anatomic position. The supine or prone position compresses the subcutaneous fat of the lateral thigh in the anteroposterior direction while causing it to protrude laterally. Flexion, extension, or rotation of the hip changes the shape and proportions of this subcutaneous fat (Figure 32-3).

A clinically important form of a thigh lipowarp occurs with simple anterior flexion of the hip. The maneuver distorts the lateral thigh, stretching the posterolateral aspect and compressing its anterolateral aspect. When performing lipo-
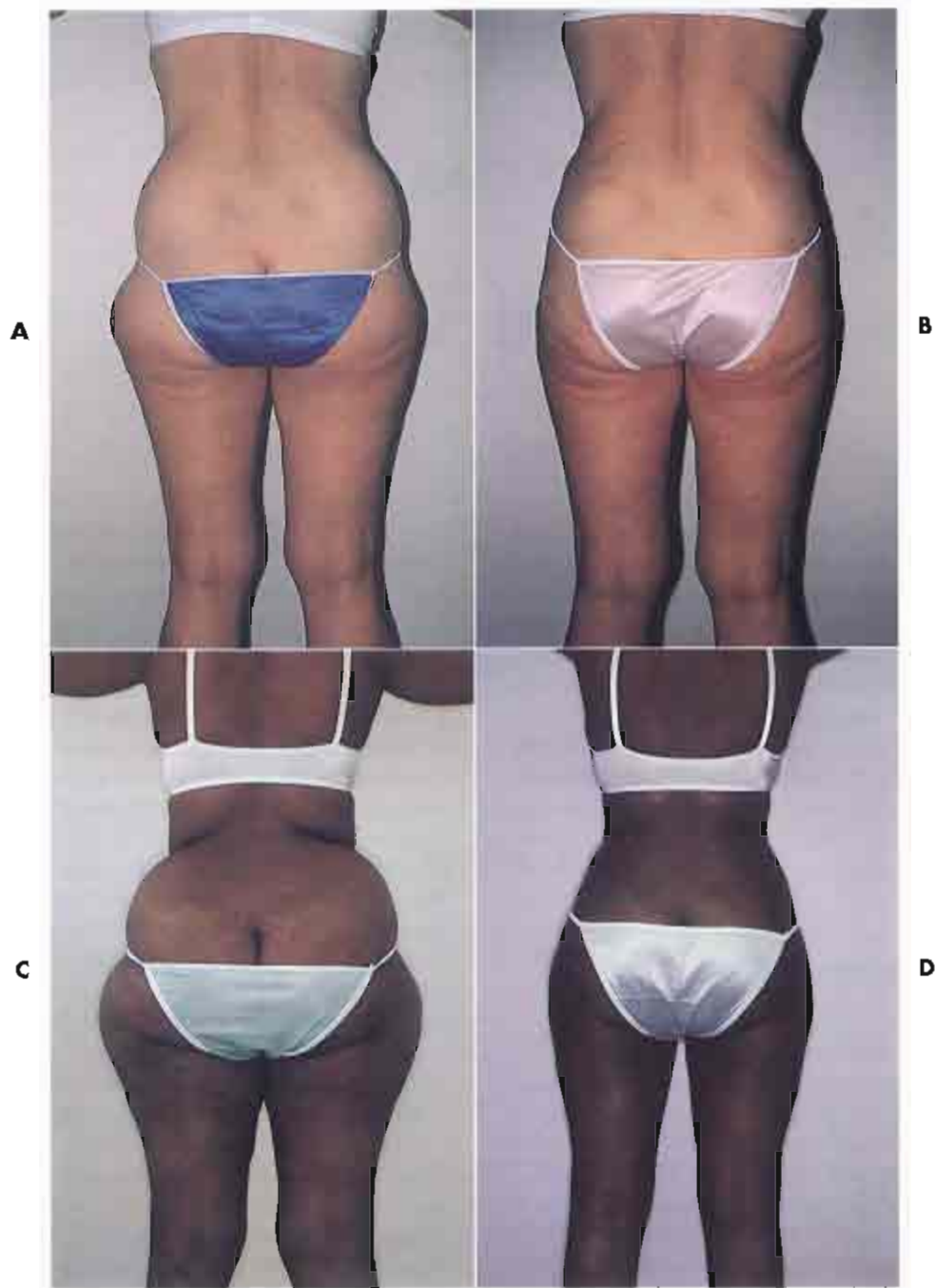
Figure 32-1

Preoperative and postoperative photographs illustrating degree of cosmetic improvement that can be achieved with tumescent liposuction of outer thighs and hips. **A** and **B,** Focally bulging outer thighs. **C** and **D,** Large lateral thighs and hips yielded 4 L of supranatant fat with one session of liposuction. Inner thighs and knees were treated in separate procedure.
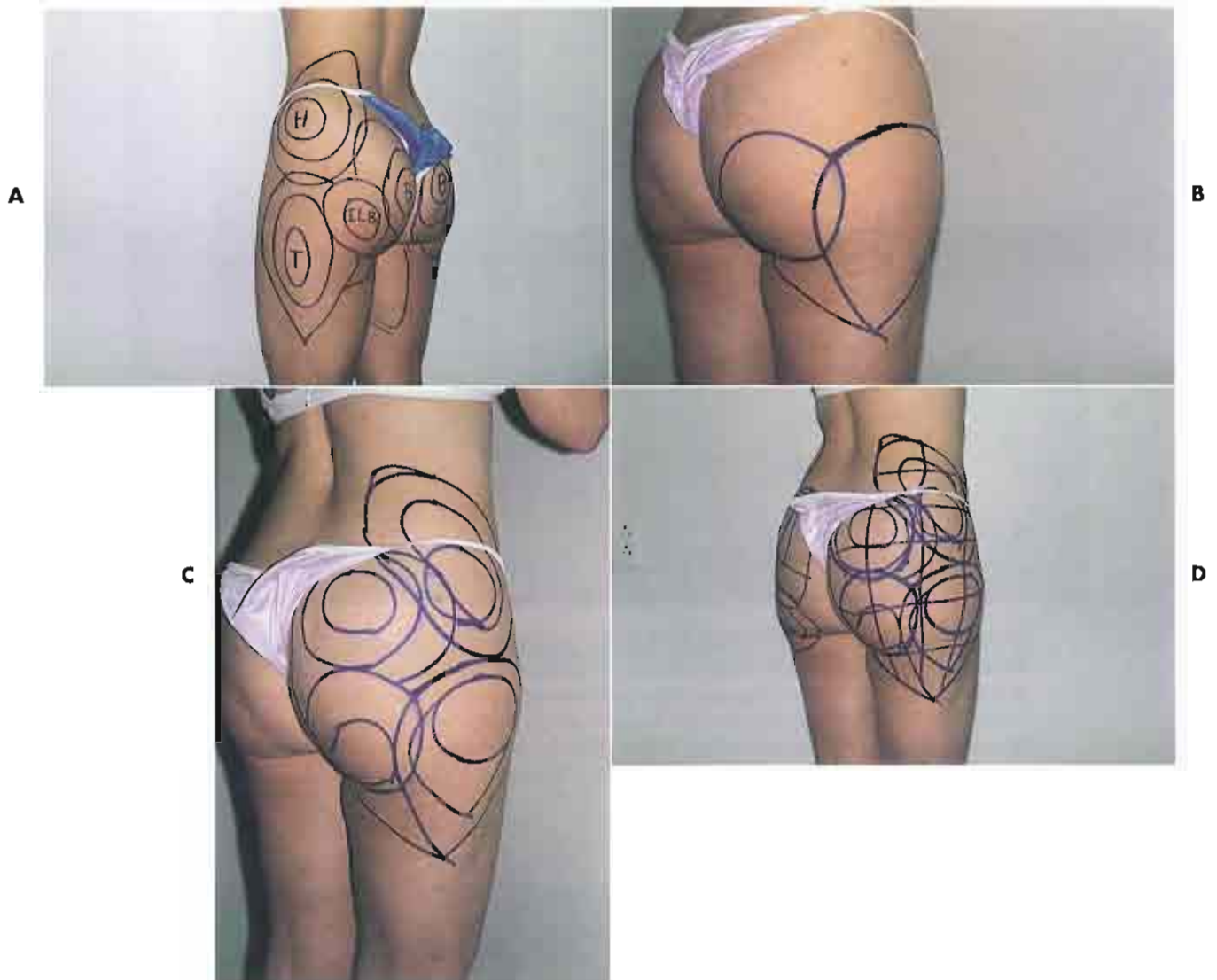
Figure 32-2

A, Topographic contour map of hip (H), lateral thigh (T), inferior lateral buttock (ILB), and buttock (B). Lateral thigh is ovate (egg-shaped) area; inferior lateral buttock is usually round or oval shaped. Banana-form fold of proximal posterior thigh is not conspicuous in this patient. **B,** Lateral thigh aggregate is cordate (heart-shaped) area consisting of lateral thigh and inferior lateral buttock. **C,** Same patient with additional contour drawings on hips and entire buttock. **D,** Orthogonal grid helps nurse infiltrate tumescent anesthetic solution.
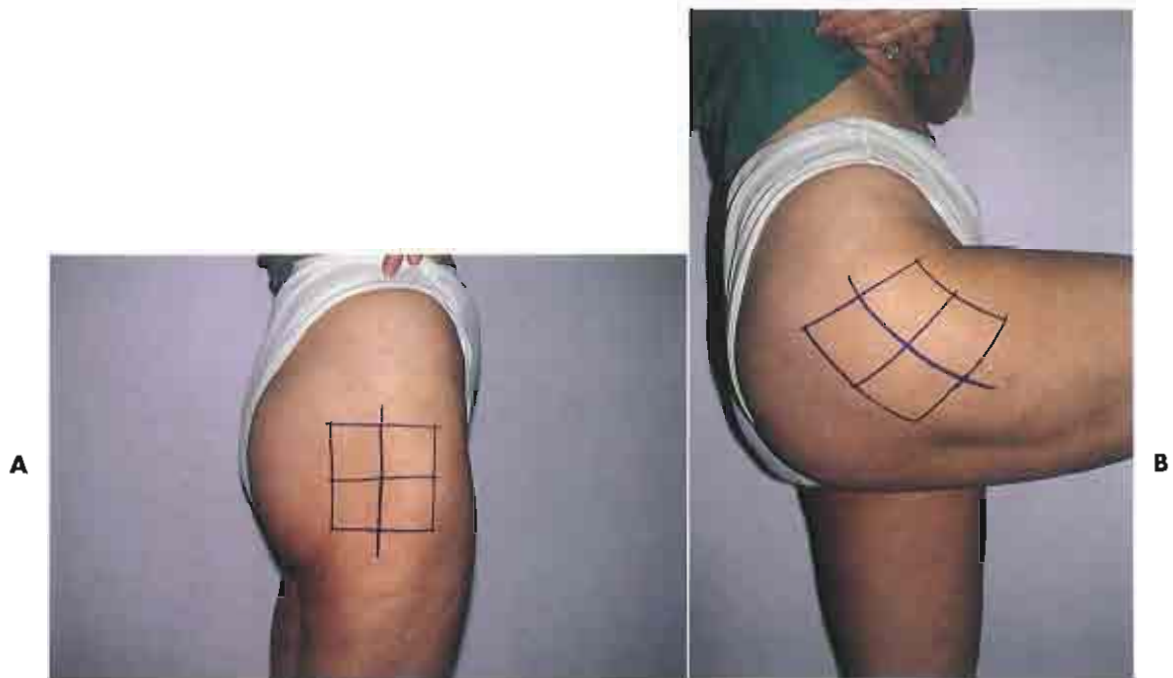
Figure 32-3

A, Four adjacent 5 × 5–cm² squares drawn with patient in anatomic position. **B,** When hip is flexed, 5 × 5–cm² squares are distorted by lipowarp (in mathematic terms, squares are transformed by topologic isomorphism into trapezoids). Posterior pair of trapezoids have vertical sides 6 and 5 cm, whereas anterior pair of trapezoids have vertical sides 5 and 4 cm.
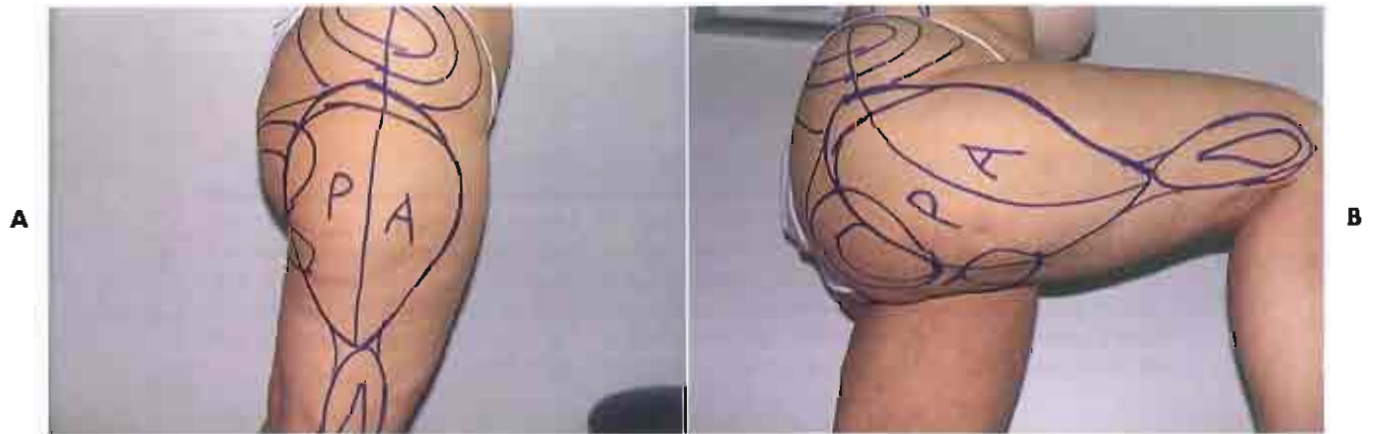
Figure 32-4

Lipowarps predispose to distorted liposuction results. **A,** Posterior (P) and anterior (A) halves of lateral thigh are approximately of equal area when patient is in anatomic position. **B,** With hip flexed, posterior thigh is expanded and anterior thigh compressed.

suction with the hip flexed, the surgeon tends to do too much liposuction posteriorly and not enough liposuction anteriorly. Although a skillful surgeon can compensate for this distortion, the deviation from the anatomic position poses an unnecessary risk of iatrogenic aesthetic defects (Figure 32-4).

Double Infragluteal Crease. A patient who has a prominent banana-form fold of the proximal posterior thigh will usually expect liposuction to remove this aesthetic "defect." This is usually a difficult task, with a significant risk of doing too much liposuction and creating an
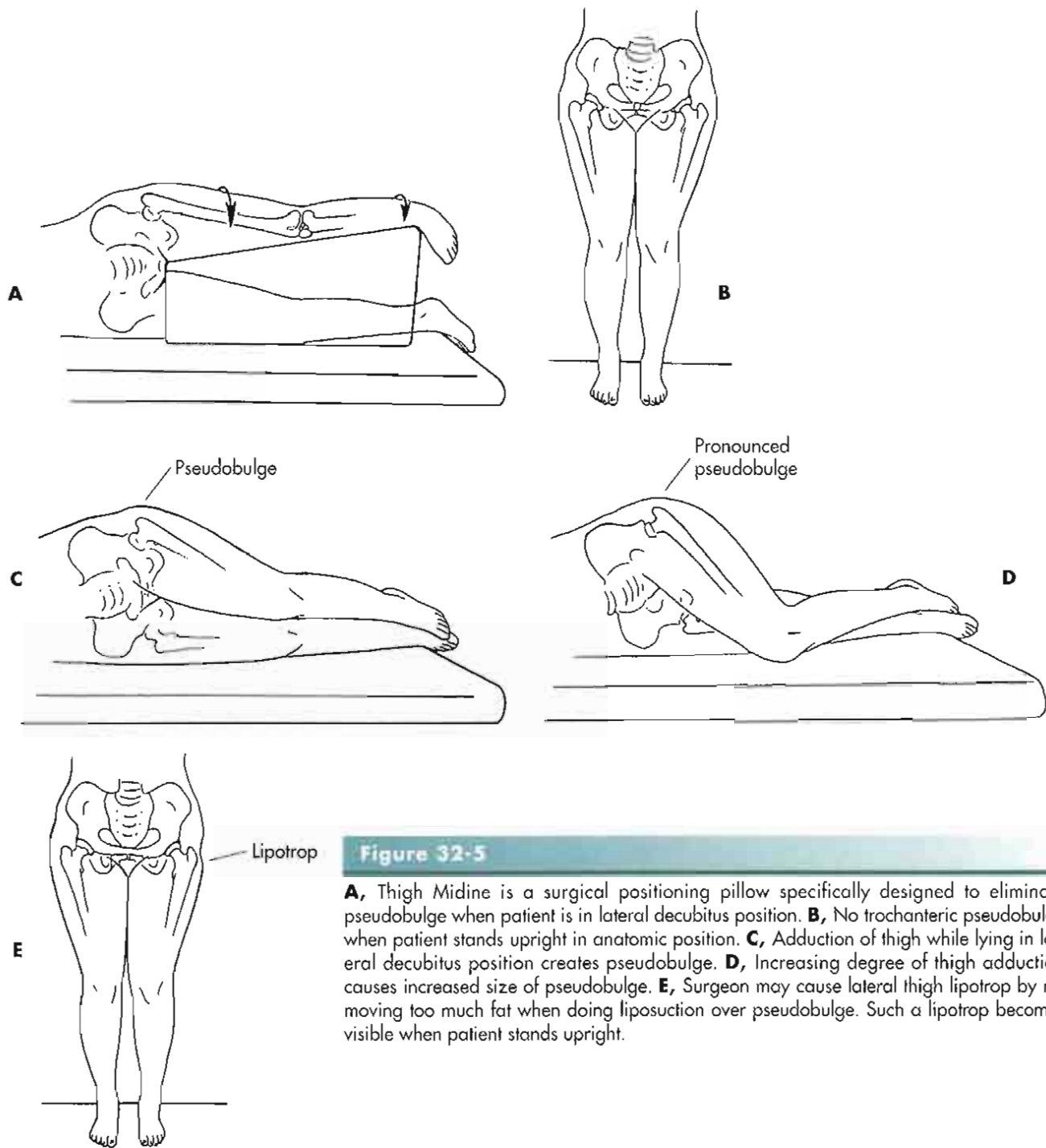
A, Thigh Midine is a surgical positioning pillow specifically designed to eliminate pseudobulge when patient is in lateral decubitus position. **B,** No trochanteric pseudobulge when patient stands upright in anatomic position. **C,** Adduction of thigh while lying in lateral decubitus position creates pseudobulge. **D,** Increasing degree of thigh adduction causes increased size of pseudobulge. **E,** Surgeon may cause lateral thigh lipotrop by removing too much fat when doing liposuction over pseudobulge. Such a lipotrop becomes visible when patient stands upright.

extra horizontal infragluteal crease. Such a double infragluteal crease is both displeasing and distressing for the patient.

Trochanteric Pseudobulge. A special type of lipowarp is the trochanteric pseudobulge. Of all areas treated by liposuction, the lateral thigh is probably the most vulnerable to poor intraoperative positioning. Adduction of the thigh causes the greater trochanter to protrude outwardly, elevating and distorting the overlying fat and creating a pseudobulge. The greater the degree of thigh adduction, the greater is the size of the pseudobulge. The pseudobulge is maximal in the lateral decubitus "high-step" position (hip flexed forward and thigh adducted) (Figure 32-5).

By a simple self-examination, one can appreciate the relationship of femur and trochanteric position to pseudobulge size (Figure 32-6).

Lipotrop and Liponot. A *lipotrop* is an iatrogenic depression of the skin caused by localized excessive liposuction. This iatrogenic disfigurement can be avoided with an awareness of the dynamic nature of outer thigh surface anatomy, careful intraoperative positioning, and meticulous surgical technique (Figure 32-7).
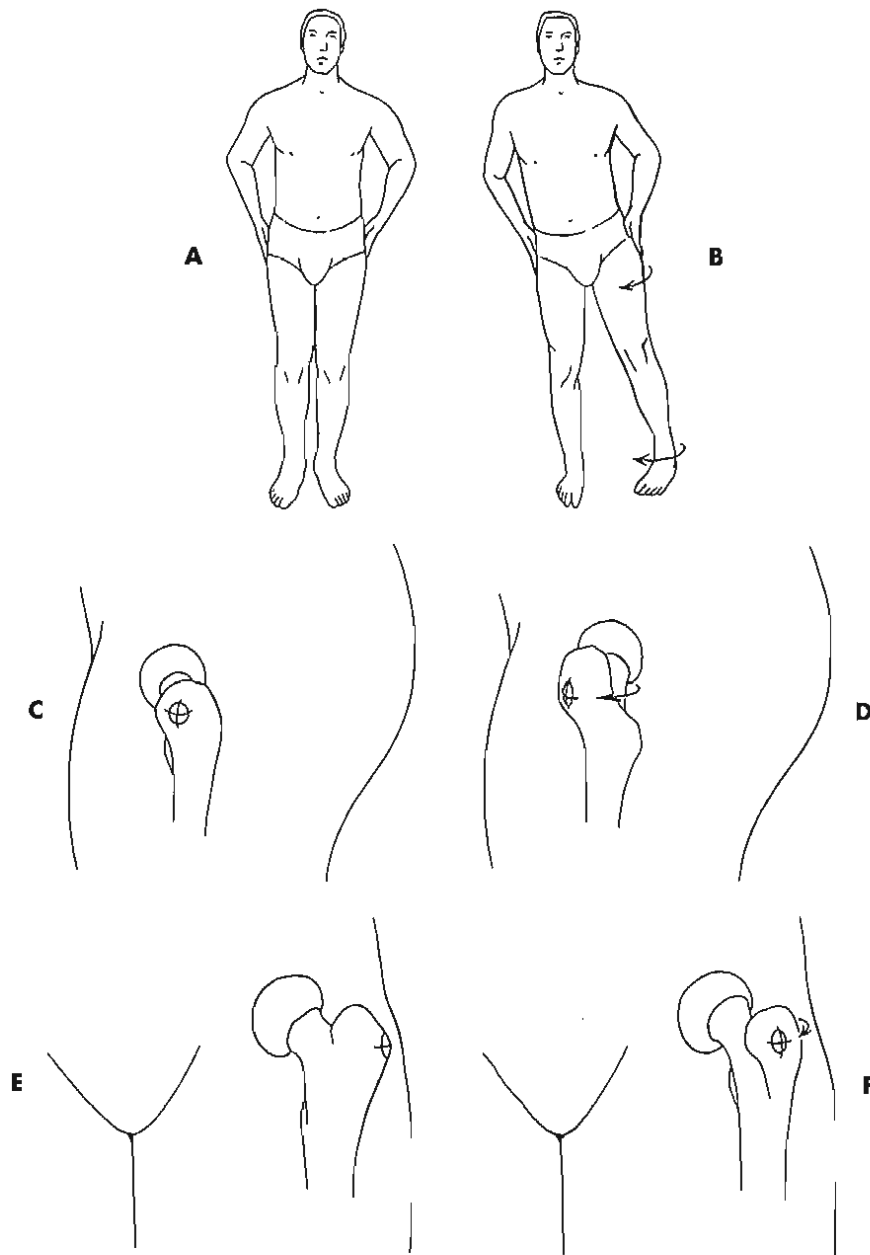
Figure 32-6

A, While standing upright, palpate trochanteric protuberances; then lean to one side, slightly raise opposite foot off ground, and adduct raised thigh toward midline; notice that pseudobulge becomes more prominent. **B,** Abduct raised thigh away from midline and medially rotate knee and ankle into exaggerated "pigeon-toed" position; notice that pseudobulge disappears as trochanter is displaced anteriorly and medially. **C,** Lateral view of trochanteric tubercle in upright position. **D,** Lateral view with hip rotated medially, showing anterior displacement of trochanteric tubercle. **E,** Anterior view of trochanteric tubercle in upright position. **F,** Anterior view with hip rotated medially, showing medial displacement of trochanteric tubercle.

A   B   C
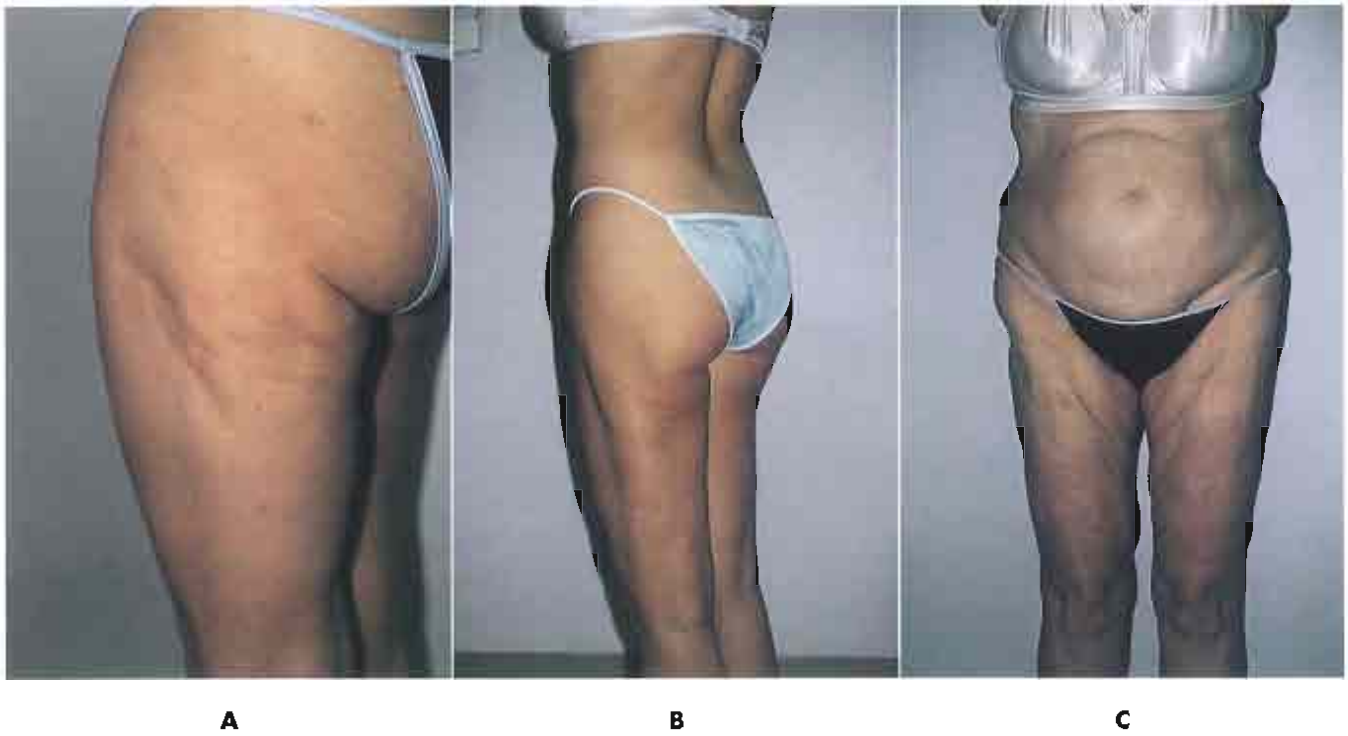
Figure 32-7

Excessive liposuction can occur anywhere on thigh. **A,** Liposuction removed too much fat from localized area, resulting in lipotrop. **B,** Too much liposuction of entire lateral thigh. **C,** Excessive liposuction of right lateral thigh. Maximal fat removal is unsatisfactory. An appropriate amount of residual fat is necessary for optimal aesthetic results. The surgeons responsible for these cases were careless.
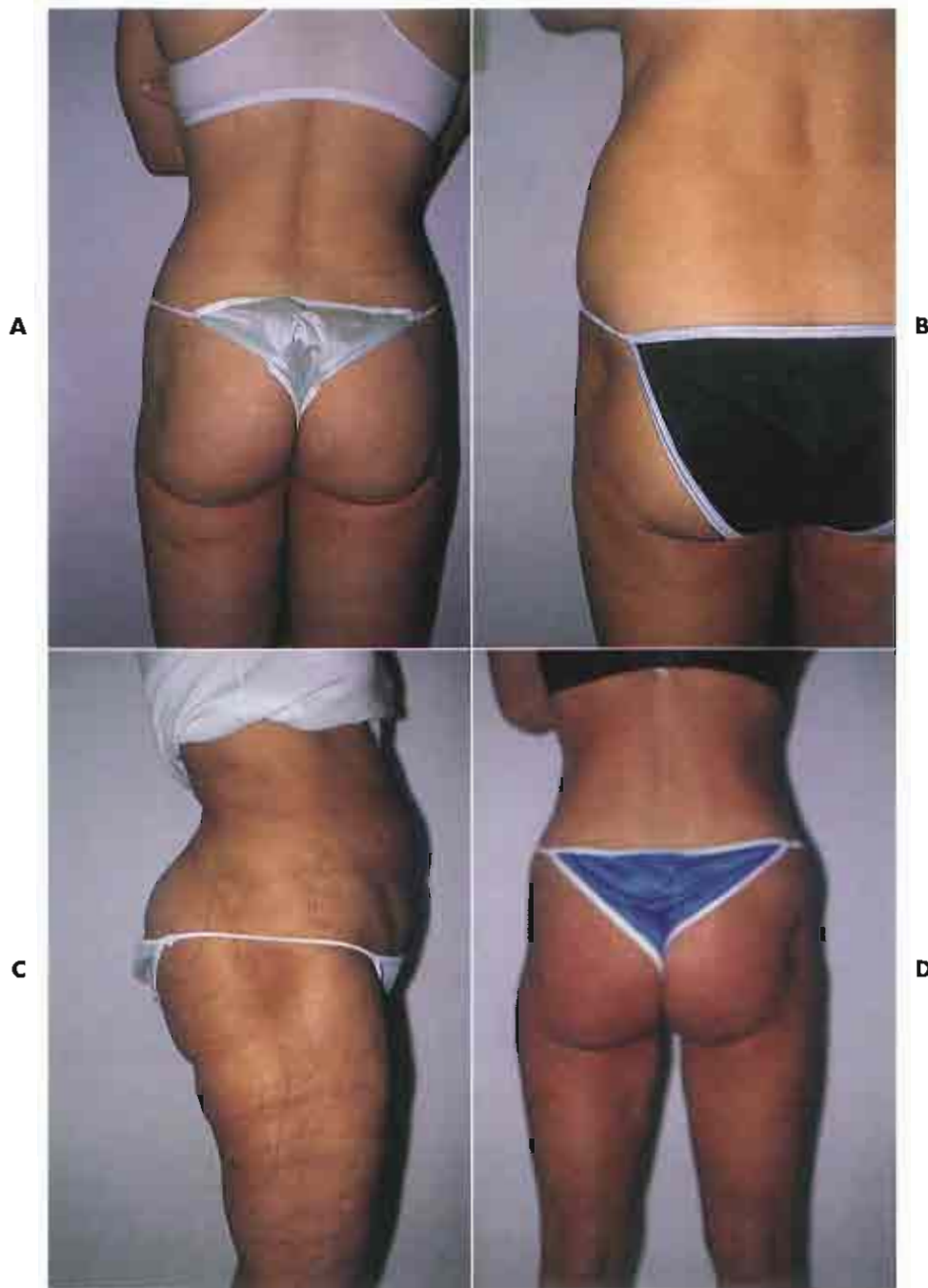
Figure 32-8

Trochanteric lipotrops in four patients resulted from too much liposuction of trochanteric pseudo-bulge. Poor intraoperative surgical positioning predisposes to this common iatrogenic cosmetic defect. **A** and **B,** Left thigh trochanteric lipotrops. **C** and **D,** Right thigh trochanteric lipotrops.

Excessive liposuction of fat overlying the trochanteric tubercle on the lateral thigh typically produces a lipotrop. The surgeon tends to overcompensate and remove too much fat, thereby creating a trochanteric lipotrop, a discrete depression over the trochanter (Figures 32-8 and 32-9).

Appropriate patient positioning provides the confidence to do enough liposuction for cosmetic improvement while minimizing the risks of a lipotrop or a liponot. A *liponot* is a focal area of insufficient liposuction.
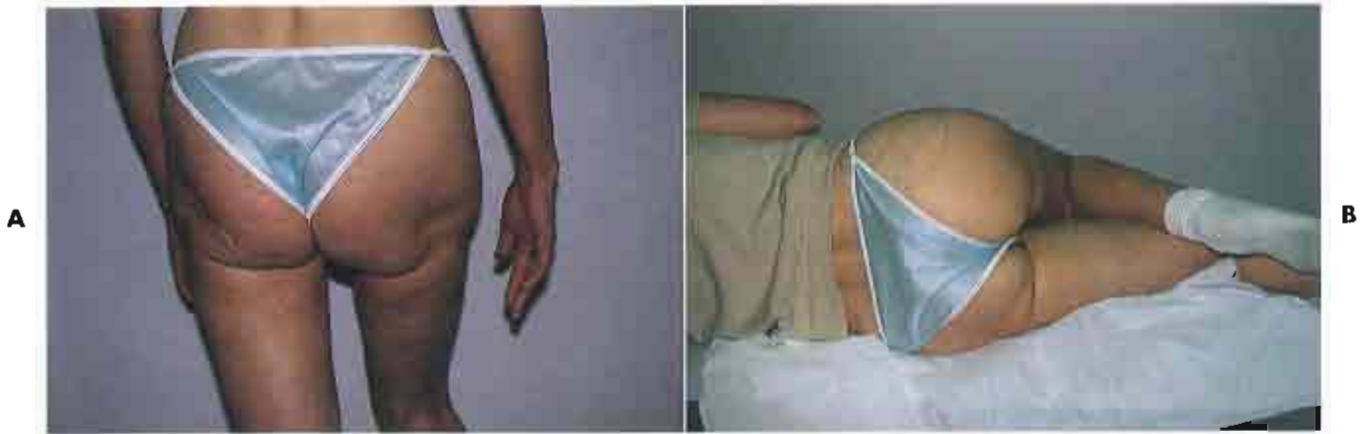
Figure 32-9

Lipotrop can result from suboptimal intraoperative positioning. **A,** Upright position shows results of excessive amount of liposuction overlying trochanter. Note cosmetically displeasing lipotrops (divots) of posterior thigh and lateral buttock areas. **B,** When same patient is placed in modified left lateral decubitus and high-step position, trochanteric tubercle protrudes and obscures lipotrop.

PREOPERATIVE EVALUATION

During the preoperative examination the surgeon should assist the patient to achieve a realist perspective. Photographs of both posterior and anterior views are helpful.

For example, although a woman may be certain that her only disproportionate area is the obovate lateral thigh, another observer might judge the hips to be a greater cosmetic problem. Such a patient may be unaware that her hips or buttocks are much more capacious and are more of an aesthetic problem than the lateral thighs. During the consultation a photograph often gives the prospective patient a more realistic understanding of the cosmetic contour problems.

It is important to evaluate and discuss the inferolateral buttocks and infragluteal banana-form fold. Ignoring these areas and only treating the large subcutaneous compartment of the thigh's lateral obovate portion can result in a disappointed patient.

INTRAOPERATIVE POSITIONING

The optimal position for liposuction of the thighs is a version of the lateral decubitus position, modified so that the intraoperative position of the thighs approximates the anatomic position.

Liposuction of the lateral thighs using the supine or prone position presents both a warped target and an awkward access for the surgeon. The weight of the patient's body compresses the targeted fat compartment in the anteroposterior direction and causes an accentuated bulge laterally. Whenever the patient is not properly positioned, achieving a smooth result is problematic.

The optimal surgical position during liposuction of the thighs recreates the anatomic position. The shape of an area of subcutaneous fat is influenced by the position of the subjacent musculoskeletal structures. The anatomic position minimizes the distortion of subcutaneous fat that occurs in other positions.

A patient's preoperative shape is usually assessed with the patient standing in the anatomic position. With an intraoperative position that approximates the anatomic position, the nuances and subtleties of the preoperative shape will be more easily discerned during surgery. In addition, patients usually judge the results of their surgery while standing in front of a mirror in a manner that approximates the anatomic position. When surgery is done in the position used for postoperative assessment, smooth intraoperative results will more likely be appreciated as smooth postoperative results (see also Chapter 28).

THIGH MIDINE AND THIGH ASIDE

The Thigh Midine and Thigh Aside are surgical pillows that do the following:

1. Optimize the biomechanical positioning of the patient's thighs during surgery
2. Facilitate superior aesthetic results for liposuction of the lateral thigh
3. Allow the surgeon to remove enough fat confidently to achieve significant improvement
4. Reduce the risk of excessive fat extraction

The Thigh Midine is a wedge-shaped surgical positioning pillow that helps approximate the anatomic position with the patient in the lateral decubitus position. Normally the patient's uppermost thigh is adducted in the lateral decubitus position.
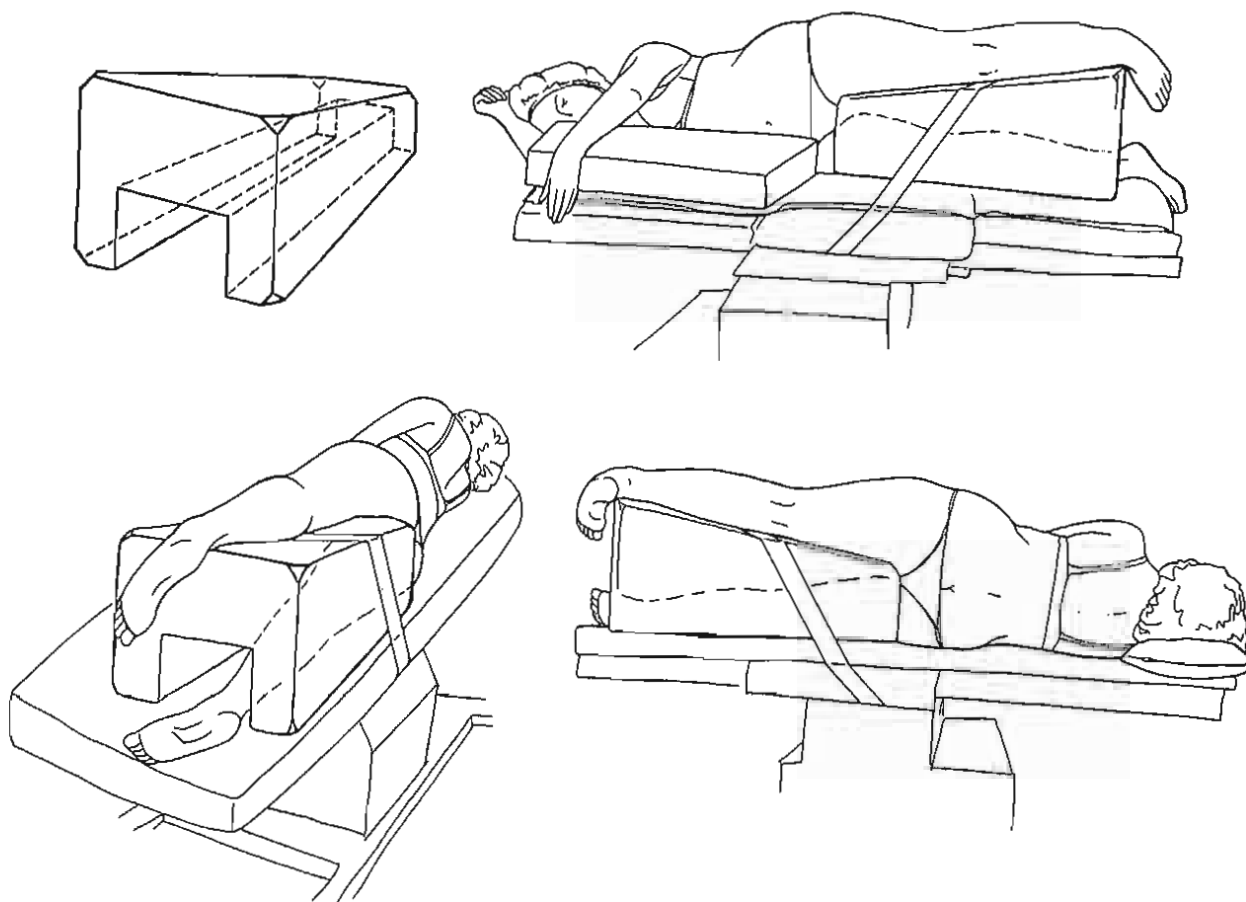
Thigh Midine positioning pillow helps maintain uppermost lateral thigh in an intraoperative posture that approximates anatomic position.

Adduction of the thigh accentuates the pseudobulge, whereas abduction minimizes the trochanteric protrusion.

The pseudobulge can be virtually eliminated with proper positioning of the femur. By rotating the femur anteriorly and medially and pointing the toes of that foot in a "pigeon-toed" manner, the trochanteric tubercle is displaced anteriorly. This significantly reduces the risk of a trochanteric lipotrop.

To position the Thigh Midine correctly, the patient should be in the lateral decubitus position with both legs straight. The uppermost part of the thigh is elevated and the Midine placed between the thighs. To minimize the risk of blood-borne pathogens, before each use the Midine should be placed within a previously sterilized zip-lock plastic bag. To prevent the Midine from sliding, it can be taped to the surgical table (Figure 32-10).

SURGICAL TECHNIQUE

Liposuction of the lateral thighs requires preoperative topographic contour diagrams drawn directly on the patient's skin (Figures 32-11 and 32-12).

Because the lateral thigh is adjacent to the hip, it is logistically convenient to treat these two areas on the same day. For the same reason the buttocks can be treated concomitantly. In an obese patient it might be excessive to treat the lateral thigh, hips, and buttock on a single day.

The number of incisions on the lateral thigh is determined by an effort to minimize scars and maximize the smoothness and completeness of results. Too few incisions will decrease the likelihood of optimally smooth results. Also, the fewer the number of incisions, the greater is the amount of trauma and friction on the existing incisions. For patients with darker pigmentation, extra care is required to minimize trauma to the skin surrounding the incisions and thus the risk of postinflammatory hyperpigmentation.

The deepest layer of fat should be the first to be liposuctioned in the lateral thigh. Analogous to the situation with infiltration, once a plane of liposuction has been created, it is difficult to judge the thickness of deeper layers of fat by palpation or to distinguish the interface between deep tumescent fat and muscle fascia.

For the initial stages of liposuction the cannula is inserted through several incisions located near the posterior border of the peripheral contour line of the lateral thigh. The cannula
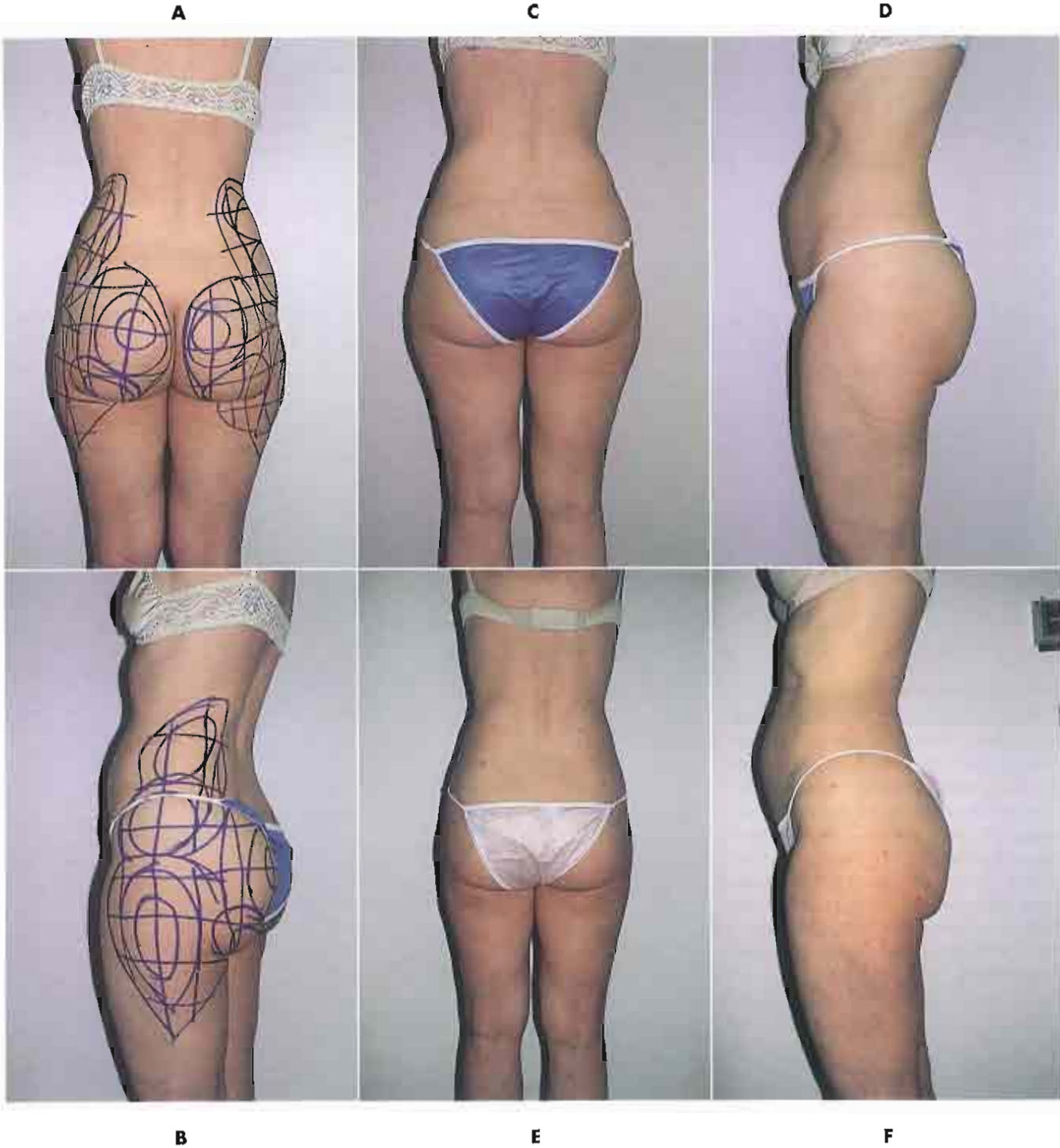
Figure 32-11

Tumescent liposuction of lateral thighs, hips, waist, and buttocks. Topographic contour diagrams delineate relevant surface anatomy: **A,** posterior; **B,** lateral. Preoperative views: **C,** posterior; **D,** lateral. Postoperative views 6 weeks after surgery: **E,** posterior; **F,** lateral.
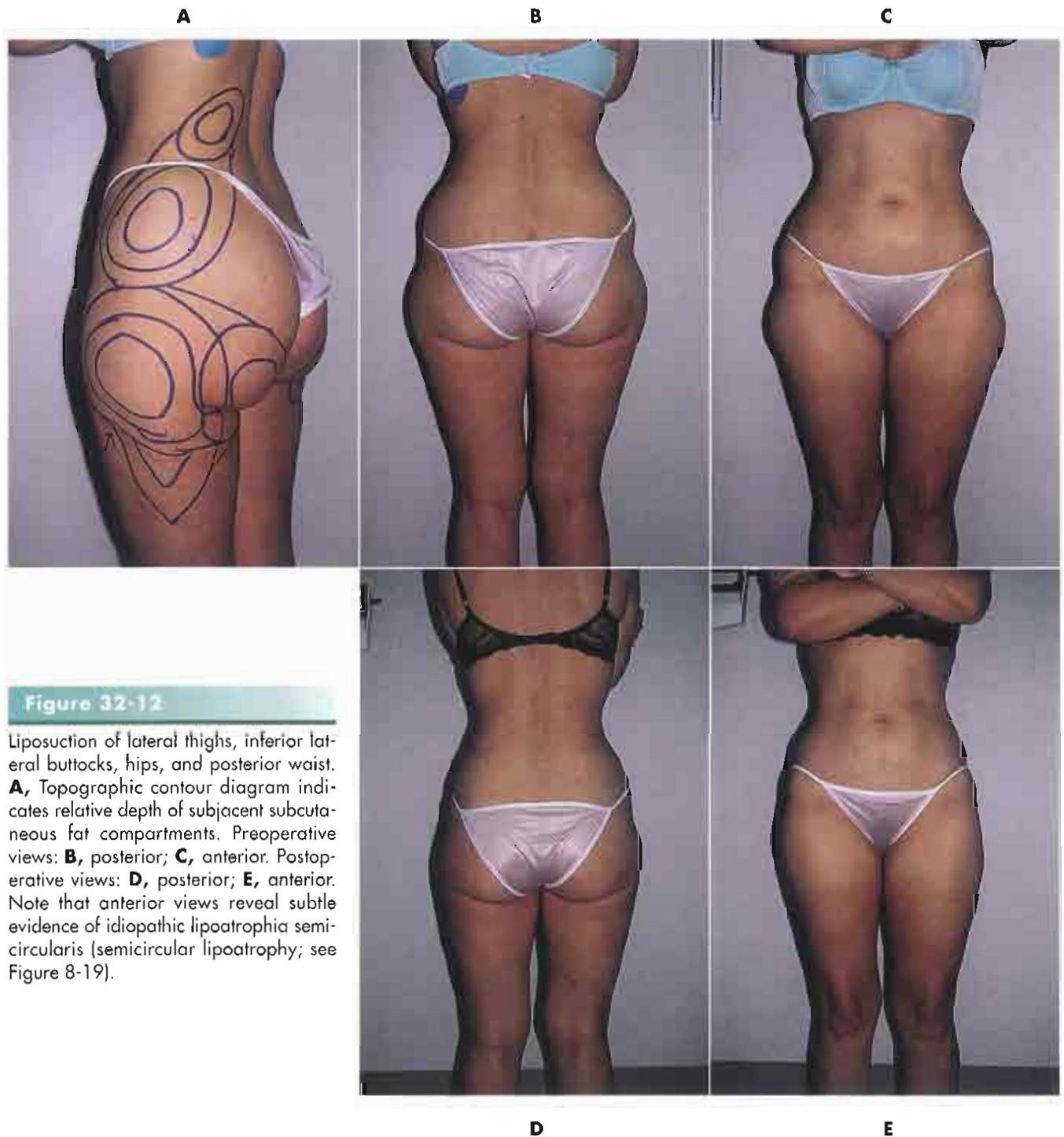
Figure 32-12

Liposuction of lateral thighs, inferior lateral buttocks, hips, and posterior waist. **A,** Topographic contour diagram indicates relative depth of subjacent subcutaneous fat compartments. Preoperative views: **B,** posterior; **C,** anterior. Postoperative views: **D,** posterior; **E,** anterior. Note that anterior views reveal subtle evidence of idiopathic lipoatrophia semicircularis (semicircular lipoatrophy; see Figure 8-19).

paths radiate anteriorly in a crisscross pattern toward the anterior margin of the lateral thigh (Figure 32-13).

With the cannula in one hand, the surgeon gently grasps and elevates the tumescent fat with the other hand while advancing the microcannula. This gentle grasping technique stretches the deepest fat away from the subjacent muscle. This allows the surgeon to accomplish liposuction within the deepest planes of subcutaneous fat while minimizing the risk that the microcannula might encounter muscle fascia.

Once the deepest plane is established in this way, the surgeon can more easily and accurately do liposuction in a proximal-to-distal direction, and vice versa, along the entire extent of the thigh's long axis. The flexion of a microcannula increases with increasing length, and thus longer microcannulas cannot be directed as accurately or advanced with as much control as shorter cannulas. After multiple transverse tunnels have been established throughout the lateral thigh fat, longer cannulas can be directed longitudinally with more accuracy.
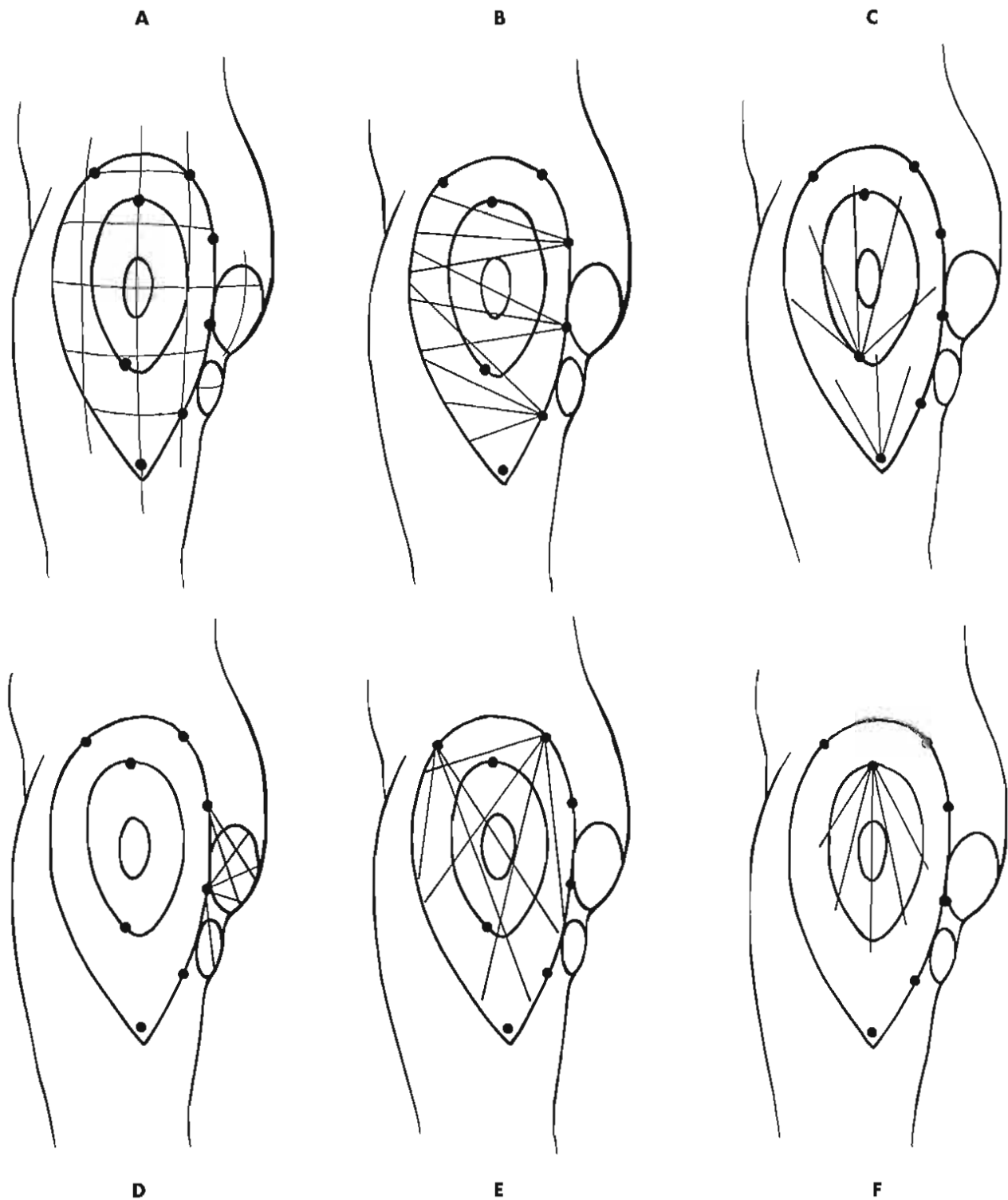
Microincisions and microcannular paths that might be used for liposuction on a typical large lateral thigh, inferolateral buttock, and banana-form fold. These patterns are repeated multiple times sequentially to accomplish incremental liposuction. **A,** Approximate location of multiple adits or microincisions and orthogonal grid pattern that facilitates infiltration. **B,** Initial microcannular paths are directed transversely along deepest level. **C,** Liposuction through dependent adits to facilitate postoperative drainage. **D,** Crisscross pattern through inferolateral buttock and banana-form fold. **E,** Using longest microcannulas to do liposuction throughout targeted area. **F,** Slightly more liposuction might be needed in deepest portions of targeted fat.
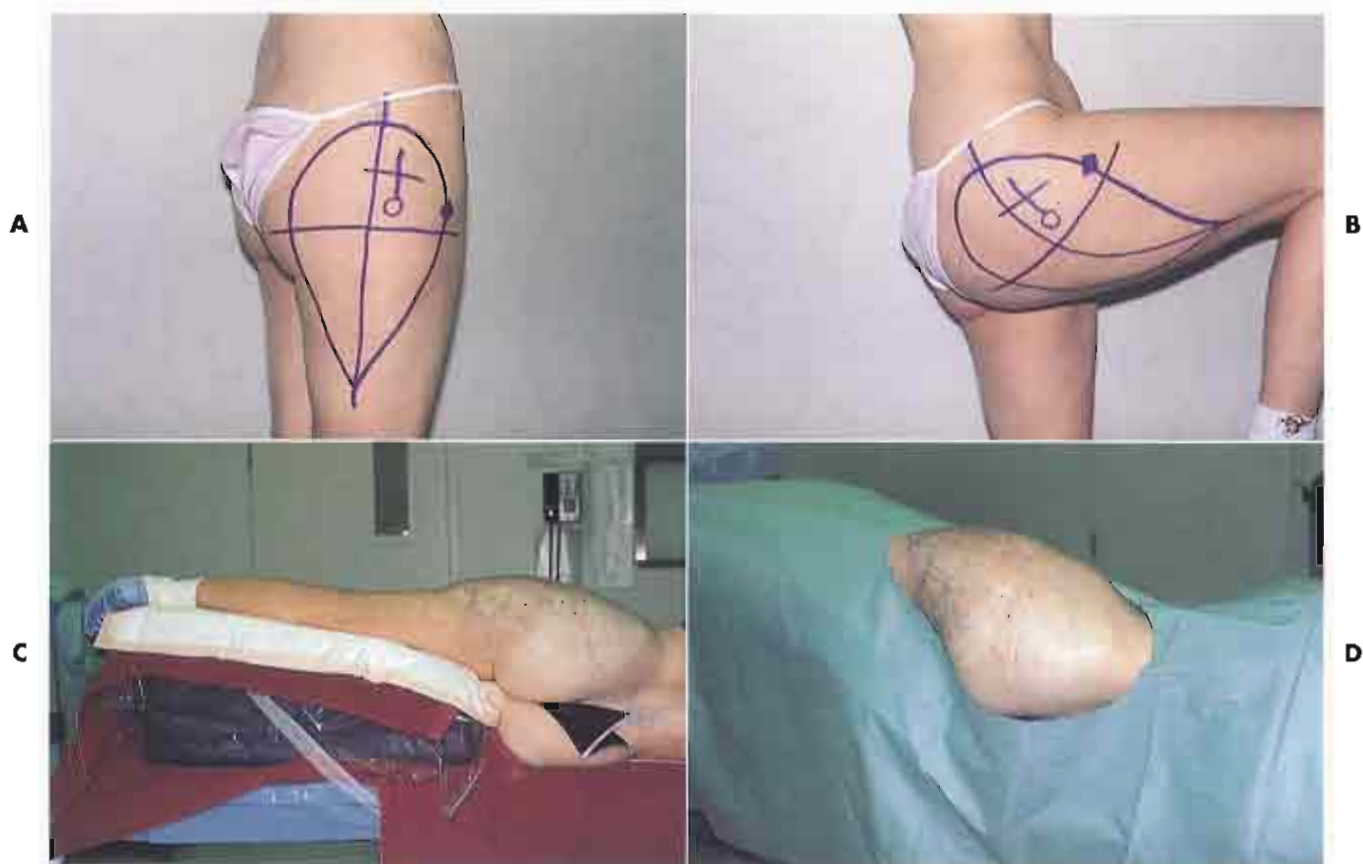
Figure 32-14

Position of trochanteric tubercle relative to overlying skin varies as function of hip joint position. **A,** In anatomic position, with trochanteric tubercle indicated by cross. **B,** When hip is flexed 90 degrees, open circle indicates position of trochanteric tubercle. Solid diamond indicates position of trochanteric tubercle when patient is lying on Thigh Midine with hip maximally rotated anteriorly and medially. **C,** Patient in position for liposuction with sterile superabsorbent sheet placed over Thigh Midine and beneath patient's thigh. Before placing it on surgical table, Thigh Midine is inserted, large end first, into sterilized, single-use, disposable zip-lock plastic bag. Thus, when in place between patient's legs, zip-lock end of cover should be closest to patient. Long piece of 5-cm (2-inch)–wide paper tape is used to secure plastic cover table so that Thigh Midine does not slide toward end of table. **D,** Sterile surgical drape placed on top of patient.

During liposuction the surgeon should intermittently check the amount of fat that has been removed from the area overlying the trochanter. This is accomplished by having the patient straighten the leg and medially rotate the toe, pointing it toward the floor. This maneuver displaces the trochanter anteriorly and flattens the area of the lateral thigh that is particularly susceptible to excessive liposuction. This area immediately overlying the trochanter should look flat but never concave (Figure 32-14).

DISTAL ADIT

It is important to place an adit (1.5-mm punch excision) at the most dependent or distal portion of the treated area of the

lateral thigh. To permit maximal drainage of the blood-tinged anesthetic solution, this hole is not closed with suture. Encouraging rapid drainage of the residual bloody anesthetic solution results in a dramatic decrease in postoperative swelling, bruising, and tenderness.

POSTOPERATIVE CARE

All microincisions are allowed to remain open to maximize the postoperative drainage of the blood-tinged anesthetic solution. Sterile superabsorbent pads are placed over the incision to absorb the drainage and uniformly distribute the compression from postoperative garments (Figure 32-15).
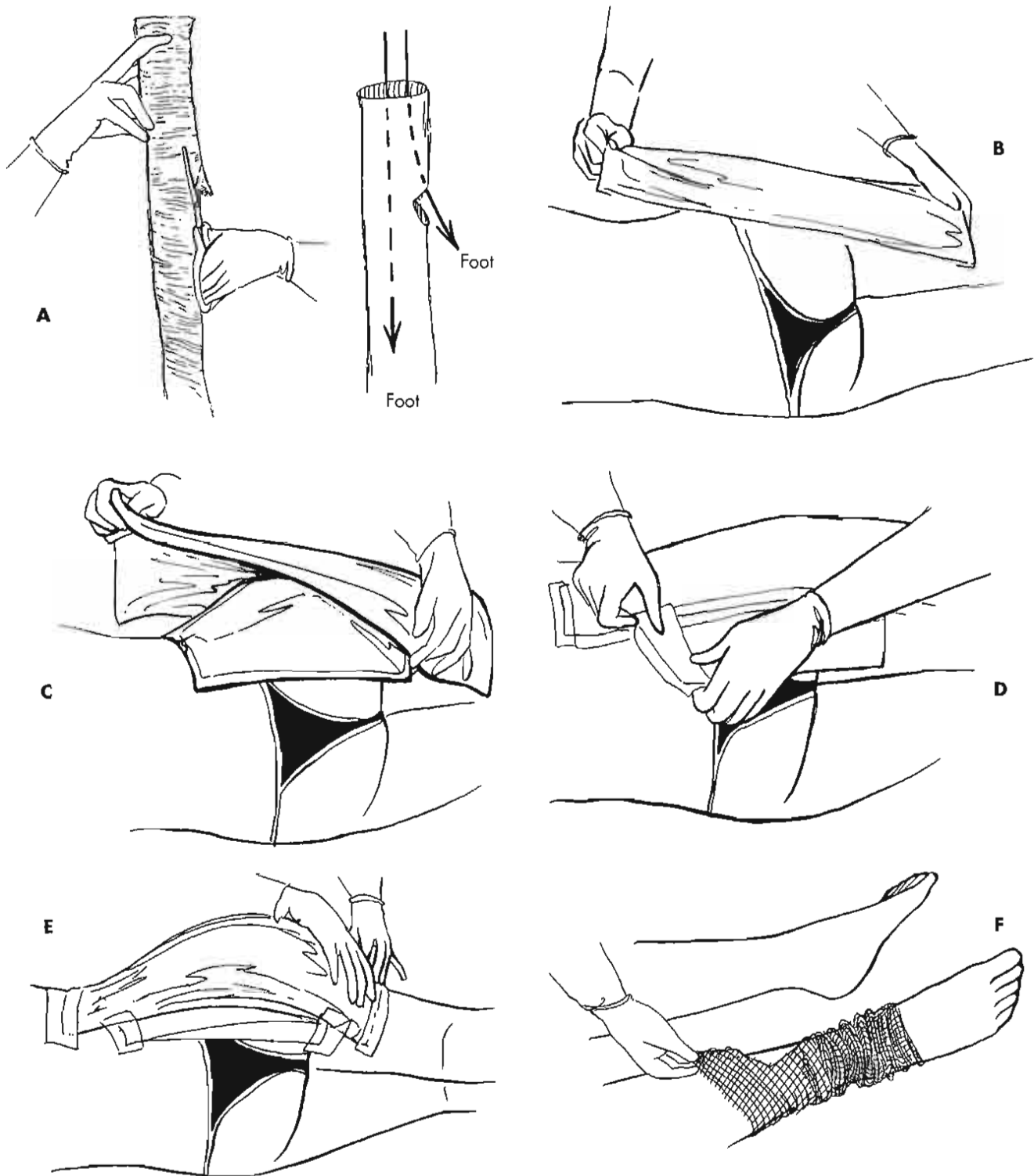
Figure 32-15

Step-by-step instructions for using superabsorbent compression pads and bimodal compression garments for postliposuction care. **A,** Select appropriate length and size of elastic tube netting for outer thigh. Cut side hole in midportion of netting to accommodate opposite leg and thigh. **B,** Apply one or more superabsorbent pads over treated area. **C,** Layer pads so they overlap. **D,** Use 5-cm (2-inch)–wide paper tape to hold pads in place. **E,** Place tape along distal edge of pads to prevent leakage of drainage fluid. **F,** Pull elastic tube netting onto leg. *Continued*
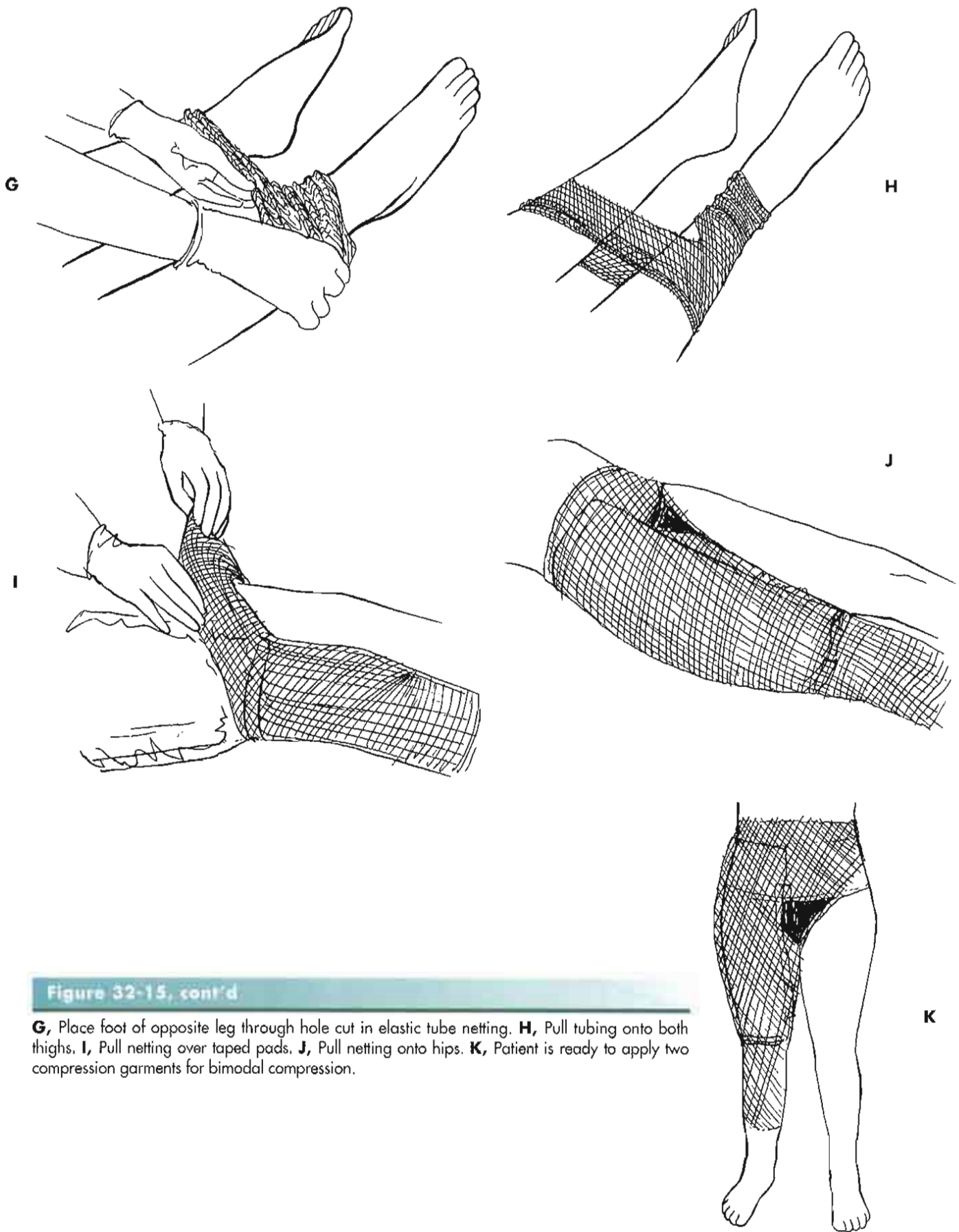
Figure 32-15, cont'd

G, Place foot of opposite leg through hole cut in elastic tube netting. **H,** Pull tubing onto both thighs. **I,** Pull netting over taped pads. **J,** Pull netting onto hips. **K,** Patient is ready to apply two compression garments for bimodal compression.

Figure 32·16

This patient first had liposuction of lateral thighs and hips. More than a month later, she had liposuction of inner thighs and knees. **A,** Preoperative view; **B,** postoperative view. After each procedure, she was able to return to work the following day. She had no pedal edema after either procedure.

PITFALLS AND SPECIAL CONSIDERATIONS

Soon after completion of liposuction on a lateral thigh, an occasional patient will experience transient burning and aching in that area for about a half hour. This discomfort has no clinical consequence, its cause is obscure, and the situation resolves spontaneously. I am not aware of a similar syndrome affecting other areas of the body treated by liposuction. Patients under general anesthesia are not likely to experience this situation.

CIRCUMFERENTIAL THIGH LIPOSUCTION

Excessively prolonged healing and swelling are the predictable consequences of doing liposuction over the entire circumference of the thighs on a single day. The trauma of liposuction causes postoperative edema of the treated tissues.

Circumferential liposuction of the entire thigh produces circumferential inflammation, with consequent obstruction of the lymphatic and venous drainage from distal tissues. Impaired lymphatic flow leads to distal edema for the foot and leg. Edema and impaired venous drainage increase the risk of venostasis and venous thrombosis (see Chapter 34).

To minimize postoperative pain, swelling, and immobility, circumferential thigh liposuction should be done as a two-stage procedure and on two different days, preferably 1 or 2 months apart. A 4-week to 12-week interval between surgeries is usually sufficient to allow adequate decrease in swelling and soreness and partial recovery of lymphatic drainage. For example, with a staged procedure the surgeon might initially treat the hips and outer thigh, then complete the anterior and inner thigh a month or more later (see Figure 32-1, C and D).

By separating circumferential thigh liposuction into two surgeries, patients can return to normal activity almost immediately after each procedure, with minimal distal edema. The total duration of postoperative disability is significantly less than if all the liposuction were done on a single day (Figure 32-16).

CHAPTER 33

Female Hips and Back and Male Flanks

The surface anatomy of the female hips and back is the visible manifestation of the local fat compartments. For the purposes of liposuction, surface anatomy of the back can be subdivided into the following clinically important subsets (Figure 33-1):

1. Cervicodorsal (neck/back) hump
2. Posterior axillary back
3. Subscapular back (or flank)
4. Waist
5. Lumbar pad
6. Sacral pad

In defining areas targeted for liposuction, the *waist* is regarded as the bilateral portion of the torso between the costal margin and the iliac crest. Patients often consider the waist as the entire circumference of the midtorso, including the abdomen. In slender persons the waist is typically the smallest circumference of the torso. As a degree of obesity increases, the waist and abdominal girth expand, and the greatest circumference of the torso becomes the waist.

FEMALE HIPS

ANATOMIC CONSIDERATIONS

The hips typically extend over the posterolateral torso, bounded above by the waist and anteriorly by the anterior iliac crest. The proximal extent of the hip fat pad is the costal margin. The distal margin is typically defined by the *lateral gluteofemoral dell,* located between the hip and the lateral thigh at approximately the level of the maximum concavity of the lateral gluteus muscle (Figure 33-2).

The fat of the hips has relatively little fibrous tissue content. In contrast, proximal to the hips, fat pads of the waist and subscapular back are increasingly fibrous.

The fatty content of the female hips increases with advancing age. When viewing a woman from her backside, it is not difficult to assess her approximate age; hip size provides

a good estimate. Photographs of the backsides of women ages 20, 30, 40, 50, and 60 can often be ranked according to age based on size and shape of the hips. Liposuction of the hips usually helps a woman's body look younger, at least from the perspective of the backside.

Some women might not appreciate the aesthetic necessity of a liposuction of the hips and waist. A woman with large hips and outer thighs is often more concerned about the thighs and pays little heed to her hips. She may simply not understand her aesthetic problem and thus not see the necessity of hip liposuction. Her thighs may have always been a problem, whereas her hips may have become a problem only recently.

At the initial consultation, if the size of the hips cannot be ignored, it is proper for the surgeon to discuss the relative merits of doing liposuction of the hips. In a woman with disproportionately large hips, aggressive liposuction of the outer thighs but not treating the hips will yield a suboptimal result and a dissatisfied patient. Although it might be inappropriate to insist that the hips be treated, the surgeon has an obligation not to ignore the situation. The patient should be made aware that treating the thighs while not treating the hips may yield disproportionate aesthetic results.

If, despite having large hips, a patient elects to have only the thighs treated, the liposuction of the outer thighs cannot be done as completely. Ignoring the hips while aggressively doing liposuction of the outer thighs risks producing a disproportionate result. By including the hips, the surgeon can also be more aggressive in reducing the size of the outer thighs.

A woman who has both a large abdomen and large hips may believe that the abdomen alone is responsible for her inability to look good in clothes. If the abdomen alone is treated, the patient will be dissatisfied when she realizes the effect of not treating her disproportionately large hips.

PREOPERATIVE EVALUATION

The hips contain deep fat deposits. When drawing the topographic contour mapping on the patient's skin, the goal is to de-
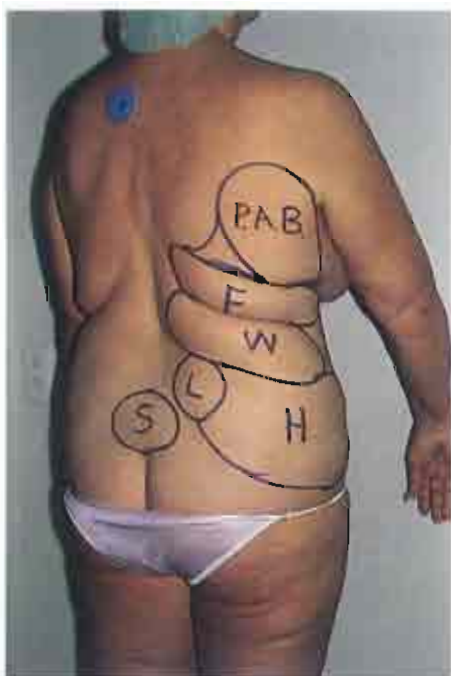
Figure 33-1

Surface anatomy of back includes regularly identifiable areas: *PAB*, posterior axillary back; *F*, flanks (or subscapular back); *W*, waist; *L*, lumbar pad; *S*, sacral pad. Hip *H* is often liposuctioned concomitantly with back.

Figure 33-2

Lateral gluteofemoral dell is transverse saddleback concavity between lateral iliac crest and trochanter. This dell is not apparent in every female.

pict accurately the areas of deepest fat deposits (Figure 33-3). The orientation of the deepest fat deposits of the female hips, however, is deceptive.

Hip fat has a different orientation than the fat of the outer thighs. The perpendicular line to the deepest plane of fat on the outer thigh is oriented horizontally. In contrast, because of the shape of the female bony pelvis, the perpendicular line to the deepest plane of fat on the hip is oriented approximately 30 to 45 degrees superiorly from the horizontal (Figure 33-4).

Accurate tumescent liposuction requires precise topographic contour lines drawn on the patient before infiltration and surgery. If the surgeon draws the concentric circles on the hip so that the perpendicular line to the central circle is horizontal, the deepest fat on the hip will usually escape liposuction.

To indicate the intended area for deepest liposuction, this basic anatomic fact must be taken into account when planning and executing the drawing on the patient. If the central concentric circles are placed too distally, liposuction will inadequately treat the proximal extent of the hips.

INTRAOPERATIVE POSITIONING

The entire hip usually is easily accessible when the patient is in the lateral decubitus position.

Occasionally, part of the waist may be obscured by inordinately large hips because of the lateral flexion of the spine and

the cephalad rotation of the iliac crest toward the lateral costal margin. For this patient it is often helpful to place a folded towel or flat pillow under the dependent waist. This maneuver straightens the spine and exposes the sulcus between the rib and the hip. Placing a pillow between the patient's leg and providing an armrest might improve patient comfort (Figure 33-5).

SURGICAL TECHNIQUE

The hip is one of the easiest areas to treat by liposuction. Because the degree of fibrousness of the fat is usually minimal, the hip fat comes out with minimal effort. Smooth, natural-appearing results require careful attention to achieving a subtle zone of transition between the hip and the adjacent areas of the buttock, lateral thigh, abdomen, and waist.

Incisions placed on the lateral aspect of the torso have less of a tendency to become hyperpigmented and therefore are less likely to remain visible than incisions on or near the back. This should be taken into account when deciding where to place incisions or adits.

If the hips/waist and abdomen are to be treated on separate days, the surgeon must be certain not to ignore or overlook the transitional area between the lateral abdomen and the anterior waist.

The posterior margin of the hip typically trails off into the waist, with a wedge-shaped bulge or tail of fat tapering as it
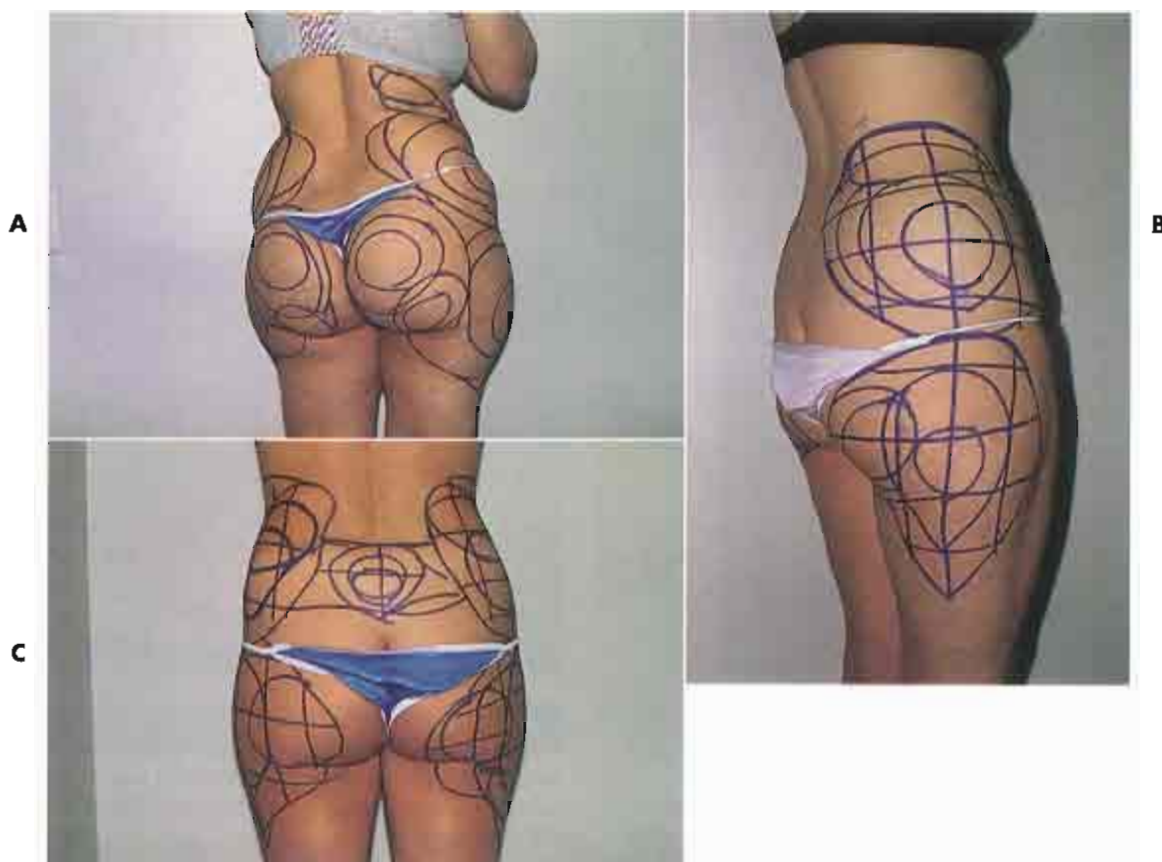
Figure 33-3

Typical contour drawings on hips. **A,** Hip is contiguous with buttock and lateral thigh. In patients who are not too obese, all three of these areas may be liposuctioned on same day. **B,** Combination of hip, lateral thigh, and inferior lateral buttock is one of the most common areas treated on same day. **C,** Occasionally, lumbosacral areas are treated at same time as hips.

Figure 33-4

Point on hip that corresponds to greatest depth of fat (D_1) is located proximal to and different from point of maximum lateral protrusion (D_2). Being aware of this visual illusion, surgeon should carefully palpate and gently squeeze hip before marking concentric circles that will dictate area where liposuction will be most thorough.
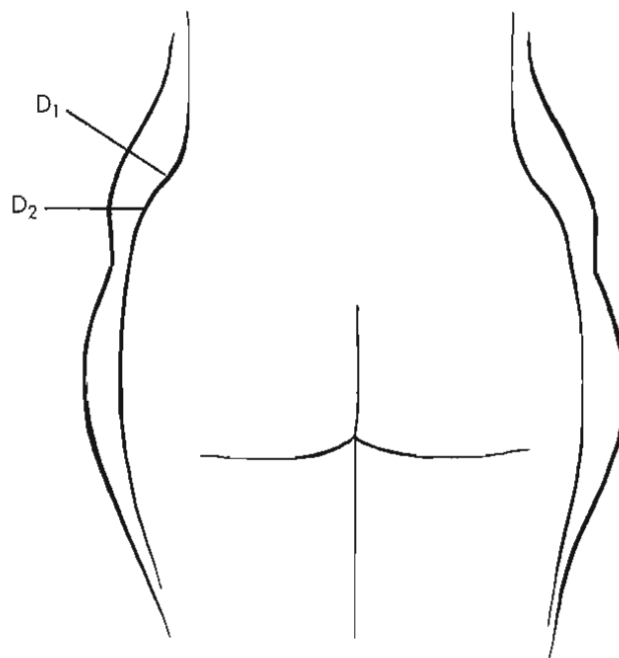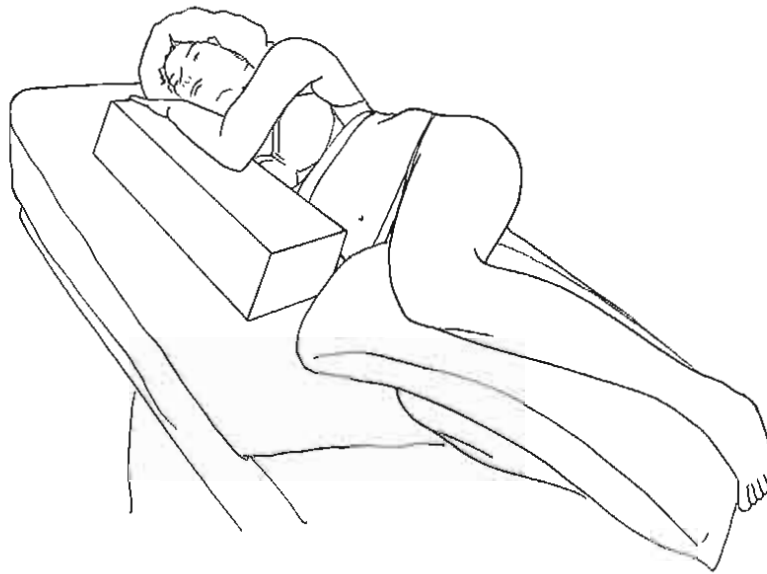
Position for liposuction of hip. When lying on one side in lateral decubitus position, patient is more comfortable when pillows support uppermost contralateral arm and leg.

A, Relatively thin medial tail of hip. **B,** Thicker lateral portion of proximal hip.

extends posteriorly and superiorly below the inferior costal margin. When this tail of fat is prominent, it should not be ignored during liposuction of the hips. The surgeon may regard it as a "time capsule"; if untreated initially, it will often "return" and require treatment at a later date to placate a dissatisfied patient (Figure 33-6).

The inferior margin of the hip is often delineated by a transverse dell that courses distal to the iliac crest and proximal to the trochanteric tubercle. This dell accounts for the violin-like appearance of the female posterior perspective. Some women have little or no dell between their hips and outer thighs.
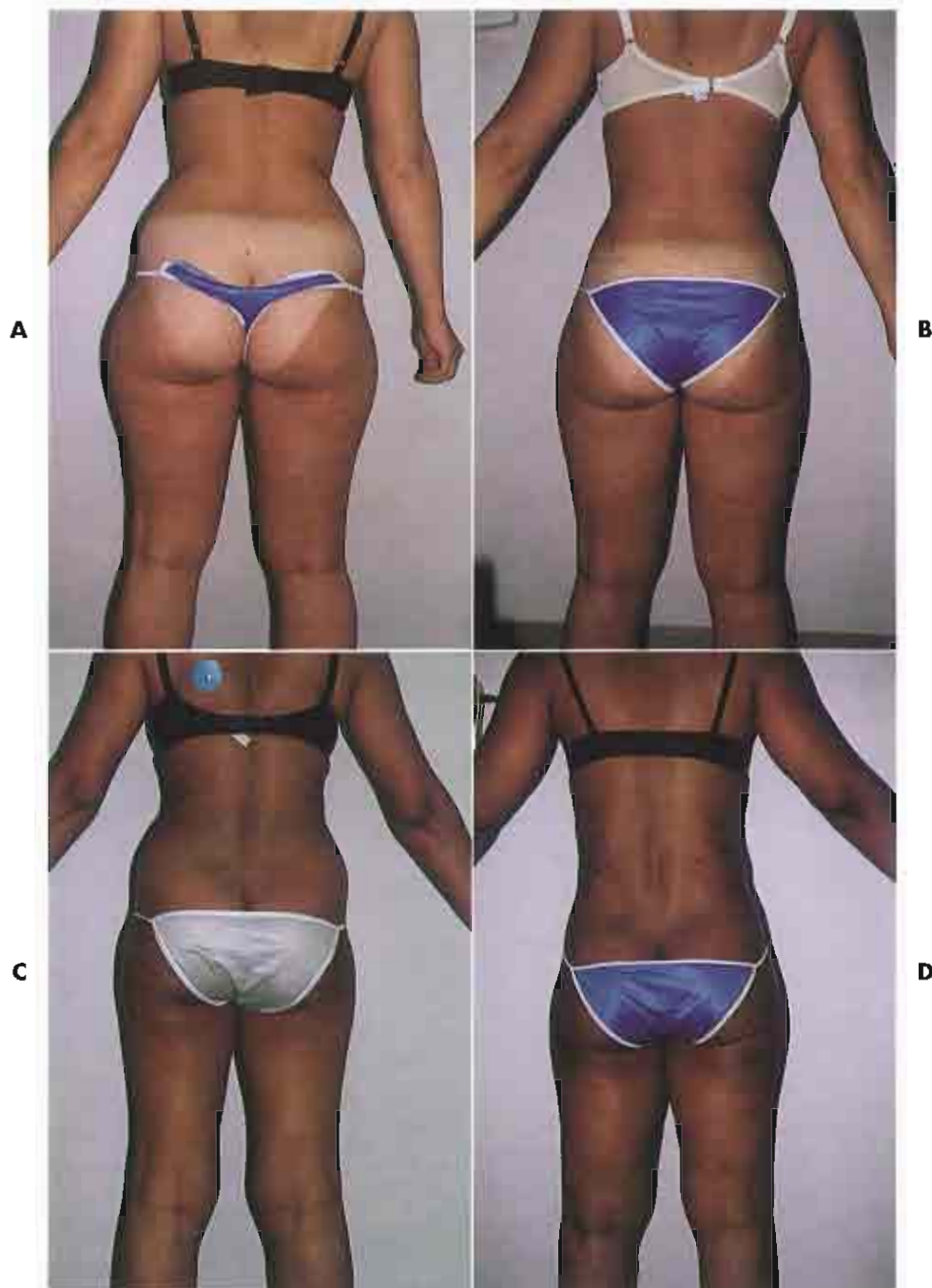
Figure 33-7

Posterior perspectives of four patients before and after liposuction of hips. **A** and **B**, Typical vo-luminous hips and result of liposuction. Additional liposuction could be done on outer thighs. **C** and **D**, Hip liposuction in darkly pigmented patient showing temporary but slowly resolving hyperpigmentation at incision sites.

In a moderately obese woman, lack of a dell usually indicates a relatively deep deposit of fat in the zone between the hip and lateral thigh. This deposit demands careful attention during li-posuction. The smoothest results are often achieved when the hip and outer thigh are treated at the same time (Figure 33-7).

POSTOPERATIVE CARE

Postoperative care of the hips is relatively simple, with the use of absorptive pads and two garments to provide bimodal compression.
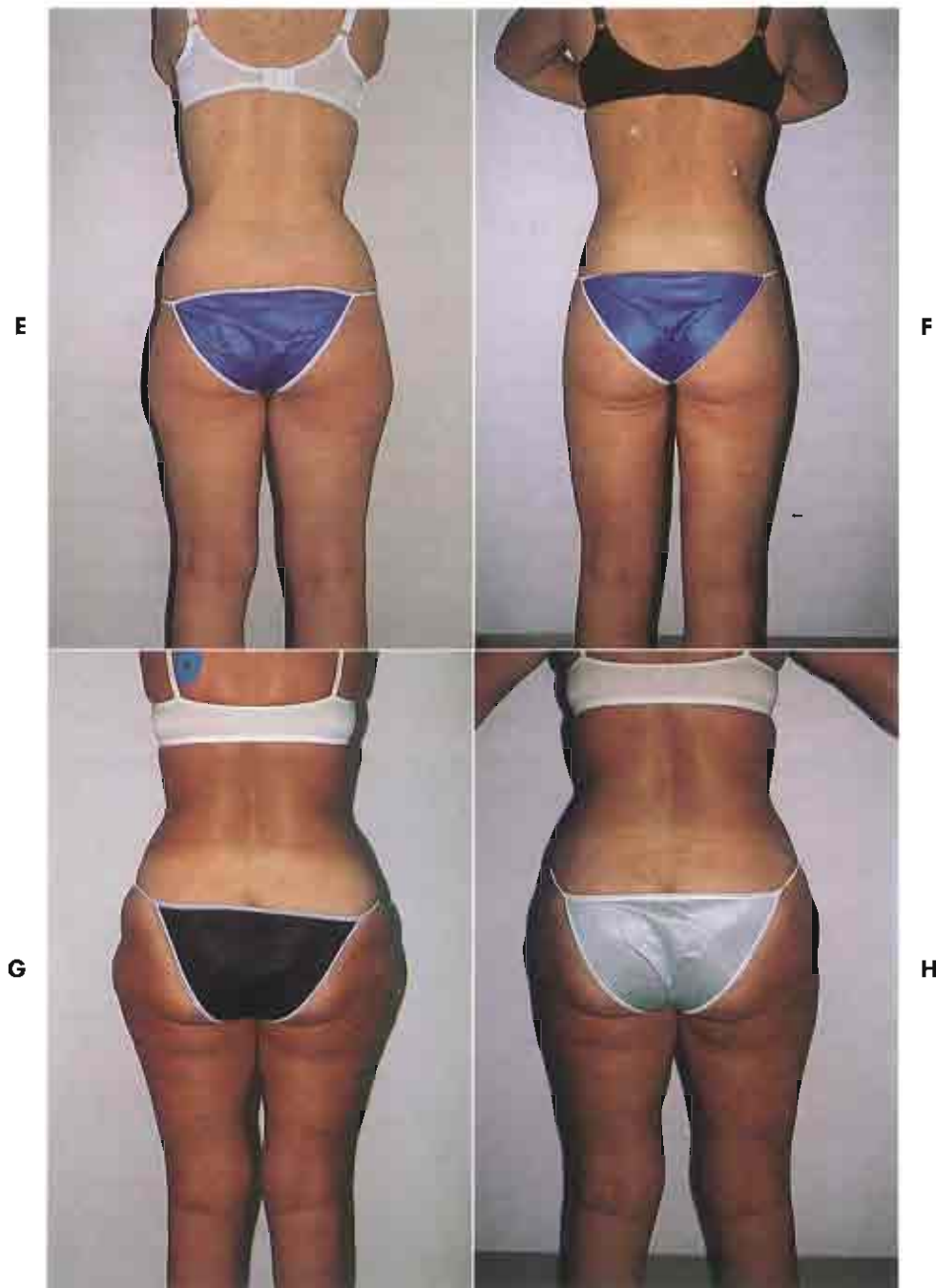
Figure 33-7, cont'd

E and F, Liposuction of hips, outer thighs, inner thighs, and inner knees was accomplished with two separate surgical procedures. Left posterior medial thigh shows subtle horizontal double gluteal crease consistent with excess liposuction in this area. G and H, This patient previously weighed 20 kg (45 pounds) more than her weight at surgery. After great weight loss, total number of fat cells does not decrease significantly; thus adipose tissue is relatively high in collagen content and relatively low in lipid content. Liposuction results are less dramatic for patients who previously had great weight loss.

PITFALLS AND SPECIAL CONSIDERATIONS

Liposuction of the hips, waist, and entire abdomen on the same day produces significant circumferential swelling and tenderness. This restricts the patient's ability to perform such routine tasks as bending over to tie shoes and getting in and out of a car. The unanticipated postoperative pain, impaired flexibility, and frustration limit patient satisfaction.

Preoperatively the determined patient wants to "do it all at one time and get it over with" and is willing to endure the resulting soreness and immobility. Postoperatively the overambitious surgeon soon learns the realities of patients' ability to tolerate circumferential liposuction of the waist and abdomen. Virtually every patient will complain of the unanticipated pain and difficulty of the recovery.

By dividing one complex surgery into two simpler surgeries, the surgeon can pay greater attention to the art and finesse of liposuction and often achieve better cosmetic results. An easier recovery and superior results will increase patient satisfaction.

An unusual type of fibrosis of the hips can make liposuction of this area somewhat challenging. An occasional patient might have had drugs injected into the hips. Multiple deep subcutaneous injections of the hips can eventually produce a nodular fibrosis as a result of an inflammatory sclerotic reaction induced by the vehicle of the injection. The surgeon may not anticipate this unusual situation but with extra effort will achieve a satisfactory result.

FEMALE BACK

ANATOMIC CONSIDERATIONS

The gross anatomy of the subcutaneous fat of the back, including the area distal to the scapula, the cervicothoracic dorsal hump, sacral fat pad, and posterior axillary fold, is not particularly distinctive. Only the dorsal hump and the sacral fat pad seem to have discrete localized compartments of fat. From the liposuction surgeon's perspective, the subcutaneous fat on the back is a rather uniform layer, partitioned in only a few areas by fibrous reticulations that force excessive fat to bunch up in *cordilleras* (hills) or parallel rolls (Figure 33-8).
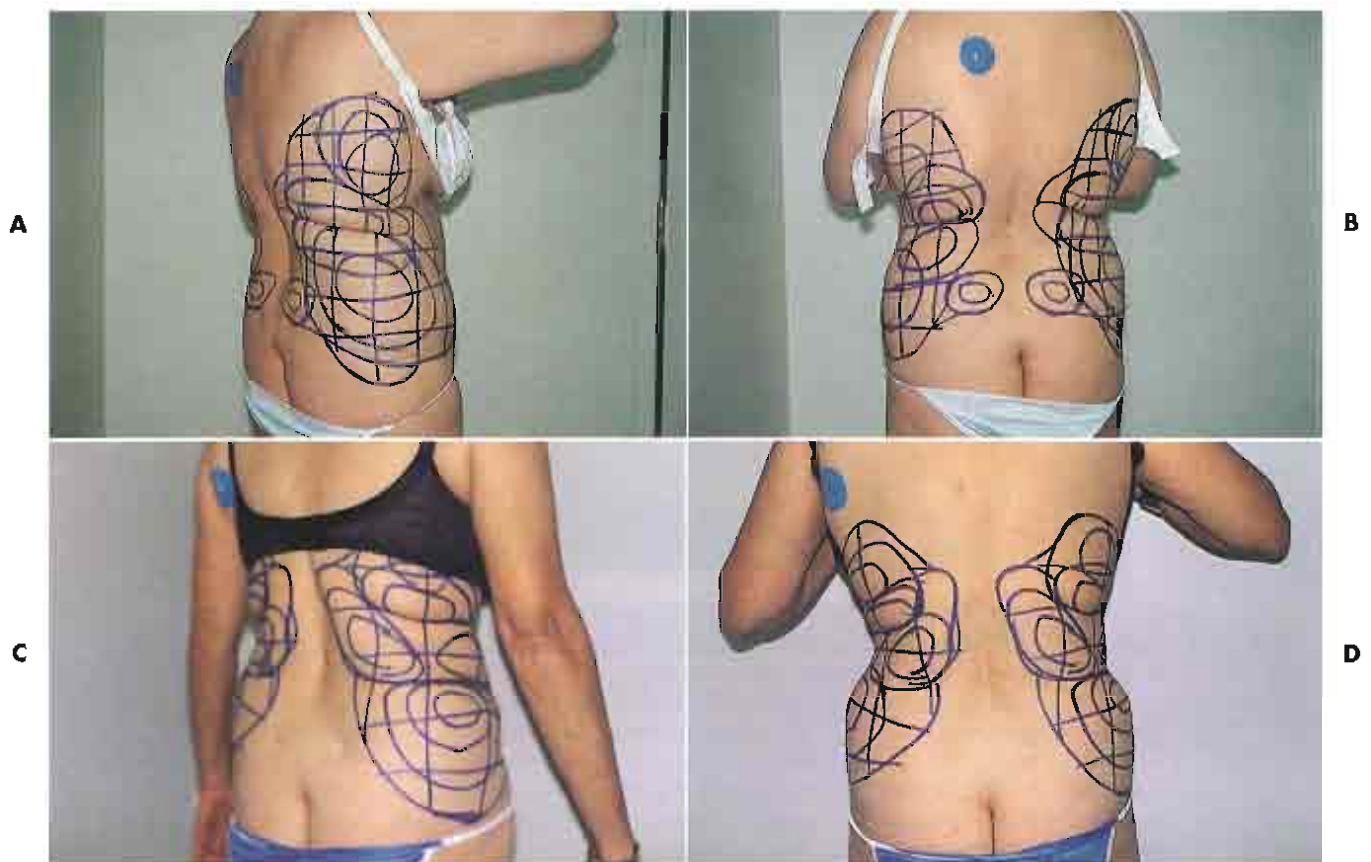
Figure 33-8

Contour drawings on hips, waist, and back demonstrated on two patients. **A** and **B,** First patient before liposuction of hips, waist, flanks, and posterior axillary back. **C** and **D,** Second patient before liposuction of hips, waist, and flanks.

Infrascapular Back. The infrascapular back is the area just caudal to the scapula. The fat overlying the midposterior back is more fibrous than in most other areas. The liposuction surgeon can regard the fat distal to the scapula as a single subcutaneous layer, devoid of any well-defined deep compartment of fat. In some obese persons, with fat caudal to the scapula, the surgeon sees two or three transverse rolls of fat parallel to the underlying ribs.

Discrete linear condensations of fibrous tissue seem to subdivide the back into a cordillera of rolling hills or a mullion of folded parallel rolls of fat. Microcannular tumescent liposuction can provide significant cosmetic improvement to the female back as well as the hips (Figure 33-9).
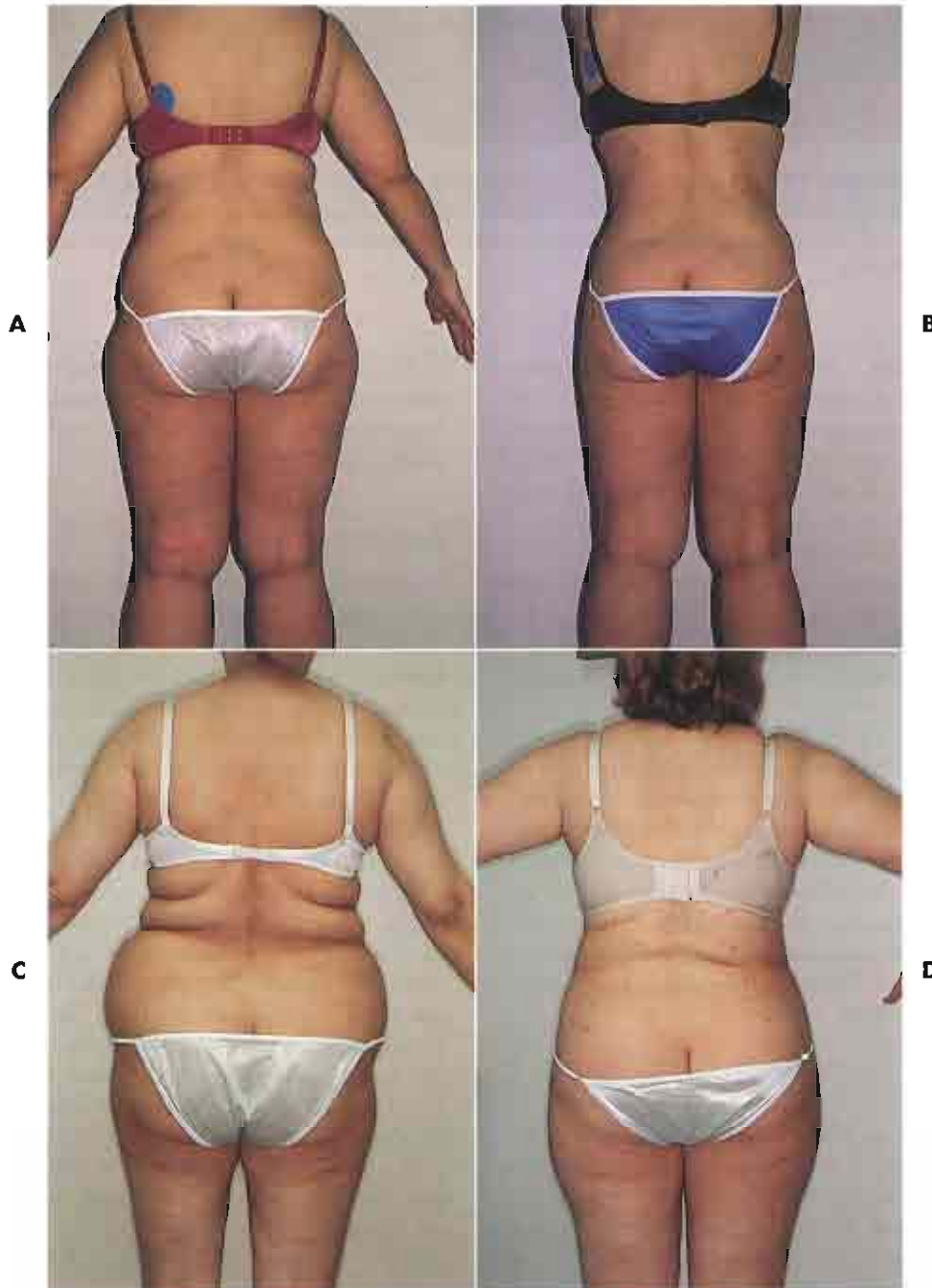
figure 33-9

Microcannulas facilitate liposuction of fibrous areas on back. **A** and **B,** Microcannular tumescent liposuction provided this patient with a narrow waist for first time in her life. **C** and **D,** Cordilleras (hills) of dorsal fat respond well to microcannular liposuction.   *Continued*

Figure 33-9, cont'd

E and **F,** Results of microcannular liposuction were impressive even before this patient lost weight by dieting.

Ultrasonic Liposuction.   Because of the difficulty in penetrating a densely fibrous area of fat with liposuction cannulas with an outside diameter greater than 2.0 mm, some surgeons have resorted to ultrasonic-assisted liposuction (UAL) for the back. I believe that most surgeons who advocate UAL have had little experience with using 16-gauge microcannulas to initiate liposuction in fibrous areas.

UAL uses larger cannulas, necessitates larger incisions and scars, takes longer to complete, and is associated with an increased risk of seromas and dermal necrosis. Ultimately, aesthetic results are not better than results achieved with microcannular liposuction.

Fibrous Content.   The greater the fibrous content of a fat compartment, the more resistance to penetration by a cannula, and the more difficult it is to achieve a satisfactory degree of liposuction. The use of smallest diameter cannulas (16 gauge) greatly facilitates liposuction in areas that are especially fibrous, such as the midlateral back. Furthermore, the initial use of small cannulas, followed by larger microcannulas, permits more thorough liposuction and is more comfortable for the patient.

SURGICAL TECHNIQUE

The highly fibrous nature of fat in the subscapular area makes liposuction a challenge. This densely fibrous tissue is nearly impossible to penetrate with large cannulas. With the use of microcannulas and tumescent infiltration, however, this area can be successfully treated.

The 16-gauge Capistrano cannulas are particularly helpful in initiating liposuction. Once the deeper plane of liposuction tunnels has been established using 16-gauge microcannulas, the surgeon can then use 14-gauge cannulas. With artistic patience and persistence the surgeon can achieve gratifying results totally by local anesthesia.

Incision sites on the back tend to cause hyperpigmentation considerably more than incisions located more laterally. Incision sites for back liposuction should be placed as far laterally as practical.

POSTOPERATIVE CARE

Postoperative care after liposuction of the back merely requires adequate coverage with superabsorbent pads, held in place with an appropriate torso compression garment. A high degree of external compression is not necessary. The motion of the torso during respiration and other normal daily activities are sufficient to expel the residual blood-tinged anesthetic solution completely from treated areas overlying the rib cage (Figure 33-10).

Absorptive compression sponges are applied in a manner similar to that used for the abdomen and breasts. First, an appropriate length of the proper-size elastic tube netting is selected for the torso. For the hips and waist a simple cylinder-shaped segment of netting is sufficient; it is often not necessary to cut side holes for the arms (see Figure 31-20). If the pads are to be placed over the back or flanks, however, the tube netting should be cut similar to the netting used for the breast, with two lateral arm holes (see Figure 38-12). The absorptive compression sponges are then applied, with 5-cm (2-inch)–wide paper tape used to hold them in place. After pulling the elastic tube netting into place, appropriate elastic compression garments are applied.

PITFALLS AND SPECIAL CONSIDERATIONS

The skin on the back is especially susceptible to hyperpigmentation of scars from incisions for liposuction. The number of scars should be minimized and care taken to avoid unnecessary trauma to the epidermis near incision sites on the

Liposuction from back to lateral thigh requires two types of garments worn simultaneously to hold absorptive pads in place and to provide postliposuction compression. Torso garment provides compression for back and hips while Overall garment provides compression for hips and thighs.

Erythema ab liporaspiration showing reticulate pattern of erythema resulting from aggressive superficial liposuction on undersurface of skin.

back. Trauma to the dermal-epidermal junction predisposes to postinflammatory hyperpigmentation.

Because there is no deep compartment of fat on the back but merely a thick layer of subdermal fat, the surgeon may tend to do too much superficial liposuction. The result of excessive liposuction that attacks the subdermal surface is disfiguring erythema ab liporaspiration (Figure 33-11). Similarly, the tendency to perform excessive liposuction on the back risks penetrating too deeply and injuring striated muscle.

When treating patients with dorsal cordilleras or rolls of fat, liposuction is easier if the patient is about her maximum weight. For patients who have rolls of fat distal to the scapula and who have lost considerable weight, liposuction is relatively more difficult. For mildly obese patients who have no obvious fatty cordilleras, liposuction can provide great improvement. Particularly with liposuction of the back, significant weight gain after liposuction may negate much of the surgical improvement.

Lumbosacral Fat Pads. The relatively small areas at the lower back are easily treated. Removal of a prominent sacral fat pad minimizes the appearance of obesity.

The surgeon should use caution during the preoperative physical examination of this area. A focal lipoma or hairy nevus may indicate occult spina bifida. If in doubt, a consultation with a knowledgeable radiologist may be appropriate.

Cervicothoracic Dorsal Hump. An increasing degree of obesity is often associated with a prominent localized accumulation of fatty tissue on the middle part of the upper back, overlying the proximal thoracic vertebrae. In younger patients this dorsal hump can be rather fibrous. In middle-age and older female patients this hump becomes less fibrous and more easily suctioned.

Because of generalized obesity, patients with a fatty dorsal hump are unlikely to be good candidates for extensive liposuction. Nevertheless, liposuction of the dorsal hump is easily accomplished, with great patient satisfaction (Figure 33-12).

Examination. Preoperative physical examination should readily distinguish between a soft fatty dorsal hump and a more rigid kyphosis. A radiologic examination rarely is necessary to confirm the diagnosis of excessive localized subcutaneous fat.

Surgery. Before tumescent anesthetic infiltration, concentric topographic contour drawings should accurately delineate the breadth and depth of the targeted fatty deposit.

Liposuction is accomplished through several small, transversely oriented incisions or through adits; their precise location is not critical but should appear random.

The skin in this area is thicker than anywhere else on the body; therefore incisions need to be slightly larger than in
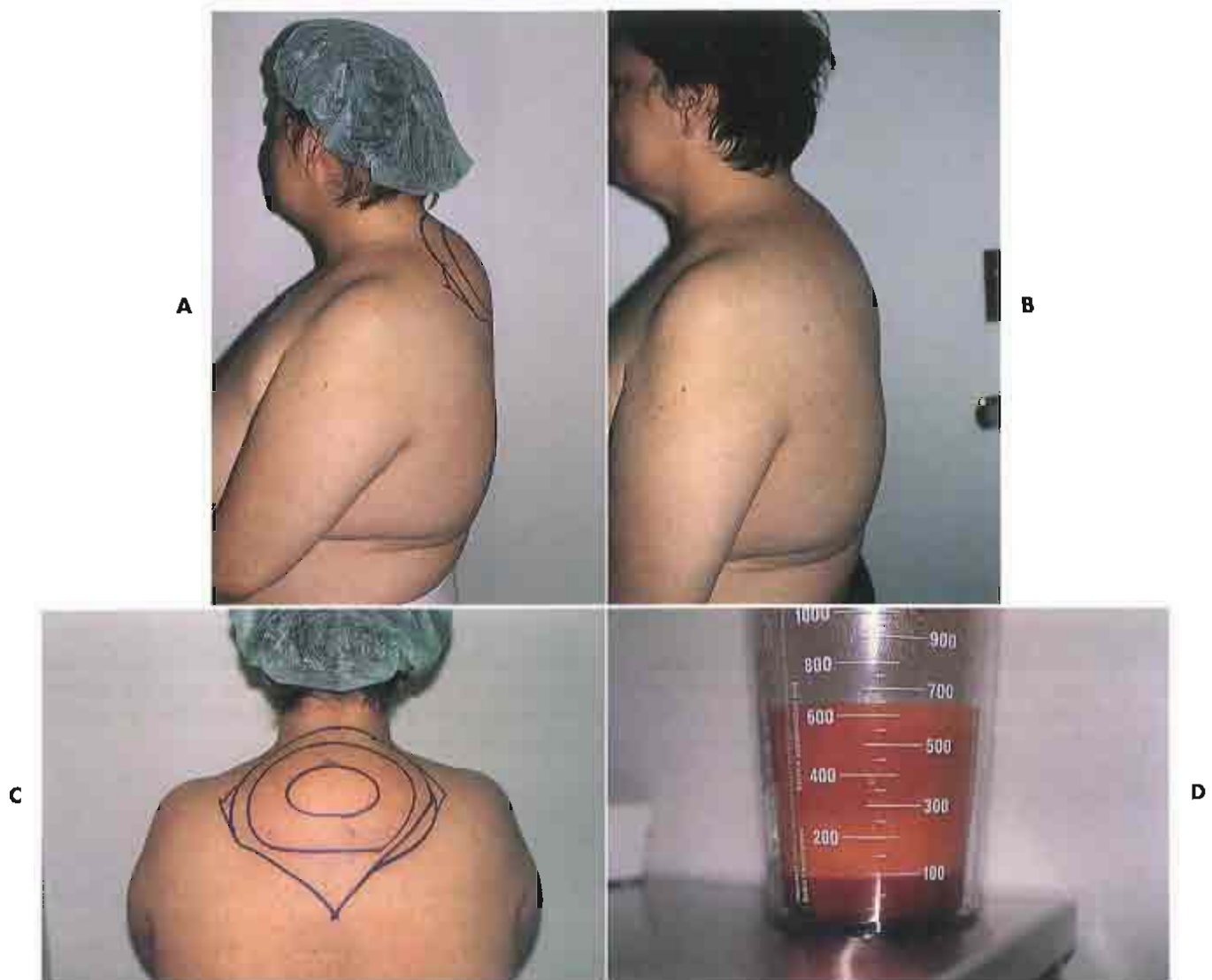
Figure 33-12

Cervical dorsal hump before **(A)** and after **(B)** microcannular tumescent liposuction. **C,** Contour drawing of hump. **D,** Supranatant fat (about 550 ml) removed by liposuction.

thinner skin. The liposuction is easily done using 16-, 14-, and 12-gauge microcannulas.

Drainage.   Postoperative drainage is facilitated by normal movement of the shoulders and neck, so no need exists for extra compression. Drainage, which usually ceases within 24 to 36 hours, is accommodated by taping a superabsorbent pad over the treated area.

MALE FLANKS

The term *flanks* is generally understood by the average patient and is more appropriate than the vernacular "love handles." The subcutaneous fat of male flanks tends to be rather fibrous. Nevertheless, by using microcannulas, es-

pecially Capistrano microcannulas, virtually every male flank can be satisfactorily aspirated with relative ease (Figure 33-13).

ANATOMIC CONSIDERATIONS

Gross Anatomy of Subcutaneous Fat.   With increasing age, males tend to accumulate subcutaneous fat overlying the lateral oblique muscles, although not every bulge in this area is caused by fat. Even when no fat exists in this area, a muscular individual will have some fullness attributable to the muscles.

The normal degree of skin laxity that appears in this area with increasing age is accentuated by the waist band of a tight pair of pants. Liposuction will not eliminate this exaggerated appearance of redundant skin.

Figure 33-13

Male flanks of all types and sizes respond well to microcannular tumescent liposuction. **A** and **B**, Flanks of thin male, preoperative and long-term postoperative views. **C** and **D**, Flanks of male of average weight before and two months after surgery. **E** and **F**, Flanks of relatively obese male before surgery and 1 day after microcannular tumescent liposuction.

Surface Anatomy.   In the female the anatomic area identical to the male flanks is called the "waist." One of the most characteristic features that distinguish the male and female silhouette is the location of the "belt line." In men the belt line is below (caudal to) the flanks and iliac rim, whereas in women the belt line is above the hips and iliac rim and just below the costal margin.

The male flanks extend between the iliac rim and the costal margin, approximately from the anterior to the posterior iliac crest. Typically the deepest and thickest deposit of fat on the male flank is located posterior to the most lateral extent of the flank. Thus, when viewed anteriorly, male flanks do not appear as prominent as when viewed posteriorly.

In the female the area below the bra strap (infrascapular back) is often designated the "female flank." Although a common target for liposuction in women, this same infrascapular area on men rarely undergoes liposuction.

Figure 33-14

Flanks of obese male. **A** and **B,** Preoperative topographic contour drawings show posterodorsal extent of fat compartment. **C** and **D,** Preoperative views. **E** and **F,** Two months after tumescent liposuction totally by local anesthesia.

In contrast to the female, the typical male has little fat immediately caudal to the iliac rim. Therefore attempting liposuction below the iliac rim on a male is unlikely to provide significant cosmetic improvement.

The fat of the flanks is most accurately delineated by nested or roughly concentric topographic contour rings that correlate with the relative depth of the fat; the central rings correspond to the deepest deposits. These topographic markings are most effectively drawn with the patient standing erect, approximately in the anatomic position (Figures 33-14 and 33-15).

INTRAOPERATIVE POSITIONING

The lateral decubitus position facilitates accurate and thorough liposuction of the male flanks. The patient's back, hips, and knees should be slightly flexed to provide comfort.

Liposuction of the male flanks with the patient in the supine position does not allow sufficient access to the posterior extent of the fat compartment, and this area may be insufficiently treated. When the surgery is accomplished under general anesthesia, the patient is in the supine position for endotracheal intubation. Changing positions when the
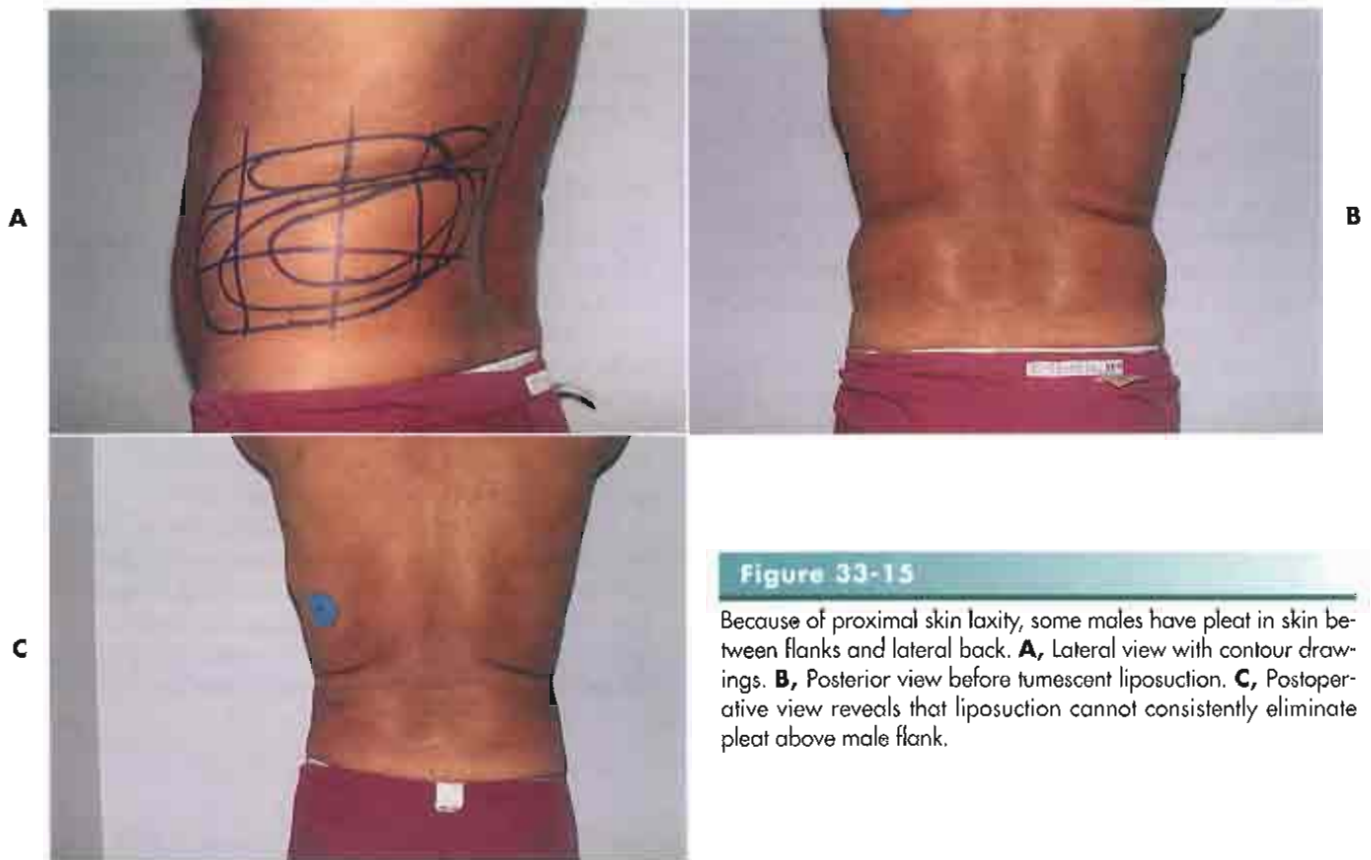
Figure 33-15

Because of proximal skin laxity, some males have pleat in skin between flanks and lateral back. **A,** Lateral view with contour drawings. **B,** Posterior view before tumescent liposuction. **C,** Postoperative view reveals that liposuction cannot consistently eliminate pleat above male flank.

trachea is intubated risks displacing the patient's endotracheal tube and causing hypoventilation or hypoxemia. Thus, when using general anesthesia, the surgeon tends to treat the posterior male flank inadequately. Also, it is difficult to move a patient who is unconscious and unable to cooperate. When liposuction is accomplished totally by local anesthesia, the surgeon merely asks the patient to roll over on his side.

ANESTHETIC INFILTRATION

Infiltration into the fibrous fat of a male is easier with a spinal needle than a blunt-tipped, multiholed infiltrating cannula with a larger diameter. Infiltration with the spinal needle encounters little resistance from the fibrous fat and therefore causes less patient discomfort. With spinal needles, infiltration is more uniform and complete and local anesthesia and vasoconstriction are more profound than with a larger cannula. Therefore liposuction can be more easily accomplished totally by local anesthesia when a spinal needle is used for infiltration.

After placing the anesthetic blebs in the dermis with a 30-gauge needle, the infiltration spinal needle is passed through the anesthetized bleb without requiring an incision. The spinal needle does not cause scarring or hyperpigmentation, and thus it can be inserted through as many sites as deemed convenient and advantageous.

Infiltration is initiated in the deepest plane of the fat deposit and then directed more superficially. From its insertion site the infiltration spinal needle is directed radially in many

directions and depths, overlapping the paths of other needles from adjacent insertion sites.

To ensure patient comfort during liposuction along the margins of the flank area, the infiltration is extended at least 1 cm beyond the boundaries of the intended area of liposuction.

SURGICAL TECHNIQUE

Microcannular access into the subcutaneous fat is provided by microincisions or surgical adits. A conscious effort must be made to minimize incisions, which might eventually be visible as small scars.

I prefer to use surgical adits, consisting of 1.5-mm and 2.0-mm punch excisions. The 2.0-mm adits are placed just below the belt line to minimize the appearance of incision sites when the patient is shirtless. Because a 1.5-mm punch excision leaves a minimal scar, a limited number of 1.5-mm adits can be located anywhere within the treated area. Because incisions on the back are more likely to result in hyperpigmentation or a visible scar, incisions are placed laterally rather than posteriorly, when feasible.

The liposuction sequence is analogous to the infiltration process in that liposuction is initiated in the deepest layer of fat and then carried out more superficially. The initial stages of liposuction in this fibrous area employ 16-gauge cannulas; 14-gauge and occasionally 12-gauge Capistrano cannulas are used to complete the liposuction procedure.

Microcannulas allow excellent liposuction results for the fibrous male flanks. UAL is not necessary for successful liposuction of the male flank.

POSTOPERATIVE CARE

Early in my liposuction experience, I discovered that male patients routinely ignored my instructions to wear a postoperative compression garment for at least a week. Almost every male patient simply discontinued compression binders as soon as the drainage had ceased.

Realizing that no adverse effects occurred with such brief compression, I modified instructions for postoperative care. With open drainage, prolonged postliposuction compression is no longer required. Bimodal compression minimizes duration of compression and accelerates rapid resolution of postliposuction edema, soreness, and bruising.

After liposuction of the male flanks, patients are instructed to wear superabsorbent compression pads to accommodate the open drainage. Obese patients and those with liposuction of both the abdomen and the flanks usually do best with a breast and torso garment and one or two elastic torso binders. Nonobese patients may require only a single torso binder to secure the absorptive pads and provide compression for 2 to 3 days. Elastic torso binders may be 15 cm (6 inches) or 22.5 cm (9 inches) wide.

PITFALLS AND SPECIAL CONSIDERATIONS

The most lateral extent of the male flank is not the most visible part of the fatty deposit. In most patients the deepest area of fat is deposited more posteriorly. If this posterior flank fat is not included in the area treated by liposuction, most male patients will be disappointed in the results. For example, liposuction of the male abdomen and flanks during a single procedure under general anesthesia with the patient remaining in the supine position will invariably result in undertreatment of the posterior extent of the male flanks.

An overaggressive approach to liposuction of the flanks can injure the subdermal vascular plexus and produce *erythema ab liporaspiration*, a chronic reticulated erythema that resembles erythema ab igne. Avoiding this complication requires caution not to rasp the skin's undersurface and injure the delicate subdermal capillary vasculature (see Chapter 8).

CHAPTER 34

Medial Thighs, Knees, and Anterior Thighs

Aesthetically, fat pads of the medial thigh and the medial knee are not isolated or separate from each other. Most thin patients have minimal fat midway between the knee and the proximal medial thigh. Most middle-age women have fat that extends over the entire extent of the medial thigh.

Liposuction over the entire contiguous area of the medial thigh and knee is preferred to treating the medial thigh and medial knee as isolated areas. More fat can be removed, and the results are consistently smoother than when the two areas are treated separately. Treating these areas as discrete or cosmetically separate often produces a distinct line of demarcation at the margin of the liposuction area. By treating the entire extent of the medial thigh and knee, the surgeon can minimize the incidence of a visible border zone between the proximal medial thigh and the medial knee.

An occasional male patient will benefit from medial thigh liposuction; the surgical technique is the same as for the female medial thigh. I have not done liposuction on the medial knee of a male.

MEDIAL THIGH

ANATOMIC CONSIDERATIONS

Without tumescence, the medial thigh is one of the most difficult areas in which to achieve smooth results. The fat of the proximal medial thigh contains little fibrous tissue and has a soft, jellylike quality. Such fat may be liposuctioned too easily and rapidly, resulting in areas of excessive and irregular liposuction.

With tumescent anesthetic infiltration of the medial thigh and careful microcannular liposuction, the surgeon can consistently achieve complete and smooth results.

Gross Anatomy of Subcutaneous Fat. The subcutaneous fat of the medial thigh lacks significant fibrousness and thus

has minimal antitypy (resistance to penetration). This fat becomes sparse along the sulcus at the medial thigh–perineum junction. The subcutaneous fat of the inner thigh is most prominent and deepest a few centimeters distal to the groin.

Distally the depth of medial thigh subcutaneous fat tends to diminish gradually and reaches its nadir in an area approximately two thirds the thigh's length. Beyond the nadir, subcutaneous fat of the medial knee becomes prominent.

The greater saphenous vein courses superficially within the subcutaneous fat from the proximal saphenofemoral junction to the distal posteromedial condyle. The femoral artery is deep to the muscle and therefore relatively remote from the subcutaneous fat.

The muscles underlying the medial thigh are the proximal adductor group, sartorius, and semitendinosus.

Surface Anatomy. The distribution of subcutaneous fat is the principal determinant of human female surface anatomy. In certain areas, such as the medial and anterior thigh, acceptable liposuction results can be achieved only by using precise technique. In particular, detailed contour drawings of the medial thigh/knee are essential for accurate liposuction of the subjacent subcutaneous fat. In addition to concentric contour drawings, an infiltration grid with 8-cm (3-inch) squares is drawn. This grid helps the nurse or surgeon keep track of the areas being infiltrated with tumescent anesthesia (Figure 34-1).

Medial Thigh Furrow. A subtle but important linear depression or shallow furrow courses diagonally from the proximal anterior thigh distally over the medial thigh toward the posterior knee. Although the path of this furrow approximates the position of the sartorius muscle, the furrow is usually less prominent in thin women. The visibility of the medial thigh furrow is accentuated by accumulations of fat in the proximal medial thigh and the knee (Figure 34-2).

Figure 34-1

Topographic contour mappings designate location and depth of fat on medial thigh and medial knee. **A,** Basic outline of fat compartments. **B,** Detailed contour mapping of medial thigh plus orthogonal grid pattern to facilitate tumescent infiltration.

Figure 34-2

Medial thigh furrow *(wide line)* is surface depression extending from proximal anterior to distal posterior thigh. Furrow divides area into medial thigh (proximal) and medial knee (distal).

This furrow accentuates the appearance of obesity. The liposuction surgeon can diminish this visual effect by not highlighting the furrow with liposuction. More liposuction should be done within the proximal and distal compartments of fat (Figure 34-3).

Fat Compartment Access. The medial thigh fat pad gives the inner thigh a drumstick appearance. The area of greatest medial prominence is the area where the two thighs rub together.

The medial thigh, including the posterior aspect, is most easily accessed for liposuction when the patient is lying in the lateral decubitus position with uppermost hip flexed in the "high-step" position and uppermost leg resting on a supportive pillow (e.g., Thigh Aside) (Figure 34-4).

Posterior extension of the medial thigh fat compartment can be prominent and disproportionate in some women. The posterior portion cannot be easily or completely accessed for liposuction when the patient is supine (Figure 34-5). Surgeons who use systemic anesthesia often prefer not to move
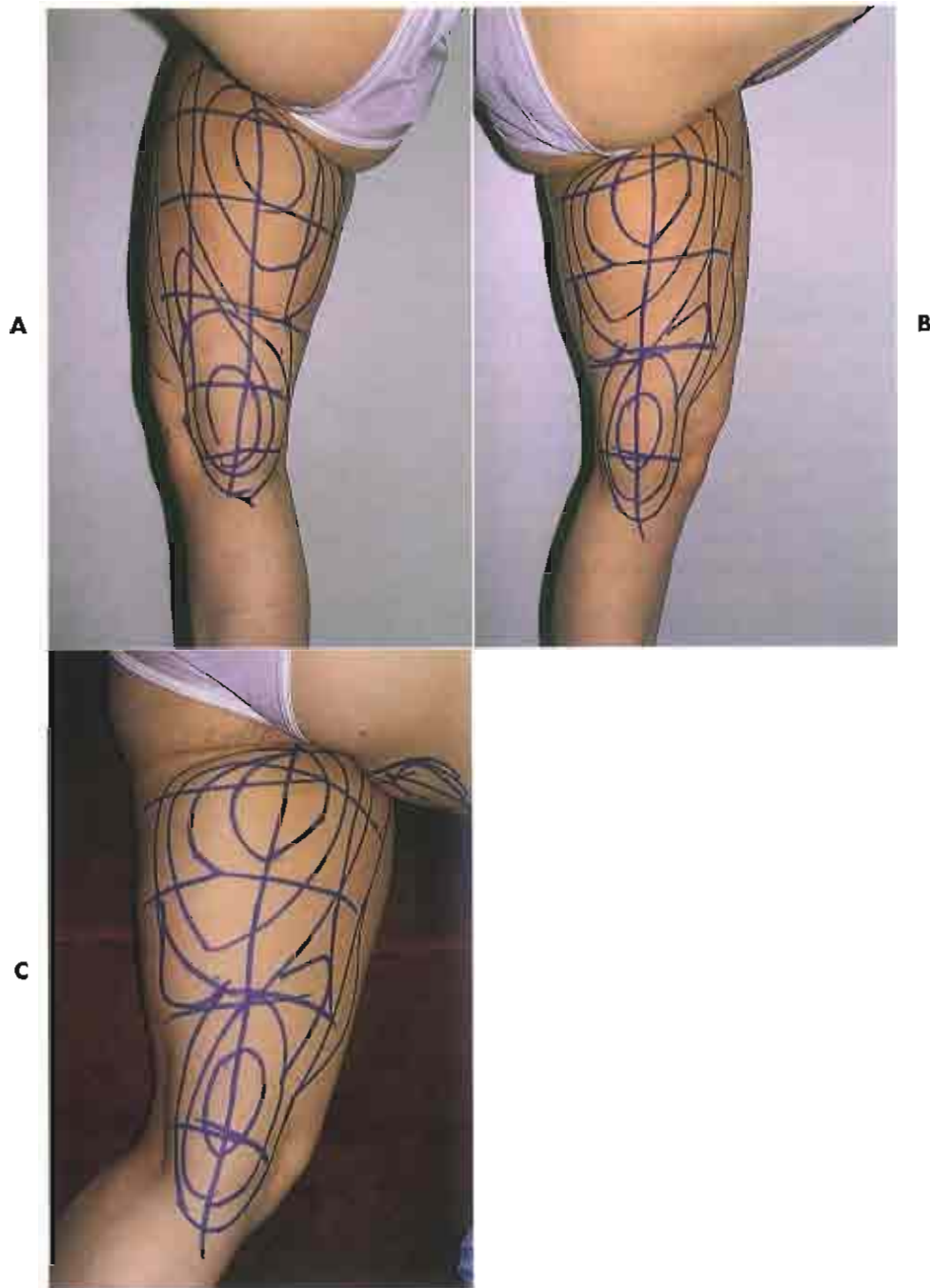
Figure 34-3

Full view of medial thigh/knee contour drawings. **A,** Right medial thigh, with patient standing and raising left thigh. This view demonstrates medial thigh furrow. **B,** Left medial thigh, with patient standing and raising right thigh. **C,** Left medial thigh approximately in anatomic position, with patient lying on left side and right thigh resting on Thigh Aside pillow.
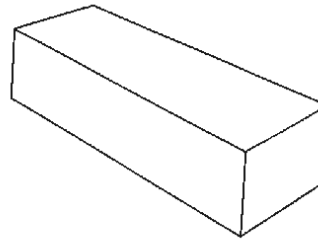
Figure 34-4

Medial thigh/knee position for liposuction of inner thigh and knee is modified lateral decubitus with uppermost hip flexed in high-step position and ipsilateral leg resting on Thigh Aside, a brick-shaped 58 × 23 × 15–cm (23 × 9 × 6–inch) surgical positioning pillow. By placing targeted inner thigh and inner knee in approximated anatomic position, inadvertent liposuction-induced irregularity of skin is less likely. Before positioning patient, Thigh Aside is placed inside sterilized, single-use plastic bag, which in turn is covered by a sterile superabsorptive operating room sheet (see also Figure 40-5).
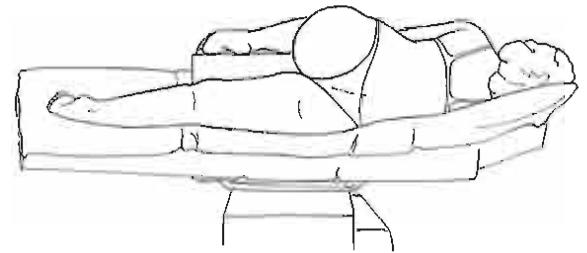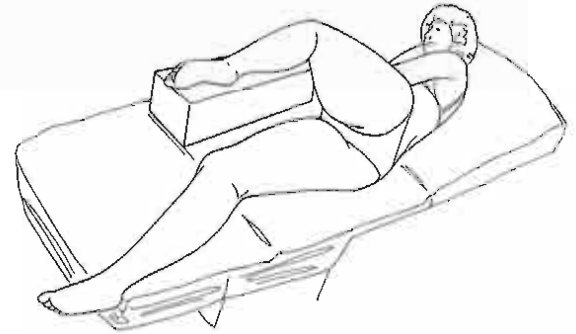
Figure 34-5

Posterior extension of medial thigh fat pad, even when disproportionately large, is easily accessible from lateral decubitus/high-step position. When inner thighs are treated with patient in supine position, posterior extent of inner thigh cannot be adequately accessed or treated. Contour lines are drawn on left side; only the outline is drawn on right side.

Figure 34-6

Proximal anterior extension of medial thigh fat compartment may become more prominent with increasing obesity.

Figure 34-7

Anterior extension of medial thigh fat compartment may not be accessible from lateral decubitus position and may require liposuction in supine position.

the patient from the supine position. They must therefore attempt, often unsuccessfully, to treat the entire medial thigh from the supine position.

Anterior extension of medial thigh fat pad extends onto the proximal anterior thigh in some women (Figure 34-6). When particularly prominent, anterior portion is best treated with the patient supine (Figure 34-7).

Younger women have prominent medial thigh fat and good skin elasticity.

Rugosity. When the medial thigh skin is excessively rugose and crepelike, liposuction may not provide satisfactory improvement. In older women and especially in women who have lost considerable weight, the skin overlying the anterior portion of the medial thigh tends to be rugose.

Liposuction will not improve this wrinkled appearance and even may worsen the degree of rugosity. Prospective patients whose anteromedial thighs already show some "crepiness" should be informed that liposuction may improve the shape while exacerbating the wrinkled appearance.

Surgical Options and Outcomes. Liposuction can significantly improve the shape of the medial thigh and create a smoother surface. The patient should see no unusual lumpiness, irregularity of shape, or visible evidence of a surgical procedure. The bulge of the medial thigh should be flattened so that the silhouette more closely approximates the contour of the musculature (Figure 34-8).

Women who find rugosity objectionable have the option of a *medial thigh lift.* In my experience, however, most patients
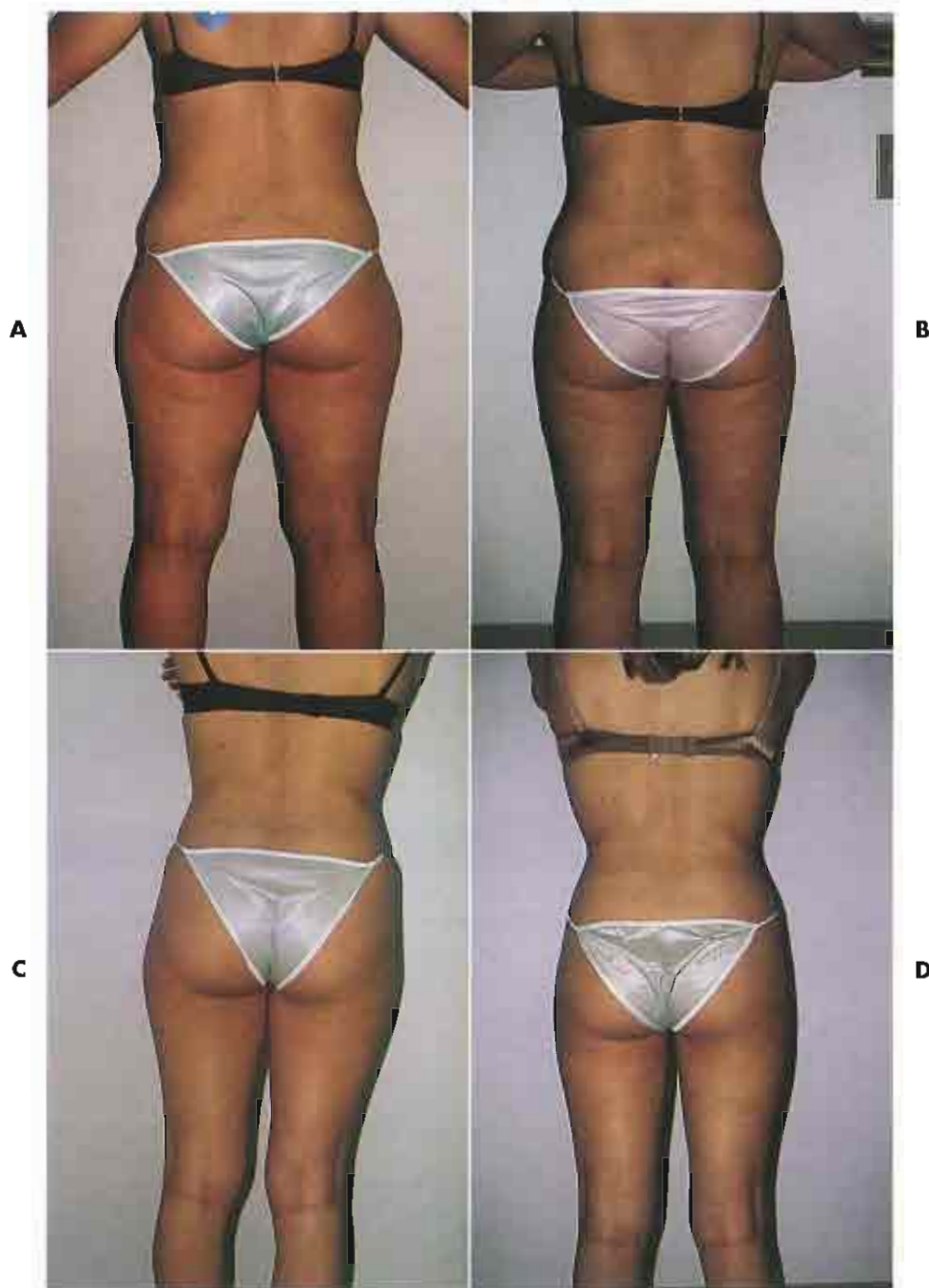
Figure 34-8

Medial thigh/knee liposuction. Three patients before (**A, C,** and **E**) and after (**B, D,** and **F**) microcannular tumescent technique. Outer thighs were treated in separate procedure.

Figure 34-8, cont'd

For legend, see opposite page.

are disappointed by the aesthetic results. They often cannot accept the scarring associated with medial thigh lift.

For patients with marked rugosity and minimal medial thigh fat, the most reasonable option may be no surgical treatment.

PREOPERATIVE EVALUATION

When drawing the topographic lines on the medial thigh, it is important to mark carefully the most proximal area to be infiltrated and suctioned. If the most proximal area along the sulcus between the thigh and the perineum is not well marked, it might be inadequately anesthetized and incompletely treated.

The diagonal course of the medial thigh furrow should be noted. The most prominent mounds of fat on the medial surface of the thigh and knee should be well designated by careful topographic markings before infiltration.

INTRAOPERATIVE POSITIONING

The subcutaneous fat of the medial thigh is susceptible to distortions that result from positions that deviate from the anatomic position.

The use of a Thigh Aside surgical positioning pillow helps place the targeted medial thigh in a position that approximates the anatomic position. The Thigh Aside is a rectangular foam pillow used for liposuction of the medial aspects of the thigh

and knee. It supports the nontargeted leg in the high-step position and facilitates access to the entire length of the targeted medial thigh and knee in the anatomic position.

Other surgical positions used for medial thigh liposuction, such as the supine "frog-leg" position, tend to distort or warp the medial thigh fat and predispose to liposuction irregularities, such as lipowarp (Figure 34-9). With the patient in the anatomic position for medial thigh liposuction, subcutaneous fat is not unnecessarily stretched or distorted. Proper positioning minimizes the risk of inadvertent liposuction irregularities and improves patient comfort.

The lateral decubitus position does not always allow adequate access to all the medial thigh fat when it extends onto the proximal anterior thigh. In this situation, relatively small amount of liposuction is done with the patient lying supine and the thigh slightly spread apart (see Figure 34-7).

ANESTHETIC INFILTRATION

Because of the soft, minimally fibrous nature of medial thigh fat, an irregular infiltration may predispose to a lumpy liposuction result. To ensure homogeneous enlargement of the tumescent tissue, infiltration of the medial thigh must be done uniformly, which requires patience and thorough, deliberate technique. Attempting to complete the infiltration in the shortest time may decrease its accuracy and homogeneity.

A

B

Figure 34-9

Lipowarp of medial thigh is distortion of cutaneous surface and subcutaneous fat caused by deviation from anatomic position: **A,** 5-cm squares drawn on inner thigh when approximately in anatomic position; **B,** distortion of squares showing lipowarp with thigh in "frog-leg" position.

Figure 34-10

Medial thigh lipotrops (too much liposuction) resulted from (1) not using contour drawings to designate location of fat, (2) positioning patient in frog-leg position, and (3) using large-diameter liposuction cannula.

SURGICAL TECHNIQUE

Before the tumescent technique, liposuction was accomplished using large cannulas. Large cannulas created large tunnels. Because medial thigh fat is relatively mobile, it is readily deflected by a large cannula. Large cannulas would tend to reenter existing tunnels by following the path of least resistance. The result was an unintentional and undesirable enlargement of existing tunnels and uneven liposuction results (Figure 34-10).

With the tumescent technique and careful use of microcannulas, liposuction of the medial thigh should consistently yield smooth results (Figure 34-11). With tumescence the medial thigh fat is firm and immobile. Tumescence also produces profound hemostasis, which in turn permits the use of microcannulas.

Because microcannulas have a small cross-sectional area, they encounter minimal resistance when advanced through fat and thus can be accurately directed through the sessile fat, with minimal tendency to reenter preexisting tunnels. By producing a crisscross pattern of tunnels, microcannular liposuction of the medial thighs yields smooth, natural-looking results.

The adits or incisions on the medial thigh tend to be distributed along the diagonal medial thigh groove, along the posterior border of the medial thigh, and 2 to 4 cm from the anterior border of the medial thigh. The most important considerations when deciding where to place the adits are as follows:

1. Convenient access to the targeted fat compartments
2. Minimal visibility of the adits during the healing phase
3. Optimal drainage of residual blood-tinged anesthetic solution

A

B

Figure 34-11

Naturally occurring irregularities of medial thigh can be improved with microcannular liposuction. **A,** Preoperative view with surface irregularities. **B,** Smoother skin after microcannular liposuction.

The initial phase of liposuction is accomplished using the smallest microcannulas, which are directed along the deepest planes of the subcutaneous fat. I prefer to use Capistrano microcannulas initially; however, a surgeon unaccustomed to these efficient cannulas should use a Finesse microcannula. Using a crisscross pattern, the surgeon directs microcannulas both proximally, from microincisions along the midportion of the medial thigh, and anteriorly, from adits along the posterior border.

On thin to average-size patients the entire medial thigh is typically treated using only 16-gauge and 14-gauge cannulas. A 12-gauge Capistrano cannula is used only for larger patients.

For patients who want a straight or vertical silhouette for the medial thigh, the last portion of the liposuction is accomplished using a 12-gauge Finesse cannula directed toward the area of the proximal medial thigh where the subcutaneous fat is the most prominent. The Finesse microcannula permits aggressive liposuction to be directed deeply while minimizing the risk of cannula injury to the overlying dermis.

To access the medial thigh fat that extends far onto the proximal anterior thigh, the patient is placed in a supine position with the thigh slightly spread apart. One incision or adit, placed at the proximal anterior margin of the medial thigh fat, is sufficient to treat this relatively small accumulation.

POSTOPERATIVE CARE

Postoperative care for the medial thighs or knees is simple and designed so that most patients can change dressings easily and without assistance. Recovery is rapid provided that (1) the surgeon has done some liposuction through an incision placed along the most dependent margin of the treated area and (2) this incision has not been sutured. Having thus guaranteed maximum drainage of the blood-tinged anesthetic solution, one need only apply adequate absorptive padding and moderately firm compression (see Chapter 30).

With multiple adits, drainage usually ceases within 36 to 48 hours. It is recommended that the garments be worn for an additional 24 hours after all drainage has ceased. Many women choose to wear the garments longer because of the comfort and security they provide (Figure 34-12).

PITFALLS AND SPECIAL CONSIDERATIONS

The fat of the medial thigh is easily aspirated, so excessive liposuction can result without careful attention to proper surgical technique. Using microcannulas with multiple incisions and a pattern of crisscrossing diagonal and longitudinal cannula paths will minimize the risks of excessive liposuction (Figure 34-13).

The appearance of the medial thigh depends on the position of the underlying muscles. As a patient bends forward at the hip to view her own inner thigh, muscle contraction causes the midportion of the medial thigh to become more concave. When the patient stands erect, the subtle concavity disappears. Informing patients of this phenomenon before liposuction will avoid unnecessary worries and concern.

A male surgeon should always have a female assistant present during liposuction on the proximal medial thighs of a female patient.
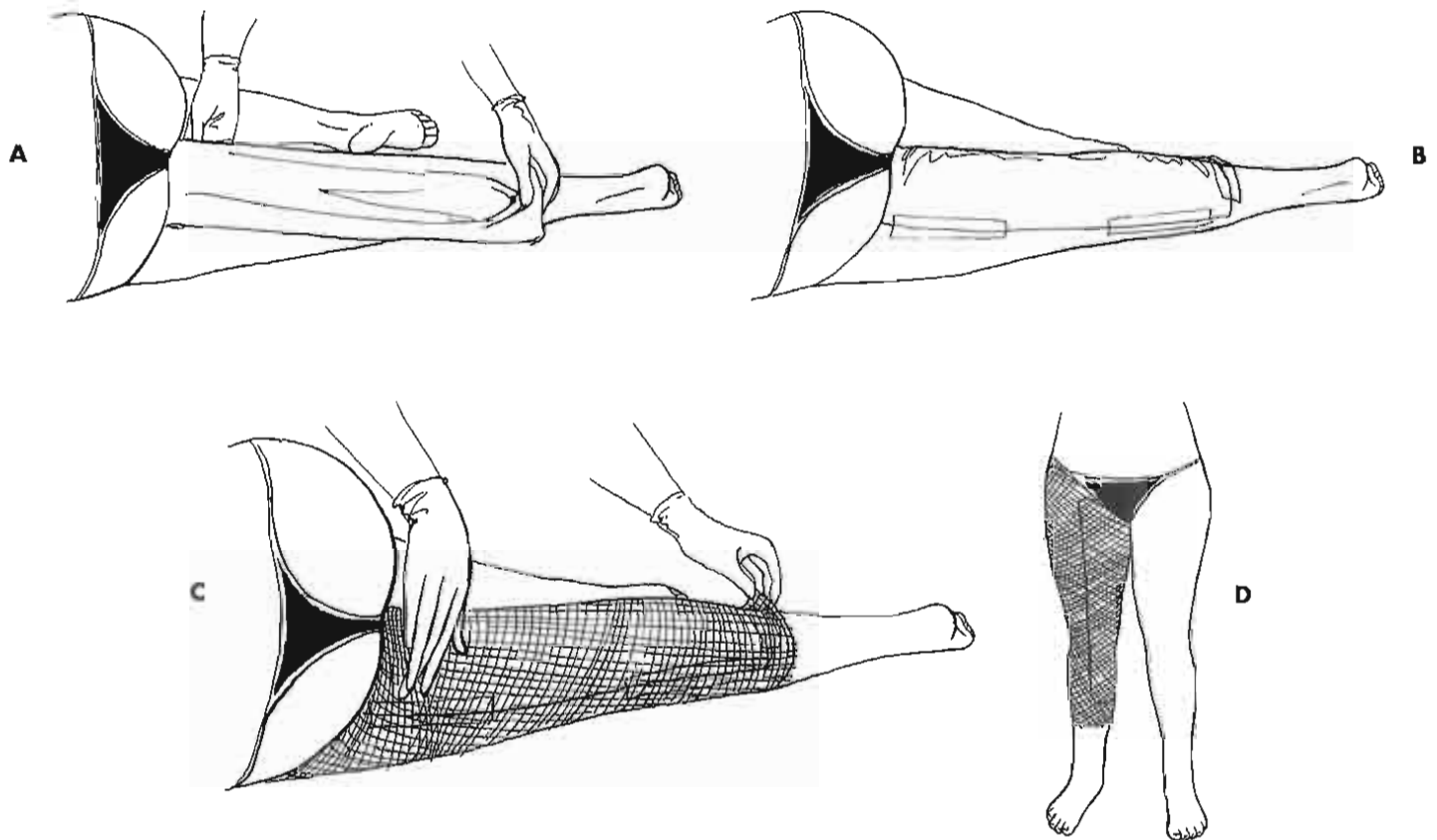
Figure 34-12

Applying absorptive compression pads and compression garments to inner thigh and knee. **A,** Choose one or more appropriate-sized absorptive compression pads. **B,** Tape pads in place on medial thigh and knee, extending from proximal inner thigh (perineum) to midcalf, using minimal amount of tape. **C,** Cut appropriate length of tube netting. Pull tube netting into place to secure absorptive pads. **D,** With dressing in place, patient is ready to place first of two compression garments.

A **B** **C**
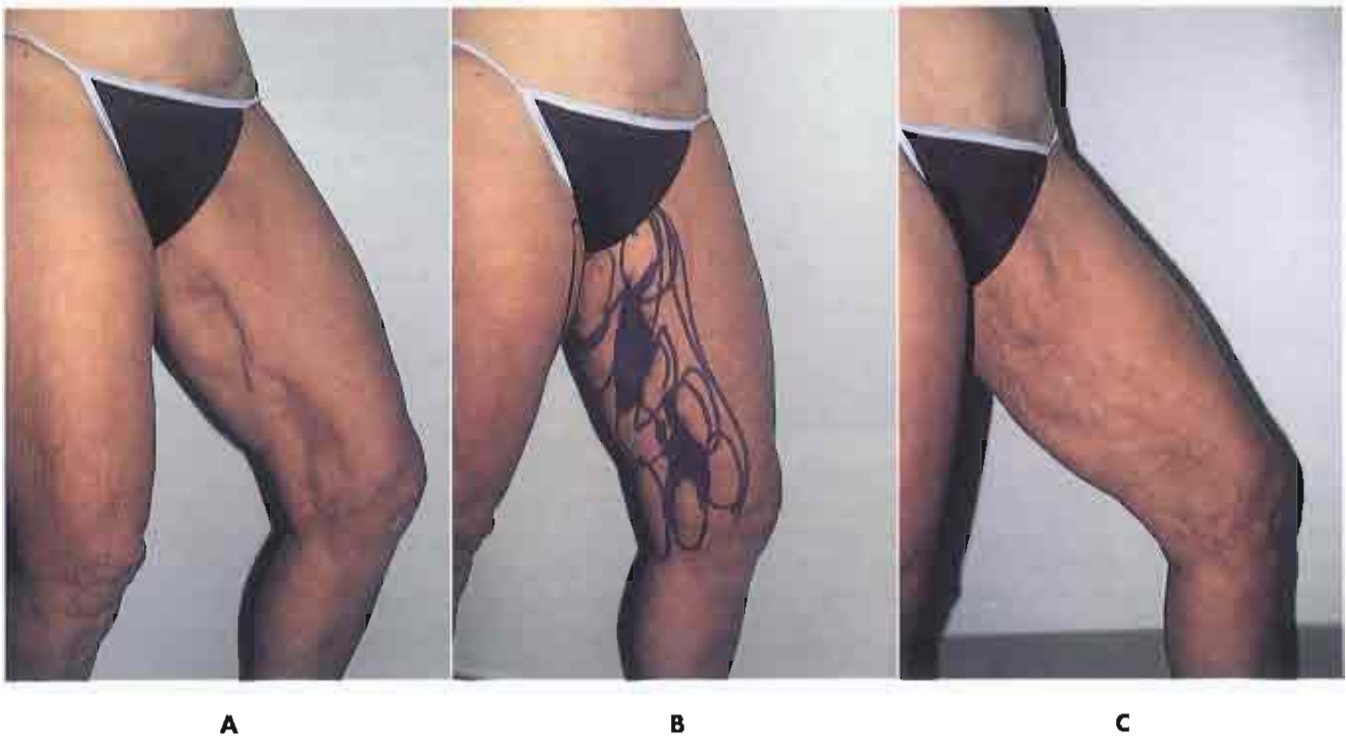
Figure 34-13

A, Conspicuous lipotrop of medial thigh and knee. **B,** Preoperative contour drawings before repair. Open areas designate liponots, small mounds of fat where liposuction was relatively inadequate. Dark areas represent lipotrops in areas where additional liposuction should be avoided. **C,** Improved appearance 6 weeks after one liposuction repair procedure using microcannulas and tumescent anesthesia.

MEDIAL KNEE

When considering liposuction of the knee, the surgeon is principally concerned with the medial knee. The area that might be regarded as the anterior knee is more properly discussed with liposuction of the anterior thigh.

ANATOMIC CONSIDERATIONS

Gross Anatomy of Subcutaneous Fat. The fat of the medial knee is fairly well localized and devoid of significant fibrous tissue. The distal course of the greater saphenous vein courses superficially over the medial posterior thigh and passes over the posterior medial condyle of the femur. Several small veins and lymphatics pass longitudinally over the medial condyle. The muscles of the medial knee are the distal vastus, sartorius, adductor group, and semitendinosus.

Surface Anatomy. In some patients the medial thigh fat seems to extend onto the anterior thigh in a localized linear mound of tissue medial and proximal to the patella. The medial knee fat may extend proximally onto the thigh just anterior to the diagonal groove of the medial thigh. The medial fat can extend distally over the anterior tibia (Figure 34-14).

The fat pad of the medial knee is most prominent when the patient is standing erect in the anatomic position. When the knee is extended, the medial knee fat pad moves anteriorly and is displaced medially by the rounded ends of the tibia, known as the *medial condyle.* This medial displacement causes the overlying fat to bulge prominently.

When this fat pad is reduced in size by liposuction, the contour of the medial knee is more attractive and well proportioned. After liposuction, however, when the knee is bent at 90 degrees, the medial knee may appear to have a slight concavity. This indentation is not unattractive, but a patient should be forewarned of this predictable consequence of liposuction.

PREOPERATIVE EVALUATION

The knee and the distal anterior thigh are often the focus of patient concerns. Liposuction can greatly improve the medial knee. With liposuction of the suprapatellar thigh, however, the degree of improvement is limited.

Figure 34-14

Prominent fat pads on proximal anteromedial leg are liposuctioned concomitantly with medial knee. Small fibrous fat pads surrounding patella are effectively treated using 16-gauge microcannulas.

When the patient expresses concern about "the knee" during the initial consultation, the surgeon must be careful to determine the exact areas of concern. Using a ball-point pen to draw on the patient's skin, the surgeon can show the patient the extent of the proposed liposuction. This prevents misconceptions and clarifies communication between the surgeon and patient.

Most of the medial knee fat is located within an oval-shaped area overlying the medial condyle. Drawing two or three concentric ovals usually suffices to designate the medial knee fat.

The adits at the distal extent of the knee should be placed 1 or 2 cm distal to the target mound of subcutaneous fat. Thus the area designated for infiltration should extend more distally than the area to be suctioned.

INTRAOPERATIVE POSITIONING

The subcutaneous fat of the knee is susceptible to distortions when the knee is bent. This distortion is eliminated when the operative position approximates the anatomic position. When the patient's knee is bent, for example, the medial fat pads move posteriorly and seem to disappear behind the medial condyle.

A modified lateral decubitus position for the medial knee generally suffices when the medial thigh is not being treated. By moving the uppermost contralateral leg anteriorly, the target medial knee is accessible in the anatomic position.

When the medial thigh and knee are treated simultaneously, the Thigh Aside pillow is recommended to help position the patient and provide optimal access to the targeted fat.

ANESTHETIC INFILTRATION

The knee is a sensitive area. In a fully awake and alert patient the infiltration of the medial knee must be done gently. The initial infiltration using a pediatric spinal needle, followed by a 20-gauge spinal needle, is generally well tolerated.

The medial knee is a small compartment and may become tumescent before the anesthetic solution has been infiltrated into the entire knee. Thus the infiltration should be done deliberately rather than as rapidly as possible.

SURGICAL TECHNIQUE

Microcannular tumescent liposuction of the medial knee consistently produces excellent results and rapid recovery (Figure 34-15).

The medial knee requires three to eight adits or incisions. A distal dependent incision or adit on the medial knee ensures adequate drainage. With liposuction by local anesthesia, medial knees are particularly sensitive; the smaller the cannula, the less the likelihood of pain and discomfort.

Knee liposuction is initiated using 16-gauge Capistrano microcannulas and is completed with a 14-gauge Capistrano cannula. Occasionally a 12-gauge Finesse microcannula is used. For knee liposuction the cannula is generally directed longitudinally rather than transversely, to minimize the risk of interrupting blood and lymphatic vessels.

Medial knee adit sites heal with minimal scarring and hyperpigmentation. The surgeon must avoid excessive superficial liposuction to prevent injury to the dermal vascular plexus and lymphatics.

POSTOPERATIVE CARE

Postoperative care for the medial knee is similar to that for the medial thigh (see earlier discussion).

When the medial thighs and medial knees have been treated concurrently, and especially when the patient is somewhat obese, drainage may persist for several days. It is recommended that the garments be worn for 24 hours after all drainage has ceased.

PITFALLS AND SPECIAL CONSIDERATIONS

The goal of medial knee liposuction is to achieve a smooth result that is natural in appearance. The goal should not be to extract as much fat as possible. Overaggressive superficial liposuction of the medial knee can injure the lymphatic vessels that pass immediately beneath the dermis and deeply over the medial condyle. Injury to these lymphatics can produce either (1) an incision site with prolonged drainage of yellow serosanguineous fluid or (2) a seroma.

Aggressive liposuction also can injure the dermal vascular plexus, causing erythema ab liporaspiration with hyperpigmentation and a persistent, mottled, reticulated vascular pattern.
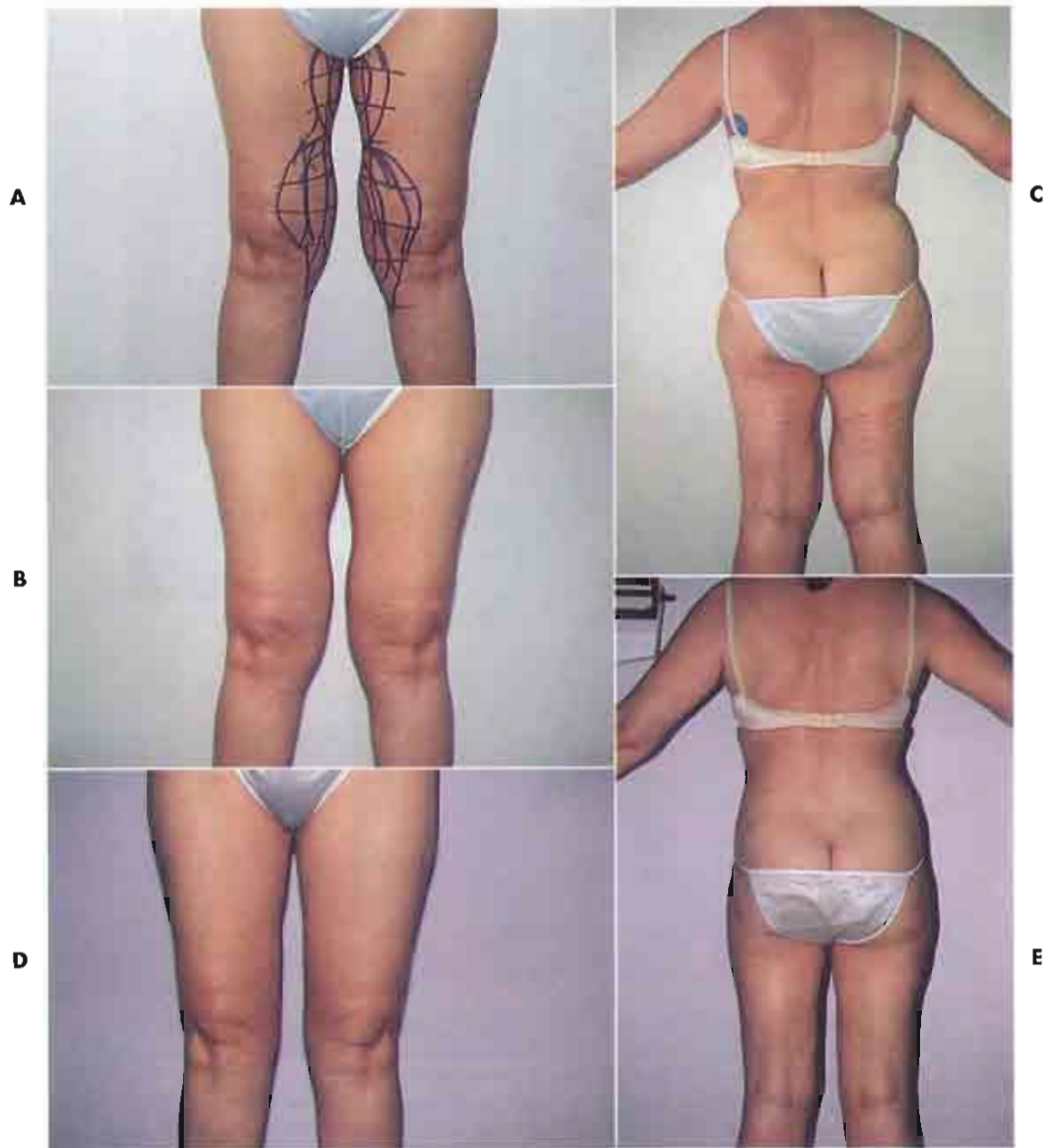
Figure 34-15

Medial knee (and thigh) liposuction. **A,** Preoperative contour drawings. Medial thighs and prominent medial knees before liposuction: **B,** anterior view; **C,** posterior view. After tumescent liposuction with microcannulas: **D,** anterior view; **E,** posterior view. Hips and lateral thighs were treated separately more than a month after liposuction of medial thigh/knees.
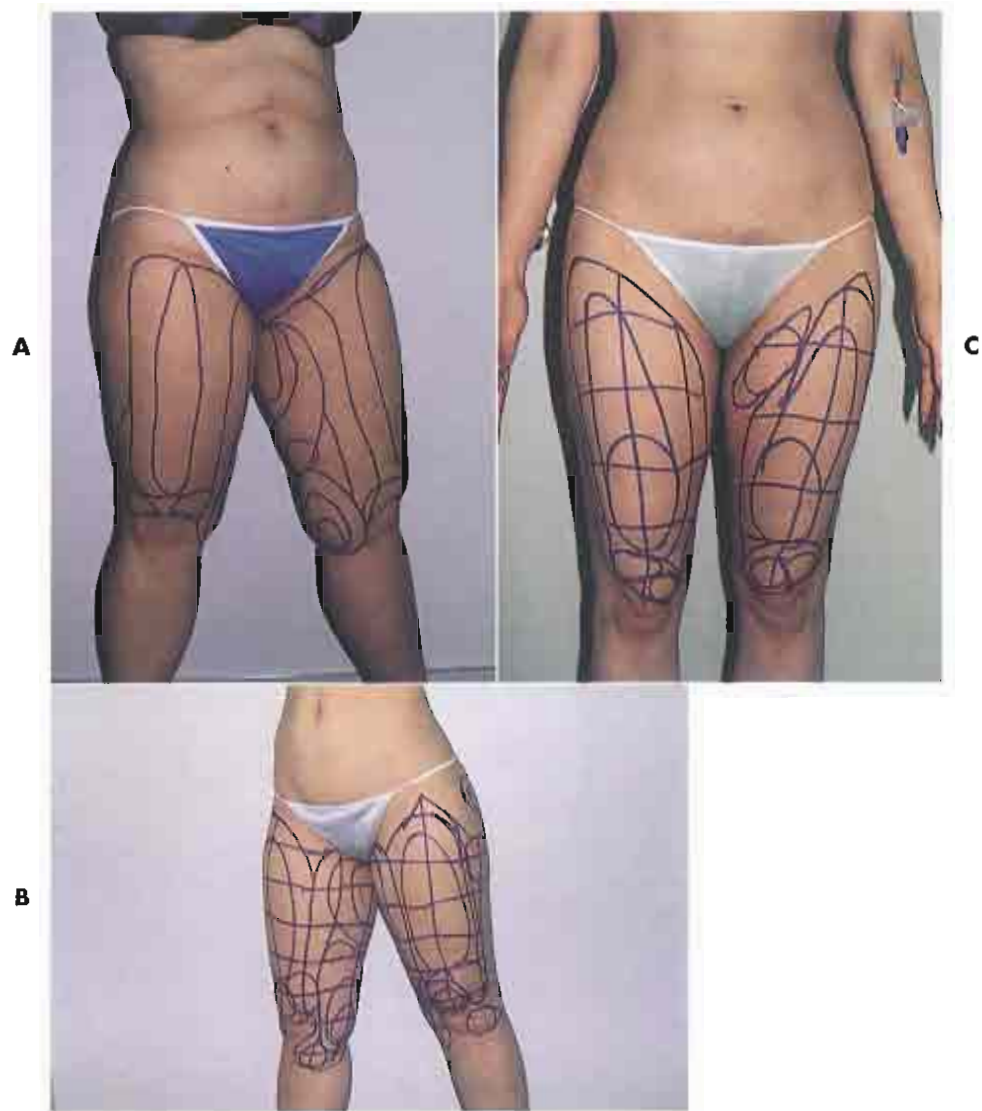
Figure 34-16

A to **C,** Typical anteromedial thigh contour drawings on three patients. Irregularities can be minimized by (1) doing liposuction only in deeper portions of anterior thigh compartment and (2) directing cannulas longitudinally and parallel with femur. Because anterior thigh is typically a smooth surface, even subtle liposuction irregularities are apparent.

ANTERIOR THIGHS

ANATOMIC CONSIDERATIONS

The gross anatomy of the subcutaneous fat of the anterior thigh is rather homogeneous. The fibrous stroma is easily penetrated with minimal resistance. The subcutaneous fat at the proximal extent of the anterior thigh is usually thicker than the distal portion. Prominent bulges of fat can extend from the lateral thigh or from the medial thigh onto the proximal anterior thigh.

Such areas require relatively more liposuction to achieve a uniformly smooth and attractive result. Careful contour draw-

ings of the subcutaneous fat are important for accurate tumescent liposuction of the anterior thighs (Figure 34-16).

SURGICAL TECHNIQUE

In the preferred intraoperative position for liposuction of the anterior thighs, the patient is supine with the knees supported and slightly elevated with a small pillow or folded towel. Infiltration follows the same principles as for infiltration of the medial thigh/knee.

Surgical technique for liposuction of the anterior thigh focuses on avoiding any superficial liposuction. The goal is to work in the deeper planes, leaving a smooth, relatively thick

layer of superficial fat. Typically the entire liposuction of the anterior thigh is suctioned using only a 16-gauge Capistrano microcannula and 14-gauge Capistrano cannulas, 15 cm (6 inches) and 23 cm (9 inches) in length.

The cannulas are principally directed parallel to the long axis of the thigh. Crisscrossing of tunnels occurs with small angles of intersection. For smooth results it is important not to direct the 14-gauge cannula paths transversely across the thigh. Since using 16-gauge microcannulas carries minimal risk of creating lipotrops, the surgeon can make transverse tunnels.

PITFALLS AND SPECIAL CONSIDERATIONS

On the anterior thighs, optimally smooth results are more important than maximal volume reduction. The anterior thighs are one of the areas most susceptible to postliposuction irregularities of the skin.

Removing more than 50% to 60% of the subcutaneous fat of the anterior thigh is associated with a high incidence of patient dissatisfaction. The fat has minimal fibrous content and therefore is aspirated rather quickly. Even with microcannulas it is difficult to achieve smooth results consistently when removing more than 60% of the fat from the anterior thigh.

The surgeon must also avoid complying with patients' requests to "take just a little more" from the area proximal to the patella. This is a common pitfall. Too often the ultimate result is a "scooped-out" appearance and a dissatisfied patient. To treat the anterior knee adequately, the surgeon usually must taper the degree of liposuction proximally over most, if not all, of the anterior thigh.

The fat immediately superficial to and surrounding the patella is more fibrous than the fat of the distal thigh. Using a 16-gauge microcannula to initiate liposuction in the peripatellar fat helps achieve smooth results.

CIRCUMFERENTIAL THIGH LIPOSUCTION

Circumferential liposuction of the thighs is most easily tolerated by the patient if it is accomplished as a serial procedure. Liposuction of the anterior thigh can be accomplished together with either the lateral thigh or the medial thigh/knee. Liposuction of the entire thigh circumference during one day is not recommended. Although the risk is small, liposuction of the entire thigh circumference may predispose to deep venous thrombosis and pulmonary thromboembolism because of distal swelling with venous stasis and subsequent postoperative immobility.

Patients may want their entire thighs treated during one session, assuming that one surgery and one recovery will be easier and preferable to two procedures. Because of safety concerns, I refuse to perform circumferential liposuction of the thighs during only one session.

In fact, circumferential liposuction accomplished by one surgical procedure will result in prolonged distal edema, more discomfort, and delayed return to normal activities. By avoiding circumferential thigh liposuction that is completed during a single procedure, the surgeon also avoids time-consuming postoperative visits and telephone calls from anxious patients.

Serial surgeries are preferred, with the sessions spaced 1 month or more apart. For example, the surgeon might treat the outer thighs, hips, and buttocks during one session, then the anterior thighs, medial thighs, and knees in the next session. This approach virtually eliminates distal lower extremity edema. Typically, patients can be expected to return to work 1 or 2 days after surgery.

Liposuction transects many lymphatics. When the entire thigh is treated, it remains swollen for a long time. Immediate circumferential liposuction causes *lymphostasis*, with delayed clearing of postoperative transudates and inflammatory exudates. The resultant osmotic pressure within the subcutaneous fat causes prolonged tissue edema.

Dividing circumferential liposuction into two separate procedures reduces total days of postoperative disability. The untreated portion of the thigh provides functioning lymphatics that compensate for the impaired lymphatic drainage in the treated area.

Similarly, sequential thigh liposuction reduces the degree of edema-induced venous stasis and the risk of thromboembolic venous disease.

CHAPTER 35

Chin, Cheeks, and Jowls

Tumescent liposuction is the technique of choice for removing subcutaneous fat in the submental chin and jowl areas. The ideal candidate is the patient who has realistic expectations and who will be satisfied with the results achievable by liposuction.

For many patients with suboptimal skin elasticity, liposuction can achieve gratifying results. Older patients, especially males, are pleased with the ability of their skin to retract and appear sufficiently smooth. Liposuction is particularly appealing to patients who do not want the prolonged recovery time, the scarring, and the risk of complications associated with a facelift.

TWO-STAGE TUMESCENT FACELIFT

Because of the scars associated with facelifts, most male patients prefer tumescent liposuction of the chin, cheek, and jowls (CCJ) over the traditional facelift.

In many women, tumescent liposuction of the CCJ can produce better cosmetic results than a facelift. Female patients also often prefer tumescent liposuction over a facelift because of the following:
1. Microcannular liposuction involves fewer risks of disfiguring scars.
2. Tumescent anesthesia eliminates the dangers of systemic anesthesia.
3. Patients have more rapid recovery.
4. Tumescent facelifts typically provide a more natural and "less surgical" appearance (Figure 35-1).

Tumescent liposuction with delayed skin resurfacing is often chosen over a facelift by older women with significant subcutaneous fat in the face and neck and marked solar elastosis and aging of the skin. The sequential two-stage cosmetic surgical procedure consists of the following:
1. Tumescent liposuction of the CCJ, with platysma muscle plication
2. At a later date, full-face carbon dioxide (CO_2) laser resurfacing using tumescent local anesthesia (Figure 35-2).

This approach can yield results that are much superior to a facelift alone (Figures 35-3 and 35-4).

Among younger women who have good skin elasticity, liposuction without ancillary procedures can also produce dramatic improvement and is much simpler than a facelift.

Some women may prefer a facelift because they have minimal subcutaneous fat below the chin but excessively wrinkled, redundant neck skin.

ANATOMIC CONSIDERATIONS

The phrase "liposuction of the face and neck" is somewhat misleading. To be more specific, liposuction in this general area involves the submental (under chin) area, the jowls, and a small area of the cheeks. Because optimal results do not necessarily require liposuction of the neck caudal to the nuchal crease, or the thyroid cartilage, this procedure is referred to as "liposuction of the chin, cheek, and jowls (CCJ)."

The *submentum* includes the area bounded proximally by the mandibular margin and submental crease and distally by the nuchal crease. The *jowl* represents a small focal accumulation of fat overlying the midportion of the mandibular ramus, which usually extends and tapers distally onto the submental area. Jowl fat is anatomically distinct and unrelated to the buccal fat pad.

SURFACE ANATOMY

The appearance of jowl fat is a sign of wisdom and maturity (advancing age). The jowls are an important anatomic feature for the cosmetic surgeon. As a source of concern for women and men of a certain age, prominent jowls rank with wrinkles and platysmal bands as unwanted facial features.

Wrinkles. Facial wrinkles are not significantly improved by liposuction. Several other techniques, however, including dermabrasion, laser resurfacing, and chemical peeling, may successfully treat facial wrinkles.

Figure 35-1

These two women had tumescent liposuction and platysma muscle plication totally by local anesthesia without intravenous or intramuscular sedation. As these before (**A** and **C**) and after (**B** and **D**) photographs demonstrate, liposuction can greatly improve the jowls and better define the mandibular margin. Platysma plication can give the submental profile a more youthful appearance. *Continued*
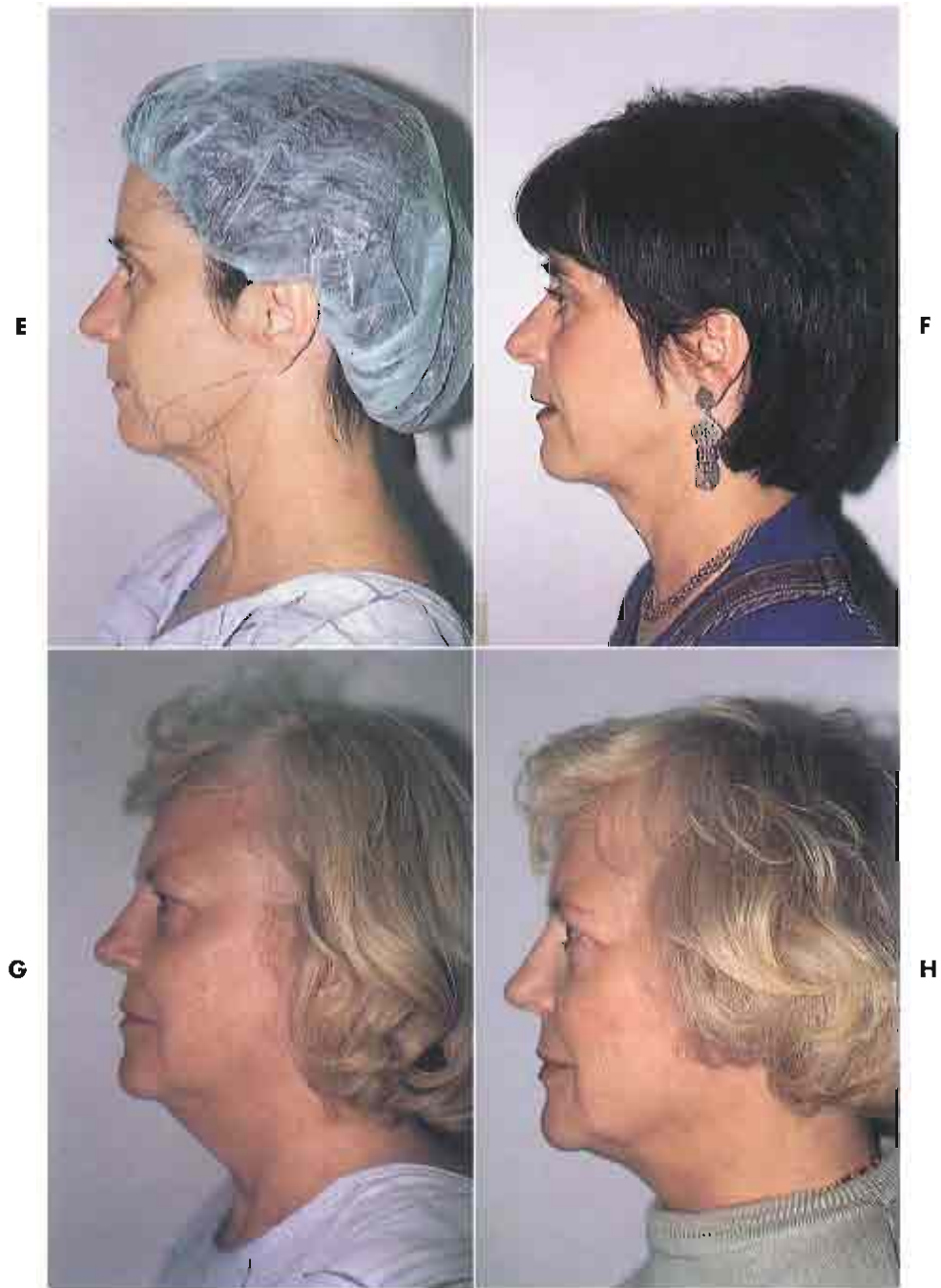
Figure 35-1, cont'd

These two women had tumescent liposuction and platysma muscle plication totally by local anesthesia without intravenous or intramuscular sedation. As these before (**E** and **G**) and after (**F** and **H**) photographs demonstrate, liposuction can greatly improve the jowls and better define the mandibular margin. Platysma plication can give the submental profile a more youthful appearance.

Figure 35-2

CO$_2$ laser resurfacing of entire face can be accomplished by tumescent infiltration. Infiltration technique requires care and gentleness to be tolerated without supplemental systemic anesthesia. The more facial subcutaneous fat that is present, the less discomfort the patient feels during subcutaneous infiltration. A thin patient is more likely to require supplemental injection of midazolam (see Chapter 26).

Figure 35-3

Two-stage "facelift" involving (1) tumescent liposuction with platysma muscle plication and (2) full-face CO$_2$ laser resurfacing using tumescent local anesthesia 4 or more weeks later. **A,** Preoperative contour drawing. **B,** Submandibular neck after liposuction and platysma muscle plication. *Continued*

Tumescent dermabrasion is probably the most successful technique for eliminating the perioral rhytids on the lips. Dermabrasion, however, depends more on clinical experience and surgical skills than do laser resurfacing or chemical peeling.

Platysmal Bands. The platysma muscle bands highly visible on the anterior neck often contain a large quantity of fat. Tumescent liposuction may improve the appearance of platysmal bands to some degree. A submental crease incision with platysma muscle plication, however, provides much greater cosmetic improvement (see later discussion).

Redundant Skin. Excessive redundant skin on the anterior neck is treated by either (1) a facelift with subcutaneous musculoaponeurotic system (SMAS) plication or (2) submental skin excision and platysma muscle plication. Newer laser methods or chemical peels might prove successful for

treating wrinkles on the neck and submental area. The risk of scarring discourages most cosmetic surgeons from aggressive resurfacing on the neck.

In certain patients, liposuction combined with facial skin resurfacing and platysma muscle plication can achieve results that are superior to the traditional facelift.

GROSS ANATOMY OF SUBCUTANEOUS FAT

The principal fat compartment of the CCJ is the midline submental fat. These fat pads, together with the fat of the droopy jowls, are the main targets for liposuction of the CCJ.

Tumescent Advantages. Tumescent infiltration improves the safety of liposuction in these areas. Careful and gentle tumescent infiltration elevates the subcutaneous fat away from the deeper neurovascular structures below the platysma

C

D

E

F

Figure 35-3, cont'd

C, After liposuction with plication but before full-face CO_2 laser resurfacing. **D,** After liposuction and CO_2 laser resurfacing. **E,** Profile before surgery. **F,** Profile after liposuction and CO_2 laser resurfacing.

Figure 35-4

Tumescent liposuction, platysma muscle plication, and full-face CO_2 laser resurfacing. **A,** Preoperative contour drawing. **B** and **C,** Preoperative views. **D** and **E,** After tumescent liposuction with platysma muscle plication and 3 weeks after full-face CO_2 laser resurfacing.

muscle. Precise tumescent infiltration and cautious micro-cannular technique reduce the risk of postliposuction skin irregularities on the jowls and cheeks.

Excessive liposuction can leave permanent depressions and lipotrops that cannot be repaired by fat transplantation. An overaggressive technique that intentionally targets the apical fat along the deep surface of the dermis can result in adhesions, scarring contractures, areas of necrosis, and dyschromia. Overenthusiastic liposuction of the medial nasolabial cheeks can easily become excessive liposuction.

Conservative liposuction of the cheeks using the smallest cannulas can achieve gratifying results. Similarly, minimal liposuction along the inferior aspect of the mandible can produce a more youthful, well-defined jaw line. The surgeon must be cautious to avoid injury to vascular structures that are subjacent to the thin platysmal muscles in this area.

Tumescent local anesthesia of the CCJ has proved to be safe provided that the infiltration is done with care and precision. To my knowledge, no reported cases of laryngeal edema have been associated with the subcutaneous infiltration of large volumes of dilute lidocaine and epinephrine into the CCJ and neck.

Larynx. The larynx is essentially a protective valve at the upper end of the respiratory passage.[1] It consists of a framework of articulating cartilages connected by ligaments. The important laryngeal cartilages are the thyroid, cricoid, arytenoid, and the epiglottis. The laryngeal ligaments and muscles connect the laryngeal cartilages.

The fasciae that invest the cartilages, ligaments, and muscles act as a barrier that protects the larynx from subcutaneous soft tissue edema. From the perspective of tumescent liposuction, these sheets of fascial tissue prevent tumescent anesthetic solution from diffusing into the larynx and causing laryngeal edema or paralysis of laryngeal nerves.

Risk Factors. Liposuction of the CCJ should be confined to the subcutaneous fat superficial to the platysma muscles. The important motor nerves and blood vessels of the face and neck are deep to the platysma muscles. To avoid risk of injury to the thyroid gland, liposuction should not be extended too far distally beyond the cricoid cartilage.

The tumescent technique is not intended for thyroid suction or inadvertent thyroidectomy. Hemorrhage into the thyroid gland can result in laryngeal edema. Hemorrhage into the neck, deep to the investing fascia of the larynx, may put external pressure on the trachea and cause airway obstruction. Trauma to and obstruction of venous or lymphatic vessels deep to the platysma may cause laryngeal edema.

It is especially important not to attempt liposuction of the CCJ if the patient may have recently taken aspirin, nonsteroidal antiinflammatory drugs (NSAIDs), or other agents that might impair hemostasis and predispose to local hematoma and direct pressure on the trachea.

INTRAOPERATIVE POSITIONING

Patient positioning is important for comfort and optimal access to the treatment area. Preferably the patient is supine or comfortably recumbent, with the back and knees slightly flexed and the neck moderately extended. Too much or too little extension of the neck will make it more difficult to palpate accurately the deep interface between the submental fat and the subjacent muscle fascia.

The patient's hands and arms should be lightly restrained by a towel wrapped around the arm and tucked under the patient. This prevents the patient from possibly contaminating the surgical field (Figure 35-5).
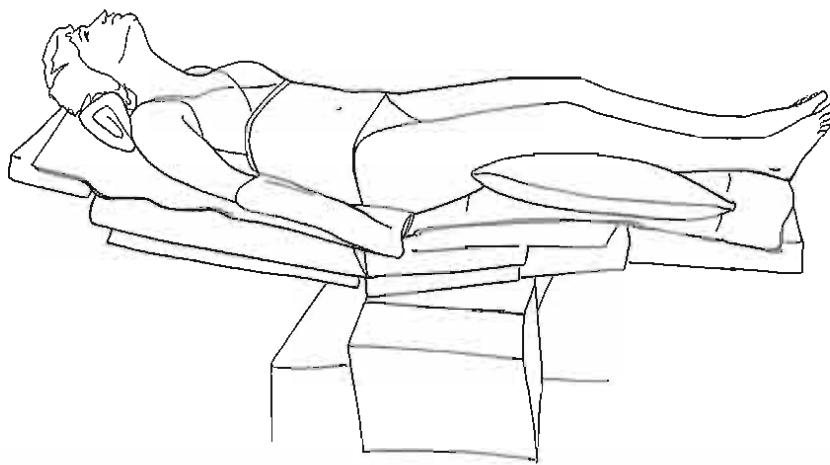
Figure 35-5

Preferred intraoperative position for liposuction of the chin, cheeks, and jowls (CCJ).

ANESTHETIC INFILTRATION

Tumescent infiltration of the neck is accomplished by first infiltrating along the deepest planes of subcutaneous fat, then more superficially. In an awake and fully alert patient, infiltration is accomplished with minimal discomfort by initially injecting small blebs of tumescent anesthetic solution into the dermis at the intended sites of 1.0-mm adits, made with a skin biopsy punch, or 2-mm to 3-mm microincisions. The microincisions can be made with a small scalpel blade (e.g., no. 11) or 16-gauge Nokor needle (Becton-Dickinson).

The tumescent local anesthetic solution for CCJ liposuction, with or without platysma plication, typically consists of 1.5 g lidocaine, 1.5 mg epinephrine, and 10 mEq sodium bicarbonate in 1 L of normal saline. The liposuction usually requires 250 to 350 ml of tumescent anesthetic solution.

The goal is to achieve optimal anesthesia and hemostasis. Moderate tumescence is preferable; extreme or massive tumescence is unnecessary and possibly unsafe.

Accurate infiltration is essential for depositing the anesthetic solution as close as possible to the deep margin of the submental fat pad. Precision infiltration is optimal using a 25-gauge, 5-cm (2-inch)–long needle on a 12-ml syringe. Using a hand-held syringe for the initial phase of the infiltration allows fine control of the rate and volume of infiltration.

After the initial deep infiltration, one can continue using syringes. Alternatively, one can use a electric motor–powered peristaltic pump, with either a 25-gauge pediatric spinal needle or a 20-gauge spinal needle, to complete the tumescent infiltration.

In a thin patient who has only a small or localized distribution of CCJ fat, the entire infiltration is best accomplished by syringe. With skill and experience, infiltration of the CCJ can be accomplished painlessly, without systemic sedation or analgesia.

CANNULA SIZE

Liposuction of the submental area was introduced in the 1980s, when liposuction was usually accomplished by general anesthesia. With early liposuction, "facial" cannulas were large and often flattened or spatula shaped. The width of different cannulas ranged from 3 to 10 mm.

Incisions sites for cannula insertion in the CCJ area vary with cannula size. To accommodate a cannula with minimal cutaneous friction, the incisions must be slightly longer than the width of the largest cannula. For large cannulas the location and number of incisions are limited by the requirement that the scars be well hidden.

With the advent of tumescent liposuction the use of microcannulas became practical. Surgeons began to appreciate that microcannulas allow greater finesse, more predictable results, less inflammation, and more rapid healing, with fewer complications.

Large Cannulas. For liposuction of the submental chin and neck, some surgeons continue to use large cannulas with one or three relatively large incisions. This traditional approach involves one of the following:

1. Single midline incision in the submental crease
2. Combination of midline incision and bilateral subauricular incisions that allow some crisscross tunneling in the submental fat

The use of large cannulas necessitates that the incision be closed by sutures. This discourages drainage and prolongs postoperative elastic compression for 2 weeks or more. Using large cannulas precludes finesse and the ability to treat small areas of the cheeks.

The preference for using large cannulas for CCJ liposuction is partly a result of surgical tradition. Surgical training is justifiably conservative and discourages extreme deviations from fundamental techniques. Once a technique is mastered, surgeons are disinclined to modify the procedure dramatically. Nevertheless, careful conservatism must not discount the possibility of innovation and improvement.

Microcannulas. Microcannulas produce excellent aesthetic results. I prefer microcannulas with an inside diameter (ID) of 2.2 mm or less (12 gauge or smaller). The microcannulas that I use to treat the CCJ are the 16-gauge and 14-gauge HK Finesse and 20-, 18-, and 16-gauge Capistrano.

Adits and microincisions do not require sutures, so drainage is unimpeded and rapid. Postoperative elastic compression of the CCJ is only necessary for 18 to 36 hours. Microincisions simply disappear rapidly without hyperpigmentation.

With 16-gauge and 14-gauge cannulas the surgeon can use microincisions that are 2 to 3 mm in length. A 1.0-mm adit or a 2-mm to 3-mm linear incision that is not excessively traumatized by a cannula will disappear within days. The risk of postinflammatory hyperpigmentation of the face is no greater than that encountered with a typical nick from a razor while shaving.

LOCATION OF ADITS

The preferred pattern for using microcannulas for liposuction of the CCJ usually involves three to 10 adits or microincisions. Multiple adits permit the extensive use of crisscrossing patterns for the microcannula paths, which allows the smoothest results.

Three 1.0-mm adits spaced equally along the submental crease are sufficient for patients requiring liposuction confined to the submental area and limited by the mandibular rami. The typical patient in this category is a young, thin female with only a few milliliters of fat under the chin.

The average patient might require five or six adit incisions, which include the three equally spaced adits in the submental crease. Two bilaterally symmetric incisions are placed beneath the mandibular rim between the angle of the jaw and the jowl area, near the anterior border of the masseter muscle.

An obese patient may require an additional pair of symmetric incisions at approximately the level of the hyoid bone and lateral to the border of the thyroid cartilage (Figure 35-6).

Figure 35-6

A, Location of microincision sites in submandibular chin immediately after tumescent liposuction. Platysma muscle plication is not always necessary. **B,** Contour drawing accentuates focal fatty deposits. Minimal platysmal bands were present. **C** and **D,** Preoperative views.

Figure 35-7

Delicate tumescent liposuction of medial cheek can be accomplished using 20-gauge Capistrano microcannula and Fine-Touch Aspiration Tubing (see Figure 28-3).

Figure 35-6, cont'd

E and **F,** One day after tumescent liposuction without platysma plication.

SURGICAL TECHNIQUE

It is preferable to wait for 20 to 30 minutes after completing the infiltration before initiating liposuction. This brief hiatus allows more complete vasoconstriction and anesthesia, as well as time for the tumescent fluid to move by bulk flow both laterally and deeply and for detumescence of the infiltrated tissue. *Detumescence* permits the anesthetized tissues to be grasped more easily and accurately without trauma to subjacent tissues.

By carefully grasping the skin and slightly elevating subcutaneous fat, liposuction is initiated at the deepest levels of the fat just above the platysma muscle. Subsequently the cannulas are directed more superficially. Liposuction of the neck can be done more superficially than in other areas of the body, but care is taken not to rasp the undersurface of the dermis

with holes of the cannula. The surgeon should not intentionally allow the cannula to rasp the dermis.

Liposuction is accomplished first with the small 20-, 18-, and 16-gauge cannulas, then with the 14-gauge cannula. The larger 12-gauge cannula is rarely used. Smaller cannulas with smaller openings are more likely to give smooth results and are less likely to injure nerves or blood vessels (Figure 35-7).

The marginal mandibular branch of the facial nerve is vulnerable to trauma from a liposuction cannula. Located at the anterior border of the masseter muscle, where it passes over the mandible, the nerve is in close association with the facial artery, the pulsations of which are easily palpated. By elevating the subcutaneous fat away from the subjacent structures, the tumescent technique minimizes the risk of injury to the marginal mandibular nerve.

The surgeon should avoid an aggressive approach to microcannular tumescent liposuction of the cheeks and the portion of the jowls that extends onto the cheeks. Extra caution should be taken in treating the nasolabial folds. It is easy to remove too much fat inadvertently, with a resulting focal depression of the skin.

Postliposuction healing is rapid and uneventful, although subcutaneous fibrosis can occur. The incidence is probably less than 5%. Clinically the patient notices one or more firm, bandlike areas of tightening in the submental area. Histologically these bands show scarring with fibrosis. The condition will resolve spontaneously, and treatment is usually not necessary. For the patient anxious to resolve the fibrosis, the physician can inject very dilute triamcinolone (1 mg/ml or less) into the affected bands and repeat the treatment every 1 to 3 weeks.

Liposuction of the submental area, cheeks, and jowls can be accompanied by skin excision and plication of the submental platysmal muscles to ameliorate a "turkey gobbler" appearance.[2]

Other applications of microcannular tumescent technique in the head and neck region include facelift and skin cancer
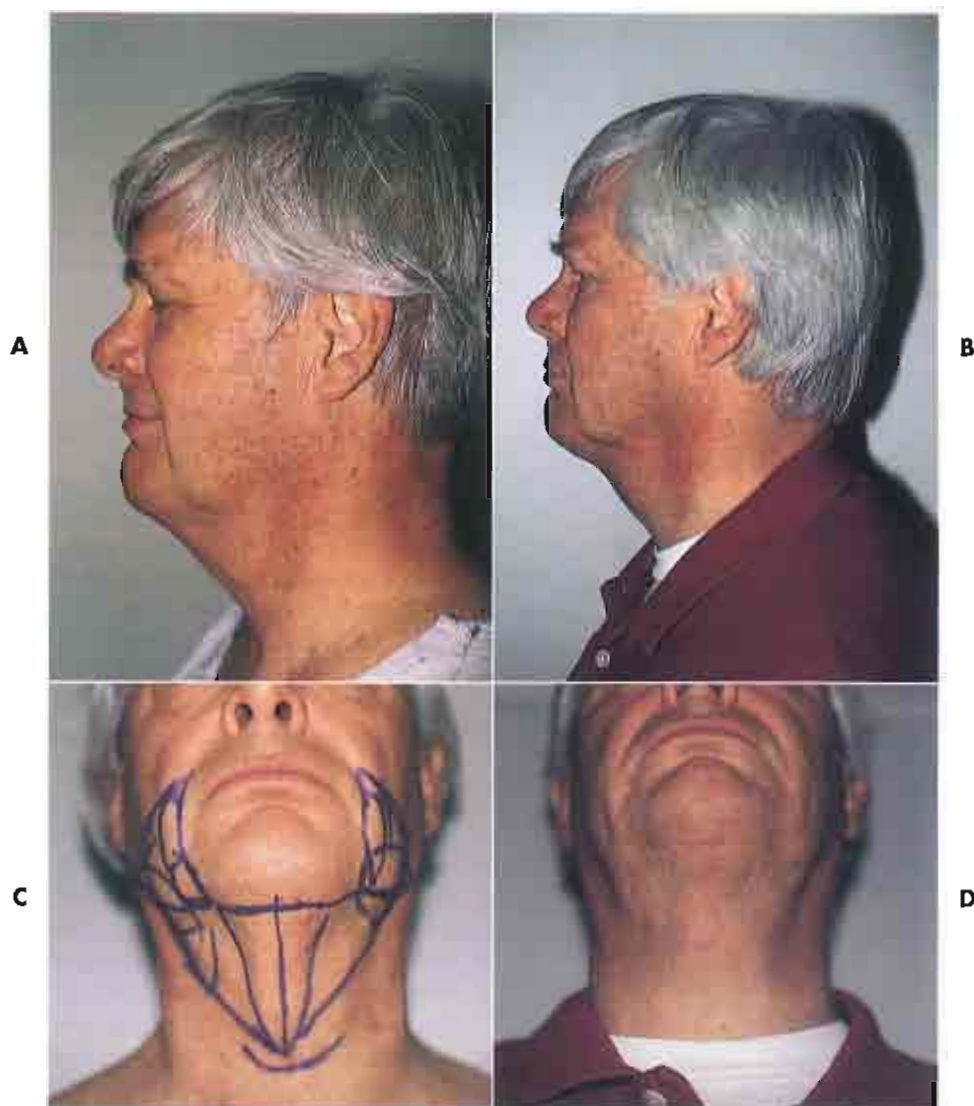
Figure 35-8

Male patient after tumescent liposuction with platysma muscle plication. **A** and **B,** Preoperative and postoperative profiles. **C,** Preoperative contour drawing. **D,** Submandibular chin/neck area more than 4 months after surgery.

repairs using flaps and grafts. Microcannulas without suction are particularly useful in undermining the tightly adherent skin behind the ears and the preauricular skin flaps during facelifts. A standard facelift can be accomplished totally by local anesthesia, without intravenous (IV) sedation, using a microcannular tumescent technique.

PLATYSMA MUSCLE PLICATION

Plication of the platysma muscle after tumescent liposuction of the submental area is a simple dermatologic procedure that can be accomplished totally by local anesthesia. Platysma plication tightens the tissue plane defined by the platysma muscles. The cervicomental angle is elevated and becomes more acute and youthful in appearance (Figure 35-8).

If a patient has minimal subcutaneous fat, liposuction alone will likely provide little improvement. Tumescent liposuction, however, although removing little fat, does undermine a skin flap and permits platysma plication with excellent local anesthesia and profound vasoconstriction (Figure 35-9). On the other hand, liposuction of the cheeks, jowls, and area under the chin can provide excellent cosmetic results without platysma plication.

Platysma plication is done after tumescent liposuction. The initial step is to make a symmetric 2.5-cm to 3-cm skin incision in the submental crease. Removing a narrow, 3- to 5-mm-wide transverse fusiform skin excision along the submental crease may yield optimal cosmetic results. An excessive skin excision, however, may limit the range of chin extension.

Figure 35-9

Tumescent liposuction with platysma muscle plication is often more acceptable to male patients than traditional facelift. Procedure provides significant improvement without distortion or telltale scars associated with facelift. **A** and **B,** Preoperative and postoperative profiles. **C,** Preoperative contour drawing. **D,** Submandibular chin/neck area 1 day after surgery. Note incision along submental crease and skin impressions from gauze, absorptive pad, and elastic compression binder.

Figure 35-10

Occasionally, patients develop temporary but disquieting postoperative induration or lumpiness at various locations in submental area. These examples probably have several different causes. Excessive or unnecessary thermal trauma from electrocautery, laser, or ultrasound can significantly impair wound healing. Insufficient postoperative drainage and compression can result in persistent hematomas or seromas. Linear fibrosis and contraction within subcutaneous tissue result in histologic appearance of scar tissue. Redundant skin or insufficient liposuction can produce a liponot in any location, including tissue distal to submental crease. Thermal trauma should be avoided. In these patients, resolution of fibrosis was facilitated by (1) intralesional injections of triamcinolone (2 mg/ml) at intervals of 1 to 3 weeks and (2) excision of a narrow fusiform strip of skin and open removal of focal residual fat.

Thermal Trauma. Using electrocautery for hemostasis, the surgeon must avoid unnecessary thermal trauma to the subcutaneous tissue, which causes prolonged inflammatory swelling and persistent induration. With minimal thermal damage, healing is rapid, and the patient has a normal appearance within a few days without bruising or swelling. I prefer to use a monopolar Hyfrecator unit with a 10 cm (4-inch)–long insulated tip. Bipolar blended cutting/coagulation can be used if care is taken to avoid excessive thermal trauma, which causes prolonged swelling and induration (Figure 35-10).

Retractors (e.g., Army-Navy) are helpful when elevating the dermal flap. It is not necessary to remove every drop of fat from the platysma. Any large residual nodules of fat overlying the platysma can be removed with scissors, being careful not to cause bleeding.

Fibrous Bands. Within the subcutaneous wound the surgeon will encounter numerous fibrous bands attached between the dermis and the connective tissue overlying the platysma muscle. Such fibrous attachments are more numerous distally along the undersurface of the nuchal crease.

Excellent lighting is necessary to see the fine details of the subcutaneous wound. I prefer a fiberoptic head lamp; others might prefer a fiberoptic light mounted on a retractor.

Some fibrous bands contain small but potentially troublesome blood vessels, which should be cauterized before being lysed. Some small vessels and fibers lyse with minimal cautery, whereas larger ones require cautery and cutting with scissors. To avoid inadvertent thermal damage and scarring, the surgeon must always be aware of the proximity of the dermis to the cautery tip.

Suture Placement. Plication of the platysma muscle involves placing inverted or buried interrupted sutures along the midline of the submental and anterior neck. The overall pattern of suture placement is fusiform: the more distal and proximal sutures approximate progressively less tissue, whereas the sutures midway along the neck approximate more tissue (Figure 35-11). Placing the needle through the platysma at the most distal extent requires care and patience. The use of bayonet forceps and needle holders may be helpful.

Tying the suture at the distal extent of the wound can be challenging. With the patient slightly flexing the neck and an assistant elevating the skin with a retractor, the surgeon can pull the suture toward the opening of the incision and thus tie it more easily.

With all plication sutures placed and wound depth reexamined for complete hemostasis, the incision can be closed. By using absorbable, inverted or buried subcuticular 5-0 sutures for strength, cuticular closure is with 6-0 mild-chromic gut (Davis and Geck). If petrolatum or an antibiotic ointment is maintained continuously on the mild-chromic suture, most of the suture will dissolve spontaneously within 5 to 7 days.
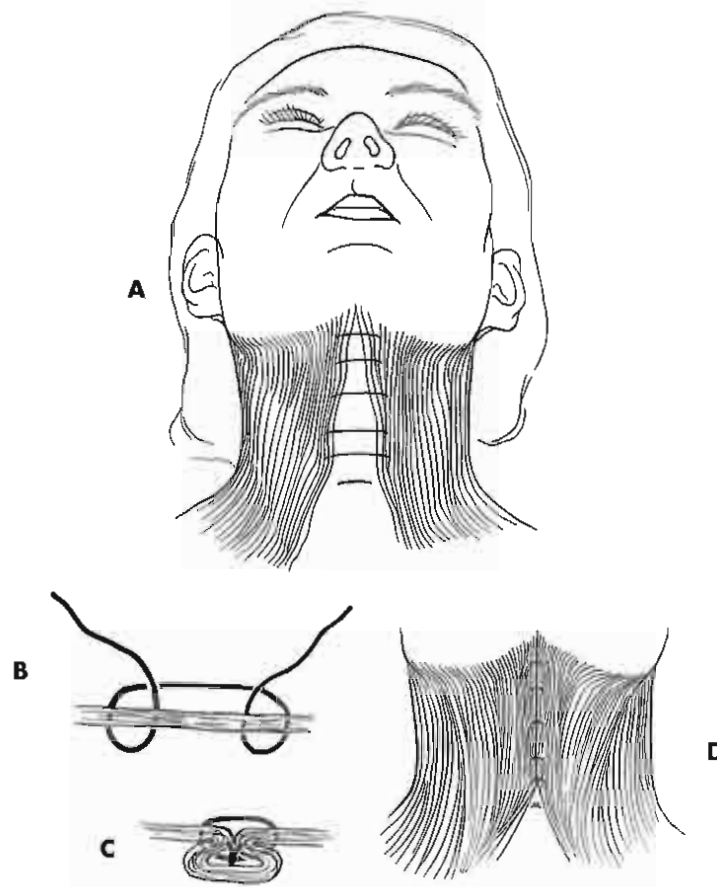
Figure 35-11

Platysma muscle plication technique. **A,** Subcutaneous platysma muscles with relative location of inverted or buried plication sutures along anterior neck. **B,** Suture path through overlying fascial tissue and platysma muscles of anterior neck. **C,** Platysma after suture is tied. **D,** Plicated platysma muscles after sutures are tied.

SUBPLATYSMAL FAT PAD

Although a subplatysmal fat pad exists, targeting this deep fat for tumescent liposuction is rarely, if ever, necessary for good aesthetic results. Blind liposuction that targets the subplatysmal fat is risky and not recommended as a routine procedure.

If the subplatysmal fat pad must be removed, it can be excised under direct visualization by opening the submental compartment. The submental fat pad is in the midline, between the two insertions of the platysma muscles on the mandible. The submental fat pad can be opened by blunt dissection, and if clinically indicated, this small pad can be carefully excised with scissors and electrocautery for hemostasis.

EXCISION OF REDUNDANT SKIN

Some patients have redundant skin extending from the submentum to the cricoid cartilage or manubrium. Cosmetic improvement in the profile of such a patient often requires a direct excision of excess skin on the anterior neck (Figure 35-12).

Excision of superfluous skin on the submental and anterior neck area has several variations. One simple procedure is accomplished totally by local anesthesia and involves the following:

1. Tumescent liposuction
2. Two perpendicular fusiform excisions
3. Platysma muscle plication
4. Wound closure

Tumescent anesthesia, as described earlier, is followed by microcannular liposuction. The first excision removes a narrow, transverse fusiform piece of skin beneath the chin, with the anterior edge coinciding with the submental crease. The second excision removes a larger, longitudinal fusiform piece of skin. After everting and retracting the margins of the longitudinal wound, the platysma muscle is plicated.

Wound closure is accomplished as follows (Figure 35-13):

1. The edges of the transverse excision are approximated with subcuticular sutures.
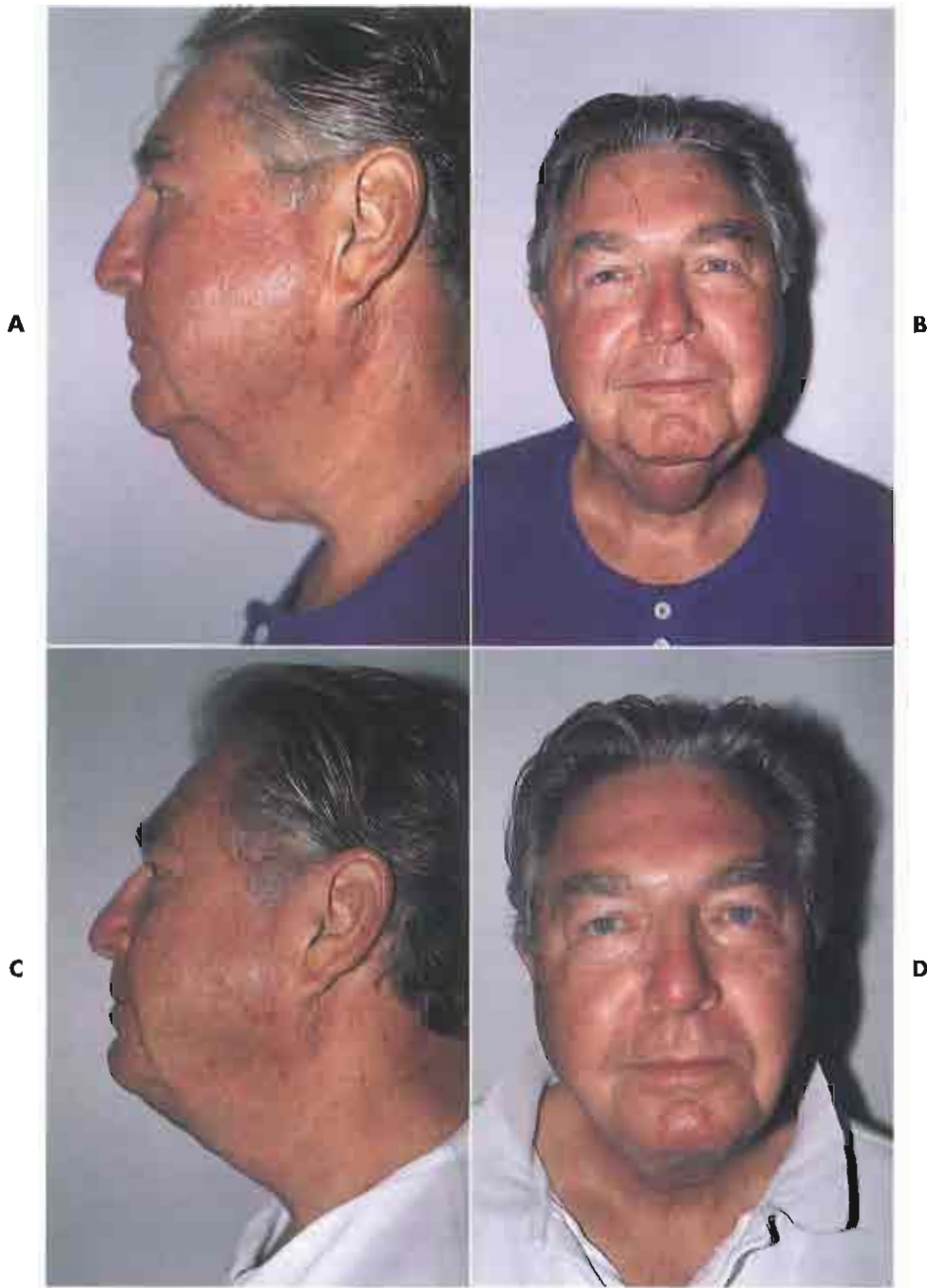
Figure 35-12

Skin resection with Z-plasty, immediately after tumescent liposuction and platysma muscle plications, can effectively eliminate excessive submandibular skin. **A** and **B,** Preoperative views. **C** and **D,** Postoperative results.

Figure 35-12, cont'd

E, Immediate postoperative view of submandibular neck with sutures in place. **F,** Submandibular excision and Z-plasty 6 weeks after surgery.
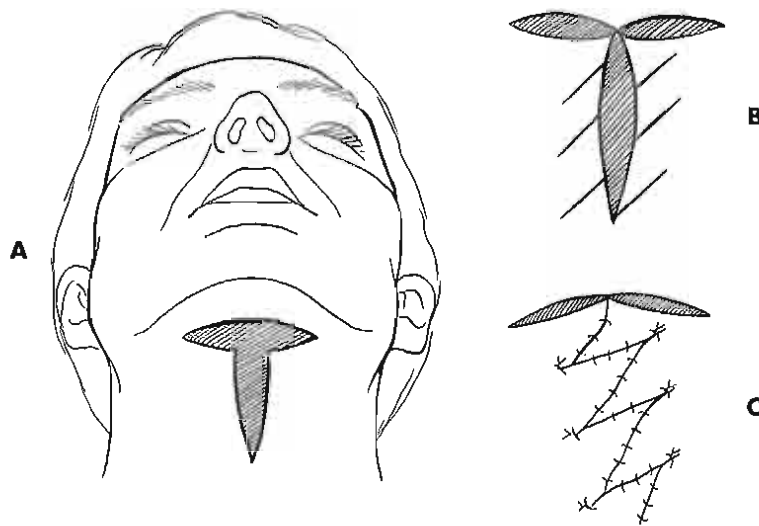
Figure 35-13

Submental skin excision and Z-plasty. **A,** Two perpendicular fusiform excisions of skin from submental neck. **B,** Edges of transverse excision are approximated with subcuticular sutures. Z-plasty incisions are made along longitudinal fusiform excision. **C,** Z-plasty is completed with half-buried corner stitches and 6-0 mild-chromic sutures.
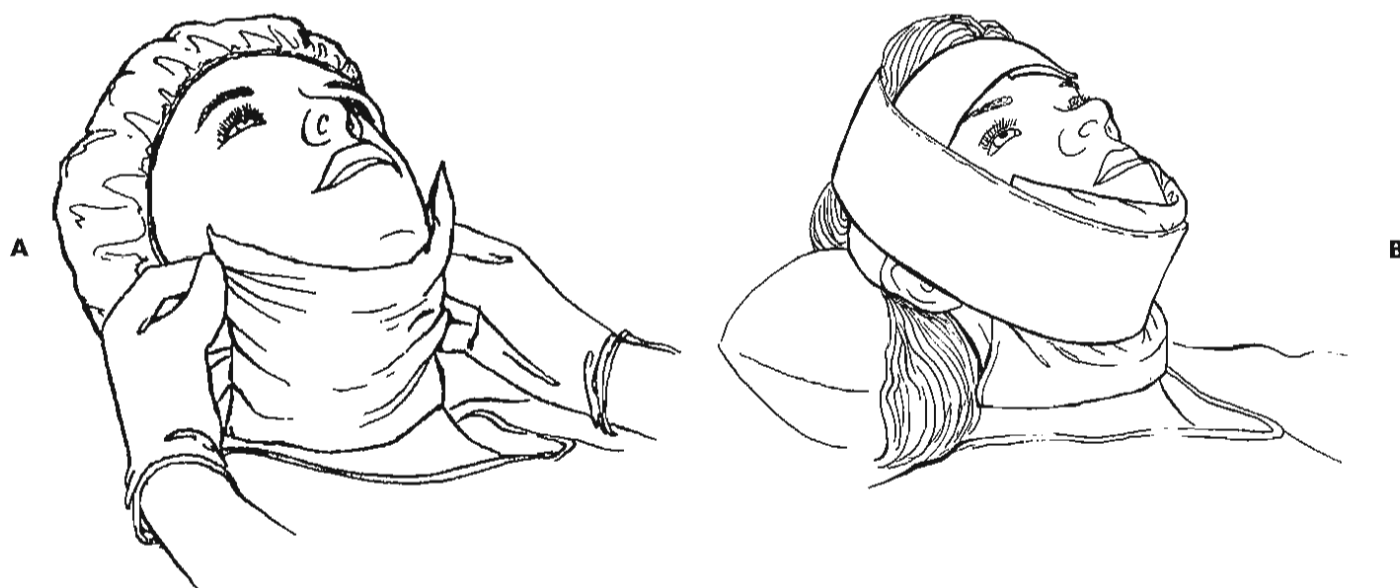
Figure 35-14

Postoperative dressings after liposuction of CCJ. **A,** Small superabsorbent pad is positioned over treated area to manage open tumescent drainage. **B,** Elastic compression binder provides adjustable and comfortable compression to treated area.

2. The longitudinal fusiform excision is converted into a Z-plasty.
3. The tips of the Z-plasty are interdigitated and sutured in place with 5-0 nylon using half-buried corner stitches.
4. Additional interrupted nylon sutures are placed where needed.
5. A superficial cuticular closure is done along the entire length of the transverse excision and Z-plasty.

POSTOPERATIVE CARE

Application of absorptive compression pads manages the open drainage after CCJ liposuction. In turn, open drainage is necessary to minimize postoperative bruising and edema. A compressive elastic garment is required only for the first 18 to 36 hours after surgery while drainage persists. Once the drainage has ceased, compression may be discontinued.

An elastic compression bandage applied over the cheeks and chin delivers the greatest compressive force over margins of the mandibular rami. To divert some of this compressive force to the submental area, a folded 10-cm (4-inch) gauze pad is placed over the medial submental area. Then a single pad is placed over the folded gauze pad on the submentum; this pad should cover most of the treated area to absorb the limited amount of drainage that follows CCJ tumescent liposuction (Figure 35-14).

TUMESCENT FACELIFT

Tumescent facelift (cervicofacial rhytidectomy) performed totally by local anesthesia using the tumescent technique was first reported in 1991[3] (Figure 35-15). Three years later a tumescent technique for facelift under general anesthesia was reported in the plastic surgery literature.[4]

SEDATION

Tumescent facelift patients do not require systemic anesthesia. The only sedation consists of oral lorazepam (1 mg) the night before surgery. On the day of surgery the patient is usually given oral lorazepam (1 mg) and clonidine (0.1 mg).

TUMESCENT ANESTHESIA

After marking the areas of focal accumulations of subcutaneous fat with a felt-tip pen, small blebs are injected at sites of 2-mm to 3-mm incisions, through which the anesthetic needle and the 16-gauge microcannulas will be passed. The tumescent facelift requires 350 to 550 ml of local anesthetic solution containing 500 mg lidocaine, 1 mg epinephrine, and 5 mEq sodium bicarbonate in 250 ml of normal saline. It usually requires 30 to 45 minutes to complete the infiltration without sedation (Figure 35-16).

The infiltration can be performed by an anesthesiologist, a well-trained registered nurse, or the surgeon using a hand-held

Figure 35-15

Facelift performed totally by local anesthesia using tumescent technique in 1989. **A,** Preoperative view. **B,** Appearance 48 hours after tumescent facelift with minimal ecchymosis and minimal edema.
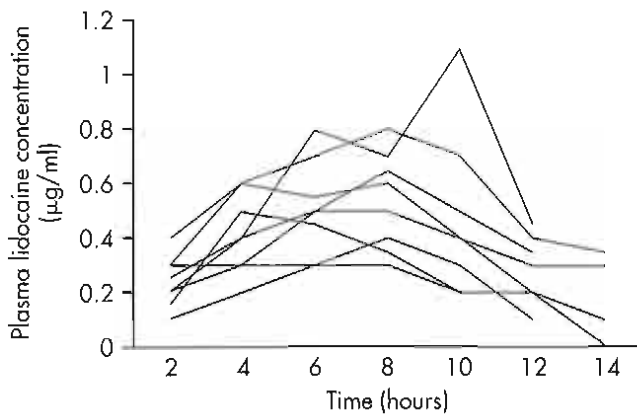
Figure 35-16

Sequential plasma lidocaine concentrations measured in eight women after tumescent facelift totally by local anesthesia (1989 to 1991). Typical lidocaine dosage was 15 mg/kg. Peak plasma lidocaine concentrations ranged from 0.3 to 1.1 μg/ml.

syringe. The infiltration can be initiated using 12-ml syringes, with a 5-cm 25-gauge needle. In some patients, after the initial infiltration, the surgeon can use more efficient 25-gauge and 20-gauge spinal needles with a foot-controlled peristaltic pump.

UNDERMINING AND LIPOSUCTION

Areas with little need for liposuction, such as the periauricular skin and superior cheeks, are undermined bluntly using microcannulas without suction. Undermining is done by attaching the microcannula to a microcannula handle, which in turn is attached to the aspirator with power on; the thumb is removed from the air vent. With a nonoccluded air vent, the aspirator provides sufficient suction to remove the small amount of messy tumescent anesthetic solution that would otherwise drip from the cannulas and incisions. Excessive fat on neck and CCJ areas is suctioned with the air vent occluded by the thumb.

After the liposuction and undermining have been accomplished, the patient may go to the bathroom to urinate. On returning, the surgical area is scrubbed and the patient draped in a sterile manner.

SKIN EXCISION

The periauricular incisions are cut and the skin flaps elevated with blunt finger and scissors dissection along the plane previously created by the microcannulas. After careful hemostasis the superficial musculoaponeurotic system (SMAS) plication is completed, the redundant skin trimmed, and the surgical site closed with sutures and staples. Adits (1.5-mm and 2.0-mm skin biopsy punch excisions) permit postoperative drainage.

STEP-BY STEP SEQUENCE

1. Right side is infiltrated, then the left side.
2. Right side is undermined or suctioned, then the left side.
3. Patient visits bathroom.
4. Periauricular skin on right side is incised, skin flap elevated, residual fibrous connections lysed, and meticulous hemostasis obtained. SMAS plication is performed. Identical sequence is completed on left side.

5. Hemostasis on right side is checked, skin flap advanced superiorly and posteriorly, redundant skin excised, and wounds closed. Identical sequence is completed on left side.

ETHICAL CONSIDERATIONS

DERMAL TRAUMA

Two antithetical theories evaluate the benefits of dermal trauma in liposuction. No published objective data support either theory.

According to one theory, liposuction of the chin yields improved cosmetic results if the undersurface of the skin is intentionally injured by mechanical liporaspiration from a cannula or by thermal trauma from a CO_2 laser.[5] This theory is predicated on the unproven assumption that such iatrogenic scarring will minimize skin redundancy, maximize skin retraction, facilitate skin adhesion to deeper tissues, and maximize cosmetic results.

The contrary theory states that intentionally traumatizing the subsurface of the dermis has no aesthetic benefit. Dermal contraction of the CCJ is the result of natural skin elasticity. The natural negative interstitial tissue pressure relative to atmospheric pressure guarantees an intimate approximation of the skin to the deepest plane of suctioned tissue.[6]

Advocates of the more gentle technique believe that intentionally rasping the deep surface of the dermis during liposuction is unnecessary and detrimental to achieving optimal aesthetic results. Intentional subdermal trauma, scarring, and fibrotic contraction merely prolong postoperative healing. When excellent results with CCJ liposuction are routinely achieved by avoiding dermal damage, intentionally damaging the skin has no advantage.

When the trauma is substantial, intentional dermal damage requires patients to use postoperative elastic compression for many weeks. Injury to the dermal undersurface causes postoperative fibrosis, focal seromas, prolonged swelling, erythema ab liporaspiration, postinflammatory hyperpigmentation, and impaired healing. With tumescent liposuction, using microcannulas and multiple incisions not closed with sutures, elastic compression bandages are worn for only 18 to 36 hours.

Rasping the platysma muscle directly over the mandible is unnecessary for good results. I have never had a patient with postoperative paresis of the marginal mandibular nerve. Adequate tumescent infiltration and careful liposuction technique with microcannulas prevent nerve injury. The goal of tumescent liposuction is to remove fat while causing minimal collateral trauma or inflammation of residual tissue.

A cosmetic surgeon's intuitive belief that intentional injury to healthy tissue is beneficial requires objective validation using ethically and scientifically acceptable controls. Surgeons who advocate intentional trauma (mechanical or laser-induced thermal trauma) to the submental wound after liposuction have an ethical and scientific obligation to present the
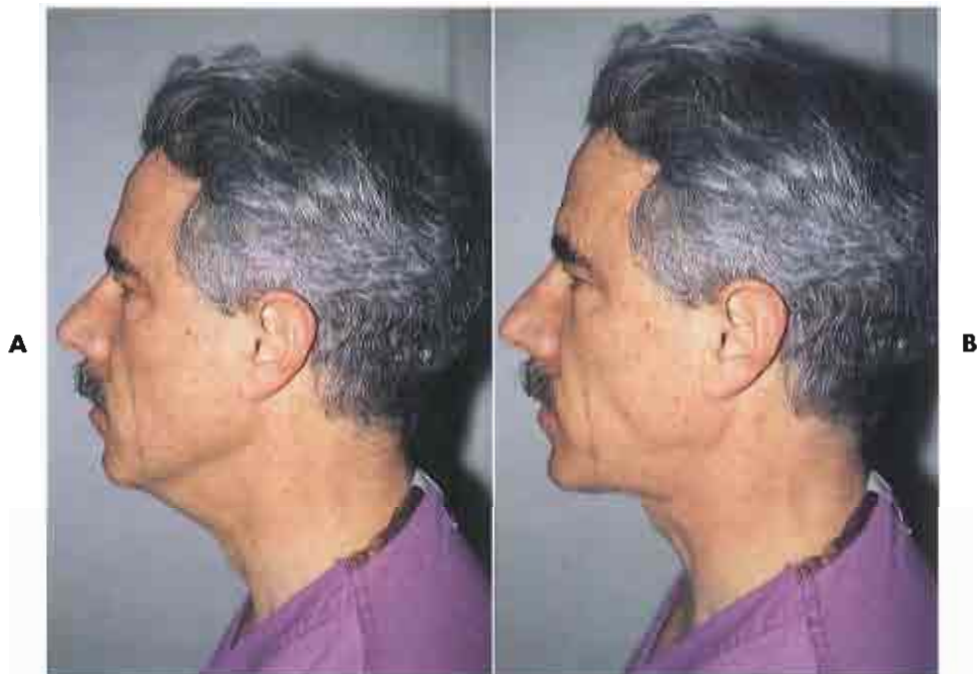
Figure 35-17

Factitious cosmetic improvement from **A** to **B** represents effects of muscle contraction. No liposuction or other cosmetic surgical procedure was done. This maneuver must be considered when evaluating "before-and-after" photographs.

results of objective, controlled studies. It is insufficient to state, "It has been my clinical experience that such trauma is beneficial."

FACTITIOUS RESULTS

With practice a person can selectively contract the muscles that elevate the hyoid bone toward the palate. "Before-and-after" photographs of a patient's profile can be improved if the patient contracts the anterior neck muscles in the postoperative photograph. Contracting these muscles elevates the base of the tongue and the entire submental compartment, decreasing the angle between the silhouette of the submental area and the neck to almost 90 degrees.

This maneuver gives the appearance of a more youthful silhouette without surgery. Having a patient perform this maneuver improves the appearance of before-and-after photographs and exaggerates the benefits of a technique (Figure 35-17).

Similar ethical considerations require that any before-and-after photographs of CCJ liposuction be accompanied by a listing of all ancillary cosmetic procedures. For example, when illustrating the results of a new liposuction technique, failure to

reveal a chin implant might give a deceptive or false-positive impression of the results.

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CHAPTER 36

Buttocks

Liposuction of the buttocks using large cannulas causes unpredictable asymmetry and irregularities. The designation of "Bermuda Triangle of the buttocks" recognizes the potential hazards of traditional liposuction techniques applied to the derriere.

Using careful microcannular tumescent liposuction techniques, surgeons can treat the entire buttocks and routinely produce excellent, symmetric, and smooth results. The youthful buttocks consist of large, smooth, dome-shaped, proximomedial mounds. Reestablishing this geometric form is one of the goals in remodeling the buttocks with microcannulas and tumescent liposuction.

Persons in early middle age begin to manifest a gibbosity (bulging) of the inferolateral buttock. Almost impossible to eliminate by liposuction without risking the appearance of a wrinkled depression, the inferior gibbosity can often be improved by about 50% with a careful conservative approach.

ANATOMIC CONSIDERATIONS

The buttocks consist of deep gluteal muscle and superficial fat. Traditionally, gross anatomists have focused on the deep-seated structures of muscle and bone. Liposuction surgeons, however, are interested in the broader and more superficial structures.

GROSS ANATOMY OF SUBCUTANEOUS FAT

Fat of the buttock is relatively homogeneous. Gluteal fat is largely devoid of any significant vascular or neurologic structures. No focal areas within the buttock fat have an excessive degree of fibrosis. Because muscle is not anesthetized by subcutaneous tumescent local anesthesia, if the cannula should contact muscle, the conscious patient will inform the surgeon immediately.

Buttock fat is not bottomless. Liposuction of the buttock must be done carefully to avoid muscle injury. Because the sciatic nerve courses approximately 2 cm deep within the gluteus muscle, however, there is little risk that a cannula will penetrate far enough to cause nerve injury.

Coursing deep within the fat are numerous fibrous septa and bands that support the buttock similar to the way the suspensory ligaments of Cooper support the female breast. These buttock ligaments, known as the suspensory *ligaments of Jacque,* are easily traversed by a microcannula. With age these ligaments lose a degree of elasticity. The visible manifestation of this ligamentous laxity is a drooping of the inferolateral quadrant of the buttock (Figure 36-1).

SURFACE ANATOMY

The study and geographic analysis of the surface anatomy of the female gluteal region is a popular pursuit. Detailed examinations of caudal topography from every perspective have been done throughout history.

The *horizontal infragluteal crease* is the visible superficial manifestation of the condensation of fibrous connective tissue. This partition is formed by a confluence of intermeshing fibrous strands originating from the fascia distal to the gluteus muscles. These strands insert diffusely into the deep dermis of the inferior horizontal gluteal crease, a distal boundary of the buttocks. The condensation of fibrous sheets and strands responsible for the infragluteal crease is known as the *ligaments of Luschka.*

The concept of the proximal posterior thigh as a pillar of support for the buttock only partly explains the surface anatomy of buttock fat. The banana-form fold provides minimal support to the buttock. The position of the buttock is more importantly determined by the suspensory ligaments of Jacque; it is suspended from the lumbar and gluteal muscle fascia by means of these ligaments.

Medially the buttocks are separated by the *intergluteal crease.* Laterally the buttocks blend into the landscape of the hip and lateral thigh. Some patients have a genetically determined lumbosacral fat pad proximal to the intergluteal crease. From an aesthetic perspective the lumbosacral pad is regarded as a component of the buttock, and the areas are usually treated concomitantly (Figure 36-2).

With increasing degrees of obesity the buttocks may develop random bumps, or *moguls.* These secondary pads are the
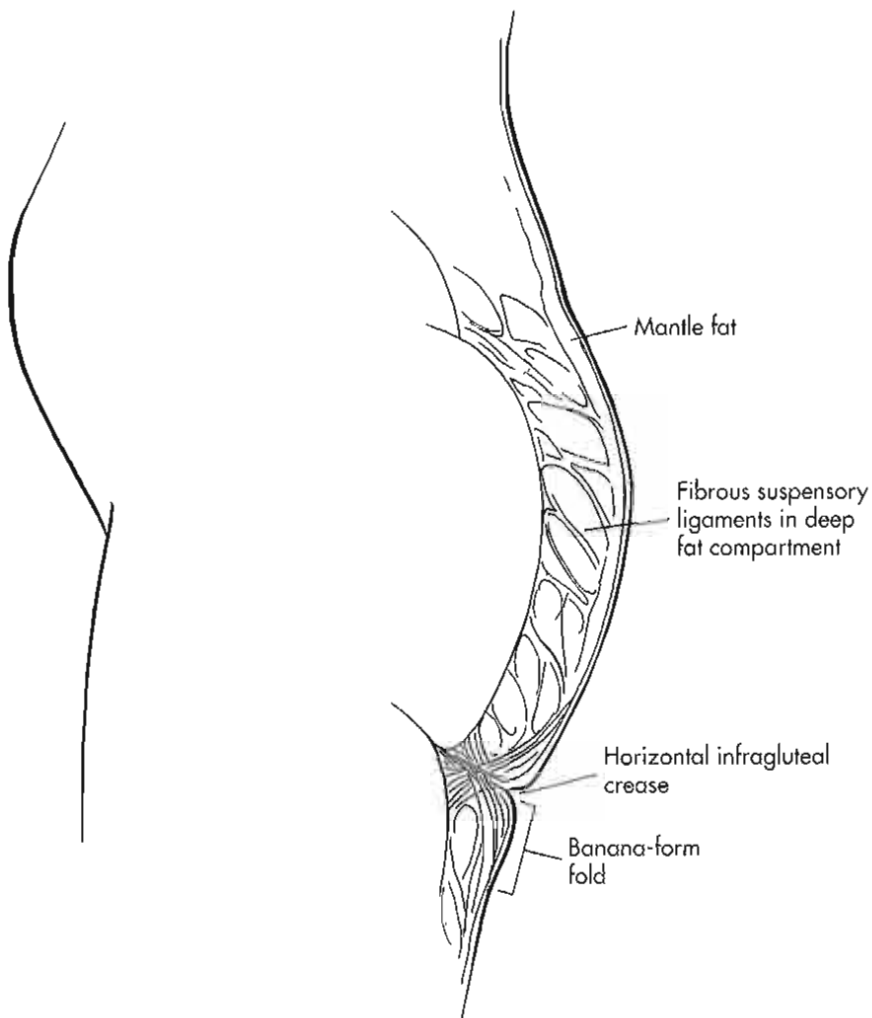
Figure 36-1

Parasagittal section through female buttock shows superficial mantle fat, deep fat compartment, and multiple sheets and bands of fibrous suspensory ligaments. Horizontal infragluteal crease is coalescence of fibrous tissue that attaches dermis to deep muscle fascia. Liposuction cannot realistically create a horizontal gluteal crease on a patient who lacks such a crease. Directing a liposuction cannula transversely in this area is likely to produce an undesirable furrow that becomes visible when patient bends forward or flexes at hip.

Figure 36-2

Buttocks and landmarks of superficial anatomy: B, buttock (proximomedial); ILB, inferior lateral buttock; BN, banana-form fold; H, hip; T, thigh (lateral).

Figure 36-3

The Callipygian Venus, a famous marble statue of a female nude discovered in Roman house of Emperor Nero and now displayed at Museo Nationale (National Museum of Archaeology) in Naples. Callipygian is derived from Greek adjective *kallipygos* (*kallos,* beautiful; *pyge,* rump).

superficial manifestations of overstuffed fat sections within the subcutaneous fat compartment. With careful use of the smallest microcannulas, moguls can be flattened.

The superficial buttocks consist of expansive volumes of subcutaneous fat having functional and aesthetic importance.

Functionally the buttock is a soft, resilient cushion that provides protection and comfort. Aesthetically a callipygian buttock is shapely and pleasing to behold (Figure 36-3).

When well proportioned, buttocks fit into clothing more comfortably. When misshapen or disproportionate, but-
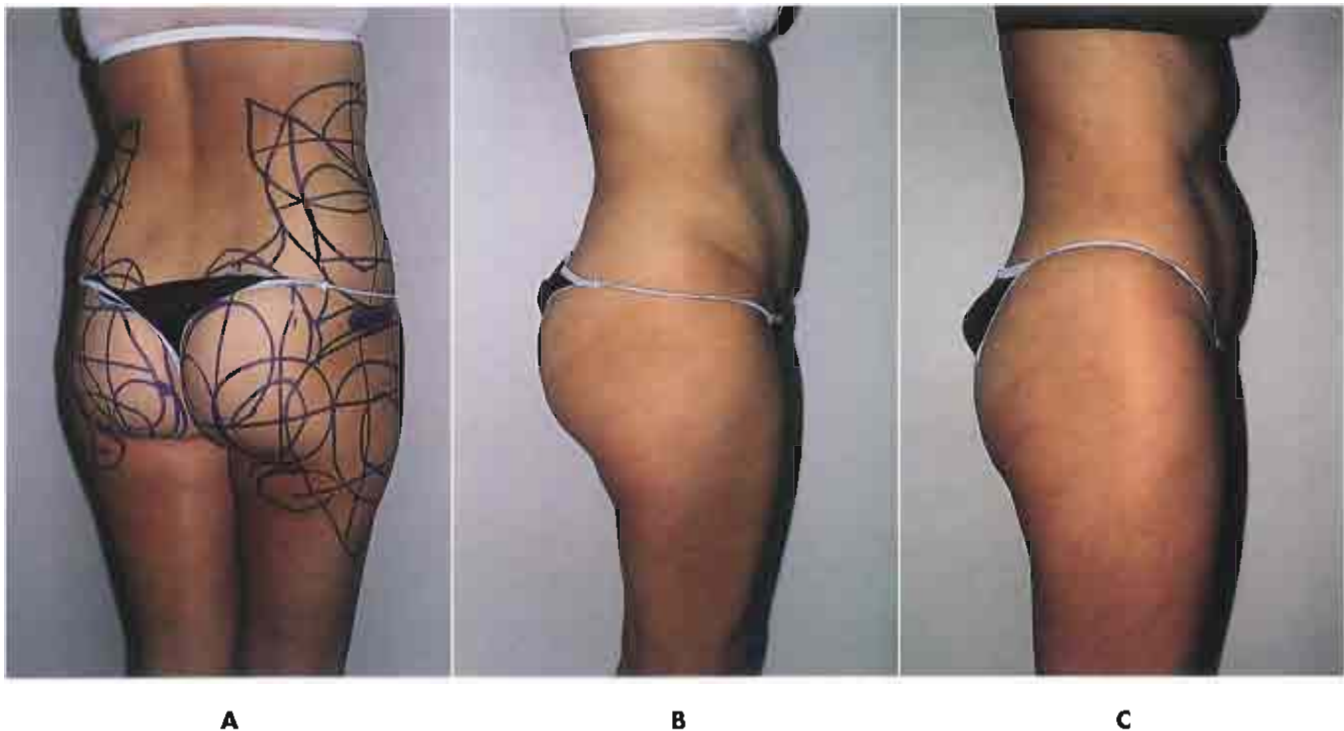
Figure 36-4

A, Topographic contour diagrams of buttock, hips, waist, and outer thighs. **B,** Lateral view of buttock before liposuction. **C,** After tumescent liposuction using microcannulas. Orthogonal grid pattern of straight lines helps to achieve uniform tumescent infiltration.

tocks may be a source of dissatisfaction, inconvenience, and embarrassment.

PREOPERATIVE EVALUATION

DESCRIPTIVE TERMS

The word *pygal,* meaning a relationship to the buttocks, is derived from the Greek stem words *pygo-* and *pyg-* (*pyge,* buttocks). These stems are often combined with other words to describe various aspects of the buttocks with scientific precision. Other words derived from Greek roots might prove helpful when documenting a preoperative examination of the buttock before liposuction.

Steatopygia (steatopygous; *steato-,* fat) describes the condition of possessing a very large or excessively fat buttock. *Leptopygian* (leptopygous; *leptos,* narrow) denotes slender, skinny buttocks. The related word *leptosomatic* describes a slender body or slender build.

Dolichopygia (*dolicho-,* long) designates long buttocks. *Skaphepygia* indicates boat-shaped buttocks.

TOPOGRAPHIC MARKINGS

The preoperative topographic markings are generally composed of two sets of nested concentric annular pat-

terns. These highlight the two principal topologic formations: the large proximomedial mounds (mountains) and the inferolateral bulges (foothills). Buttocks that have large random bumps (moguls) may require additional sets of circles to achieve the smoothest results (Figures 36-4 and 36-5).

Merely tracing an outline of an area to be treated by liposuction without detailed representation of cosmetically important features of surface anatomy is amateurish and lacks aesthetic sensibility. Nugatory markings that merely outline the periphery of the targeted area, ignoring valuable topographic information about internal geography, predispose to disappointing results. An outline is not sufficiently detailed (Figure 36-6).

INTRAOPERATIVE POSITIONING

Intraoperative positioning for liposuction of the buttocks is a modified or approximate version of the anatomic position. The patient is prone with a pillow placed under the pelvis. This position elevates the pelvis and produces slight flexion of the hip. This presents advantageous access to the entire volume of fat and facilitates symmetry and smooth results (Figure 36-7).

Providing thong-type examination panties covers the perineum while allowing easy surgical access to the buttocks.
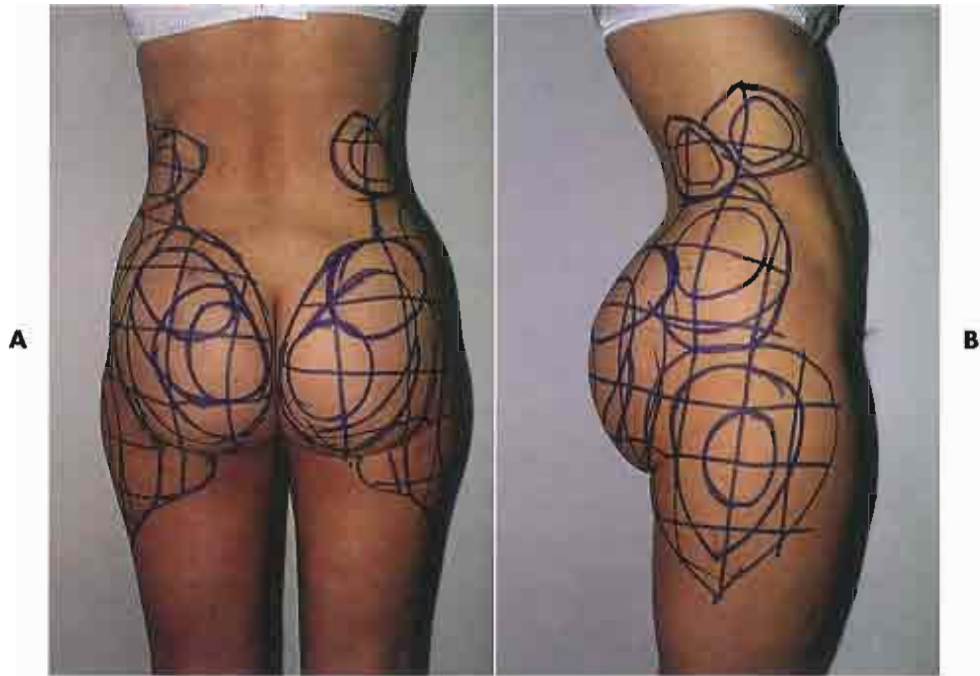
Figure 36-5

Topographic maps of buttocks showing contour lines that indicate depth of subjacent subcutaneous fat. **A,** Posterior view. **B,** Lateral view. Orthogonal grid pattern facilitates uniform infiltration of tumescent local anesthesia.
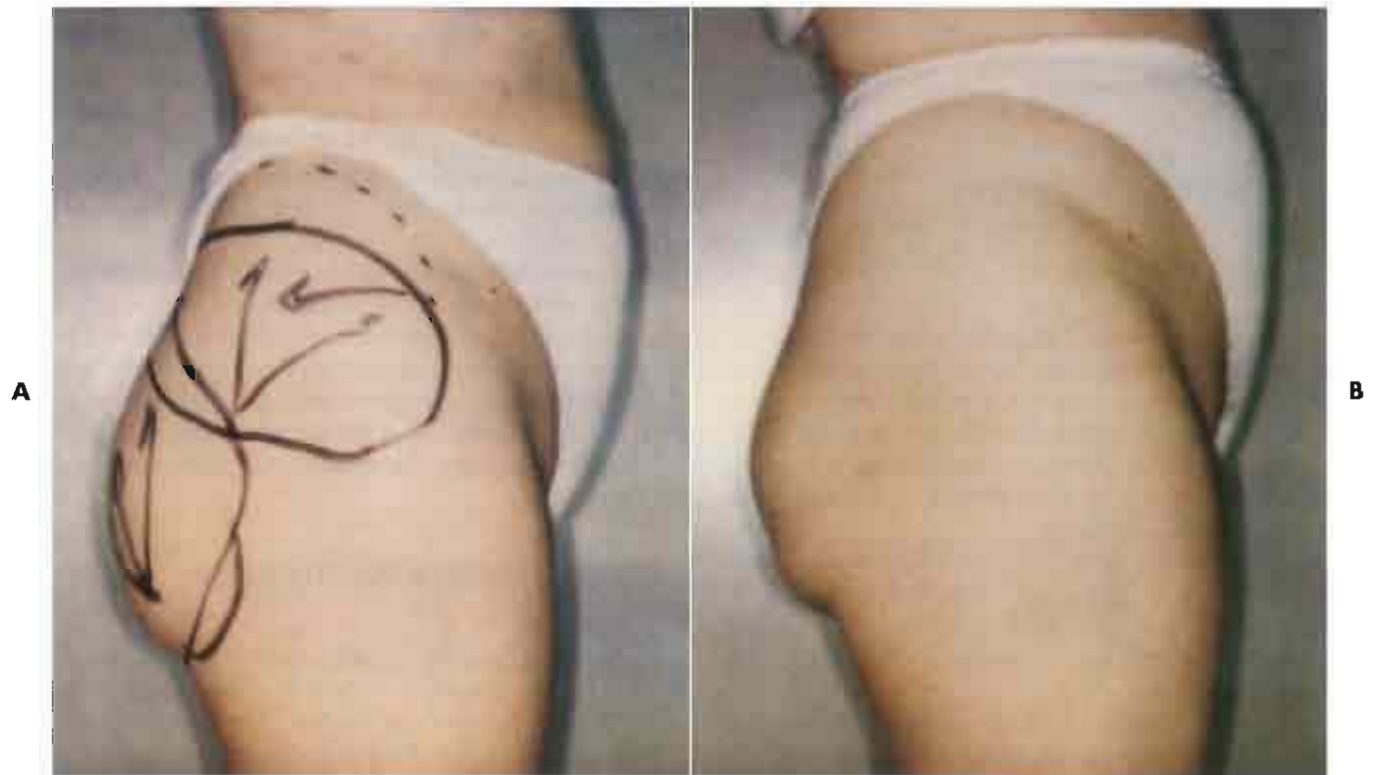
Figure 36-6

A, Merely outlining area to be treated is insufficient when marking patient before tumescent liposuction. **B,** Cosmetic results can be disappointing without precise topographic contour diagrams.
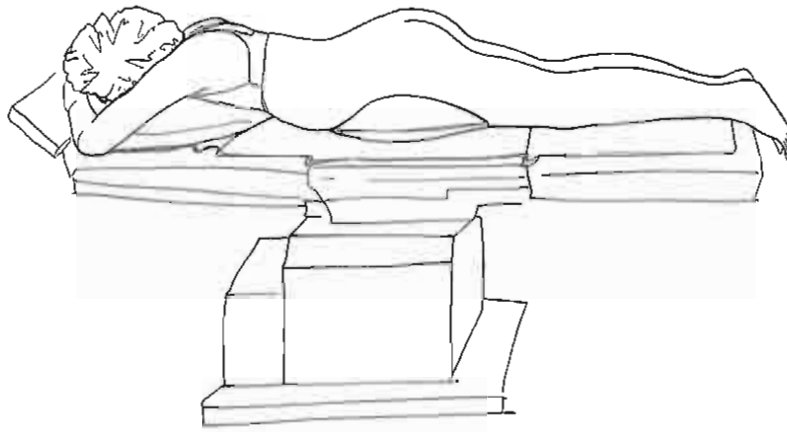
Patient in prone position with pillow under pelvis to elevate buttock and provide easier access for liposuction cannula.

ANESTHETIC INFILTRATION

Tumescent infiltration of the buttocks should be thorough, with all levels of the fat being well anesthetized. After infiltration is complete, an elapsed time of 20 to 30 minutes is required before the anesthesia and vasoconstriction are sufficient and the tissues are sufficiently detumescent.

SURGICAL TECHNIQUE

The goal of tumescent liposuction of the buttocks is to achieve a pleasing reduction in size and bulk. In attempting to achieve a noticeable reduction in posterior projection of the buttocks, the surgeon must be cautious to avoid both excessive removal and asymmetric removal of fat. Liposuction will not lift or elevate the buttock to any noticeable degree. Superficial liposuction is not done.

Using microcannulas, the goal is to remove fat gradually and deliberately to maximize the chances of smooth, uniform results. One buttock is treated first until the desired degree of reduction is achieved relative to the untreated side. The contralateral buttock is then treated until it is the mirror image of the first buttock.

Gradual uniform reduction is accomplished by careful technique that removes fat incrementally, with the entire buttock slowly decreasing in size. Through each microincision, a limited number of radiating cannula thrusts are accomplished, with the cannula paths fanning out and crisscrossing with the pattern of the adjacent incision. After a limited number of radiating thrusts (e.g., 10 to 20) the cannula is withdrawn and placed in another incision or adit.

At each stage the surgeon must check the surface for smoothness and shapeliness. A cavalier approach to liposuction of the buttock can lead to grotesque results (Figure 36-8).

In the early days of liposuction, surgeons had a well-founded fear of doing liposuction on the buttock using large, 6-mm to 10-mm cannulas. The "Bermuda Triangle" of the buttocks was an area off limits to liposuction. This area, bounded by an equilateral triangle with its base along the infragluteal crease and its apex at the lumbosacral junction, was regarded as high risk when liposuctioned with large cannulas. Large cannulas would frequently create a lumpy, furrowed derriere.

The use of microcannulas for tumescent liposuction of the buttocks has disproved the Bermuda Triangle theory, consistently yielding smooth and natural-looking results.

The location of incisions for microcannulas is generally determined by convenience and accessibility for the surgeon and by cosmetic considerations. Although no fixed location exists for microincisions, they are preferably placed at least 6 to 8 cm (2½ to 3¼ inches) lateral to the midline intergluteal crease to facilitate use of absorptive pads.

To achieve natural-looking results, the surgeon uses a conservative approach. It is important to leave a thick blanket of superficial fat to prevent dimpling. The targeted fat is the midlevel 40% to 60% of the buttock fat. The most superficial 20% to 30% of the fat deposit is avoided.

The path of a microcannula should be directed along a plane that is generally tangential to muscle. With a little care and attention, it is unlikely that a cannula will ever penetrate into muscle.

The banana-form folds are best treated using 16- and 14-gauge microcannulas, which can be advanced in deep, crisscrossed paths extending from the lateral thigh or buttock. Transverse tunnels or excessive liposuction can produce cosmetically unacceptable, double infragluteal creases. Liposuction of the banana-form fold must be done as conservatively as possible (see following discussion). Patients are told that, to prevent a double infragluteal crease, no
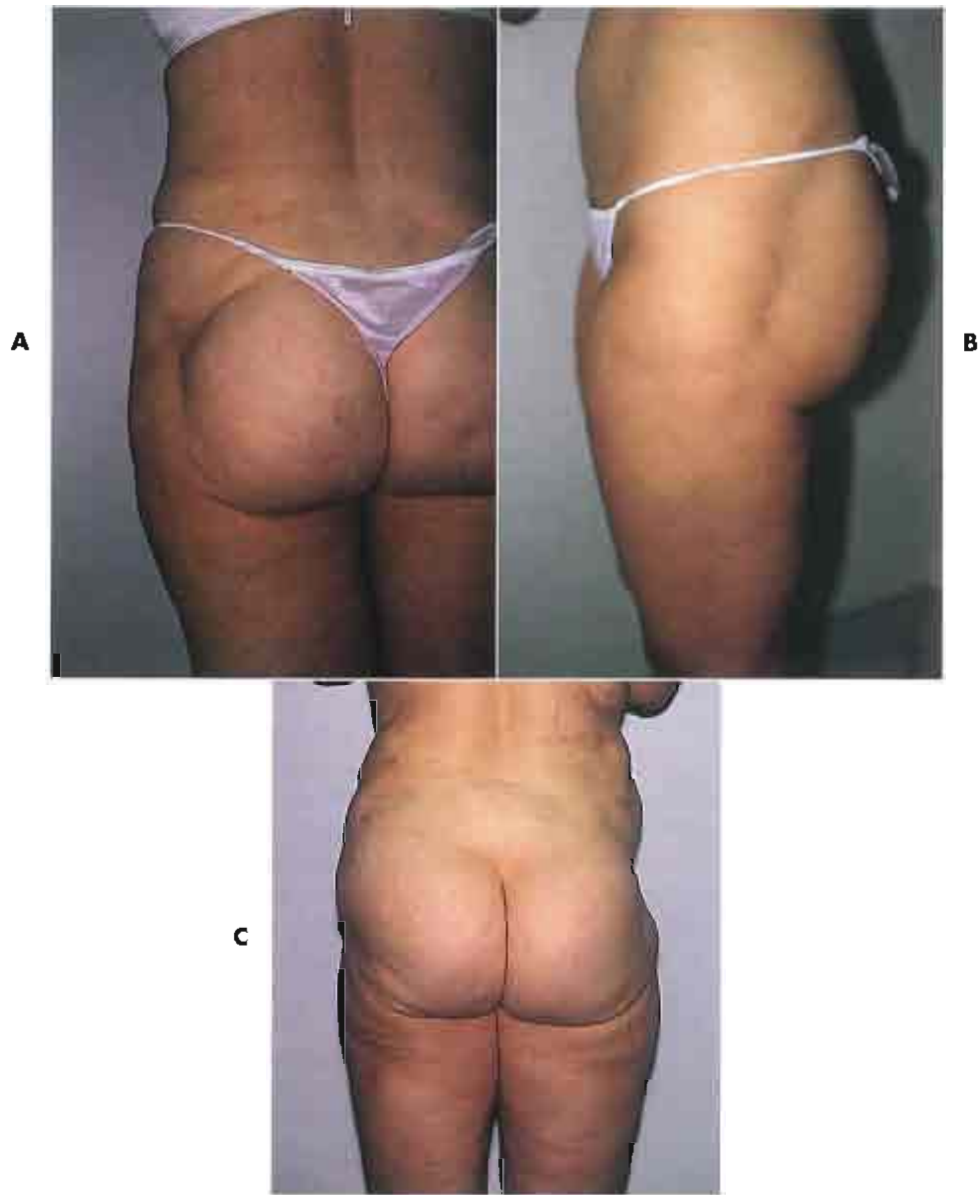
Figure 36-8

A to **C,** Three patients with deformed buttocks resulting from careless liposuction using large-diameter cannulas and minimal number of incisions.

Figure 36-9

A, Congenital asymmetry of buttocks was corrected by unilateral liposuction. **B,** Patient was satisfied with outcome despite double infragluteal crease, the necessary result of extensive liposuction.
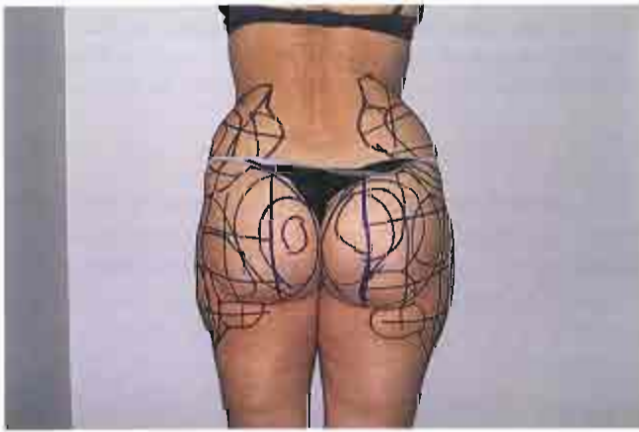
Figure 36-10

Avoiding microincisions too close to midline facilitates placement of postoperative absorptive compression pads. All adits should be lateral to the two vertical paramedian lines, as shown.

more than a 50% improvement can be attempted with liposuction of the banana-form fold (Figure 36-9).

If the buttock is one of several areas being suctioned on a given day, the surgeon should change gloves before treating another area.

POSTOPERATIVE CARE

Postoperative care involves the use of appropriate absorbent pads and compression. The surgeon should avoid placing microincisions any closer than 6 to 8 cm from the midline intergluteal crease to facilitate postoperative drainage. If incisions are too close to midline, it is both difficult to position the pads and uncomfortable and inconvenient for the patient to wear them (Figure 36-10).

PITFALLS AND SPECIAL CONSIDERATIONS

As a general rule, no more than 30% to 50% of the existent buttock fat should be removed by liposuction. Too much liposuction will leave an unacceptable degree of ptosis and residual skin irregularities.

Figure 36-11

Withered and wrinkled buttocks after excessive liposuction.

Figure 36-12

Double infragluteal creases resulting from excessive liposuction of banana-form fold in **A,** obese patient, and **B,** thin patient.

The goal is never to remove the maximal volume of fat but rather to produce the smoothest, most natural, well-proportioned result possible. Finesse is more important than mass. Until the surgeon has extensive experience, it is best to be conservative and avoid any risk of inadvertently removing too much fat from the buttock (Figure 36-11).

INFRAGLUTEAL BANANA-FORM FOLD

The fat below the horizontal infragluteal crease, the banana-form fold, must be approached with great caution during liposuction. Removing too much fat from the infragluteal banana-form fold will produce a redundant or double infragluteal crease (Figure 36-12).

A large redundant infragluteal crease probably cannot be repaired easily. On the other hand, some slight to moderate redundant infragluteal creases might be candidates for simple surgical repair. A fusiform excision located in the posteromedial portion of the infragluteal fold is least likely to produce a visible scar (Figure 36-13).

Aggressive liposuction of the banana-form fold often creates a plication of redundant skin and a second horizontal infragluteal crease. This secondary crease is difficult to repair without significant scarring.

The recommended approach for liposuction of the banana-form fold is to be conservative and to direct the microcannulas obliquely at 45 degrees to the horizontal infragluteal crease. The surgeon should not remove too much fat and should avoid doing liposuction transversely across the posterior thigh (Figures 36-14 and 36-15).

INFRAGLUTEAL HORIZONTAL CREASE

An infragluteal horizontal crease, the visible manifestation of fibrous septa that connect the skin of the infragluteal crease to deeper fat and muscle fascia, is not present in all women.[1]

Most patients and some surgeons do not appreciate the difficulty and aesthetic risks involved in attempting to create or modify a horizontal infragluteal crease. Liposuction in this area has often resulted in asymmetry and dissatisfied patients. Too much liposuction along the infragluteal crease produces a scooped-out, furrowed, unnatural depression that is most noticeable when the patient bends over or flexes at the hip and stretches the affected area (Figure 36-16).

A liposuction surgeon should not attempt to create an infragluteal crease. Suctioning subcutaneous fat cannot produce a realistic infragluteal crease. Removing too much fat

Figure 36-13

Repair of small, medial, double infragluteal crease. **A,** Double infragluteal crease of left thigh was result of excessive liposuction. **B,** To repair defect, small fusiform excision was diagrammed. **C,** One week after surgical repair. Reduced visibility of scar was achieved by placing incision in posteromedial aspect of thigh. Lateral extension of double infragluteal crease is difficult, if not impossible, to correct.
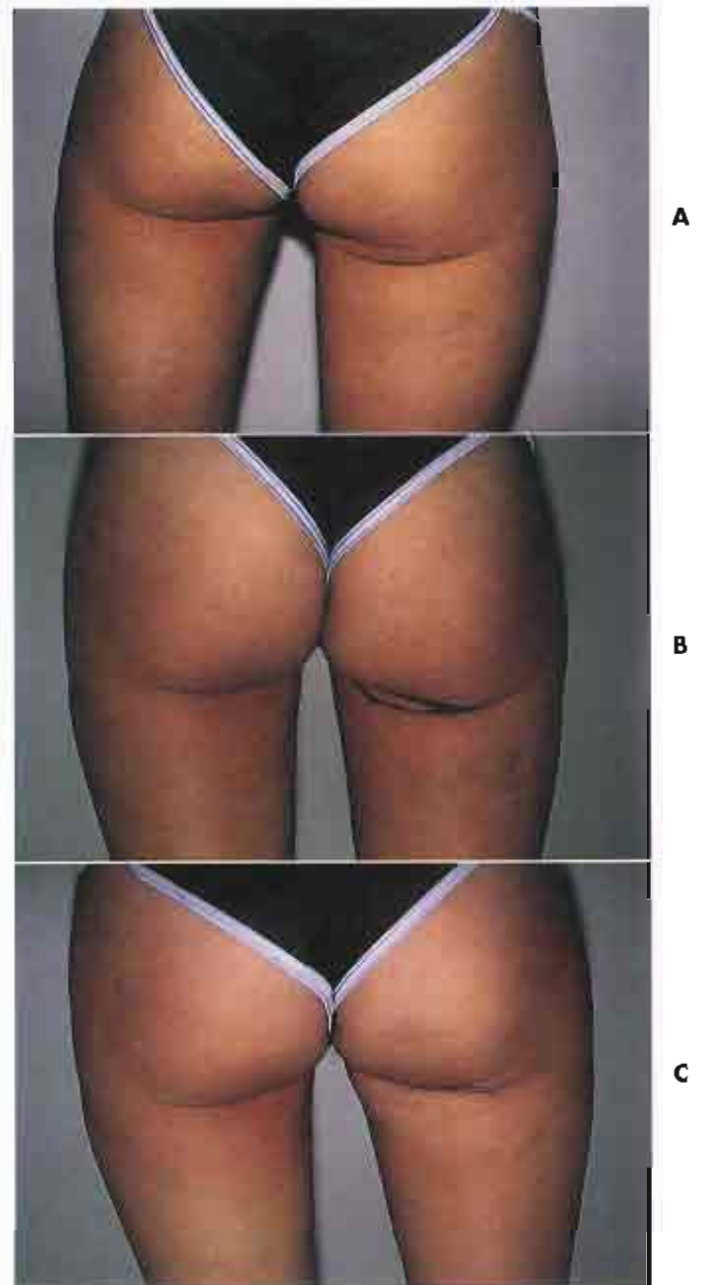
Figure 36-14

A, Small, medial, double infragluteal crease below right buttock. **B,** Small fusiform area of skin to be excised. **C,** Immediately after repair.

Figure 36-15

Liposuction of banana-form fold should be done conservatively and with great caution. Overaggressive liposuction in transverse direction risks creating secondary horizontal infragluteal crease. Microcannulas, directed medially and obliquely from above or below at about 45 degrees, help to minimize this risk.
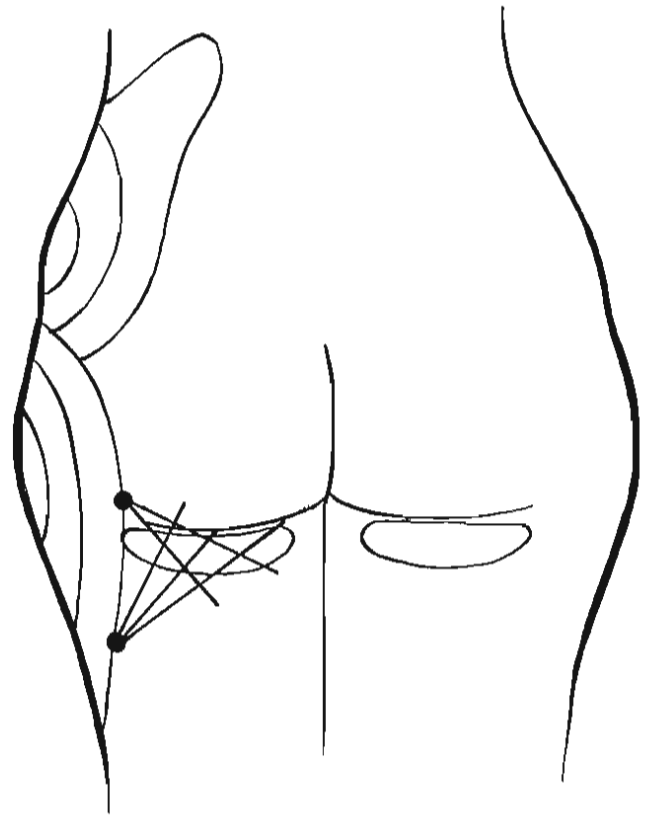
Figure 36-16

Excessive liposuction in attempt to modify shape of infragluteal crease resulted in distorted buttocks with double infragluteal crease. **A,** Posterior view. **B,** Lateral view.
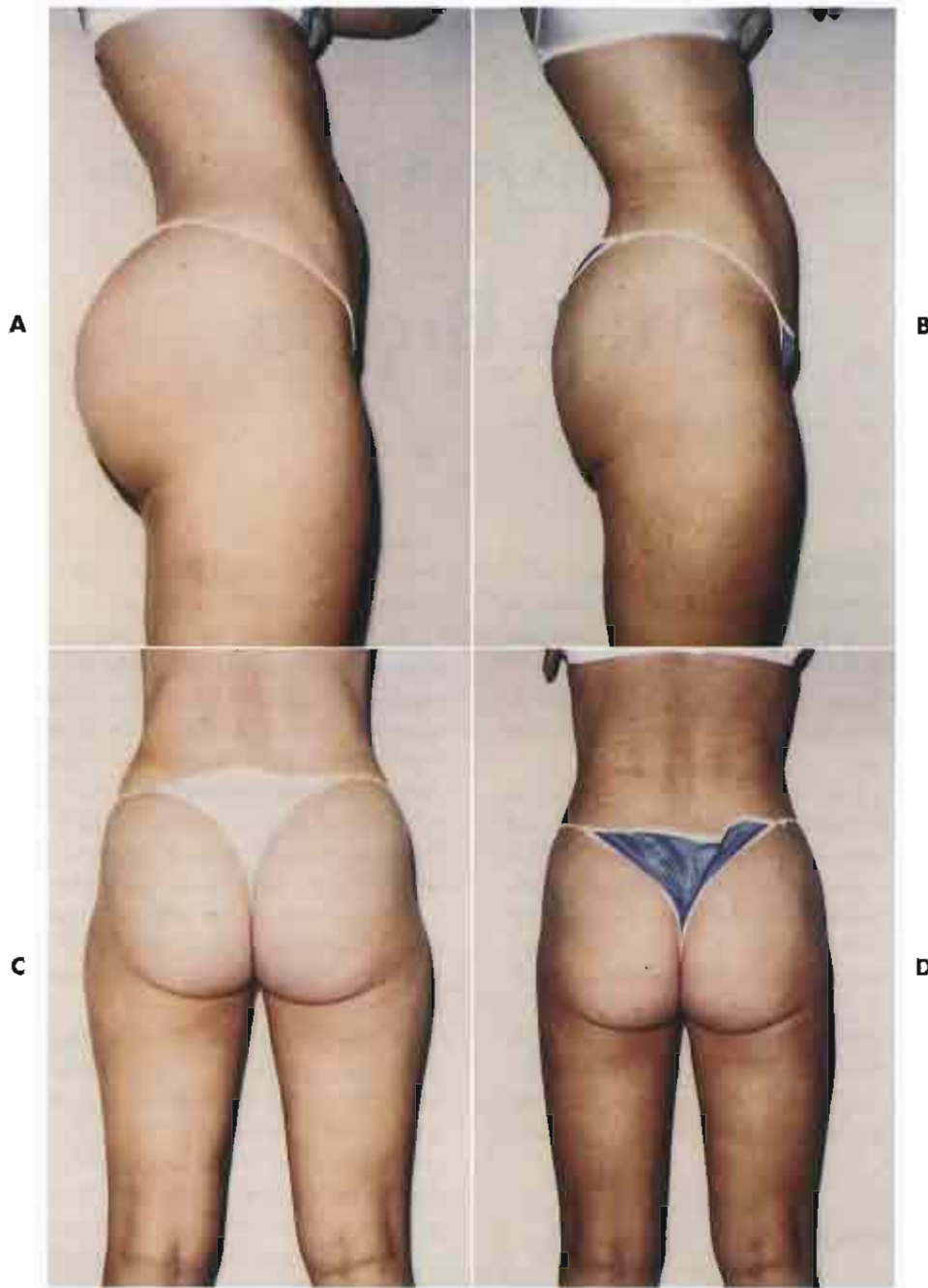
Figure 36-17

Buttocks before and after tumescent liposuction with Capistrano microcannulas. Hips and lateral thighs were also treated. **A** and **C,** Preoperative lateral and posterior views. **B** and **D,** Postoperative lateral and posterior views 10 weeks after surgery. Medial thighs and medial knee had been treated 4 weeks previously during a separate tumescent liposuction procedure.

from the infragluteal crease will result in pain when the patient sits on a hard surface because of insufficient fat overlying the ischial tuberosity.

Too much liposuction in the infragluteal crease cannot be repaired. The cosmetic risks of attempting to create an infragluteal crease outweigh the possible benefits.

For other procedures, however, with mastery of microcannulas, tumescent liposuction of the buttock can become a technique of finesse and can provide consistently reproducible, smooth results (Figure 36-17).

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CHAPTER 37

Male Breasts

The male breast is one of the four areas most requested for liposuction in men. An excessive amount of adipose tissue in the male breast, together with a normal amount of glandular breast tissue, is known as *pseudogynecomastia.*

Most enlarged male breasts are usually the result of excessive fat. Occasionally, however, a patient may have excessive glandular breast tissue.

Pseudogynecomastia is typically an idiopathic condition. Specific causes of gynecomastia include hypogonadism and alcoholism. Drugs associated with bilaterally enlarged male breasts include thyroid hormones, anabolic steroids, marijuana, estrogens, spironolactone, digitalis, diazepam, phenytoin, and clomiphene. Paraneoplastic syndromes that produce gynecomastia include testicular and adrenocorticosteroid-secreting tumors.

Unilateral breast enlargement in a male requires that a primary breast tumor be ruled out. Any significant asymmetry of the male breasts, especially with recent onset of asymmetric growth, should prompt the surgeon to consider a mammogram (Figure 37-1).

ANATOMIC CONSIDERATIONS

Tumescent liposuction of the male breast is quite successful. The goals are basic liposuction strategies: (1) remove as much fat as possible, (2) maximize the natural appearance of the result, and (3) avoid damage to the skin or subjacent muscles.

Although microcannular tumescent liposuction is satisfactory for most cases of gynecomastia, some patients may require a direct excision of the glandular breast tissue. This possibility must be discussed with patients before surgery.

GROSS ANATOMY OF SUBCUTANEOUS FAT

Breast tissue has increased vascularity compared with the flanks, abdomen, and submental area, which are the other areas for which men frequently request liposuction. The ten-

dency for bleeding with breast liposuction is greatly attenuated by the tumescent technique.

The proximity of the subjacent pectoralis muscle, its variable size, and its mobility make this muscle vulnerable to trauma during breast liposuction. Even a small muscle laceration can result in bleeding and a hematoma. Avoiding inadvertent penetration of pectoralis muscle during either infiltration or liposuction requires conscientious attention to the subtleties of the local anatomy. Before beginning infiltration the breast must be carefully palpated, with specific attention to locating the breast tissue–pectoralis muscle interface.

Normal male breast adipose tissue is relatively more fibrous than other areas in the male. The fibrousness of the male breast makes it one of the most challenging areas for liposuction.

In true gynecomastia, excess glandular breast tissue is present along with fat. This glandular tissue is extremely fibrous. Although liposuction of true gynecomastia using Capistrano microcannulas is usually successful, liposuction results can never be guaranteed. Prospective patients should understand that it is sometimes difficult to assess the amount of glandular tissue in a male breast before surgery.

True breast tissue in males is typically located immediately subjacent to the nipple-areolar complex. It is often distinctly more firm to palpation than the surrounding fatty tissue. A routine mammogram may facilitate a preoperative assessment of male breasts regarding the amount of fibrous glandular tissue versus adipose tissue.

SURFACE ANATOMY

Two simple maneuvers can help the surgeon distinguish between subcutaneous adipose tissue and subjacent deeper pectoralis muscle, as follows:

1. With the patient supine and arms at his side, he contracts the pectoralis muscles. When the pectoralis muscle is tightened, the surgeon can appreciate the palpable interface between the soft compressible fat and the firm muscle.

Figure 37-1

A, Asymmetric male breasts of longstanding duration in young man who sought liposuction to achieve unilateral breast reduction. Mammogram revealed normal glandular breast tissue with minimal fat. Patient elected not to proceed with liposuction after being told that liposuction might not adequately reduce size of left breast **(B).**

2. With the patient supine and ipsilateral arm raised, he places his hands behind his head. The pectoralis muscle is stretched and facilitates palpation of the softer, overlying fatty breast tissue.

PREOPERATIVE EVALUATION

The size of male pseudogynecomastia increases with both age and the degree of obesity. Obesity in early childhood is associated with pseudogynecomastia. Obesity is not an indication for liposuction. If there is a limited area where liposuction could provide some aesthetic improvement, however, liposuction should be considered. In an obese male patient, breast reduction by tumescent liposuction can provide gratifying cosmetic results.

In most males the extent of the excessive breast tissue is obvious to both patient and surgeon. With increasing obesity, fat may be augmented along the axillary chest wall. This lateral chest wall fat often blends into the breast area without a demarcation between the two areas. Technically the areas are distinct, but cosmetically it is difficult to achieve satisfactory results without treating both areas.

The surgeon must discuss and document the extent of the proposed "breast" surgery. All confusion about treatment areas must be eliminated before surgery. During the initial con-sultation, it is helpful to draw on the patient to define the boundaries of the proposed surgery.

At the time of surgery the contour mappings should be drawn carefully, with the innermost concentric circle designating the deepest area of subcutaneous fat. The area of deepest fat does not always coincide with the location of the nipple-areolar complex. In some males, satisfactory liposuction of the breasts may require liposuction of fat at the periphery of the breast, such as along the anterior axillary area and on the lateral chest wall (Figure 37-2).

INTRAOPERATIVE POSITIONING

Patient position during breast surgery is a matter of convenience for the surgeon. In one preferred position the patient is supine, with a small pillow or a folded towel placed beneath his ipsilateral scapular back. This slight elevation of the chest wall allows the arm to rest at the patient's side and along the lateral chest wall. This posterior displacement of the arm improves the surgical access to the breast's lateral aspect. This position also stretches the pectoralis muscle and facilitates palpation to distinguish breast fat from deeper muscle.

In another position the supine patient places his ipsilateral hand behind his head (Figure 37-3).
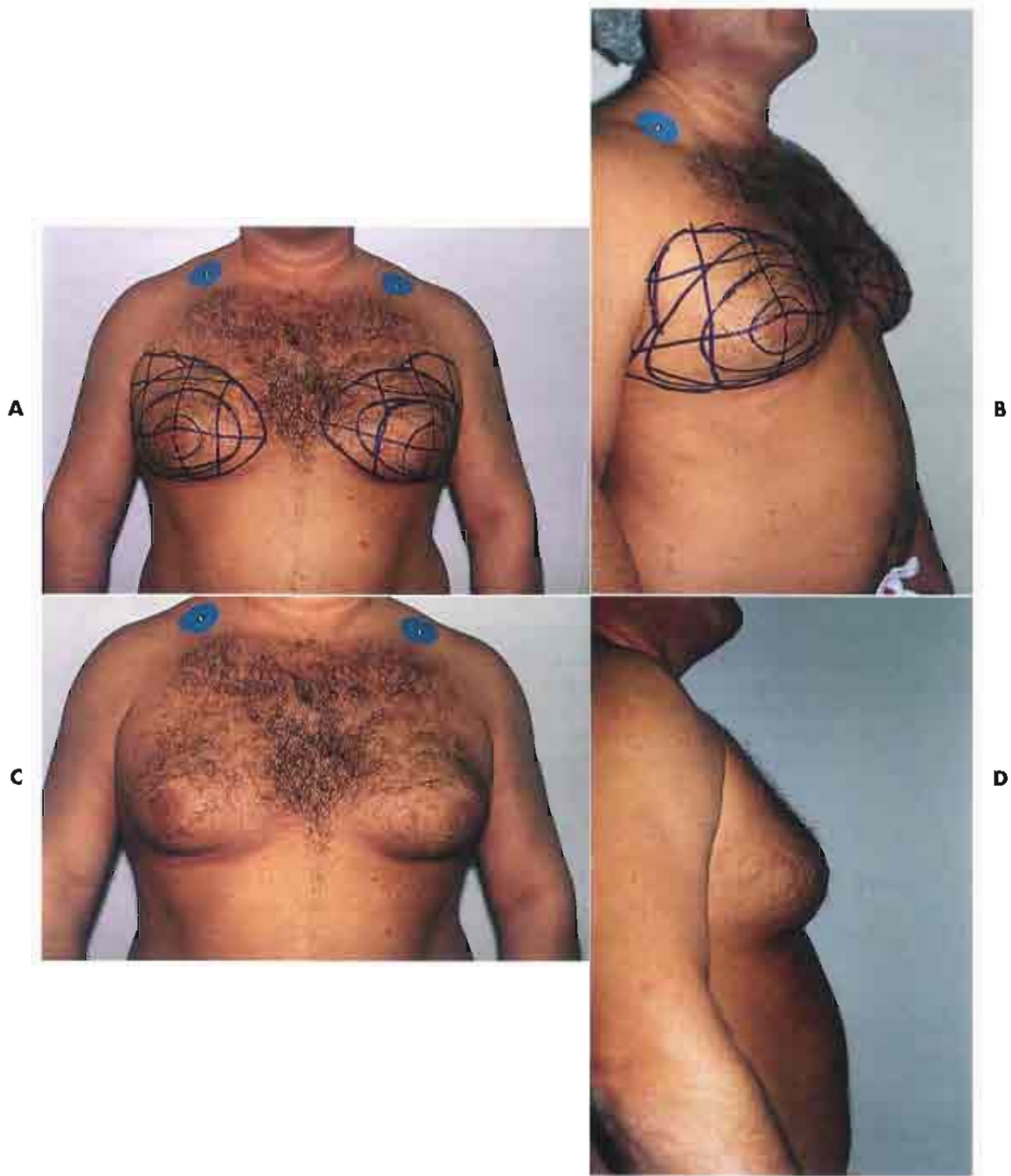
Figure 37-2

Male breast contour drawings facilitate accurate liposuction despite change of breast shape from tumescent infiltration. **A** and **B,** Topographic contour drawings on male breast, extending onto anterior axillary chest area. **C** and **D,** Preoperative anterior and lateral views.

Figure 37-2, cont'd

E and **F,** Anterior and lateral views after tumescent liposuction using microcannulas.

Figure 37-3

Proper positioning of patient during surgery facilitates access to targeted fatty tissue and minimizes risk of injury to pectoralis muscles.

Figure 37-4

Male breasts after tumescent anesthetic infiltration. Right breast was infiltrated first and therefore exhibits greater vasoconstriction and blanching than left breast.

Routine blood pressure monitoring using a traditional cuff on the arm can be a problem when doing liposuction of the breast, lateral chest, or arms. Because of the physical location of the blood pressure cuff on the proximal arm, the cuff can be contaminated with blood-borne pathogens. Also, the cuff can interfere with surgical access to the treatment area. These problems can often be eliminated by placing a pediatric blood pressure cuff on the wrist over the radial artery.

ANESTHETIC INFILTRATION

Successful and painless liposuction of the male breast totally by local anesthesia requires the following (Figure 37-4):

1. Adequate concentrations of lidocaine (1250 to 1500 mg/L) and epinephrine (1 to 1.5 mg/L)
2. Careful infiltration technique
3. Use of microcannulas

Both male and female breast tissue has a high degree of antitypy (resistance to penetration). Infiltration of the male breast requires special care and attention to detail. The glandular breast tissue can be so dense that infiltration requires extra effort.

Infiltration should be initiated with a 25-gauge needle, either a 5-cm (2-inch) hypodermic needle or a 25-gauge pediatric spinal needle. The 25-gauge needles cause little discomfort and provide enough local anesthesia to allow painless, more complete infiltration using a 20-gauge spinal needle. After the glandular nipple tissue has been made somewhat tumescent, a larger (20-gauge) spinal needle can be more easily passed through the otherwise dense and resistant tissue.

SURGICAL TECHNIQUE

Multiple 2-mm to 3-mm incisions or 1.5-mm adits (punch biopsy excisions) are made in convenient areas. Some are placed along the inframammary crease and others at the periphery or within the targeted area. The incisions are not closed with sutures. I have yet to encounter a hypertrophic or keloid postoperative scar on the chest that was caused by a liposuction incision. To minimize the risk of keloid formation on the chest, the surgeon should avoid placing incisions over the xyphoid area.

Tumescence of the subareolar glandular breast tissue decreases the tissue density and the resistance to penetration by a microcannula. Thus tumescence facilitates passage of a short (5-cm) and thus relatively inflexible 16-gauge Capistrano microcannula. Having created an initial crisscross pattern of 16-gauge cannula tunnels through the adipose and glandular tissue, the surgeon can then use a larger, more efficient 14-gauge Capistrano microcannula. The 14-gauge cannula is efficient, with small incisions; a larger cannula is rarely necessary. The use of 12-gauge cannulas is unusual except in the largest breasts.

Adipose tissue in the male breast is more fibrous than in most other areas treated by liposuction. Microcannulas can penetrate the tissue with greater accuracy and less discomfort than larger cannulas. The preferred Capistrano microcannulas include 16-gauge cannulas that are 5 cm (2 inches), 7.5 cm (3 inches), and 12 cm (4.75 inches) in length; 14-gauge cannulas; and 12-gauge cannulas that are 15 cm (6 inches) in length.

Capistrano microcannulas remove fibrous fat from within dense fibrous connective tissue by gentle rasping from multiple tiny apertures with simultaneous suction. Even glandular breast tissue can be raspirated. With careful, assiduous surgical effort, this technique will remove both adipose and normal subareolar glandular tissue.

The smaller the cannula diameter, the easier it can penetrate the dense tissues. Short (5-cm) 16-gauge cannulas are ideal for initiating liposuction within the dense subareolar male breast. This requires minuscule adit incisions beyond the periphery of the areola. Adit incisions disappear quickly without scarring or dyschromia if care is taken not to traumatize the epidermis.

Excess fatty tissue in the male breast is often seen in older patients (Case Report 37-1).

Liposuction of the male breast is a well-recognized procedure, but the technique and instrumentation have not been standardized. Some surgeons use larger cannulas with an outside diameter (OD) of at least 4 mm. I prefer microcannulas having an inside diameter (ID) ranging from 1.2 mm (16 gauge), to 1.8 mm (14 gauge), to 2.2 mm (12 gauge).

Some surgeons have advocated sharp cutting cannulas to facilitate liposuction of male breast glandular tissue. Others advocate excisional male breast mammoplasty, despite the risk of scarring and disfigurement. I have found that smaller cannulas facilitate liposuction of male breast glandular tissue and permit consistently excellent results (Figure 37-5).

Prominent subareolar breast tissue can be reduced by careful tumescent liposuction using a delicate infiltration technique and short (5-cm and 7.5-cm) 16-gauge Capistrano cannulas.

POSTOPERATIVE CARE

Optimal postoperative recovery with minimal bruising and swelling requires open drainage (no sutures) and bimodal compression provided by a breast-torso garment and a 6-inch-wide elastic binder. This combination of devices allows adjustable compression that can be applied precisely over the entire liposuction area. Adequate compression during the first 18 to 24 hours after surgery is necessary to prevent hematomas. Most commercially available postoperative compression vests may not provide enough compression, and the degree of compression is not adjustable.

Figure 37-5

For mild to moderate pseudogynecomastia, tumescent liposuction using microcannulas provides consistently satisfying results. **A** and **B,** Preoperative anterior and lateral views of fatty breasts of muscular young man. **C** and **D,** Postliposuction anterior and lateral views.
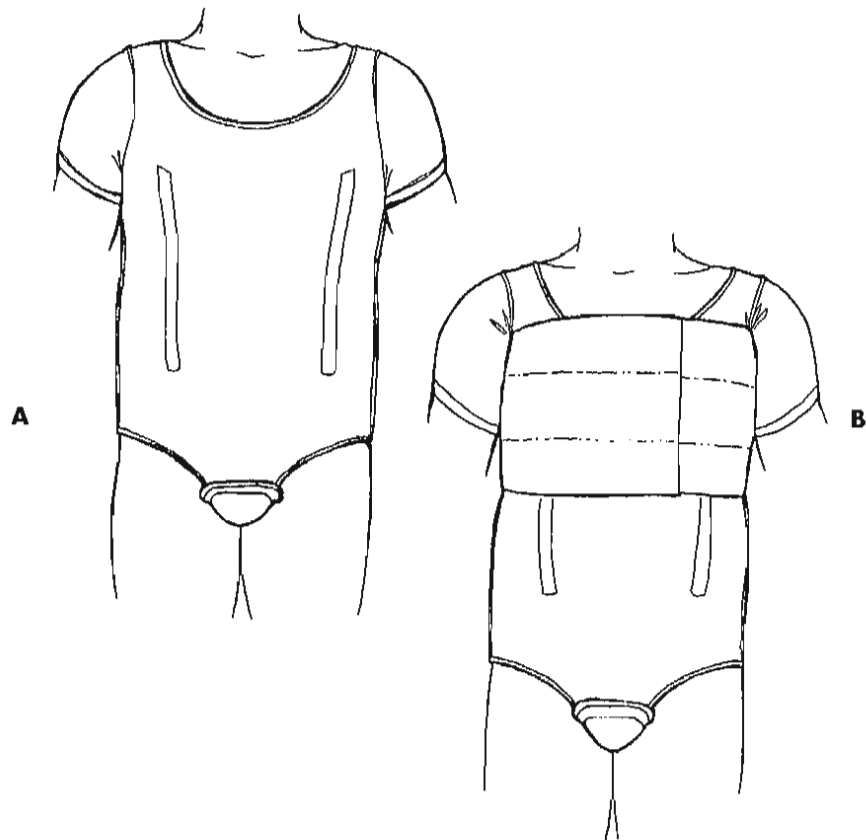
Figure 37-6

Breast-torso garment designed to provide optimal postliposuction compression after male or female breast reduction. Anterior perspectives: **A,** without elastic torso binder; **B,** with elastic torso binder in place.

Figure 37-7

Breast-torso garment with two elastic rib belts provides maximal comfortable compression and optimal open drainage and bimodal compression. Patient can adjust compression if it feels too tight. Velcro strips (black) hold binders in place.

Figure 37-8

Without breast-torso garment, rib belt compression alone may fail to provide adequate postliposuction compression above level of axilla. Excess bruising and swelling occur in liposuctioned areas not adequately compressed.
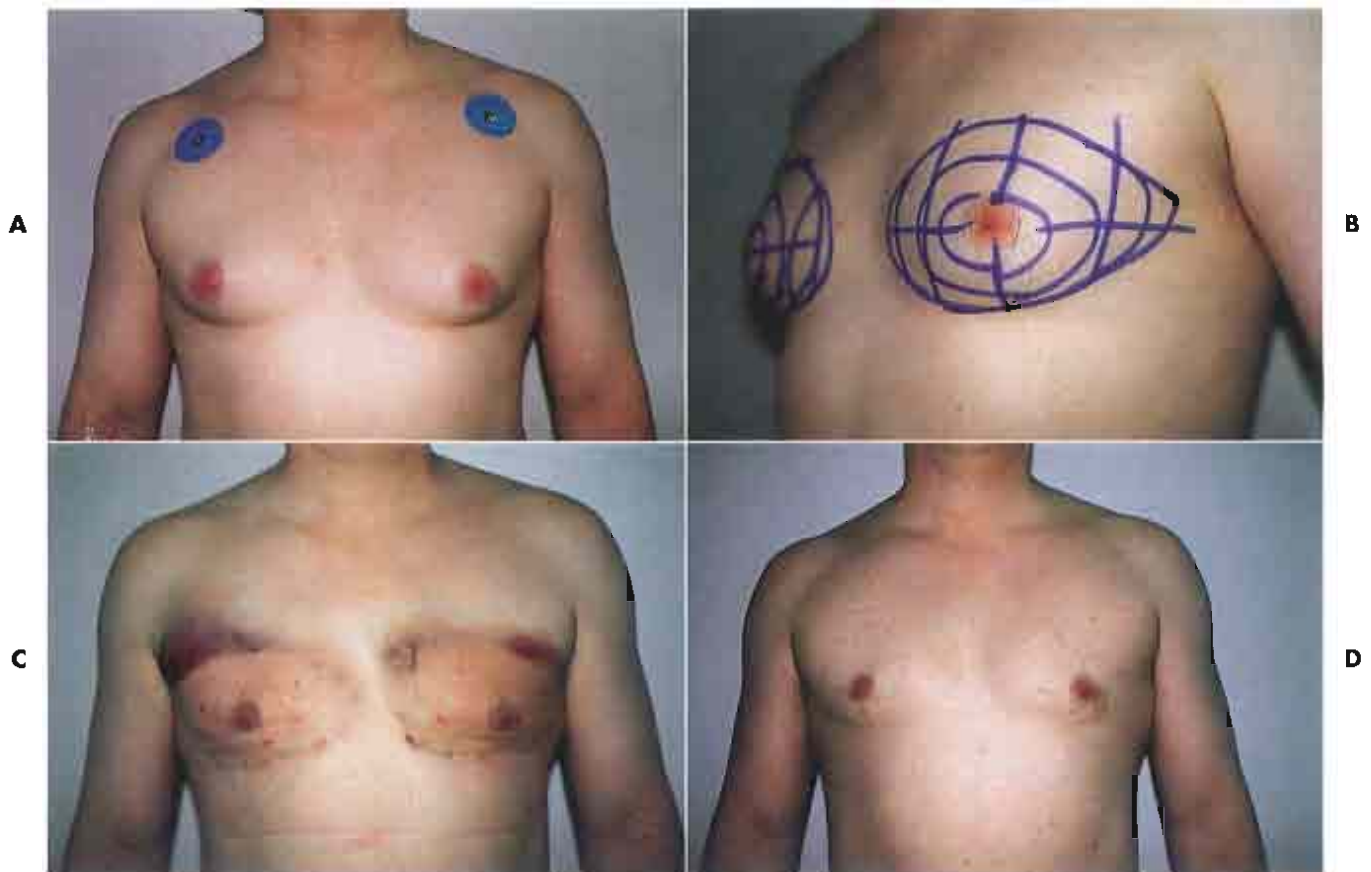
Figure 37-9

A, Cosmetically significant male pseudogynecomastia. **B,** Topographic contour drawings demonstrating relative depth of subcutaneous fat. **C,** Postliposuction view 1 day after open drainage but with incomplete compression. Two rib belts failed to compress above axillary level, resulting in bruising and swelling where compression was inadequate. **D,** Postoperative view several months after microcannular tumescent liposuction.

The breast-torso garment is a spandex garment with a pair of Velcro strips (hooks) sewn onto the front and extending from the shoulders to the midabdomen (Figure 37-6). This garment is not required to provide compression but has the following advantages:

1. The spandex garment holds the postoperative superabsorbent pads securely in place over the treated areas.
2. The garment protects the patient's axillary area from the chafing and rubbing of the elastic binder.
3. The Velcro strips prevent the elastic binder from shifting or moving out of its proper position directly over the breasts.
4. The Velcro strips optimize the positioning of the rib belt so that it can deliver compression to the uppermost (proximal) portion of the breasts, well above the level of the axillary vault (Figure 37-7).

Without the Velcro strips, anterior aspect of the axilla pushes upper edge of the rib belt below the level of the axilla (Figure 37-8). The axilla tends to limit the area of the breast that can be compressed by a rib belt. Ecchymosis and swelling often result wherever adequate compression is not maintained on a liposuctioned area (Figure 37-9).

A second binder is applied on top of the garment's initial binder and cinched more tightly. The total amount of compression should be tight but easily tolerable. Both male and female breasts seem to be more susceptible to hematomas and therefore require more firm compression during the first 12 to 24 hours than other areas treated by liposuction.

Male breasts are usually susceptible to perioperative hematomas or excessive ecchymoses. This might be explained by the vascularity of the fat and glandular tissue of the breasts. In addition, because the pectoralis muscle can be inadvertently grasped along with the fat when the surgeon grips the breast, the breast is vulnerable to injury from a misdirected thrust of the cannula.

During the first 12 to 24 hours after breast liposuction, firm compression of the breast reduces the degree of early postoperative ecchymosis.

I have seen only three postoperative liposuction-related hematomas. Two occurred in association with breast liposuc-

tion patients who had received only mild postoperative compression with an Ace bandage. The other liposuction-related hematoma occurred in an obese male who falsely denied taking aspirin the day of surgery (see Chapters 8 and 38).

PITFALLS AND SPECIAL CONSIDERATIONS

Men should be given an explicit written estimate of the expected degree of improvement. Patients are typically advised to base their decision on the assumption that they will see no more than a 50% cosmetic improvement. In some cases, patients are told not to expect more than a 30% improvement.

Possible sources of patient dissatisfaction include insufficient amount of tissue aspirated, scarring, asymmetry, skin irregularities, and redundant skin.

CHAPTER 38

Female Breasts

Tumescent liposuction for reduction mammoplasty permits significant female breast reduction with virtually no scarring. With the tumescent technique for liposuction totally by local anesthesia, patients have minimal postoperative pain, rapid postoperative recovery, and quick return to normal activities. The liposuction uses special breast microcannulas, and postoperative care requires trimodal compression garments.

BREAST HYPERTROPHY AND REDUCTION

Excessively large breasts are undesirable for the following reasons:
1. Female breast hypertrophy causes pain and suffering, physical impairment, and psychologic problems.
2. Athletic activity is significantly limited.
3. Changes in posture to compensate for the weight of excessively large breasts can lead to chronic degenerative changes and pain in the neck, shoulder, and back.
4. Chronic pressure from impinging bra straps causes permanent indentations on the shoulders. Large breasts predispose to inframammary intertrigo.
5. The woman may view her large breasts as cosmetically undesirable.
6. Finding a bra that fits and is comfortable may be impossible, and clothing does not fit well.

EXCISION

Surgical breast reduction by excision has been the only solution for women who have excessively large breasts. Excisional breast reduction surgery has various risks and postoperative complications (Box 38-1). The routine reliance on general anesthesia and prolonged postoperative pain and recovery make excisional breast reduction mammoplasty a less-than-ideal surgical procedure.

Theoretically, unweighting the female breast by removing an equal proportion of the fat volume from each cubic centimeter of breast tissue has the following two effects (Figure 38-1):
1. The breast is reduced in size in direct proportion to the fraction of fat removed.

2. The elastic suspensory Cooper's ligaments are more effective in elevating the breast, giving the appearance of a breast lift.

The application of tumescent liposuction to the female breast can elevate the nipple and areola, elevate the inferior breast margin, and reduce breast size. The surgery is accomplished totally by local anesthesia. Only 12 to 18 adits are used, each 1.0 mm in diameter and all of which become virtually invisible. Patients can return to work in 2 to 4 days.

LIPOSUCTION

Tumescent liposuction of the female breast totally by local anesthesia has proved to be successful. The technique requires specially designed 16-gauge (1.2-mm inside diameter [ID]) and 14-gauge (1.6-mm ID) breast microcannulas and multiple 1.0-mm adits that are not closed with suture. Postoperative recovery and healing are rapid. Within weeks the breasts appear normal and feel normal to routine palpation.

All patients treated have been gratified by the results. Comparison of preoperative and 6-month postoperative mammograms did not reveal new calcifications. Liposuction of the female breast is a relatively new procedure, and questions remain to be answered.

Breast reduction by liposuction under general anesthesia has been reported.[1] The clinical study described 12 patients and a high degree of patient satisfaction. The procedure reduced the ptosis of the breasts and the size of the areolae. The cannulas were large (2.4-mm to 5-mm ID), however, and postoperative edema and firmness persisted for up to 1 year.

Breast reduction by liposuction with 2 to 3 L of fluid infiltrated per breast has been reported more recently.[2] The surgeon used general anesthesia, relatively large (3-mm and 4-mm) cannulas, and only two incisions per breast.

Results and Candidates. Microcannular tumescent liposuction can remove 30% to 50% of the breast volume with minimal risk of postoperative morbidity. As much as 60% of volume can be removed from breasts with a high percentage of fat. The maximum volume of aspirate and degree of reduction should be discussed with the patient and docu-

Hypertrophic scars
Breast asymmetry
Abnormal appearance to nipple-areolar complex
Impaired nipple sensation
Nipple necrosis
Hematoma
Seroma
Fat necrosis with pseudocyst formation
Parenchymal scarring with mammogram abnormalities
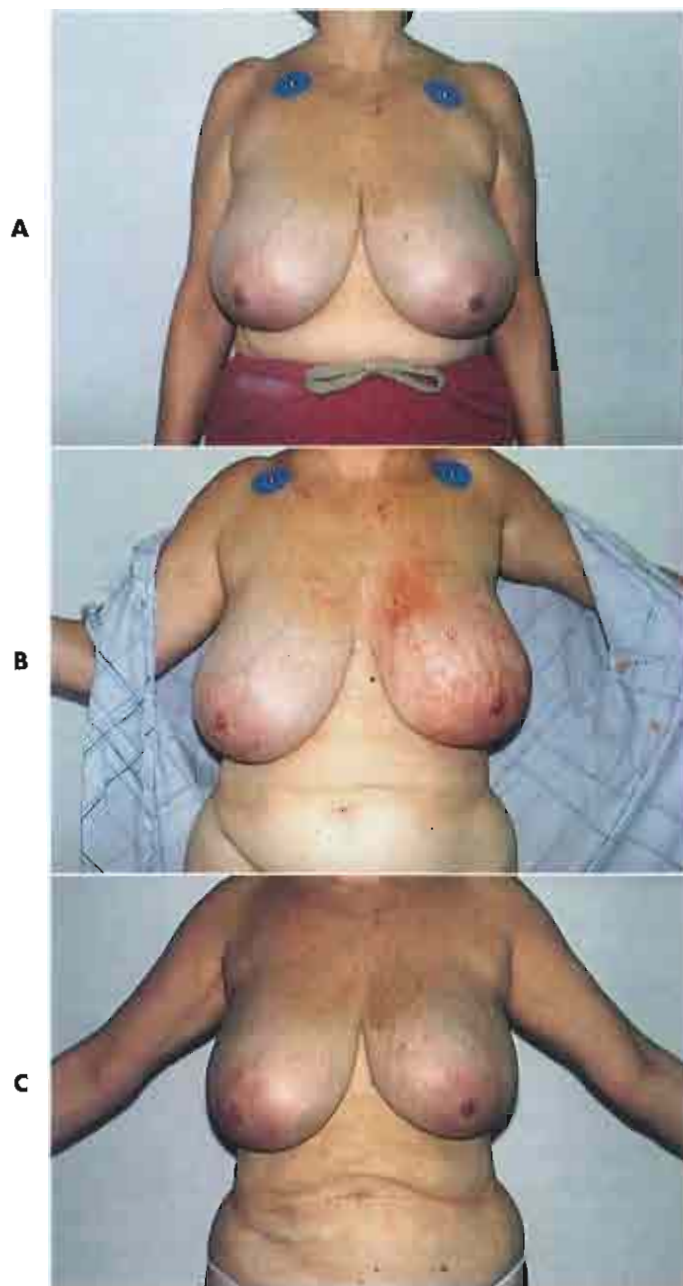
Figure 38-1

Liposuction of one breast during tumescent liposuction course demonstrates breast elevation and reduction. **A,** Preoperative view, with left breast larger than right breast. **B,** One day after surgery, with treated left breast already elevated and smaller. **C,** Six weeks after tumescent liposuction totally by local anesthesia using microcannulas, with significant improvement in size, shape, weight, and position of treated left breast compared with untreated right breast. Right breast was treated during subsequent teaching course. Breast size progressively decreases for up to 6 months after microcannular breast reduction.

mented before surgery. The typical patient can return to work and normal social activity 2 to 3 days after surgery. The technique appears to be most appropriate for breasts of moderately large volume (e.g., 600 to 1600 ml), but the limits for volume reduction by liposuction have yet to be defined.

Tumescent breast reduction is only appropriate for a select subset of women seeking reduction mammoplasty. The current technique might not be appropriate for patients who need considerably more than a 50% reduction or for those whose breasts are pendulous or largely devoid of fat. For the appropriate patient, however, the results of tumescent liposuction can be extremely gratifying. For example, evidence of adits disappears within a few weeks or months (Figure 38-2).

A modest but pleasing elevation of breast position relative to the costal margin is the result of the following (Figure 38-3):
1. Reduced breast weight
2. Postsurgical contraction of the collagenous fibers within the subcutaneous fat
3. Elastic properties of Cooper's suspensory ligaments

REALISTIC GOALS

Simplicity, symmetry, and consistency describe the surgical approach that is most likely to produce results that satisfy the patient. The goal of tumescent liposuction of the female breast is the uniform removal of tissue from the breast with no scars. Conceptually, this is achieved by reducing the volume of each cubic centimeter of breast tissue by an equal amount, such as 40% to 50%. Fundamentally, the surgeon is attempting to create a smaller version of the preexisting breast.

This simple approach produces the most desirable results as follows:
1. The breast weighs less.
2. The natural elasticity of the skin and breast tissues elevates the breast and the relative position of the nipple.
3. The breasts are better proportioned, better positioned, more symmetric, and more comfortable.
4. The postoperative recovery is rapid and relatively pain free, with no unsightly scars.

Symmetry in shape and size is an important goal, in addition to achieving the desired reduction in breast volume. The procedure should create two breasts that are similar in size and shape.
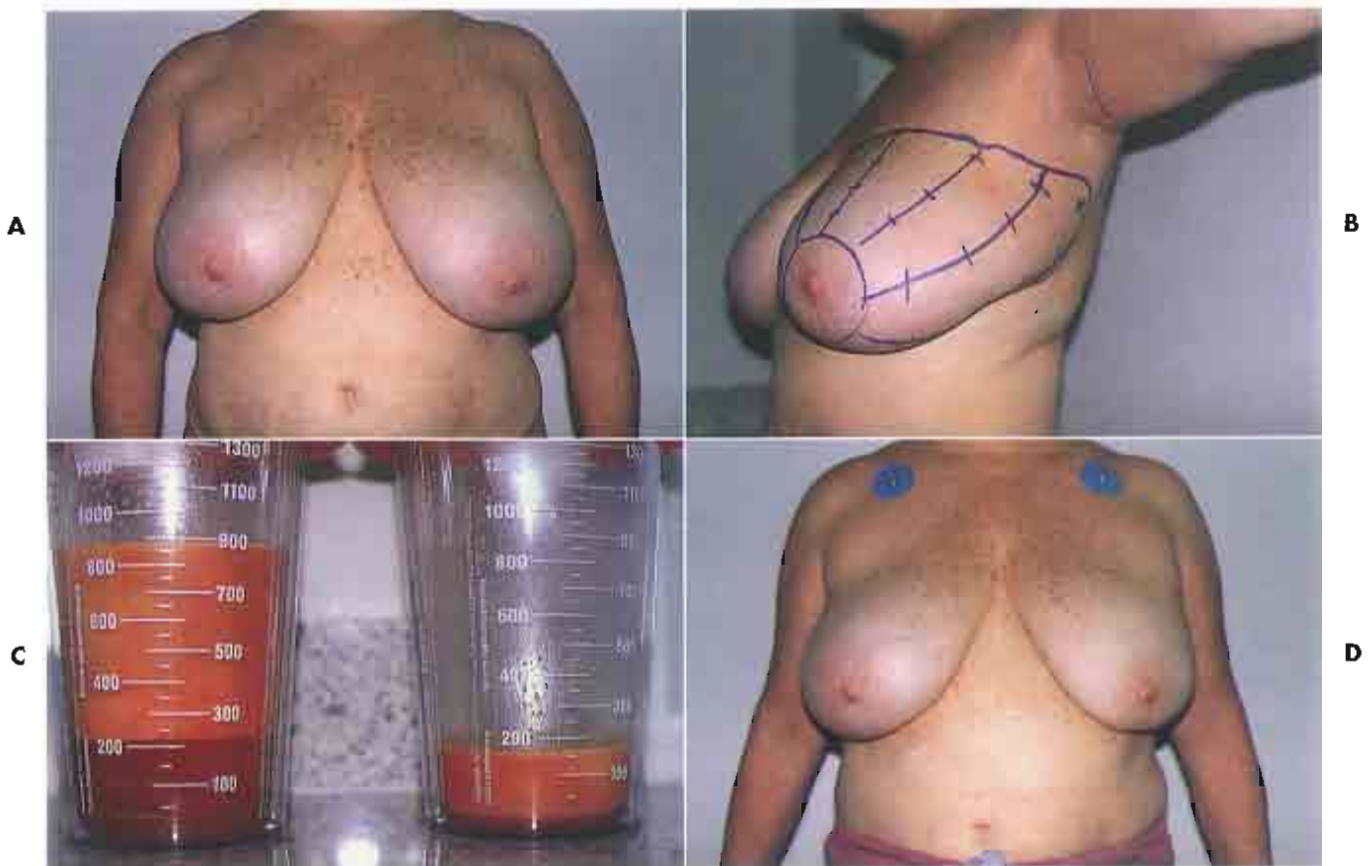
Figure 38-2

Another participant in hands-on liposuction course had liposuction of left breast; 60 days later, during another liposuction course, right breast was liposuctioned. **A,** Breast volume measurements before liposuction were 1150 ml (right breast) and 1340 ml (left breast), exclusive of breast's axillary extension. **B,** Preoperative breast markings on breast and axillary breast extension. **C,** Approximately 685 ml and 150 ml of supranatant fat was aspirated from the left breast and left axillary breast extension, respectively. Recall that 16% of supranatant fat is residual physiologic saline. **D,** Sixty days after liposuction of left breast, its volume was 742 ml, corresponding to a 45% reduction in breast volume. Patient's bra-cup size for left breast changed from a DD to C.
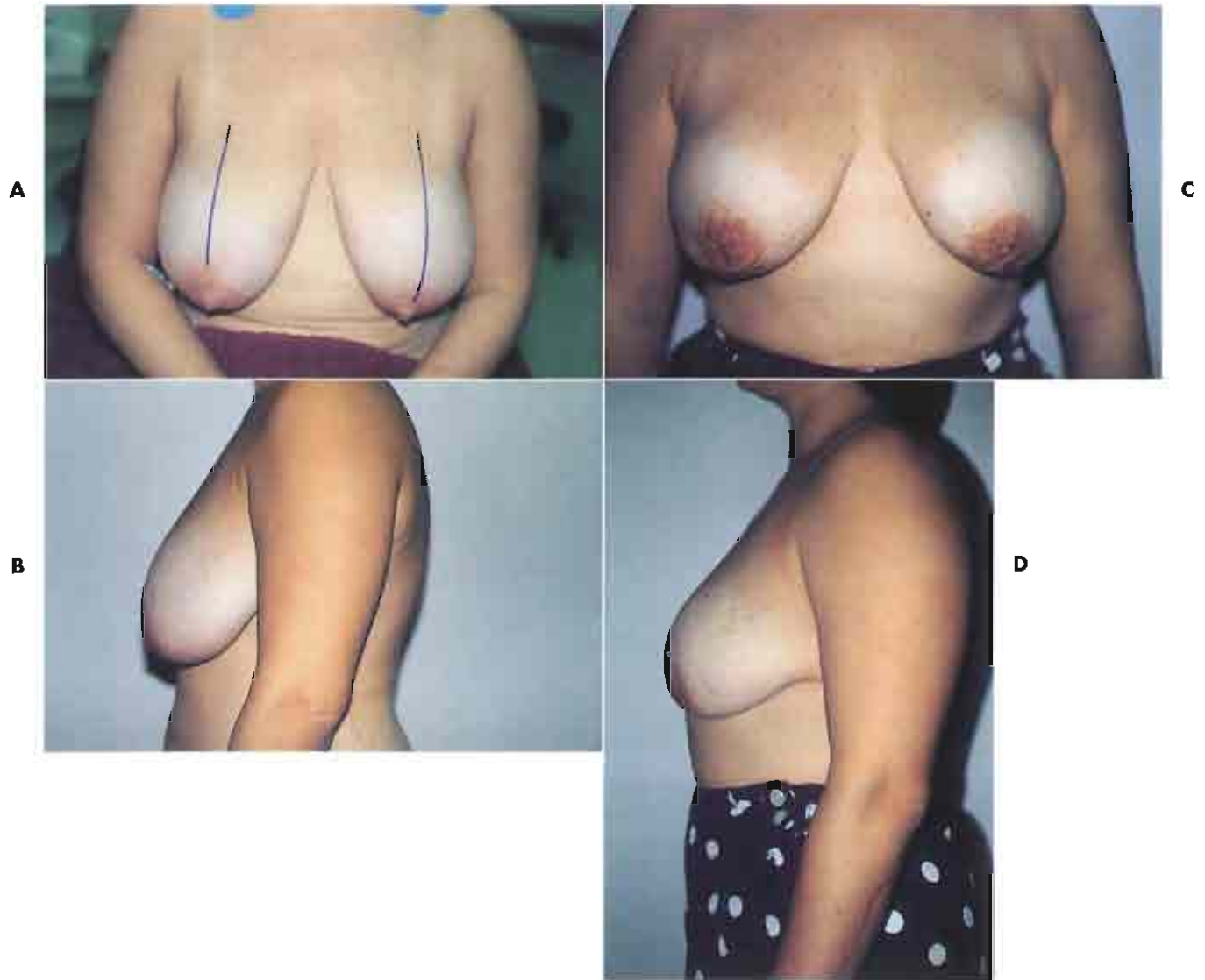
Figure 38-3

A and **B,** Preoperative anterior and lateral views. **C** and **D,** Postoperative anterior and lateral views demonstrating both reduction in size and elevation of breasts. Apparent skin retraction, or elasticity, was achieved without superficial liposuction. Excessive superficial liposuction is not necessary and can cause dermal necrosis.
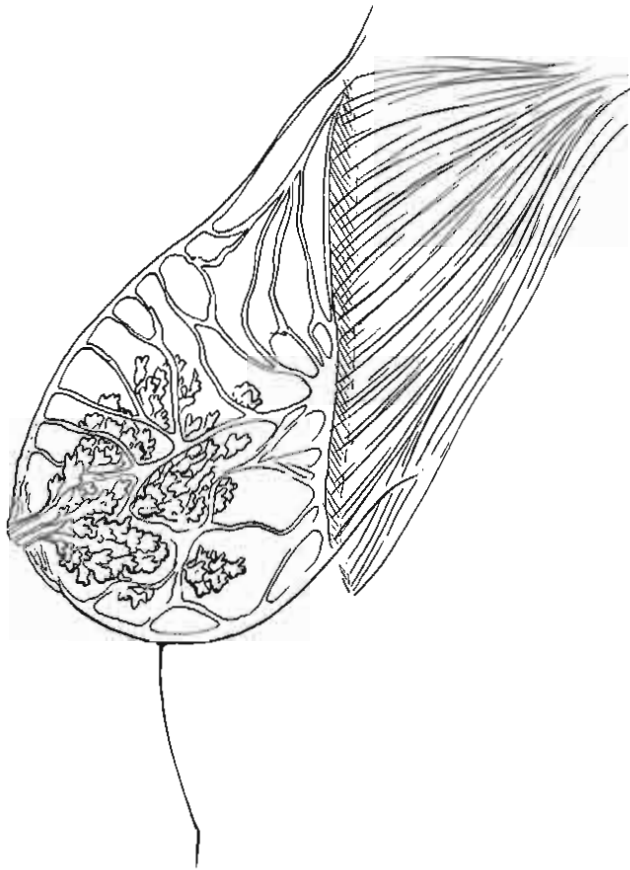
Parasagittal section through female breast illustrating relative distribution of fibrous and fatty content as well as mammary glandular tissue and lactiferous ducts. Cooper's ligaments are fibrous structures that give elastic support to pendulous breast.

ANATOMIC CONSIDERATIONS

The female breasts that are candidates for reduction mammoplasty are composed of a significant proportion of fat. The glandular breast tissue is generally located nearest the nipple. When a patient is supine, most of the glandular tissue is located within the center of the breast deep to the nipple. The dense fibrous tissues of the female breast are not easily infiltrated or aspirated. Peripheral portions of the breast are more fatty (Figure 38-4).

Sensory innervation of the nipple-areolar complex is derived from the anterior branch of the fourth intercostal nerve. Surgical impairment of nipple sensibility correlates with damage to distinct neuroanatomic nerve endings and conducting fibers.[3]

The HK Brest microcannulas are specifically designed for breast liposuction. The extra small holes of the microcannula allow selective removal of fat with little collateral injury to other tissue. Risk of nerve injury is much less with microcannulas than with large cannulas or with scalpels and cutting cautery. Any surgery risks nerve injury, however, and thus the liposuction surgeon should be aware of the anatomic path of the anterior branch of the fourth intercostal nerve, as follows:

1. The fourth intercostal nerve traverses the serratus anterior muscle at the fourth intercostal space at the midaxillary line.
2. It then travels beneath the deep fascia of the serratus.
3. It crosses over the lateral margin of the pectoralis major muscle and continues tangentially over this muscle until it passes beneath the mammary gland.
4. The nerve enters beneath the breast at the inferolateral margin of the fatty tissue, at the 4 o'clock position on base of left breast and 8 o'clock position on base of right breast.
5. It travels about 2 cm (¼ inch) beneath the breast tissue.
6. It then courses anteriorly through the breast parenchyma toward the nipple-areolar complex along a variable path.
7. Midway through the breast the nerve begins to divide into several branches, usually five, which then innervate separate but overlapping areas of the nipple-areolar complex.

The relative distribution of fat within the female breast's central portion is about 67%, in the lateral portion about 87%, and in the preaxillary area about 84%.[3a]

PREOPERATIVE EVALUATION

Preoperatively the volume of each breast is measured by a water-displacement method. Before measuring breast volume, the breast's proximal superior margin is symmetrically outlined to ensure equal depth of immersion. The breast is immersed in a beaker filled to the brim with warm water. After removing the breast from the beaker, the volume of water needed to refill the beaker to its brim is recorded.

A

B

C
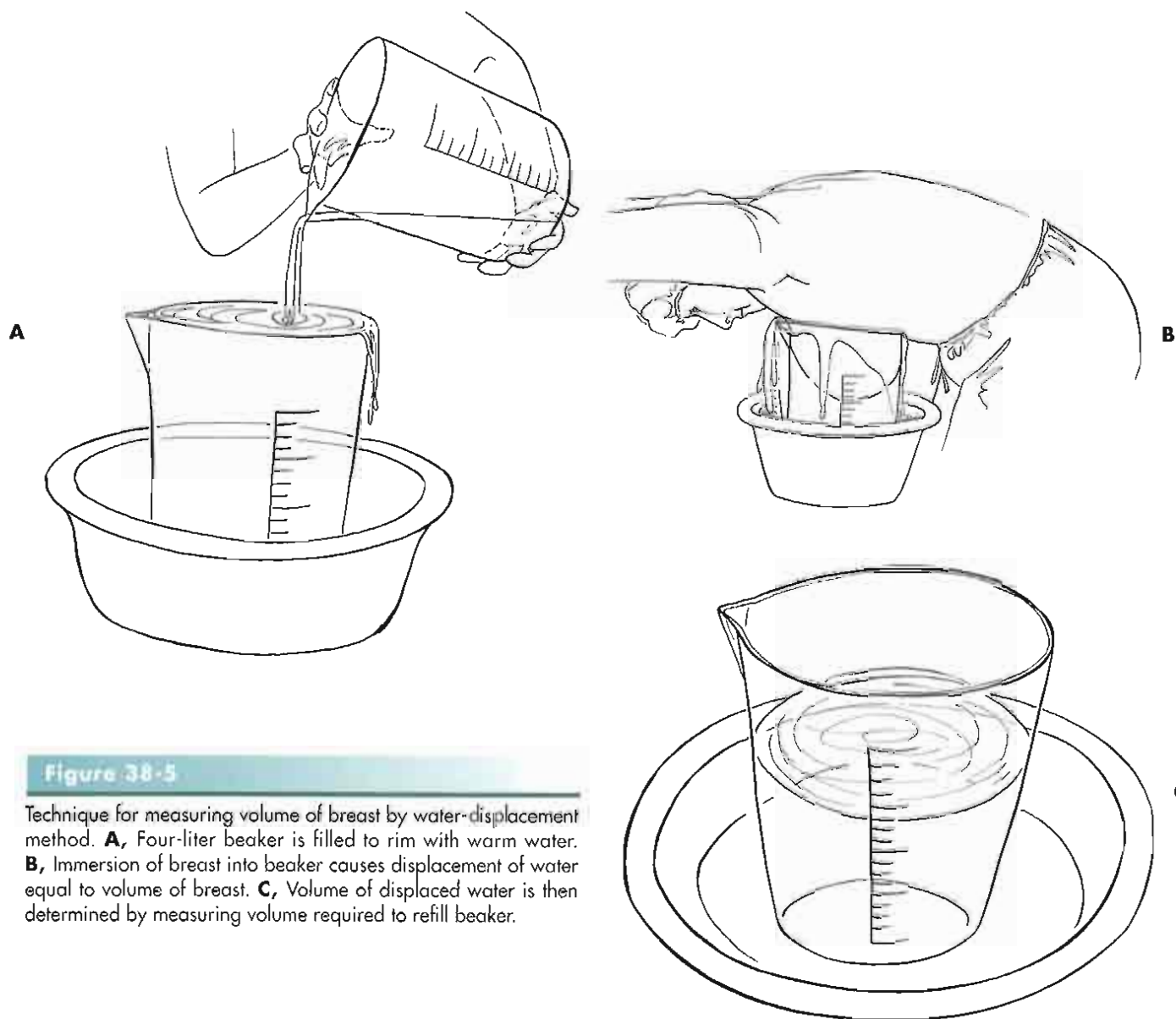
Figure 38-5

Technique for measuring volume of breast by water-displacement method. **A,** Four-liter beaker is filled to rim with warm water. **B,** Immersion of breast into beaker causes displacement of water equal to volume of breast. **C,** Volume of displaced water is then determined by measuring volume required to refill beaker.

Figure 38-6

Tumescent breast after infiltrating volume of anesthetic solution equivalent to preoperative breast volume.

It is important that the depth of breast immersion be consistent and equal for both left and right sides. The average of at least two measurements provides a good estimate of each breast's volume (Figure 38-5).

Accurate preoperative breast volume measurement is necessary for planning the appropriate amount of tissue to be removed from each breast. Significant asymmetry between the two breasts can be corrected by removing an appropriate extra amount of supranatant fat from the larger breast.

Also, preoperative breast measurements allow the surgeon to estimate the volume of tumescent anesthetic solution that will be infiltrated. The volume of solution required for complete tumescent anesthesia is about equal to the preoperative volume of that breast. In other words, the tumescent breast will be approximately twice its preinfiltration volume (Figure 38-6).

Tumescent mammoplasty permits accurate breast reduction of a specified volume by measuring the amount of tissue aspirated from each breast. Preoperative volumetric measurement has the following advantages:

1. *Quantification* of the *degree* of asymmetry between breasts
2. *Precision* when determining the *amount* of tissue to be removed
3. *Calculation* of the *volume* to be removed from each breast to achieve both symmetry and reduction

For example, a woman's left and right breasts measure 1000 and 1200 ml, respectively. She wants correction of asymmetry and 40% breast reduction. By removing 300 ml of supranatant fat from the left breast (1000 − 300 = 700) and 500 ml from the right breast (1200 − 500 = 700), postoperatively the breasts are approximately equal in size. The left breast is reduced by 30% (300/1000) and the right breast by about 42% (500/1200).

ANESTHETIC INFILTRATION

The preferred formulation of the tumescent anesthetic solution is approximately as follows:

Lidocaine 1500 mg
Epinephrine 1.50 mg
Sodium bicarbonate 10 mEq
In 1 L of 0.9% isotonic saline

The goals of tumescent infiltration of the female breast are as follows:

1. Produce complete local anesthesia.
2. Achieve optimal hemostasis.
3. Preserve the breast's relative size and shape.

In other words, infiltrate completely and inflate uniformly. Conceptually, this is achieved by injecting an equal and sufficient volume of anesthetic solution into each cubic centimeter of breast tissue so as to achieve complete local anesthesia. Precision and completeness are more important than speed. Fundamentally, goals of tumescent technique are as follows:

1. Homogeneity of infiltration
2. Completeness of local anesthesia
3. Uniformity in size of breast

TECHNIQUE

Successful delivery of tumescent anesthesia of the breasts includes the following steps (Figure 38-7):

1. With indelible ink, draw six to eight equally spaced radial lines extending from the areola. Along each radial line, draw three or four equally spaced crosshatch marks.
2. Inject small 0.25-ml intradermal blebs of tumescent anesthetic solution at each crosshatch. With skill and attention to the smallest detail, the intradermal blebs can be injected almost painlessly using a sharp 30-gauge needle. Replace the needle when it starts to become dull.
3. Gently stretch the skin between two fingers before slowly sliding the needle into the dermis. Good patient rapport and clinical experience facilitate rapid bleb infiltration.
4. After a bleb has blanched, place a minuscule 1.0-mm adit using a disposable 1.0-mm skin biopsy punch. For cosmetic reasons, minimize the number of these adits in the superomedial quadrant of the breast.
5. Using 25-gauge and 20-gauge spinal needles, initiate the infiltration in the deepest levels first, then more superficially.
6. Infiltrate the solution diffusely, widely, and completely.
7. Using a crisscross pattern, approach each area of tissue from several different directions through different incisions.
8. Adjust the flow rate of the anesthetic solution so that it is neither too slow nor so fast that infiltration is painful or inaccurate.

After infiltration the surgeon should wait at least 30 minutes for detumescence to occur before beginning surgery.

NEEDLES AND FIBROUS TISSUE

A 25-gauge spinal needle with a smaller diameter causes less discomfort as it is advanced through fibrous breast tissue than does a 20-gauge spinal needle. The initial (and incomplete) infiltration of the breast with a 25-gauge needle is intended to provide just enough anesthesia to permit a more definitive infiltration using a 20-gauge spinal needle.

Breasts that contain a relatively high proportion of fat are generally not exceedingly fibrous and are therefore easily infiltrated. On encountering an especially dense, fibrous section of breast tissue, some finesse is required to advance or push a 25-gauge needle through the tissues.

Occasionally the clinician will encounter an exceptionally dense portion of breast tissue, through which a 25-gauge spinal needle cannot easily pass. A needle may bend if pushed too vigorously through resistant breast tissue. Such focally dense tissue can usually be circumvented by pulling back slightly and then advancing toward the difficult tissue from a different direction.

Alternately, the clinician can remove the needle entirely, reenter the breast through a different adit, and approach the resistant tissue along a new path. When infiltrating especially dense breast tissue, it is sometimes easier to use a 20-gauge than a 25-gauge spinal needle.

The infiltrator should always be calm, confident, methodical, and compulsively complete (Figure 38-8).
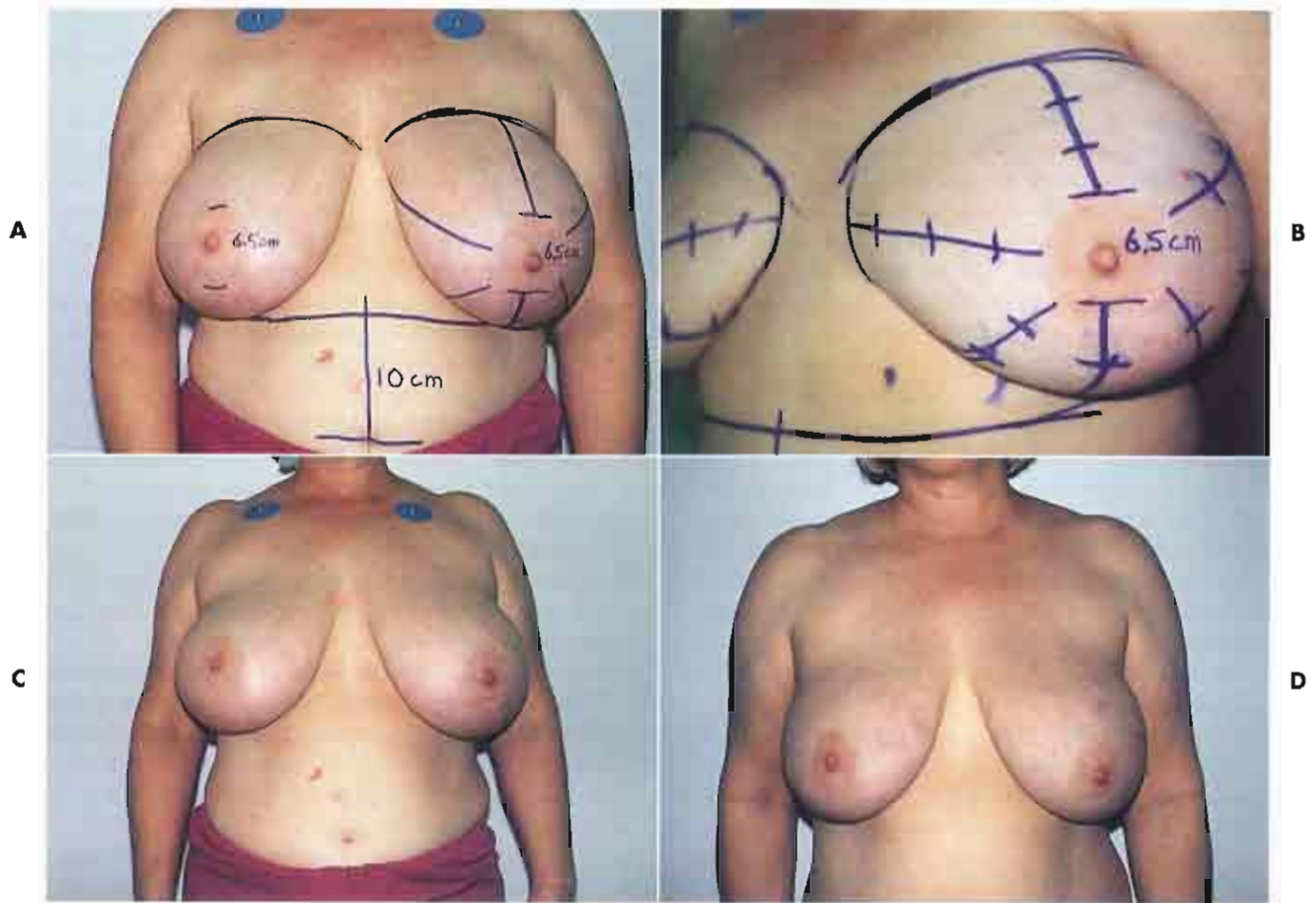
Figure 38-7

Preoperative drawings on female breast differ from topographic contour drawings used on other areas. Lines radiating from areola provide efficient geometric grid to help ensure uniform distribution of both infiltration and liposuction. **A,** Measurement of areolar diameter and distance of breast from umbilicus. **B,** Placement of crosshatch marks on radial lines. **C,** Preoperative view. **D,** Postoperative results.

Figure 38-8

Patterns for tumescent infiltration and tumescent liposuction of female breast are basically the same. For example, infiltration needle first radiates out along deepest plane and then along second and third planes. When this pattern is repeated through each of numerous other adits, overall effect is to ensure complete infiltration throughout breast. Similar pattern is used for paths of liposuction cannula.
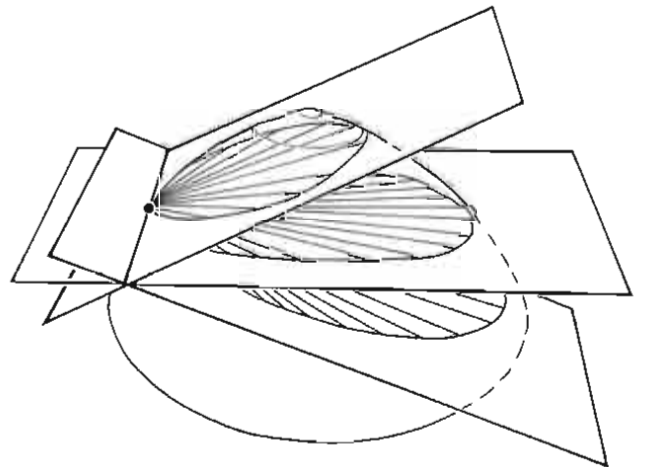
PNEUMOTHORAX

The surgeon must be aware that the infiltration needle can puncture the lung. Attention to detail, patience, and gentleness greatly reduce this risk.

Tension pneumothorax has been reported as a result of general anesthesia and infiltration of local anesthesia in a young woman undergoing breast augmentation.[4] General anesthesia with endotracheal intubation produces a positive intrathoracic pressure that predisposes to tension pneumothorax.

Similar to the situation in which general anesthesia delays the diagnosis of a punctured abdominal viscus, general anesthesia contributes to a delay in the diagnosis of a tension pneumothorax. A punctured lung is more quickly and easily diagnosed when the patient is alert and conversant.

SURGICAL TECHNIQUE

To ensure optimal vasoconstriction after tumescent infiltration into a breast, the surgeon must wait at least 30 minutes before starting liposuction.

The "secret" to being able to perform tumescent liposuction of the female breast totally by local anesthesia is that *smaller cannulas cause less pain.* The width or girth of a cannula is directly proportional to the degree of pain associated with liposuction.

Multiple small, round cannula apertures provide the greatest efficiency in terms of cannular design. When microcannular efficiency is measured in terms of the volume (ml) of aspirated supranatant fat per 100 strokes of the cannula, the Capistrano-style Brest microcannula is very efficient. Three cannulas have been specially designed for liposuction of the female breast: 16 gauge, 12 cm (4.75 inches) long; 14 gauge, 15 cm (6 inches) long; and 12 gauge, 23 cm (9 inches) long.

Liposuction is initiated in the deepest planes of the breast close to the chest wall. From among the radial lines drawn on the breast, a convenient line is chosen and liposuction begun through the adit most distant from the areola. The cannula is first directed through the deepest plane of fatty breast tissue tangential to the chest wall.

The paths of the cannula tunnels radiate from the adit. From each adit the radiating pattern of tunnels intersects and overlaps the tunnels that radiate from other adits. This patterned approach replicates the sequence used for the infiltration process. A regular pattern of radiating cannula strokes provides uniform liposuction (see Figure 38-8).

Some of the pain associated with liposuction is the result of pulling or pushing on fibrous connective tissue elements that are attached to deeper, nonanesthetized structures. Another source of pain is the surgeon's excessively firm grip on the patient's tissues.

The 16-gauge cannulas can penetrate most tissue with relatively little resistance and thus little discomfort to the patient. Creating a network of 16-gauge tunnels allows the passage of a larger, 14-gauge cannula with less resistance and discomfort than would otherwise be possible. The use of a 12-gauge breast cannula is rarely necessary.

The 16-gauge Capistrano cannula, 12 cm (4.75 inches) long, is used to initiate the liposuction. The tiny cross-sectional profile of a 16-gauge cannula allows it to be advanced through dense portions of the glandular breast tissue with relative ease. Minimal resistance means minimal discomfort with breast liposuction.

After initially fenestrating the breast tissue with 16-gauge cannulas, the larger 14-gauge (15 cm in length) Brest cannula will more easily pass through the prepared network of tunnels. The 14-gauge cannula is used for removing the largest volume of tissue, which is mostly adipose tissue, with some glandular elements.

Each breast should be treated systematically so that both breasts are treated equally. The cannula should not linger for too many thrusts within the same tunnels. Rather, the paths should spread out radially with uniform density from each incision site. The patterns of paths radiating from different incisions should intentionally crisscross and overlap each other. Uniformity with homogeneity of tissue extraction is the goal.

With gentle and skillful surgical technique, female breast liposuction can be routinely accomplished totally by local anesthesia.

POSTOPERATIVE CARE

The breast is unique in its postliposuction compression requirements. Most other areas of the body do not require an exceptionally high degree of compression after liposuction. The breasts are an exception and require greater compression for the first 12 to 18 hours after liposuction.

The extra compression is necessary to encourage a maximal degree of hemostasis. Empirically I have observed that, without adequate external compression in the immediate postliposuction period, the breasts tend to develop bruising and hematomas (Figure 38-9).

ADJUSTABLE BREAST COMPRESSION

Special postoperative breast garments have been specifically designed to allow easily adjustable compression. If the compression is too slight, there is a risk of subcutaneous bleeding. If the compression is too tight, the patient may experience pain or difficulty breathing. The solution to this situation is to use an adjustable compression garment so that the patient can easily readjust the compression to the maximum comfortable level at any time.

Postliposuction breast compression should be maximal for the initial 12 to 18 hours. The day after surgery, while there is some drainage, the compression is adjusted to a more moderate level. Ultimately, after all drainage has ceased, the compression is again adjusted to a minimal level but still sufficient to provide comfort and support.

A

B
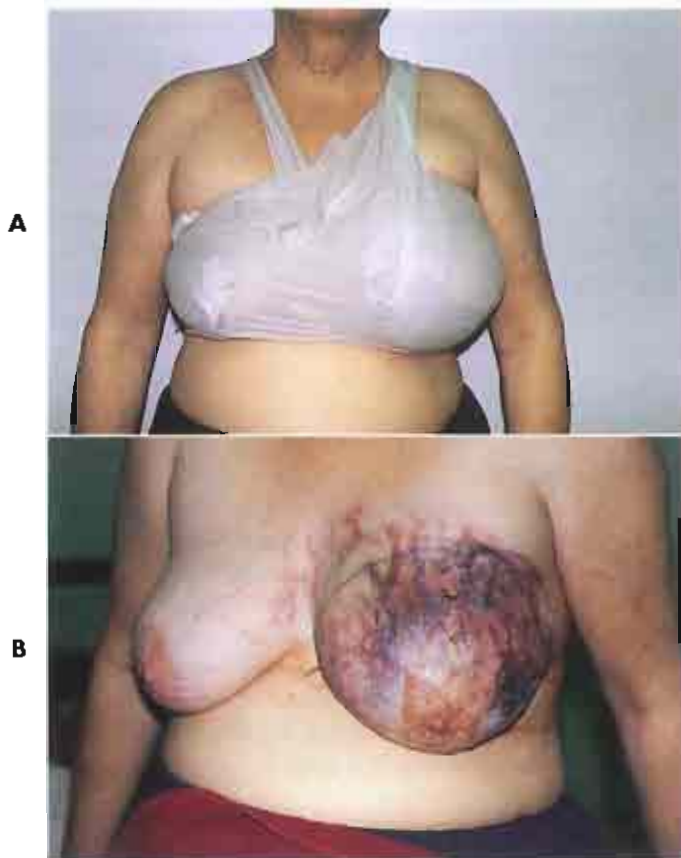
Figure 38-9

Insufficient breast compression after liposuction of female breast increases risk of poor hemostasis, excessive bruising, and possible hematomas. This patient had asymmetric breasts and sought unilateral breast reduction by liposuction to avoid asymmetric scar. **A,** Postliposuction compression consisted of only a tightly wrapped elastic bandage. **B,** Inadequate compression resulted in excessive bruising.

Figure 38-10

Postoperative dressing of absorptive pads and tightly compressive binders wrapped with elastic bandage. This arrangement proved to be inadequate to hold breast compression dressing securely in place. After patient had arrived at her home, dressing slipped from intended position, necessitating house call for reapplication.

Figure 38-11

Prototype HK Breast-Torso Garment. Patient can move arms with full range of motion; Velcro strips prevent displacement of compression binders; and binders are adjustable.

TRIMODAL COMPRESSION

The term *trimodal compression* is used to emphasize that three sequential and decreasing degrees of compression are used after breast liposuction.

The first 12 to 18 hours after breast liposuction requires the maximum compression that the patient can tolerate comfortably. This relatively intense compression is necessary to minimize the risk of postoperative hematomas and to limit the amount of bruising.

After the initial phase, continuous, moderately firm compression is required to optimize drainage and minimize postliposuction edema. This intermediate degree of compression is maintained for at least 48 hours and for 24 hours beyond the time when all drainage has ceased.

Beyond the 24 hours after all drainage has stopped, compression is needed to minimize the risk of seromas and to optimize patient comfort. At this point, only a mild to moderate degree of compression is required. The in-

tensity of the compression should be selected to maximize patient comfort. This mild to moderate compression is typically maintained 5 to 7 days or more. Maintaining compression more than a week after surgery can be at the patient's discretion.

Subsequently, many patients prefer to use a sports bra for several weeks until a regular bra can be worn comfortably.

A compression garment or binder must be not only comfortable but also securely applied to prevent slipping from its intended location. An unsecured abdominal binder placed around the chest and over the breasts can readily shift position during sleep or normal ambulatory activity. The weight and mobility of the breasts, the funneled shape of the thorax, and the narrow girth of the waist cause the entire dressing to migrate toward the hips (Figure 38-10).

Years of experience and numerous modifications have helped me to develop an effective, comfortable, and reliable system that uses absorptive pads, a spandex torso garment, and highly compressive abdominal binders (Figure 38-11).

The HK Breast-Torso Garment permits comfortable, adjustable, secure, high-pressure compression for breasts, abdomen, or hips and waist after tumescent liposuction. Because of the prolonged local effect of tumescent anesthesia, most patients require no postoperative analgesia other than acetaminophen (Tylenol) (Figure 38-12).

The garment's degree of compression should be as tight as possible but still comfortable. If the patient is uncomfortable, the degree of compression should be adjusted.

The greatest tolerable compression is maintained until the next morning, when the pads are removed while the patient takes a shower. After showering the patient applies new pads every 12 hours until all drainage has ceased, usually less than 48 hours after surgery.

After tumescent liposuction of the female breast, postoperative swelling gradually decreases over 6 months (Figure 38-13).

PITFALLS AND SPECIAL CONSIDERATIONS

The only complication that has occurred with tumescent liposuction of the female breast has been two episodes of excessive bruising caused by inadequate compression; these resolved spontaneously without sequelae (see Figure 38-9).

COMPLICATIONS OF REDUCTION MAMMOPLASTY

The complications of traditional excisional reduction mammoplasty include loss of sensation or reduced sensation to the nipple and areola and interference with future breast feeding.[5] Because of the minimal trauma to glandular breast tissue and the normal appearance of postliposuction mammograms, breast reduction by tumescent liposuction should not be expected to interfere with lactation after a subsequent pregnancy.

Galactorrhea is a rare complication but has been reported in three cases of excisional mammoplasty.[6] Hypertrophic, keloid, painful, or disfiguring scars may occur after excisional breast reduction.

Nipple necrosis is probably unique to traditional mammoplasty by excision. Some complications of traditional reduction mammoplasty, however, might also be encountered with tumescent liposuction of the female breast.

Any surgery of the breast can result in postoperative calcifications, which might hinder the mammographic detection of breast cancer.[7] Patients contemplating tumescent liposuction for breast reduction must be informed of this risk factor. Mammograms should be performed before surgical reduction of the female breast and 3 months after surgery.[8]

Although I have not seen postoperative calcifications of the breast detected by mammogram after tumescent liposuction, such calcifications may occur in some patients. An estimate of the incidence of postoperative breast calcifications will require a larger series of patients followed over a longer time.

BREAST LUMPS AFTER LIPOSUCTION

Liposuction of the female breast is occasionally associated with temporary lumpiness that can persist for many weeks after surgery. This transient lumpiness is similar to the temporary palpable lumpiness experienced after liposuction of the abdomen and thighs. In either situation, this lumpiness is usually not visible.

A breast lump is more worrisome than subcutaneous lumps in another location and thus demands special attention. Distinguishing between a benign postliposuction lump and a possible malignancy requires a preoperative baseline mammogram and a documented preoperative breast examination. If a new breast lump appears within 1 or 2 months after breast liposuction and then decreases in size over subsequent weeks, it is unlikely that the lump is malignant, and invasive diagnostic tests are probably unnecessary. A postoperative mammogram is recommended 3 to 6 months after female breast liposuction.

MAMMOGRAMS

Mammograms after tumescent liposuction have been within normal limits for my patients. Comparisons between preoperative and postoperative mammograms have revealed only one patient with calcification, which was different from calcifications associated with breast cancer. The only other radiologic changes have been (1) a notable reduction in breast size and (2) occasional mild fibrosis.

Postoperative mammograms should be considered to rule out existing malignancies and to establish an up-to-date baseline mammogram with which future mammograms might be compared. Similarly, after reduction mammoplasty, mammograms should be done within 3 to 6 months to establish new baseline mammograms.

With traditional excisional mammoplasty, postoperative inflammatory nodules and lipid-filled pseudocysts may occur. These changes may make it difficult to interpret future mammograms without good baseline mammograms for comparison.

Based on risk-benefit analyses, regular mammograms are not recommended for all women. Female patients who have had a reduction mammoplasty, however, might benefit from reliable baseline mammograms because of their surgically modified anatomy and mammographic status.

Figure 38-12

Application of HK Breast-Torso Garment. **A,** Precut segment of tubular elastic netting is slipped over feet and pulled up onto upper abdomen. One or more HK Pads are then placed on breasts. These custom-designed, extra-thick absorptive pads contain superabsorbent powder (SAP). **B,** Using strip of 5-cm (2-inch)–wide paper tape, inferior margin of HK Pads is taped onto skin to hold them against skin and minimize leakage of anesthetic solution beyond pads. Netting is then pulled up from abdomen onto chest to secure absorptive pads on breasts. **C,** Breast-torso garment is applied by pulling it over feet and legs, then onto torso. Arms are placed through sleeves. **D,** Garment is in place and arranged to fit comfortably. Two parallel, 3-cm (2.2-inch)–wide, vertical strips of Velcro hooks are sewn onto anterior portion of garment. **E,** A 22.5-cm (9-inch)–wide elastic binder is placed over lower breast and upper abdomen. Velcro adheres to fluffy fabric of elastic abdominal binders and prevents binder from slipping or shifting out of position. **F,** Second binder is applied directly over breast and arranged so that it overlaps first binder and contacts Velcro strips. This binder should be placed as tightly as patient can comfortably tolerate.
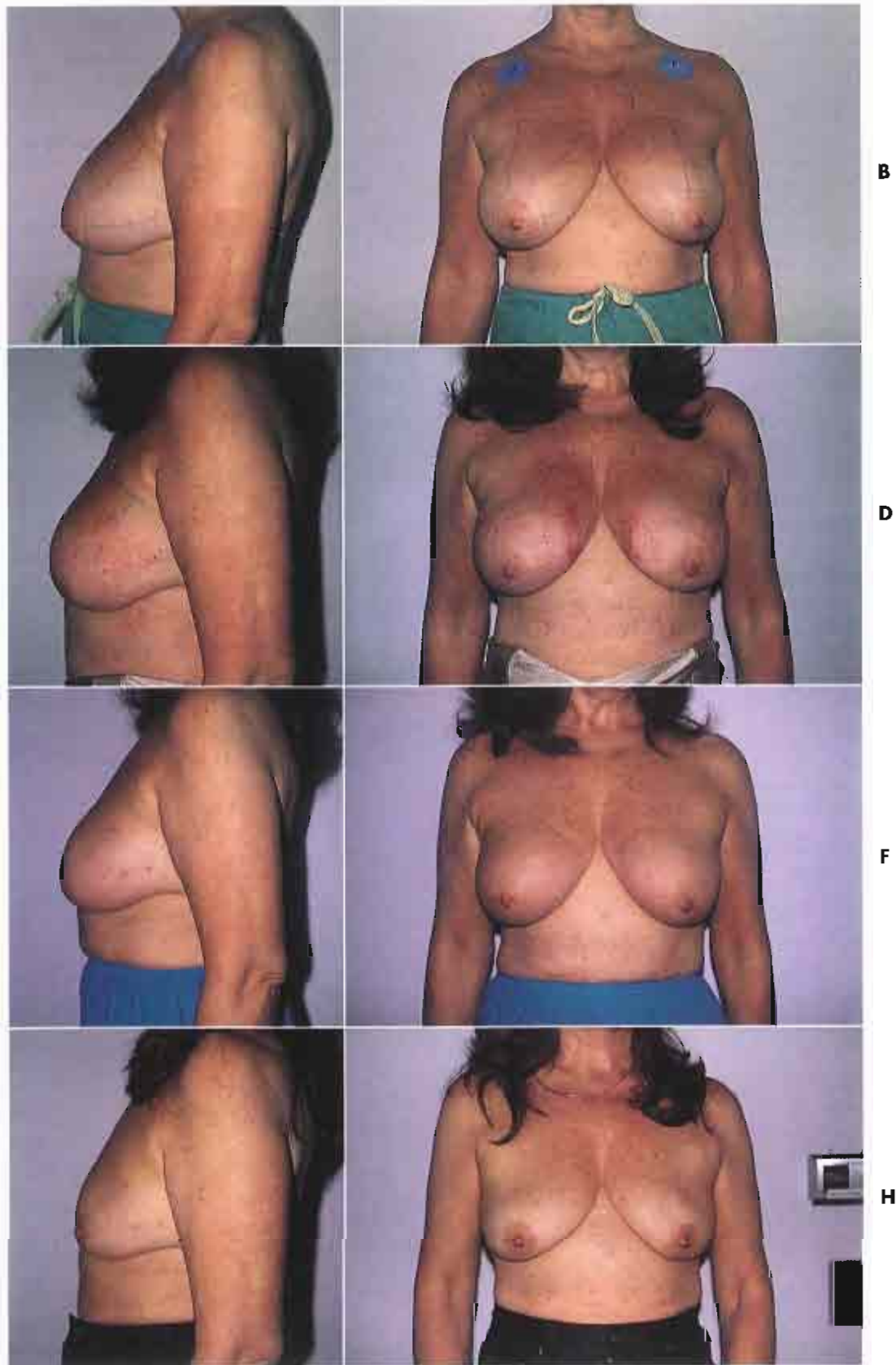
Figure 38-13

Achieving final result after female breast reduction by tumescent liposuction using open drainage and trimodal compression, with resolution of postoperative edema, typically requires 2 months or more. **A** and **B,** Preoperative views before breast reduction by tumescent liposuction. **C** and **D,** One day after breast liposuction. **E** and **F,** Ten days after liposuction. **G** and **H,** Sixty days after tumescent liposuction reduction mammoplasty.

CONTRAINDICATIONS

The relative contraindications for tumescent breast reduction include the following:

1. Excessively pendulous breasts
2. Excessively large breasts
3. Presence of palpable breast mass
4. Significant fibrocystic disease
5. Unrealistic expectations

Tumescent liposuction for breast reduction surgery in any patient with a significant family history of breast cancer requires extremely careful consideration and informed consent.

FAT TRANSPLANTATION

Some surgeons have proposed and performed augmentation mammoplasty by autologous fat transplantation. No longitudinal studies have documented the safety, efficacy, and potential long-term complications of this breast augmentation. Potential complications have included fat necrosis and liponecrotic cysts.[9]

It seems most appropriate to regard fat transplantation into the female breast as an experimental procedure that requires all the human studies research protocols for patient protection.

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CHAPTER 39

Arms

Tumescent liposuction of the arms provides excellent results. As surgeons become familiar with the technique, it becomes an increasingly popular procedure. Of all the areas that I treat by liposuction, the arms consistently yield the highest level of patient satisfaction. Although not every woman is a good candidate, the results are most gratifying for properly selected patients.

Older liposuction techniques often included *brachioplasty*, or direct excision of skin from the volar arm. The potential for significant aesthetic improvement was limited by the resulting unsightly scars. With microcannular tumescent liposuction, brachioplasty has become an anachronism.

Liposuction of the arms is almost exclusively a procedure for women. With age and a genetic predisposition, women may accumulate fat over the arms to a degree that many consider to be disproportionate and unattractive. Exercise does not reduce the volume of fat located on the arms. Microcannular tumescent liposuction of female arms easily and consistently yields results that are well proportioned and without visible surgical scars.

AESTHETIC GOALS

The goal of arm liposuction is to improve a disproportionate appearance of the arm while maintaining the aesthetic quality of female beauty. Most women do not want arms that appear muscular or masculine. The goal is for the patient to feel more comfortable and less self-conscious when wearing a sleeveless blouse.

Eliminating the pendulous appearance of the extensor aspect of the arm when it is abducted perpendicularly from the body is not sufficient. The goal is to achieve a thinner appearance of the arms when the arms are in a relaxed, dependent position alongside the torso. Whereas a heavy bulky arm augments the appearance of obesity, a thin svelte arm complements a woman's figure and provides the appearance of a thinner body (Figure 39-1).

When a woman with bulky arms stands erect and stretches her arms out in a spread-eagle or horizontal fashion, the de-

pendent tissue of the triceps area sags. The former surgical approach to treating apparently redundant arm skin has been to excise the tissue. This prompted surgeons to recommend a brachioplasty.

Women are rarely seen in a social situation with arms fully abducted in spread-eagle fashion. On the other hand, women are often seen with arms relaxed at their sides. It is in this position that the liposuction surgeon should seek to maximize cosmetic improvement.

For most women, tumescent liposuction of the arms can provide consistently dramatic and gratifying results. Even drooping extensor arm fat can be eliminated with simple liposuction (Figures 39-2 and 39-3).

The degree of improvement provided by liposuction of the arms is limited in certain patients, such as those with morbid obesity.

The guiding principle in tumescent liposuction of the arms is *uniformly unweighting the skin of subcutaneous fat*. In most patients this involves the liposuction of 75% (270 degrees) of the brachial circumference, avoiding only the arm's volar aspect. In most prospective patients the volar aspect has relatively thin fat deposits. Only in the more obese patient is circumferential liposuction of the arms of any significant cosmetic benefit (Figure 39-4).

ANATOMIC CONSIDERATIONS

The surgeon must be cautious and avoid excessive liposuction of the arms. The goal of liposuction is to improve the cosmetic appearance of the patient; this goal is not necessarily achieved by removing the maximum amount of fat. Arms that are disproportionately skinny on a woman with an otherwise shapely body might appear deformed rather than attractive.

GROSS ANATOMY OF SUBCUTANEOUS FAT

Except in obesity, the typical female arm has a distribution of fat that encompasses approximately three quarters of the arm's

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Figure 39-1

A, Topographic contour diagrams indicate relative depth of fat on arms, posterior axillary back, and infrascapular back (flanks). **B** and **C,** Preoperative posterior and lateral views. Note bulkiness of proximal posterior deltoid area and appearance of obesity. **D** and **E,** Postoperative posterior and lateral views. Note that patient appears much thinner.
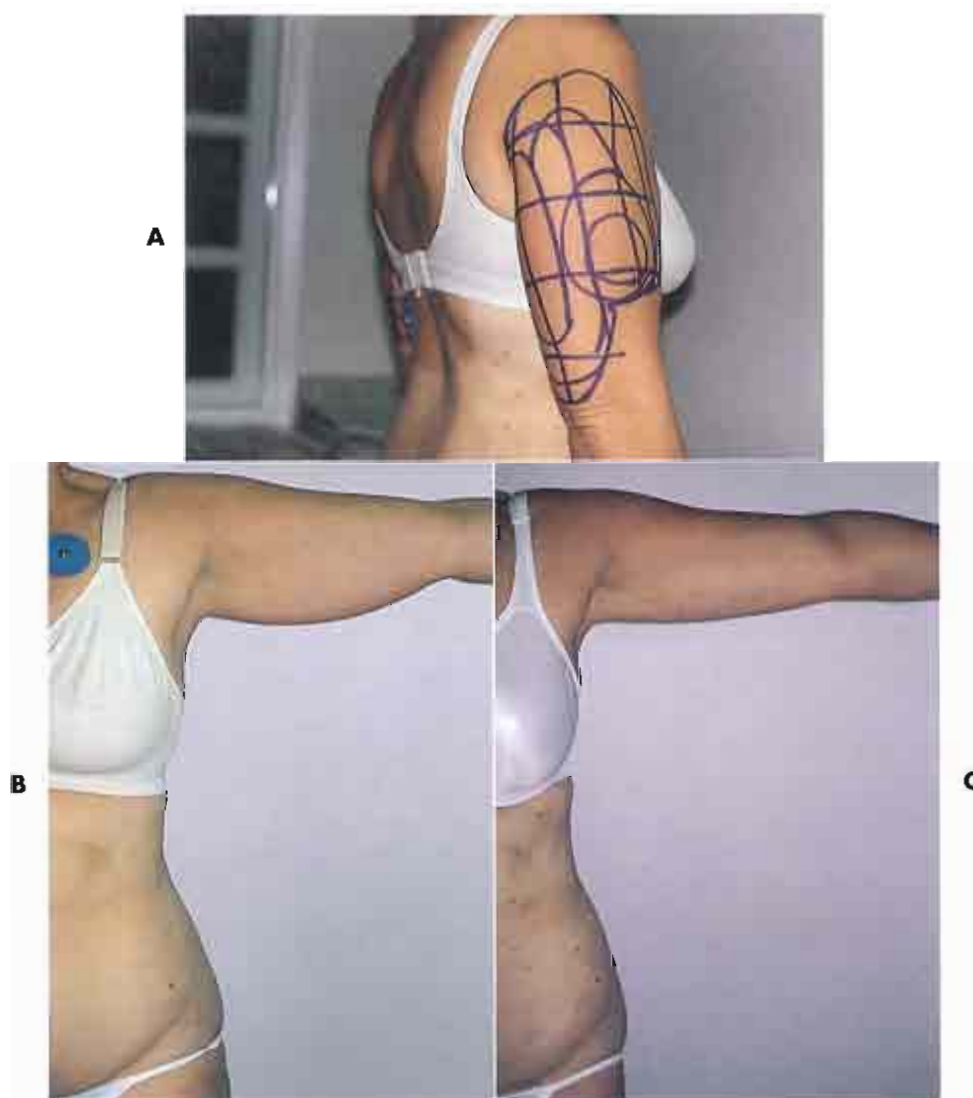
Figure 39-2

Large, sagging arms improved by tumescent liposuction; skin excision is unnecessary. **A,** Lateral view of topographic contour diagrams indicates relative depth of fat. **B,** Preoperative view of pendulous arm. **C,** After tumescent liposuction totally by local anesthesia using microcannulas.
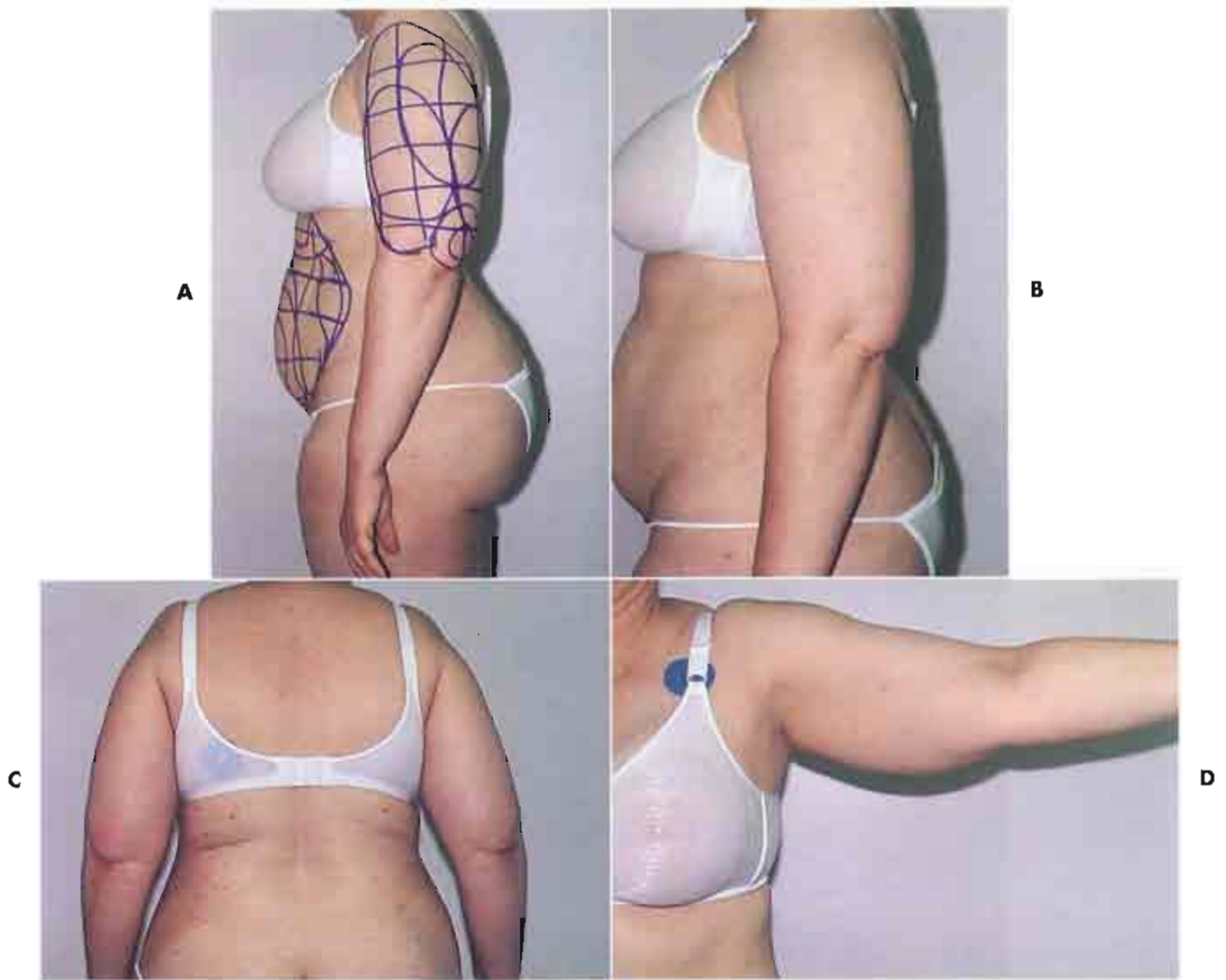
Figure 39-3

Disproportionately bulky arms give overall appearance of obesity. **A,** Lateral view of topographic contour diagrams of arms and abdomen. Preoperative views: **B,** lateral; **C,** posterior; **D,** anterior.
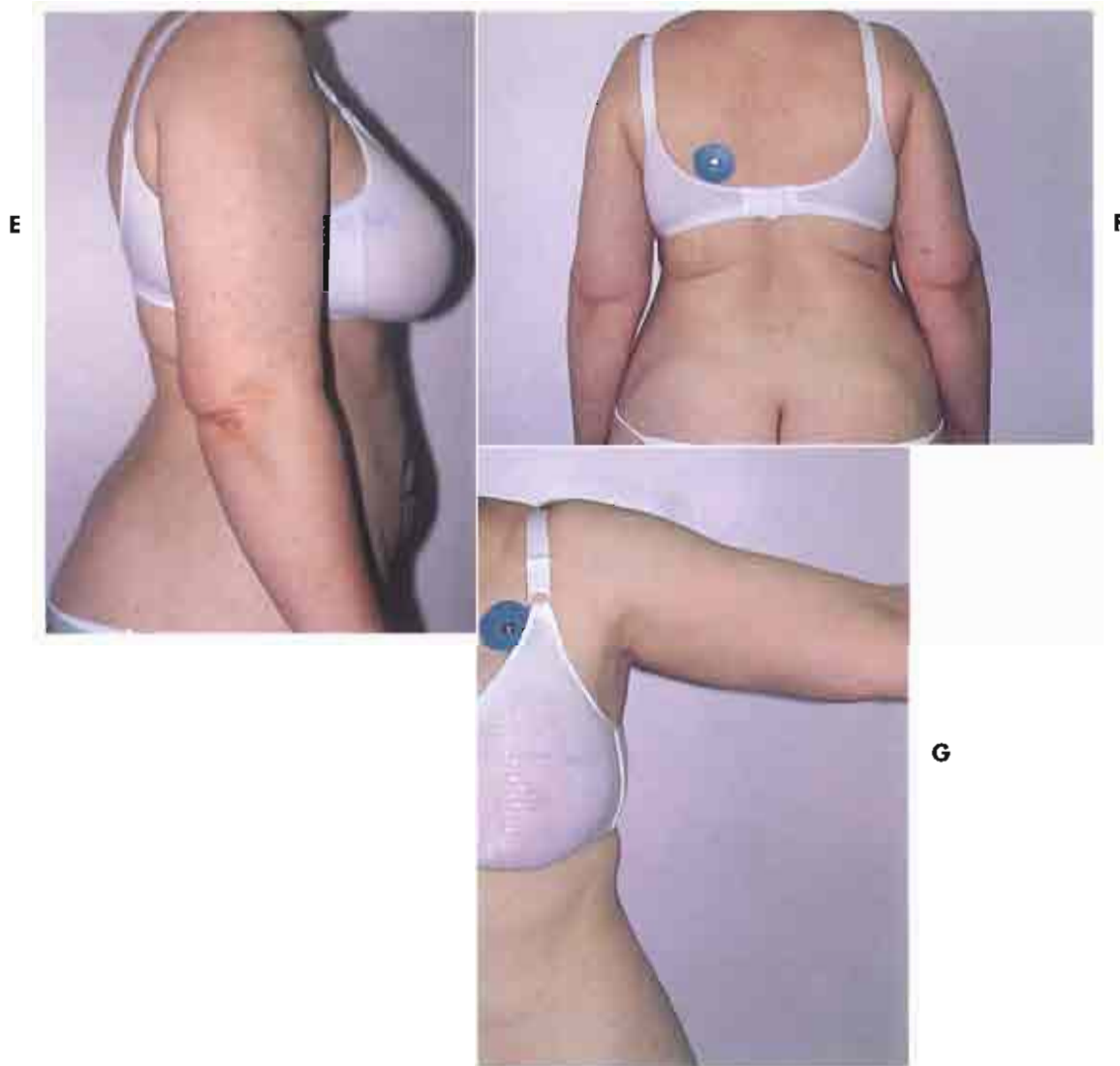
Figure 39-3, cont'd

Postoperative views: **E,** lateral; **F,** posterior; **G,** anterior. Note thinner and more proportionate appearance of arms.

circumference. The deep subcutaneous fat compartment of the arm extends over the biceps and triceps. The volar aspect of the female arm overlying the biceps has relatively little deep subcutaneous fat.

In most women, excellent cosmetic results can be obtained by limiting the area of liposuction to the 270 degrees of the arm's circumference that contains the deep fat compartment. For the majority of women, liposuction of the medial 90 degrees of the arm's circumference can be avoided while achieving excellent results.

The medial or volar aspect of the arm is relatively devoid of significant subcutaneous fat deposits. Because most of the important subcutaneous neurovascular structures of the arm are found in the medial compartment, liposuction surgery in this quadrant should be done with caution.

The largest mass of soft subcutaneous fat in the arm is found in the posterior or extensor compartment, overlying the triceps muscle. On careful palpation, however, it is evident that a significant amount of subcutaneous fat can be found extending anteriorly, overlying the biceps muscle. This fat is more fibrous than the fat of the triceps area.

Careful microcannular liposuction of the entire deep subcutaneous fat compartment of the arm will "unweight" the cutaneous tissues. Most women, even those with significant solar damage, have enough natural elastic recoil of the brachial skin for liposuction to yield gratifying results.

The underlying muscles of the arm include the triceps, biceps, and distal portion of the deltoid. With increasing obesity, fat of the arm may extend along the extensor aspect of the elbow over the proximal aspect of the long supinator muscle. The fat overlying the lateral portions of the latissimus dorsi, teres major, and teres minor (posterior axillary back) is often treated simultaneously with the contiguous fat of the arm.
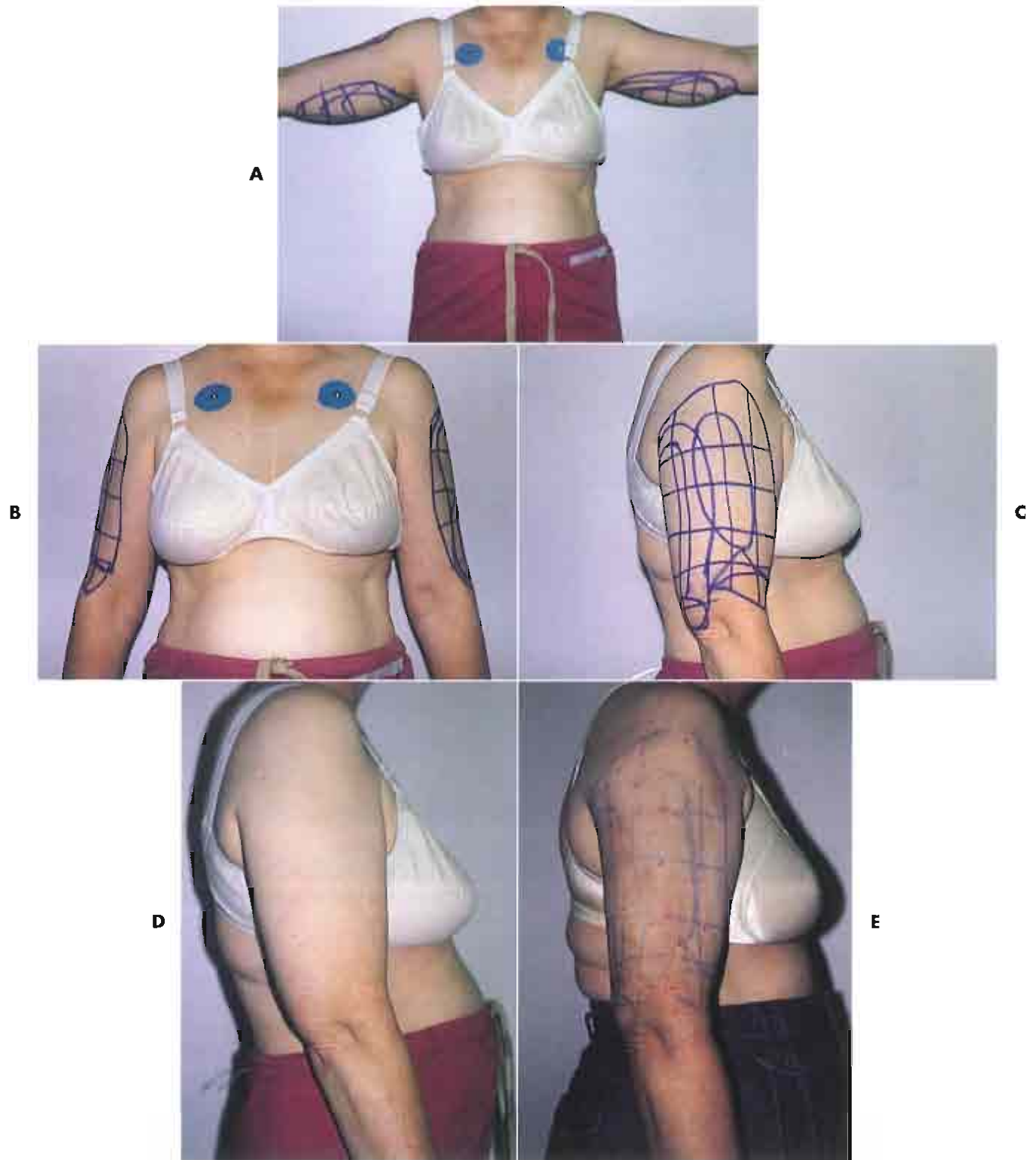
Figure 39-4

Topographic contour diagrams of arms demonstrating 75% (270 degrees) of brachial circumference targeted for microcannular tumescent liposuction: **A,** anterior view with arms spread horizontally; **B,** anterior view with arms at side; **C,** lateral view. **D,** Preoperative lateral view. **E,** One day after surgery.
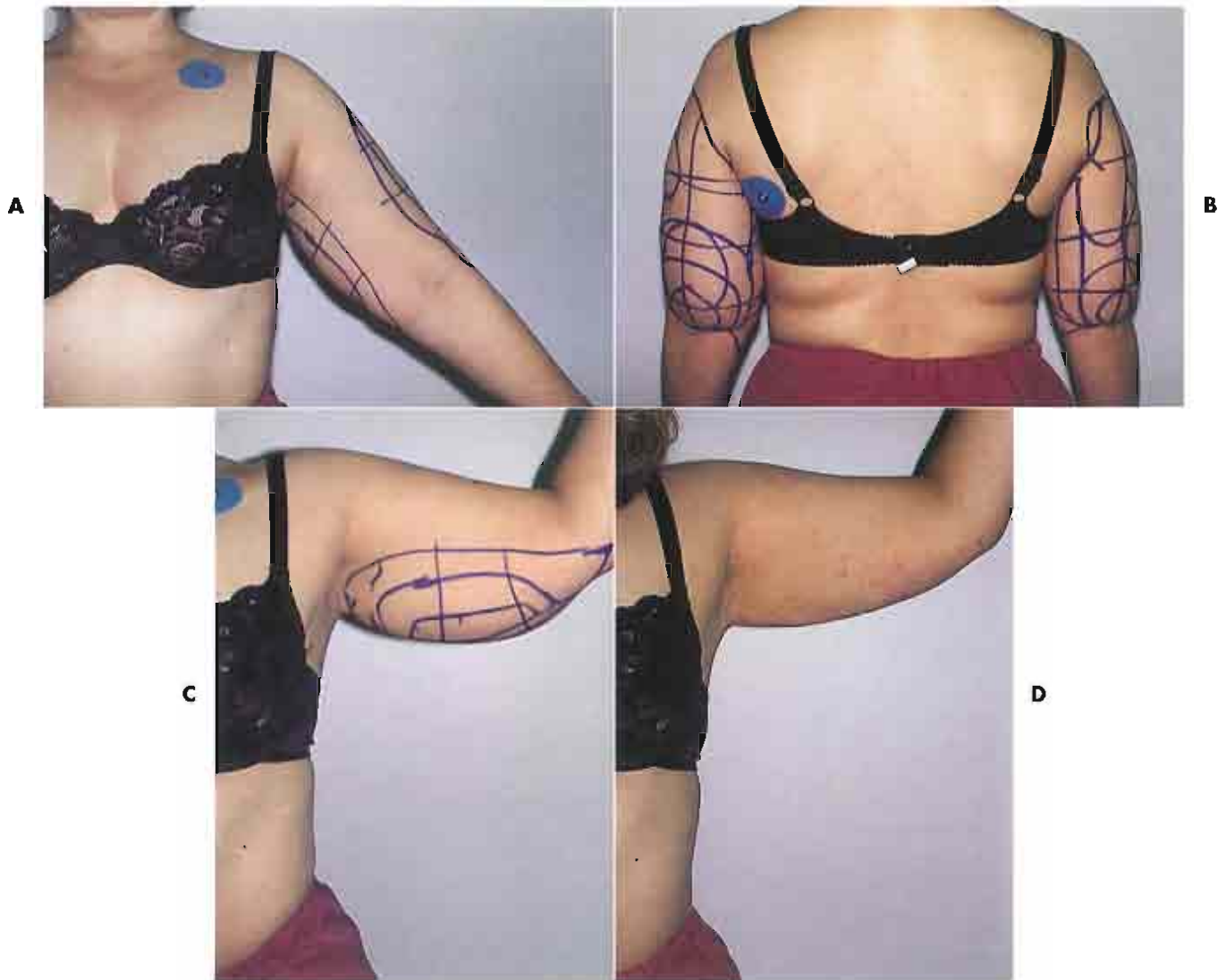
Figure 39-5

A and **B,** Topographic contour diagrams of arms demonstrating more than 75% of circumference targeted for microcannular tumescent liposuction. **C** and **D,** Preoperative and postoperative anterior views with arms held horizontally. *Continued*

SURFACE ANATOMY

For liposuction purposes the medial (volar) surface of the arm is defined as the area closest to the chest wall when palms are held flat against the lateral thighs. The definition of the anterior, lateral, and posterior surfaces of the arm is based on this position.

Anterior axillary–lateral pectoralis fat becomes more prominent with age. The fat pads of the posterior axillary–posterior shoulder and lateral back become more prominent with increasing degrees of obesity. These are areas of cosmetic concern for many women. The small focal collection of fat is accentuated by the compressive effects of a bra. Both these areas respond well to microcannular tumescent liposuction.

PREOPERATIVE EVALUATION

Marking the arms for liposuction requires the same careful attention to subtle detail as do other areas of the body. The volar arm overlying the biceps muscle is usually excluded from liposuction because this area has little fat. The volar fat overlying the triceps muscle is almost always included in the markings (Figure 39-5).

INTRAOPERATIVE POSITIONING

There is no single or ideal patient position for liposuction of the arm. At least two different positions are required to gain

Figure 39-5, cont'd

E and **F,** Preoperative and postoperative posterior views. **G** and **H,** Preoperative and postoperative lateral views.

convenient access to the entire extent of the arm's deep fat compartments.

Most of the fat may be suctioned with the patient lying in a lateral decubitus position. The arm may be positioned slightly akimbo by placing a folded towel between the elbow and the lateral chest wall. Liposuction of the anterior, lateral, and extensor areas of the arm is approached with the elbow somewhat bent and the hand resting somewhere along the lateral thigh and hip area, depending on the surgeon's preference (Figure 39-6).

The volar fat overlying the medial triceps muscles may be easily approached by having the patient raise the elbow over the head and resting the palm on the pillow beyond the head. The anterior axillary fat pad area is treated with the patient supine and the arm at the side or raised over the head.

ANESTHETIC INFILTRATION

Tumescent infiltration of the arm is simple and relatively well tolerated.

Circumferential liposuction of the arm is usually not necessary but can be accomplished. Tumescent infiltration of the arm's entire circumference is unlikely to produce a "compartment syndrome," but some caution is required. The surgeon should avoid excessive tumescence that produces a functional tourniquet by elevating interstitial pressure beyond the arterial pressures of the upper extremity.

In practice, such an iatrogenic compartment syndrome is unlikely. Circumferential tumescence of the arm can exceed the brachial venous pressure, however, causing a distal capacitance or venous reservoir effect. If a small venule is lac-

Figure 39·6

Arm liposuction requires two positions to ensure easy access to all 270 degrees (75%) of arm circumference. For both, patient is in lateral decubitus position. **A,** For extensor portion of arm fat pad that overlies triceps and biceps, arm rests on patient's uppermost side. **B,** For volar or axillary portion of arm fat that overlies medial triceps, arm is raised, with ipsilateral hand resting over or behind head. Large, sterilized, superabsorbent surgical table sheet (not shown) placed immediately beneath arm helps control intraoperative drainage.

erated during subsequent liposuction, the resultant bleeding might appear somewhat exaggerated (i.e., more than normally expected).

SURGICAL TECHNIQUE

Microcannulas permit a decisive approach to liposuction of the arms while minimizing the risks of skin irregularities. Multiple small incisions or 1.5-mm adits give access to the arms' entire circumference.

The surgeon should avoid unnecessary adits but should make extra adits if it will improve the smoothness or completeness of the results. The minuscule incisions required to accommodate 16-gauge and 14-gauge microcannulas produce virtually no scarring.

At the distal extent of the arm, two to four 1.5-mm adits are made. Additional adits along the long axis of the arm are placed judiciously for optimal access to the targeted fat pads but are distributed randomly to avoid more than two incisions along a straight line.

Fat over the proximal arm and overlying the distal deltoid muscle may often be approached from distal incisions. Because incisions over the deltoid have an increased incidence of scarring, the number of incisions in this area should be minimal.

Although one can begin with a 14-gauge microcannula, liposuction is usually initiated with a 16-gauge microcannula, which is used to establish the deepest plane of liposuction. The smallest cannulas permit the greatest accuracy and are the least likely to cause pain if the surgeon encounters an area of insufficient anesthesia.

Once the deepest plane of liposuction has been defined, the cannula is directed throughout the fat to perforate the fibrous tissue septa. This pretunneling with small cannulas will permit the use of larger cannulas with less resistance from fibrous tissue. The 16-gauge and 14-gauge microcannulas are
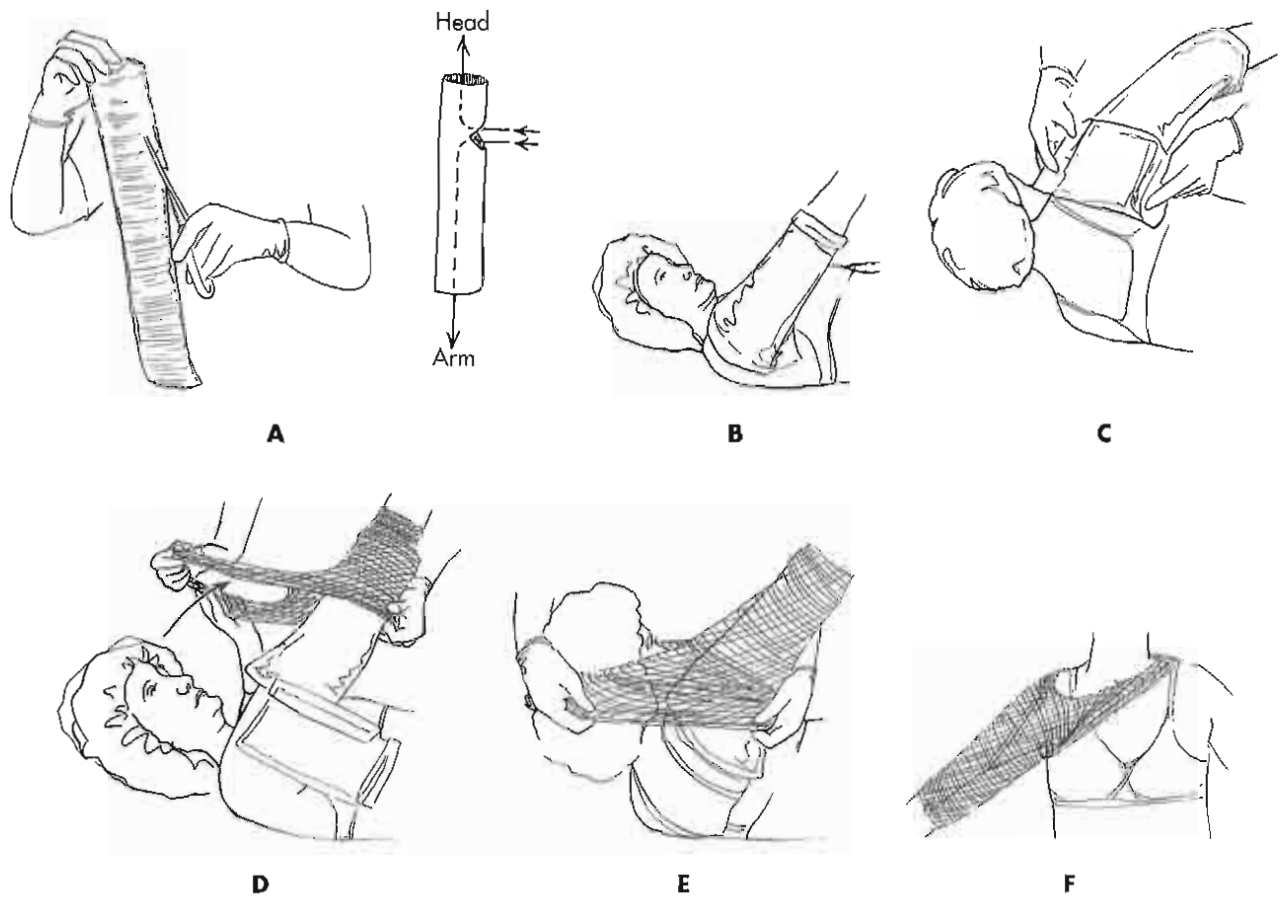
Figure 39-7

Postliposuction care of arms. **A,** Cut sufficient length of tube netting with appropriate diameter, then cut small "bite" out of proximal end. **B,** Place absorptive pads over arms, covering all treated areas. Use tape to secure position of pads until tube netting can be pulled into place. **C,** Place absorptive pads over posterior axillary area, if suctioned. **D,** Move tube netting over arm, on top of absorptive pads. **E,** Place loop of netting over head. **F,** Arrange netting so that it fits comfortably around neck. Use torso garment to provide compression over proximal arm and axillary back. Arm compression is achieved by wrapping 15-cm (6-inch)–wide elastic bandage around tube netting.

sufficient for most female arms. Occasionally a 12-gauge cannula is required.

The paths of the microcannula along the arm are largely directed parallel to the long axis of the arm, using numerous oblique and diagonal strokes to ensure the smoothest results. Transversely directed paths are usually not necessary.

The end point of the suction is determined by the uniformity of a pinch test over the entire extent of the treated area. A thin layer of residual fat should remain to ensure a mature female appearance and the natural tactile softness of a female body. Overenthusiastic liposuction can produce masculine-appearing arms, which some may regard as a deformity.

Fat in the anterior axillary fold becomes more prominent with age. Using 16-gauge microcannulas and a deliberate effort to achieve smooth uniform extraction, the surgeon can achieve excellent results in this area. To achieve uniform liposuction throughout the targeted area, some of the adits or

incisions should be located at least 2 to 3 cm beyond the proximal and distal peripheries of the targeted area.

POSTOPERATIVE CARE

Because only moderate compression is necessary for the arms, postoperative care after liposuction of the arms is relatively simple. Drainage infrequently lasts more than 24 to 48 hours after surgery. Although absorptive padding must be worn until all drainage ceases, typically only a minimal amount of padding is necessary after 24 to 48 hours.

Dressings consist of absorbent compression pads, initially held loosely in place by tubular elastic netting, over which are wrapped elastic nonadhesive Ace-type bandages. The patient can easily remove and reapply these dressings without assistance (Figure 39-7).

Figure 39-8

Arm dressings for open drainage immediately after surgery. **A,** Absorptive pads are secured to arms and posterior axillary back with paper tape until elastic bandage is applied. **B,** Placement of elastic compression bandage on top of pads, which cover arm and anterior and posterior axillary areas. Arms require compression only for about 24 to 36 hours, until drainage has ceased. **C,** After arms have been wrapped, torso garment provides sufficient compression over anterior and posterior axillary areas and lateral back and secures absorptive compression pads.

Postoperative improvement is rapid. Patients improve significantly within a few days after surgery; 90% of patients attain 90% improvement in 1 to 2 weeks.

Stiff compression garments are not necessary for the arms. They are difficult to apply without assistance and often cause edema of the forearms and hands.

The anterior axillary, posterior axillary, and scapular areas require absorptive padding for only 1 to 2 days. The absorptive pads are held in place with a torso compression garment (Figure 39-8).

PITFALLS AND SPECIAL CONSIDERATIONS

Excessive liposuction causes the most common aesthetically adverse result. Some regard arms that are devoid of subcutaneous fat as neither attractive nor beautiful and not normal female arms. When liposuction of the arms is done too aggres-sively, some areas have no subcutaneous fat, whereas adjacent areas do have residual fat. Such overaggressive liposuction yields an unappealing lumpy result, which is grossly accentuated when the patient gains a minimal amount of weight.

AXILLA

The surgeon should avoid liposuction of the axilla, which has no cosmetically significant fat. Furthermore, whereas anterior, posterior, and thoracic axillary fat can be safely treated by liposuction, the axilla proper has important neurovascular structures that are vulnerable to liposuction trauma.

Hyperhidrosis. Some surgeons have advocated liposuction of the axilla as an effective treatment for axillary hyperhidrosis. The advantages of liposuction in the destruction of axillary apocrine sweat glands are questionable. The traumatic destruction of apocrine glands by liposuction causes

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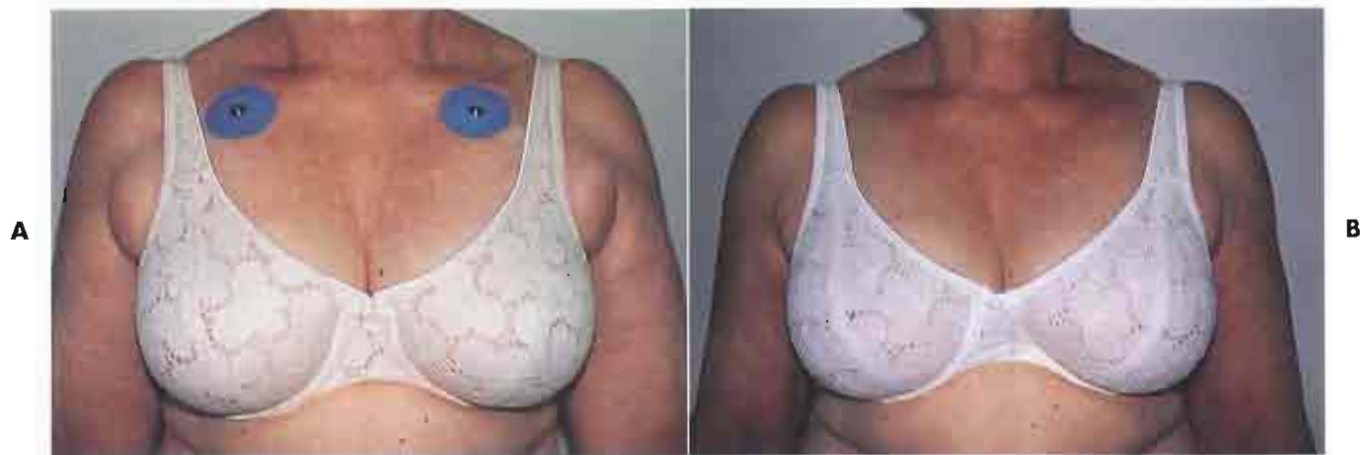
Figure 39-9

Bulging anterior axillary pads are easily reduced to a smooth and inconspicuous area with tumescent liposuction using 16-gauge and 14-gauge Capistrano microcannulas. **A,** Preoperative view. **B,** Postoperative results.

Figure 39-10

Surgical position for liposuction of anterior axillary fat pad.
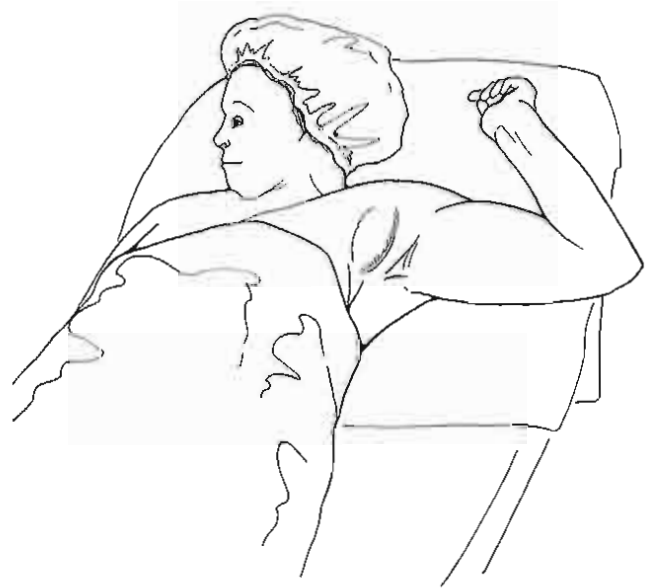
some dermal necrosis and axillary scarring. Even with the tumescent technique, the risk of damaging important axillary neurovascular structures outweighs the purported advantages of liposuction.

The safest surgical approach for axillary hyperhidrosis is with tumescent local anesthesia, simple excision of more than 80% of the hair-bearing skin, and primary Z-plasty closure. Therapeutic results are excellent, healing is rapid, and risks are minimal.

DISTAL FAT PAD

The surgeon must carefully assess the entire arm for accessible subcutaneous fat. For example, it is easy to overlook the common localized collection of fat at the distal aspect of the extensor arm. This small fat pad often appears insignifi-

cant when examined preoperatively. If this fat is not specifically treated by liposuction, however, the patient will often comment on the oversight at a follow-up examination.

ANTERIOR AXILLARY FAT PAD

The anterior axillary fat pad may become prominent with increasing age. Even in some relatively thin women, this fat pad can be disproportionately large. Careful, deliberate liposuction technique using Capistrano microcannulas can easily reduce the fat pad to a smooth and inconspicuous area (Figure 39-9).

The patient lies supine with the ipsilateral arm raised over the head, stretching the pectoralis muscle and making it taut and firm (Figure 39-10). Using this position, the surgeon can easily palpate and appreciate the difference between the fat

Figure 39-11

Goal of tumescent liposuction of arms is to achieve more slender appearance when patient's arms are held normally alongside body. **A,** Preoperative view. Bulky proximal arm contributes to appearance of generalized obesity. **B,** Postliposuction view. Natural appearance of thinner upper arm is more proportional to rest of patient's body size and weight.

and the subjacent muscle. Tumescent infiltration should be directed throughout the pad, as well as in a 2-cm periphery beyond the fat pad's margins. Microincisions or adits are placed at both the proximal and the distal ends of the pads.

Tumescent liposuction using 16-gauge Capistrano microcannulas can provide excellent results. Liposuction tunnels should be distributed throughout the targeted tissue in proportion to the depth of the compartment. If a large-diameter cannula is used, the surgeon may tend to remove too much fat in the midportion of fat pad and leave too much fat at the periphery. This limits the smoothness and the aesthetic appeal of the results. Often, this lack of finesse

results in an unsightly crease through the middle of the fat pad, as well as residual fat at the periphery. When microcannulas are directed more accurately, results are smoother and more uniform.

Postoperative compression is necessary only for approximately 24 hours. The sleeves of the torso garment hold the absorptive pads in place and provide adequate compression.

The goal of tumescent liposuction of the arms is to achieve an improved appearance of proportionality in size and shape between the body and the arms. Careful tumescent liposuction using microcannulas can consistently achieve this goal (Figure 39-11).

CHAPTER 40

Female Legs and Ankles

Liposuction of the legs is requested much less frequently than liposuction of areas on the thighs and torso. The disproportionate and displeasing distribution of fat on the female ankles and legs is most often genetically predetermined. Exercise and diet usually do not improve this disproportionality.

ANATOMIC CONSIDERATIONS

The leg is defined as the portion of the lower extremity between the knee and the ankle. The fat on the legs and the ankles primarily is mantle fat. Typically, there is a negligible amount of deep fat that is distinct and separate from the subcutaneous mantle fat. Nevertheless, focal areas exist where the fat on the legs is more prominent.

PREOPERATIVE EVALUATION

The areas of bulging subcutaneous fat can be subtle or obvious. In some patients the entire leg, except for the pretibial area, can benefit from liposuction. In others, liposuction should be limited to discrete areas.

Areas of fat may be easily seen but difficult to document with photographs. Consequently, before-and-after photographs might not demonstrate the degree of improvement that is seen clinically. Patients should be informed of this before surgery, with the discussion documented in the patient's chart.

It is often difficult to appreciate the degree of fat in the legs when the patient is standing upright with equal weight on both feet. In the vertical standing position the cutaneous envelope is pressed outward and made more taut by the bulging action of the calf muscles.

The quantity of fat in the leg is more easily appreciated when the knee is bent and the leg is held in a horizontal position, resting on a stool or chair. In this position the skin and subcutaneous fat are more easily grasped, and the "pinch test" provides a more accurate assessment of the amount of fat (Figure 40-1).

Prominent focal areas of fat on the leg are relatively subtle compared with other parts of the body. Because tumescent infiltration can easily obscure the subtleties of fullness in the ankles and lateral calf, it is important to draw the topographic contour lines accurately on the areas to be reduced by liposuction (Figures 40-2 to 40-4).

INTRAOPERATIVE POSITIONING

A modified lateral decubitus position, using a Thigh Aside pillow to elevate the uppermost leg, is comfortable for the patient and allows easy surgical access for liposuction of the legs and ankles. After surgically preparing and scrubbing the legs, ankles, and feet, placing them on a sterilized superabsorbent sheet is more convenient than using a nonabsorbent sterile drape.

From this position the surgeon can do liposuction on both the lateral and the posterior aspects of the uppermost leg and the medial and posterior aspects of the dependent leg. The patient then rotates onto her other side, and the process is repeated (Figure 40-5).

The prone position can also be used occasionally.

ANESTHETIC INFILTRATION

Infiltration with a spinal needle requires care and attention to avoid inadvertent infiltration into subjacent calf muscles. A gentle technique with spinal needles is usually well tolerated but takes time and patience to be accomplished painlessly and without ancillary analgesia. Infiltration with a larger cannula is more uncomfortable and probably requires parenteral narcotic analgesia and sedation.

Achieving optimal tumescence as an end point of infiltration increases the likelihood of complete anesthesia and optimal vasoconstriction. Once complete local anesthesia has been achieved, however, complete tumescence is not necessary when initiating liposuction. In fact, with the decreased tumescence that occurs approximately 30 minutes after infiltration
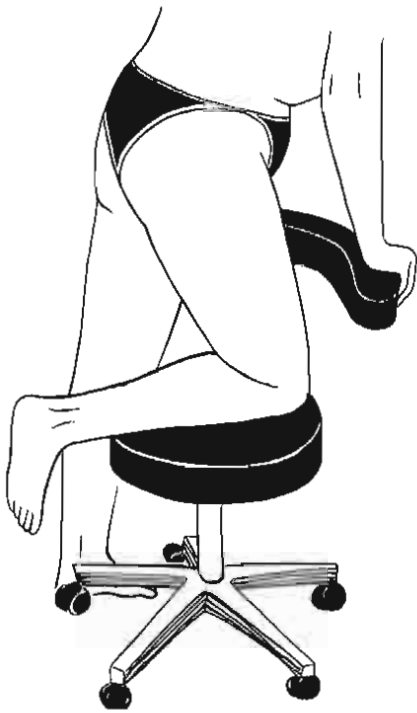
Figure 40-1

Recommended position for assessing subcutaneous fat of leg.

Figure 40-2

A and **B,** Preoperative lateral and posterior views with contour drawings on legs. **C** and **D,** Lateral and posterior views 1 day after liposuction with open drainage and bimodal compression.

Figure 40-3

Contour drawings on ankles. Relatively small areas of cosmetically displeasing deposits of fat can be accurately delineated before tumescent infiltration for liposuction totally by local anesthesia.

A

B

C

D
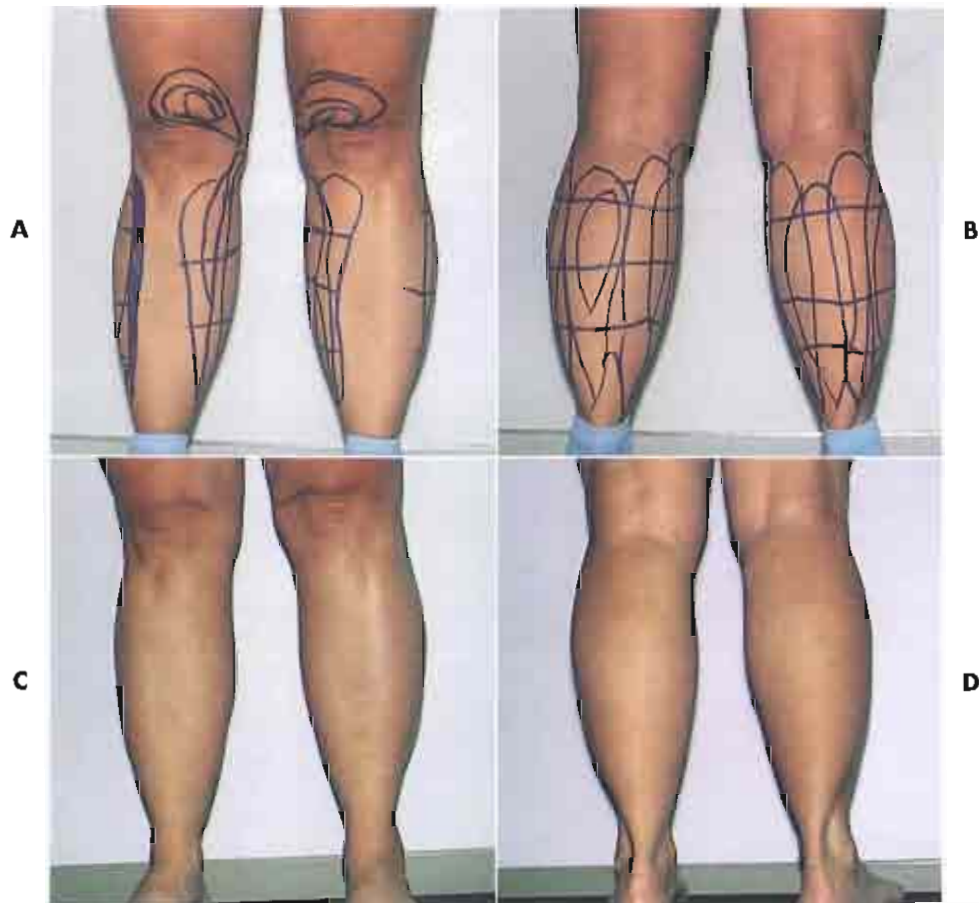
Figure 40-4

With liposuction of large legs, surgeon should not remove too much fat. Conservative reduction of legs with results proportionate to thighs is better than dramatic liposuction that removes so much fat that legs and thighs appear incongruous. This patient was satisfied with improvement after liposuction of 400 ml of supranatant fat from each leg. **A** and **B,** Anterior and posterior views with preoperative contour drawings. **C** and **D,** Postoperative anterior and posterior views.

Positioning legs and ankles during infiltration and liposuction. Thigh Aside positioning pillow is covered with single-use, clear plastic bag. Legs rest on sterile, superabsorbent, operating room table sheet.

is complete, liposuction becomes easier. After the infiltrated tissue has become tumescent, the surgeon can more easily grasp the tissues and more accurately direct the microcannula to the deepest layers.

SURGICAL TECHNIQUE

The microcannulas are principally directed parallel to the leg's long axis. Some crisscrossing is necessary to ensure smooth, uniform results. Because the subcutaneous blood vessels and lymphatics are oriented parallel to the long axis, directing a cannula transversely is more likely to injure these vessels.

It is not clear how liposuction-induced injury to dermal vasculature of the ankles or lower leg might affect the risk of venous insufficiency many years later. The ankles are especially susceptible to long-term effects of vascular injury. Clinical experience has shown that a history of cellulitis or phlebitis of the leg predisposes to late onset of postphlebitis

syndrome. This condition is associated with chronic venous insufficiency, stasis dermatitis, and increased risk of cutaneous ulcerations. Because of this concern, I believe that superficial liposuction and internal ultrasonic-assisted liposuction are contraindicated in the leg and ankle.

Excessive superficial liposuction that risks injury of the subdermal vascular plexus is unnecessary. The popliteal fossa contains important neurovascular structures that are vulnerable to injury by a liposuction cannula. The surgeon should never attempt liposuction within the popliteal fossa.

POSTOPERATIVE CARE

Postoperative care is simple. The legs are wrapped in absorbent pads, which are temporarily secured with elastic tube netting and then wrapped with elastic bandages. Compression bandages are necessary until all drainage has ceased, after which compression is optional.

The multiple adits almost guarantee that drainage of residual blood-tinged anesthetic solution will be achieved with minimal compression. With multiple adits and open drainage, prolonged or extreme compression is unnecessary.

Residual edema is minimal and largely resolves within a few days. Patients are encouraged to ambulate during the first few postoperative days to encourage drainage and decrease edema. Bed rest and leg elevation are unnecessary.

PITFALLS AND SPECIAL CONSIDERATIONS

Attempting to remove all leg fat is generally a mistake. Maximum liposuction of the legs results in an incongruously muscular appearance. A masculine, muscular leg on a female figure is usually undesirable.

More importantly, future weight gain will accentuate irregularities. Slight variations always occur from area to area in the amount of fat removed. In later years, when the patient gains weight, the skin will remain adherent to muscle in areas with no fat. Areas with residual fat will be the sites of additional fat accumulation. The ultimate result is a cobblestone appearance that is difficult to repair without significant risk of dermal injury and scarring.

Patient Forms

Liposuction Consent Request for Surgical Services

Patient's name _____ Height/weight _____ Date _____

I authorize the surgeon, associate surgeons, and staff to perform liposuction surgery on the following areas (*indicates that less than a 50% improvement can be expected):

Approximate duration, 1st surgery (hours)	Approximate duration, 2nd surgery (hours)
(Total $) − (Consult $) = $ Due	(Total $) − (Consult $) = $ Due
Deposit & (date paid)	Deposit & (date paid)
Balance & (due date)	Balance & (due date)
Preoperative examination time & date	Preoperative examination time & date
Time/day/date of surgery	Time/day/date of surgery

I understand that if I gain excessive weight after the time of the initial consultation or preoperative examination and the day of surgery, the physician reserves the right to change the areas to be treated if the planned areas would result in too much surgery.

The quoted surgical fee remains valid provided that (1) surgery is scheduled and the deposit is paid within 4 months of the date the quote was made, (2) the surgery is done within 1 year of the quote, and (3) the patient's weight does not increase excessively after the time of the quote. The balance of the fee must be paid at least 14 days before surgery. There is no charge for routine follow-up care after the surgery. However, in the unlikely event of complications, the patient is responsible for fees charged by other physicians or hospitals. In the event of a secondary procedure to correct an unsatisfactory result, the surgical fee will be no more than 50% of the above.

I agree to allow the surgeon and staff to photograph or video me before, during, and after the operation. The photographs, videos, and tapes shall be the property of the surgeon, and may be used for teaching, publication, or scientific research purposes. The patient's identity will not be revealed. I agree to routine preoperative laboratory blood tests, including a test for HIV (AIDS). I agree to allow laboratory blood specimens to be obtained to evaluate the amount of anesthetic solution that has reached the circulation and to measure the amount of blood lost during surgery. I request local anesthesia and other medications deemed necessary by the surgeon.

Liposuction is associated with certain expected temporary side effects, including soreness, inflammation, bruising, swelling, numbness, and minor irregularities of the skin. Some of these effects can take several months to resolve. Scars, pigment changes, or an irregularity that persists for more than 6 months may or may not be correctable by a secondary procedure. Any surgery may involve risks of more serious and unexpected problems. Although rare, examples of such complications include blood clots, excessive bleeding, scarring, infection, seroma (temporary accumulation of fluid under the skin), injury to other tissues, and allergic or toxic reactions to drugs.

The surgeon and staff have explained the nature, purpose, possible alternative methods of treatment, the risks involved, and possible complications associated with liposuction surgery. I acknowledge that no guarantee has been made as to the results. I agree to have any issue of medical malpractice decided by neutral arbitration rather than by jury or court trial. I know that liposuction should not be done if a woman patient is pregnant; I have no reason to suspect that I might be pregnant.

		Plausible risks have been discussed, the 8 pages of this document reviewed, and all of patient's questions	
Patient's signature & date	Witness's signature & date	have been answered.	Surgeon's signature & date

To be signed on the day of surgery: I have carefully read all eight (8) pages of this document, including a copy of the postoperative care instructions, and all of my questions have been well answered. I hereby request and give authorization to the above surgery.

Day of surgery (1st surgery)

Day of surgery (2nd surgery)

Patient's signature & date	Witness's signature & date	Patient's signature & date	Witness's signature & date

Important Information about Tumescent Liposuction

1. **Risks of liposuction surgery.** Any surgery involves the risk of thromboembolism (blood clots), infection, bleeding, scarring, or serious injury; however, tumescent liposuction has an amazingly good safety record. One of the reasons that tumescent liposuction is so safe is that neither general anesthesia nor intravenous (IV) sedation is required. A recent survey involving over 15,000 patients who had tumescent liposuction without general anesthesia revealed no serious complications, no serious infection, no hospitalizations, no blood transfusions, and no deaths. The greatest risks of liposuction are those associated with general anesthesia. By eliminating general anesthesia, the risks of liposuction are dramatically reduced.

   Patients can minimize the risk of surgical complications by not taking medications or over-the-counter preparations that might adversely affect the surgery. Patients should inform the surgeon of any medications being taken either regularly, or occasionally, including herbal remedies.

2. **Risk of irregularities of the skin.** Tumescent liposuction using microcannulas is the least likely to cause any significant or noticeable postsurgical irregularities of the skin. By magnifying the fatty compartment, the tumescent technique permits more accurate removal of fat, with greater assurance that the liposuction cannula will not inadvertently approach too near the undersurface of the skin, which would cause irregularities. Thus the tumescent technique helps to minimize the risk of postsurgical irregularities or rippling of the skin. Liposuction might improve preexisting irregularities of the skin, such as dimpling or "cellulite," but prospective patients should not assume that there will be significant improvement. It is unrealistic to expect perfectly smooth skin. Patients should expect that their skin will have approximately the same degree of dimpling and irregularities as existed before tumescent liposuction surgery. Ultimately, after liposuction the skin texture should be within normal limits. A casual observer should not notice any evidence of surgical irregularities of the skin. However, it is possible that a noticeable skin irregularity may result and require a little touch-up liposuction.

3. **Risk of scarring of the skin.** Incisions for liposuction may result in scarring. The incisions made for inserting the cannulas are usually less than 2 to 3 mm in length and are usually virtually invisible once healed. Although you may be able to find them on close examination, most other people would not be able to see them. Some patients may experience temporary hyperpigmentation (darkening), which usually fades after several months. Some patients may have a genetic predisposition for persistent discoloration at incision sites. Patients that have experienced hyperpigmentation or hypopigmentation (pale or light-colored scars) in the past might expect also to experience it with these incisions. Certain areas of the body, such as the back or upper flanks, may be more likely to have pigmentation changes.

4. **Cellulite.** Liposuction of the thighs, while improving the silhouette, does not necessarily eliminate the subtle "puckering" of the skin, often called "cellulite." Cellulite results from the pull of fibrous tissue that connects skin to underlying muscle. Although tumescent liposuction may reduce the degree of cellulite, it is unlikely to eliminate it. Liposuction should not worsen cellulite.

5. **Liposuction and obesity.** Liposuction is not an appropriate treatment for obesity. Liposuction is not a substitute for a prudent diet, good nutrition, and regular exercise. Obese patients may be good candidates for limited liposuction if their goal is simply to improve the shape of certain limited areas of the body.

6. **Postoperative healing.** Normal healing after tumescent liposuction involves a limited but definite degree of soreness, swelling, bruising, and lumpy firmness. A temporary mild numbness (paresthesia) of the skin may persist for up to 4 months. Most patients can actually see some improvement of their silhouette within one week after surgery. However, because of the slow resolution of postsurgical swelling, the ultimate results following liposuction usually require 12 to 20 weeks to be achieved.

7. **Realistic expectations.** Although the results of liposuction are often quite spectacular, it is not realistic to expect perfection. It is impossible to guarantee the precise amount of improvement that will result from liposuction. Patients should not have unrealistic expectations. Although patients can usually expect to achieve at least a 50% improvement, it is unreasonable to expect 95% improvement or near perfection. For the perfectionist, or for liposuction of a very large area, maximum improvement may require a second procedure, for which there would be an additional fee.

   Patients who would be satisfied with a 50% improvement would be reasonably good candidates for liposuction.

   The "50% improvement" is intentionally a vague measure. It indicates a definite perceptible improvement, but something short of perfection. If a 50% improvement would make a patient happy, it is likely that these expectations will be met. Our patients generally achieve more than a 50% improvement.

8. **Longevity of results.** The fat cells that are removed by liposuction do not grow back. If the patient later gains or loses weight, the change tends to be distributed proportionately over the entire body. Although one can expect some changes with aging, provided that the patient does not gain large amounts of weight, the patient's new, more pleasing silhouette is relatively permanent. If there is a large weight gain after liposuction surgery, new fat cells may be created.

Tumescent Liposuction Preoperative Checklist

Please initial each item to confirm your agreement. Print "NO" if you disagree.

_____ Please circle the following locations where we can telephone you (crossout if NO): **Home   Work   Other**

_____ Please circle the following locations where we can leave a message (crossout if NO): **Home   Work   Other**

If we cannot telephone you at home or work, please provide other number(s) where we can reach you by telephone:

(   ) _____   (   ) _____   (   ) _____
    Home Telephone   Work Telephone   Other Telephone Number

_____ You permit visiting physicians or nurses to observe your surgery.

_____ You permit us to show your preoperative and postoperative photos to prospective patients (no name will identify the photos).

_____ You agree to avoid **aspirin, ibuprofen,** and **decongestants** for one (1) week before surgery; not to take **thyroid medication** on the day of surgery; and not to take **Fastin (phentermine), Zoloft (setraline),** and **herbal remedies** (unless specifically approved by your surgeon) two (2) weeks before surgery. We recommend that you remove all aspirin and ibuprofen products from your medicine chest.

_____ If another physician prescribes new medications for you, you will notify the surgical facility's staff.

_____ You agree not to drive yourself home after surgery and not to drive an automobile until the day after surgery.

_____ If you develop a rash, skin infection, open wound, or illness any time before surgery, you will notify the surgical facility's staff.

_____ If your preoperative examination and laboratory studies are done out of town by your own primary care physician, you guarantee that the results will arrive at our office at least 1 month before surgery.

Cosmetic Surgery Policies

_____ **Payment schedule.**

_____ **Schedule changes or cancellations.** If it is necessary to change or cancel the date of the surgical procedure, at least 1-week notice is required. It is the patient's responsibility to document both the date and the time, as well as the name of our office staff member who received the notice of cancellation or change. If all preoperative laboratory results and any necessary preoperative clearance letters are not received by 14 days before surgery, your date will be forfeited and rescheduled. Last-minute cancellations due to illness must be well documented in writing by a physician, including a copy of the physician's physical examination and diagnosis. If you want to revise the plan of body areas designated for liposuction, you will need to notify us at least 1 week before surgery.

_____ **Cancellation charges.** Once the initial down payment is made, your preoperative physical examination and laboratory studies will be completed. Next, our staff will begin the administrative task of scheduling the surgery. This includes scheduling nurses and preparation of numerous documents, which are required of any state licensed facility. If your surgery date is rescheduled more than a total of two times for your convenience or by us because you have not completed the preoperative work or other medical clearance in a timely manner, there will be a fee for each additional reschedule. Any reschedule that is done with less than 1-week notice will result in a rescheduling fee. If the surgery is canceled with adequate notice, for any reason, there will be a fee to cover administrative, laboratory, and additional overhead expenses. If you cancel without adequate notice, or if the surgeon must cancel the surgery because you have not complied with explicit instructions, half the total surgical fee will be retained. Thank you for your understanding in this matter.

_____ **Preoperative telephone calls.** Our staff routinely telephones patients for confirmation 2 to 4 days before surgery. If we are unable to reach you, we would appreciate it if you would telephone us 48 hours before the surgery to confirm the exact date and time of arrival.

I have read the above policy and consent to the routine preoperative laboratory studies, including an HIV test. The results of these tests will be placed in the patient's chart and will remain strictly confidential.

_____   _____
Patient's signature   Date

Before Liposuction Instructions

Our office wants to provide you with the very best surgical care. You can help to minimize the risk of complications by carefully reading and following your preoperative and postoperative instructions. Please ask us to clarify any item about which you have questions.

1. **Do not take aspirin** (Anacin, Bufferin, baby aspirin), **ibuprofen** (Advil, Motrin, Nuprin), naproxen (Aleve), or any other nonsteroidal antiinflammatory drugs (NSAIDs) similar to these medications, for 1 week before surgery; these will promote bleeding and bruising. It is permissible to take acetaminophen (Tylenol, Anacin-3).

2. **Do not drink alcohol for 4 days before surgery,** this might decrease resistance to infections. Similarly red wine, garlic powder supplements, and vitamin E impairs normal clotting and can predispose to excessive bleeding, and bruising.

3. **Do not take decongestants,** such as Sudafed or Actifed, for 1 week before surgery. **Do not take appetite suppressants,** such as Fastin (phentermine), for at least 2 weeks before surgery. **Do not take thyroid medication,** such as Synthroid (levothyroxine), on the day of surgery. These drugs can cause the heart to beat too rapidly. **Do not take antidepressants,** such as Zoloft (setraline), and herbal remedies, unless specifically approved by your surgeon, for 2 weeks before surgery.

4. **Do not drive home.** Before the day of surgery, make arrangements to have someone drive you home from the surgical facility.

5. **Do not wear** unnecessary jewelry; do not apply perfume (deodorant permissible); and minimize use of cosmetics.

6. **Diet before surgery.** If your surgery is scheduled to begin before 9:30 AM, do not eat solid food after midnight prior to surgery. If surgery is scheduled to begin after 9:30 AM, you may have a light breakfast before 8 AM, but only clear liquid for lunch. Please minimize caffeine the day of surgery. You will be given a snack as soon as surgery is completed.

7. **Dressings.** Changing your dressing the morning after surgery can usually be accomplished without assistance, but it is easier if you have someone to help you.

8. **Loose clothing.** There is usually considerable drainage of slightly blood-tinged anesthetic solution after surgery. Since this drainage might stain clothing, we suggest that you choose your clothing with this in mind. Because we will apply elastic support garments on top of some bulky absorbent gauze padding, your clothing should be very loose and comfortable.
   a. **Women.** Wear a comfortable bra that you would not mind getting stained from the blue ink that is used to mark the surgical areas. Do not wear an exercise sports bra if you are having liposuction on your abdomen or torso.
   b. **Men.** For liposuction of the abdomen or flanks, Speedo-type swim trunks are the easiest type of garment to wear into the operating room for surgery. Jockey-type underpants are acceptable. Boxer-type underpants are less convenient and may prevent optimal results. Bring extra underpants to wear after surgery.

9. **Socks and mittens.** You will be provided with cloth foot covers, but if your feet easily become cold, bring warm socks to prevent cold toes during surgery. If you tend to get cold hands, you are welcome to bring clean mittens (no leather gloves) to wear during the surgery. The operating room is kept relatively warm, about 72° to 75° F.

10. **Moisturizers.** Do not use moisturizers or soap that contains moisturizers for at least a week before surgery. The ink markers used to outline the areas on your body to be treated by liposuction will rub off too easily if you have recently applied a moisturizer to your skin.

11. **Towels and plastic sheets.** Plan ahead and avoid staining the car seat with blood-tinged anesthetic solution. Bring a towel and a plastic sheet (such as a trash can liner) to cover the car seat during your ride home. Before surgery, pad your bed at home and your living room chair with towels and plastic. Be careful to avoid allowing drainage to stain carpets.

12. **Weight and diet.** Do not fast or undergo dramatic weight loss just before surgery. All patients should be on a stable, healthy, well-balanced diet for at least 2 weeks before surgery. Liquid diets, extreme low-calorie diets, and rapid weight loss diets may predispose to cardiac irregularities, surgical complications, and poor wound healing.

13. **Music.** Patients usually enjoy listening to soothing quiet music during surgery. We have a large selection of compact discs (CDs). If you have any favorite CDs that you would like to share with us on the day of surgery, you are welcome to bring them with you. Please write your name on the plastic case that holds your CD.

Medications and Beverage that *Potentially* Interact with Tumescent Anesthetic

Consult your surgeon if you are taking any of the following:

Anesthetics
propofol (Diprovan)

Antibiotics/antimicrobials
clarithromycin (Biaxin)
chloramphenicol (Chloromycetin)
erythromycin
isoniazid
tetracycline
troleandomycin (TAO)

Anti–cardiac arrhythmia (antidysrhythmic) drugs
propafenone (Rythmol)
quinidine (Quinaglute, Quinidex)

Antidepressants
amitriptyline (Elavil)
clomipramine (Anafranil)
fluoxetine (Prozac)
fluvoxamine (Luvox)
nefazodone (Serzone)
paroxetine (Paxil)
sertraline (Zoloft)

Antiestrogen
tamoxifen (Nolvadex)

Antifungal Medications
fluconazole (Diflucan)
itraconazole (Sporanox)
ketoconazole (Nizoral)
metronidazole (Flagyl)
miconazole (Monistat)

Antihistamines
astemizole (Hismanal)
terfenadine (Seldane)

Antiseizure medications
carbamazepine (Tegretol)
divalproex (Depakote)
valproic acid (Depakene)

Benzodiazepines
alprazolam (Xanax)
flurazepam (Dalmane)
midazolam (Versed)
triazolam (Halcion)

Beta blocker
propranolol (Inderol)

Beverage
grapefruit juice

Calcium channel blockers
amiodarone (Cordarone)
diltiazem (Cardizem)
felodipine (Plendil)
nicardipine (Cardene)
nifedipine (Procardia)
verapamil (Calan)

H_2 Blockers
cimetidine (Tagamet)

Hormones
thyroxine
ethinylestradiol

Immunosuppressants
cyclosporine (Neoral, Sandimmune)

Miscellaneous
danozol (Danocrine)
methadone
mibefradil (Posicor)
pentoxifylline (Trental)
zileuton (Zyflo)

Protease inhibitors
indinavir (Crixivan)
nelfinavir (Viracept)
ritonavir (Norvir)
saquinavir (Invirase)

Psychotherapeutic drugs
clozapine (Clozaril)
pimozide (Orap)

Steroidal Antiinflammatory drugs
dexamethasone (Decadron)
methylprednisolone
prednisone

Information About Prescriptions and Medications

1. **Antibiotics,** such as cefadroxil and cephalexin (relatives of penicillin) or doxycycline (relative of tetracycline), are to be taken twice daily to minimize the risk of a surgical infection. Antibiotics should be taken with food to reduce the risk of gastric upset. Please start taking your antibiotic the day before surgery, and continue until the entire supply is completed. If your surgery is scheduled to begin in the early morning (before 9 AM), taking your antibiotic and eating should be postponed until after surgery.
2. **Lorazepam** is a <u>mild</u> sedative and a <u>mild</u> sleeping pill that does not make one feel "drugged." Surgery is more easily tolerated if the patient is well rested and relaxed. We suggest that you take one lorazepam the night before surgery.
3. **Mephyton** (vitamin K) will theoretically minimize bleeding and postoperative bruising. Although it is not essential to take vitamin K, we do recommend it. Take one 5-mg tablet daily, beginning 2 weeks before the surgery.
4. **Acetaminophen** (extra-strength Tylenol, 500-mg capsules or tablets) does not require a prescription. Taking two tablets three or four times daily, beginning after surgery should help minimize postoperative swelling. Take two tablets as needed to treat any minor pain before surgery. If for some reason Tylenol is not acceptable, notify us so that we can arrange for a suitable substitute.
5. **Diphenhydramine** (Benadryl 25-mg capsules or tablets) does not require a prescription. Taking as directed can help to reduce postoperative itching. Be aware that Benadryl may cause drowsiness.

Medication Precautions for Surgery Patients

1. **Do not take aspirin** (Anacin, Bufferin), **ibuprofen** (Advil, Motrin, Nuprin), **naproxen** (Aleve), or any medications that contain these drugs or any similar antiinflammatory medications for 1 week before and 3 days after surgery. These drugs will promote bleeding and bruising. Check the labels of all your medications, even those which you purchase without a prescription, to be sure you are not taking any aspirin or aspirin-like substances. Remove any products containing aspirin from your medicine chest so that you do not inadvertently take it during the week before your surgery. Consult your physician before you stop taking any prescribed medicines. Please inform us if you are taking any medications to treat arthritis or any blood-thinning anticoagulant medications. The following medications must be stopped:

Advil	Cephalgesic	Empirin	Indomethacin	Orudis	Sine-Off
Aleve	Cheracol Caps	Emprazil	ketoprofen	Oruvail	Sine-Aid
Alcohol	Children's Aspirin	Endodan	Ketorolac	Oxyphenbutazone	Sodium thiosalicylate
Alka-Seltzer	Choline salicylate	Excedrin	Lortab ASA	Oxybutazone	Soma Compound
Amigesic	Clinoril	Feldene	Magan	oxaprozin	Sulindac
Anacin	Congesprin	Fenoprofen	Magnesium	Pamprin	Synalgos DC
Anaprox	Cope	Feverfew	salicylate	Pepto Bismol	*Tanacetum*
Anaproxin	Coricidin	Fiorinal	Meclofenamate	Percodan	*parthenium*
Ansaid	Corticosteroids	Flurbiprofen	Meclofen	Persantine	Tolectin
APC	Coumadin	Froben	Medipren	Phenaphen	Tolmetin
Argesic	Darvon ASA	4-Way Cold Tabs	Mefenamic acid	Phenylbutazone	Toradol
Arthra G	Darvon Compound	Garlic capsules	Menadob	Piroxicam	Trandate
Arthropan	Daypro	Gelpirin	Midol	Ponstel	Trendan
A.S.A.	Depakote	Genpril	Mobidin	Prednisone	Trental
Ascodeen	Dexamethasone	Genprin	Monogesic	Quagesic	Trigesic
Ascriptin	Diclofenac	Ginko Biloba	Motrin	Relafen	Trilisate
Aspergum	Dipyridamole	Goody's Body Pain	Nabumetone	Rexolate	Tusal
Aspirin	Disalcid	Haltran	Nalfon	Robasissal	Vanquish
BC Powder	Divalproex	Halfprin	Naprosyn	Roxiprin	**Vitamin E**
Baby Aspirin	Doan's Pills	Ibuprin	Naproxen	Rufin	Voltaren
Bayer	Dolobid	**Ibuprofen**	Norgesic	Saleto	Warfarin
Brufen	Dristan	Ibuprohm	Norwich	Salflex	Willow bark
Bufferin	Easprin	Indameth	Nuprin	Salsalate	Zactrin
Butazolidin	Ecotrin	Indocin	Ocufen	Salsitab	Zorprin

2. Do not take decongestant medication containing pseudoephedrine (Sudafed, Actifed) for 1 week before surgery. These can cause the heart rate to beat too rapidly.
3. Do not take thyroid hormone such as Synthroid (levothyroxine) on the day of the surgery. Thyroid medication might interact with the anesthetic solution and cause a rapid heart rate.
4. Appetite suppressant drugs such as Fastin (phentermine) should not be taken for at least 2 weeks before surgery. Do not stop appetite suppressants abruptly because you may have side effects. To avoid side effects such as depression, it is better to begin decreasing the dose gradually 2 weeks before surgery. Maintain a healthy diet. Do not attempt an aggressive weight loss diet before surgery.
5. Do not take antidepressants, such as Zoloft (setraline) or tricyclics for 2 weeks before surgery. Please consult your prescribing physician before discontinuing any of your prescribed medications.

What to Expect on the Day of Tumescent Liposuction

1. On arriving in the surgical facility reception area, you will be greeted and asked to sign your surgical-consent forms. You will then change into a surgical gown and be escorted to the operating room. After one last trip to the bathroom, preoperative photographs will be taken, and the areas on your body that are to be treated with liposuction are marked with a felt-tip pen. Next, you will lie down on the surgical table, and the nurse will show you the various positions you will be required to assume during the surgery. Practicing these positions before the surgery helps make the surgery go faster and easier. It usually takes about 30 to 45 minutes after arrival before the surgery begins.

2. For safety purposes, we routinely place an intravenous (IV) access in your arm; it consists of a small plastic IV tube with a rubber stopper on the outside through which medication can be injected if needed. The IV access is much like the car seat belt; it is put in place routinely but it is only rarely needed. A blood pressure cuff is placed on your opposite arm, and cardiac monitor leads are placed on your chest. Next, using extremely thin and short little needles, the physician or the nurse will anesthetize the skin at sites where the longer needles will be inserted to anesthetize the subcutaneous fat. Patients usually experience a slight pricking sensation as the skin becomes "numb."

3. A large volume of dilute tumescent anesthetic solution is carefully and gently injected into the targeted fat. Once an area has been well infiltrated with the anesthetic solution, the fat is usually completely numb. The infiltration of the local anesthetic is a slow, careful process that can occasionally take as long to complete as the liposuction itself. After the infiltration of the anesthetic is complete, but before beginning liposuction, you will be escorted to the bathroom one more time.

4. Experience has shown that giving a sedative by mouth permits better local anesthesia than when IV sedatives are used. This is because an alert patient is more capable of detecting subtle areas of incomplete anesthesia. A patient who is too sedated might easily ignore an incompletely anesthetized area, then feel more discomfort when liposuction is actually done. Therefore minimizing sedation actually maximizes patient comfort.

5. After completing liposuction, patients are offered a snack. Absorbent pads are placed over the incisions. The incisions are so small that no stitches are required. Finally, after the IV line is discontinued and the compression garments are pulled on, you are ready to go home. Because of residual local anesthetic, no significant soreness begins for several hours after completing the liposuction. Although you will feel well enough after surgery to drive yourself home, you must not do so because large amounts of local anesthetic may cause some drowsiness.

6. The tumescent technique minimizes postoperative discomfort. Because the residual local anesthesia lasts for 18 to 36 hours, plain Tylenol is sufficient to treat postoperative discomfort. With the tumescent technique the patient has no postsurgical nausea and no unpleasant feeling of a "hangover" usually associated with general anesthesia.

After Liposuction Instructions

1. **Going home.** You should not plan to drive yourself home. It is recommended but not essential that you have a responsible adult be with you on the day of surgery. Resume your usual diet immediately. Drink adequate amounts of water, fruit juices, or soft drinks to prevent dehydration. Avoid drinking alcoholic beverages for 4 days before surgery and 48 hours after surgery.

2. **Activities.** Quiet rest is recommended immediately after surgery. After surgery do not drive or operate hazardous machinery the rest of the day. Do not make any important personal decisions for 24 hours after surgery. Later in the day or the evening of surgery you may take a short walk if desired. The day after liposuction surgery you should feel well enough to drive your car and engage in light to moderate physical activities. You may carefully resume exercise and vigorous physical activity 2 to 4 days after surgery. It is suggested that you begin with 25% of your normal workout and then increase your activity daily as tolerated. Most people can return to a desk job within 1 to 2 days after surgery, although one must expect to be sore and easily fatigued for several days.

3. **Postoperative garments.** After tumescent liposuction, postoperative garments (two garments or one garment plus elastic binders) are worn to hold the absorbent pads in place and to provide sufficient compression to accelerate the drainage of the blood-tinged anesthetic solution. The morning after surgery, when the garments are first removed in order to take a shower, the patient may experience a brief sensation of dizziness. Feeling lightheaded is similar to what you might experience when standing up too quickly. It is the result of rapid decompression of the legs as the garments are initially removed. Should dizziness occur, simply sit or lie down until it passes. Dizziness may be prevented by removing the first (top) garment 10 to 15 minutes before removing the second garment.

   Beginning the day after surgery the garments are to be removed daily to permit you to wash the garments and to shower and change the absorptive pads. Do not be concerned if you drain for several days. The garments and binders should be worn day and night until all drainage has ceased, *plus an additional 24 hours*. Discontinuing the use of the garments and binders too soon may result in prolonged drainage. Subsequently, garments and binders can be worn for comfort but are not essential. Wearing garment for more than the minimal number of days is of no significant advantage in terms of the ultimate cosmetic results, but some patients wear the garment for additional days or weeks because of the comfort provided by the support.

4. **Postoperative drainage.** One should expect a large volume of blood-tinged anesthetic solution to drain from the small incisions during the first 24 to 48 hours following tumescent liposuction. In general, the more drainage there is, the less bruising and swelling there will be. For the first 24 to 36 hours, bulky superabsorbent dressings are worn under the garment. After most of the drainage has stopped, patients need only place thin, absorbent gauze dressings over the incision sites that continue to drain. During the first 36 hours after surgery there is a risk that drainage may leak beyond the pads. To prevent staining furniture or fabric, it is advisable to sit or lie on a plastic sheet covered by towels.

5. **Wound care and bathing.** Keep incisions clean. Shower once or twice daily. First, wash your hands, then wash incisions gently with soap and water; afterward, gently pat incisions dry with a clean towel. Apply new absorbent dressings. Incisions that have stopped draining for more than 24 hours need not be covered with absorptive pads. *Take antibiotics as directed until the prescription is finished.* Take antibiotics with food. Call our office if you notice signs of infection, such as fever, foul-smelling drainage, or focal redness, swelling, or exceptional pain in a treated area.

   a. Do not apply ice packs or a heating pad to skin overlying the areas treated by liposuction.

   b. Do not apply hydrogen peroxide or plastic Band-Aids to incision sites.

   c. Do not soak in a bath, Jacuzzi, swimming pool, or the ocean for 7 days after surgery.

6. **Common side effects of tumescent liposuction.** *Menstrual irregularities* with premature or delayed onset of monthly menstruation are common side effects of any significant surgery. *Flushing* of the face, neck, and upper chest may occur after liposuction surgery and usually lasts for 1 or 2 days. *Slight temperature elevation* during the first 48 hours after surgery is a natural consequence of the body's reaction to surgical trauma. *Discomfort and soreness* is worse the second day after surgery, then improves daily. Two extra-strength Tylenol every 4 hours, while awake, for the first 48 hours, will reduce the inflammation, swelling, and soreness associated with surgery. Do not take aspirin, ibuprofen, or medications that contain these drugs, (Bufferin, Anacin, Advil, Nuprin) for at least 4 days after surgery; these can promote bleeding. *Bruising* is minimal with tumescent liposuction. Nevertheless, the more extensive the liposuction surgery, the more bruising one can expect. *Pain and swelling* due to an inflammatory reaction to surgical trauma may occur and increase 5 to 10 days after surgery; this is treated with antibiotics and antiinflammatory drugs. *Itching* of the treated areas several days after surgery may occur as part of the normal healing process. To help relieve the itching, you may try taking Benadryl as directed on the packaging. Be aware that Benadryl causes drowsiness. Benadryl may be purchased without a prescription at most drugstores.

7. Schedule a follow-up appointment at our office for approximately 6 weeks after surgery. You are welcome to return to our office for follow-up visits at no charge as often as you like. Please contact us by telephone or beeper if you have any urgent questions.

Surgical facility During office hours Tel: After office hours: Tel:	Name of surgeon, MD #1 After hours Pager: Home tel:	Name of surgeon, MD #2 After hours Pager: Home tel:	Name of Nurse, RN, *or supervisor* Pager:

Patient's signature	Patient's telephone number immediately after surgery	Nurse's signature

Short History and Physical Examination

Patient's name _____ Age _____

Chief concern/complaint: Localized adiposity

Maximum weight _____   Maximum weight pregnant _____   Present weight _____

Significant past medical history:

Medications causing adverse or allergic reactions:

Prescription medications, regular/intermittent:

Over-the-counter and, nonprescription medication, herbal remedies, vitamins, and weight loss drugs:

Previous surgeries:

Review of systems

Yes	No	
( )	( )	Prior liposuction?
( )	( )	Any complications with previous surgeries?
( )	( )	Hepatitis or liver disease?
( )	( )	Heart problems or irregular heartbeat?
( )	( )	Problems with high blood pressure?
( )	( )	Abdominal or inguinal hernias?
( )	( )	Asthma or lung problems?
( )	( )	Kidney or thyroid problems or diabetes?
( )	( )	Previous back injury or nerve injuries?
( )	( )	History of seizures or neurologic or psychiatric problems?
( )	( )	History of lightheadedness or fainting?
( )	( )	History of excessive bleeding or scarring?
( )	( )	Personal or family history of blood clots in legs or lungs or leg swelling?
( )	( )	History of a transfusion?
( )	( )	History of chronic viral infection?
( )	( )	Are you pregnant?
( )	( )	Any family history of severe reactions to anesthesia or malignant hyperthermia?

Physical examination

Preoperative examination vital signs: Blood pressure: Temperature: Heart Rate: Respiratory rate: Height: Weight:

Normal	Abnormal	
( )	( )	General appearance
( )	( )	Head, eyes, ears/nose/throat
( )	( )	Heart: cardiac rhythm, heart sounds
( )	( )	Lung sounds
( )	( )	Abdominal examination (periumbilical hernia)
( )	( )	Genitourinary examination (if indicated)
( )	( )	Neurologic, spinal, or extremity examination

Provisional diagnosis: Localized adiposity

Surgeon's signature _____   Date/time: _____

Tumescent Anesthesia Operating Room (OR) Record

Allergies:	ASA status: I or II	Preoperative hematocrit:	Circulating nurse:	Infiltrating nurse:	Prepared by:	Diagnosis: Localized adiposity
Time arrived in OR:	OR #		Anesthesia start:	Surgery start:	Surgery stop:	Anesthesia stop:
Surgeon:	IV saline lock: 22-gauge 1-inch, left/right antecubital fossa, started by:				Observer:	

Initial medications in bag of 0.9% NaCl	1	2	3	4	5	6	7	TOTALS
Epinephrine (mg ordered & hung)								
Sodium bicarbonate	10 mEq	10 mEq	10 mEq	10 mEq	10 mEq	10 mEq	10 mEq	
Lidocaine (mg ordered & hung) [A]								
Milliliters (ml) of bag infiltrated [B]								
Initial ml in bag [C]								
Lidocaine mg infiltrated [A × (B/C)]								

Intraoperative medications	Dosage	Route	Time	Given by	Reason given	Effect

Physician informed of patient's lidocaine dosage _____ mg/kg at _____ by _____, RN

Preoperative checklist   Times

- ☐ Patient's ID checked
- ☐ Consent signed
- ☐ Preoperative laboratory studies in chart
- ☐ History and physical exam complete
- ☐ Temperature _____
- ☐ Preoperative medications
- ☐ IV saline lock
- ☐ Blood pressure and ECG monitor

ECG rhythm oximeter %

(graph grid: 200, 190, 180, 170, 160, 150, 140, 130, 120, 110, 100, 90, 80, 70, 60, 50, 40, 30, 20, 10)

Areas treated	Infiltration Begin	End	Suction Begin	End	Areas Treated	Infiltration Begin	End	Suction Begin	End

Volume total aspirate:	ml	Total ml anesthetic solution:	ml	Total lidocaine dose:	mg
Volume supranatant fat:	ml	Total volume IV fluids infused:	ml	Patient's weight: lb;	kg
Volume infranatant blood-tinged anesthetic:	ml	Urine voided ×		Lidocaine dosage:	mg/kg

Patient recovered in OR at _____. See Postoperative care plan for further charting and orthostatic blood pressure and vital signs _____, RN

Abdomen lower	Thighs, lateral	Hips	Date and patient information:
Abdomen upper	Inferolateral buttocks	Waist	
Female breasts	Thighs, inner	Female flanks	
Male flanks	Knees, inner	Postaxillary areas	
Male breasts	Thighs, anterior	Arms	
Chin, jowls, neck	Knees, anterior	Buttocks	

Tumescent Liposuction Orders

Preoperative

1. Patient's name: _____ Account no: _____ Date of surgery: _____.
2. Diagnosis: Lipodystrophy/localized adiposity (278.1)
3. Signed surgical consent for liposuction
4. Anticipated duration of case:
5. Preoperative laboratory test results in chart: chem panel, CBC, PT, PTT, HCV, HIV
6. Diet: Patient may take clear liquids before and during surgery
7. Start IV access: PRN adapter (saline lock)
8. Photo consent signed and in chart
9. On arrival to surgical facility, give preoperative oral medications: acetaminophen, 500 mg, two tablets; clonidine, 0.1 mg if blood pressure greater than 100/60 and heart rate greater than 60; after markings, give lorazepam, 1 or 2 mg, as necessary for anxiety only.
10. Give atropine, 0.3 to 0.4 mg IV before surgery, only with physician's signature.

    Physician signature: _____.
11. Do not prepare anesthetic solution until surgeon has written and signed the orders below.
12. Additional orders:

Intraoperative

1. Recipe for anesthetic solution: (today's preoperative weight _____ kg).

   Lidocaine administered by RN should be less than _____ mg/kg.

   Area(s): _____ : Lidocaine _____(mg) Epi _____(mg)

   Area(s): _____ : Lidocaine _____(mg) Epi _____(mg)

   Area(s): _____ : Lidocaine _____(mg) Epi _____(mg)

   Area(s): _____ : Lidocaine _____(mg) Epi _____(mg)

   Add sodium bicarbonate 10 mEq per 1000-ml bag of 0.9% NaCl or Ringer's lactate.

2. May give midazolam, 1 mg slow IV push over 1.5 minutes or IM, as necessary for anxiety. May repeat in 15 minutes.
3. If midazolam is required, place pulse oximeter on patient before administration.
4. Inform physician of lidocaine dosage (mg/kg) before suction.
5. Additional orders:

Postoperative

1. After orthostatic blood pressure and pulse are taken and within normal limits, may discontinue IV access (PRN adapter).
2. Postoperative dressings: Apply standard sterile absorbent pads and compression garment.
3. Give to patient written aftercare instructions. Instruct patient to avoid taking lorazepam for 24 hours.
4. Patient in recovery area until discharge criteria met and orthostatic vital signs stable; may discharge 30 minutes after surgery. If midazolam or narcotic analgesics have been given, discharge 60 minutes after last dose.
5. Acetaminophen, 500 mg, two tablets orally, every 4 hours, while awake, as necessary for pain.

Signature_____ Date/Time_____

Tumescent Liposuction Preoperative and Postoperative Care Record

Preoperative Nursing Evaluation Liposuction of: _____

Admission date & arrival time:	Driver's name/phone no:	Time will call us:
Vital signs: Temp: BP: HR: RR: Wt: LOC:	General appearance/major complaints:	
Regular medications taken:	Any SSRI antidepressants, erythromycin, or antifungal drugs taken within 10 days?	
Occasional medications taken:	Any ASA, baby aspirin, ibuprofen, red wine, or vitamin E taken within 10 days?	
Preoperative medications taken:	Drug Allergies:	
Previous surgeries:	Any Complications:	

Yes	No		Yes	No		Yes	No	
		ID Check			Smoker			Dentures/partials
		History and physical exam present and complete			Chronic cough/lung problems			Hearing aid
		Consent signed			Heart problems/palpitations/HTN			Glasses
		Laboratory results complete/date drawn			Gastrointestional problems			Contact lenses
		NPO except liquids since _____			Liver problems			Necklace(s)
		Recent skin injuries or rash			Kidney problems			Ring(s)
		History of bleeding disorder			Diabetes			Earrings
		History of bad reaction to anesthesia, self/family			Hypoglycemia			Wristwatch
		History of serious back or nerve injury			Breast implants			Music CDs
		Nursing diagnosis: Alteration in body image with regard to localized fat and/or obesity						Belongings locked; (*) if taken to OR

Preoperative Teaching Plan

Yes	No			
		Description of drawings and photos	Time at which patient entered OR:	
		Description of IV access and therapy	Signature of RN who admitted patient:	
		Description of infiltration of local anesthetic		
		Description of pain control	Signature of RN who gave preoperative teaching:	
		Preoperative medications given:		

Postoperative Care and Discharge Plan (See Anesthesia/OR Record for vital signs)

Yes	No		
		Recovered in OR or recovery room (circle one) with RN in constant attendance	Medications given in recovery period:
		Patient tolerated procedure well	
		Fruit plate/snack and oral fluids offered (_____ % taken, _____ ml taken)	
		Moderate blood-tinged anesthetic fluid draining from incision sites	
		Absorbent dressings applied and explained (two extra sets given)	Signature of RN giving medications:
		Compression garments applied: garment(s), binders, Ace wrap; sizes: _____	
		IV access disconnected with cannula intact and no redness or edema noted	Postoperative orthostatic vital signs:
		Verbal and written postoperative instructions given	Supine—BP: _____ HR: _____ Time: _____
		Ambulatory, steady gait, to lavatory to void, to dressing room, dressed self (time: _____)	Sitting—BP: _____ HR: _____ Time: _____
			Standing—BP: _____ HR: _____ Time: _____
		Skin warm, dry, color normal; alert and oriented × _____	

Discharged from surgical facility to: _____ Time: _____ RN signature: _____

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