

Updates and Advances in Liposuction

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Learning Objective

At the conclusion of this CME activity, the participant should be able to analyze anatomic, biochemical and physiological considerations in liposuction, classify risk factors, and formulate a liposuction surgical plan for optimum patient safety and aesthetic results.

Abstract

Liposuction has evolved tremendously over the past three decades. Since its introduction by Illouz it has progressed into one of the most popular procedures in plastic surgery. The objective of this CME is to provide a foundation of knowledge with respect to anatomy, physiology, preoperative, intraoperative, and postoperative management of patients scheduled to undergo liposuction. A review of both the immediate and delayed complications related to liposuction is addressed, as well as relevant surgical site-specific pearls for patients undergoing liposuction. Finally a summary of the various operative techniques available for surgeons is discussed along with information related to relevant emerging technology in body contouring.

Keywords

lipoplasty, liposuction, body contouring

Disclosures

Dr. Kenkel is a paid consultant for UltraShape, an investigator for UltraShape and Lumenis, and a consultant for Ethicon Endosurgery. He receives honoraria from Lumenis and Ethicon Endosurgery. He also receives equipment for research from Sciton, Eclipse, and Lumenis. This article underwent a special Conflict Resolution mechanism to ensure balance, independence, and objectivity. This activity will include the off-label uses of Mesotherapy, Lipodissolve™, UltraShape®, LipoSonix™, Bobytite™ and Zeltiq™. The planners of this activity have nothing to disclose.

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Liposuction has long been one of the most popular treatment modalities in aesthetic surgery in the United States. According to the American Society for Aesthetic Plastic Surgery, more than 341,000 liposuction procedures were performed in 2008 and it was ranked second among all invasive cosmetic procedures.¹ Introduced by Illouz in the early 1980s, the liposuction technique has undergone a great transformation to get to its current state,² part of which is attributable to the tremendous advances in medical technology over the past 30 years. A greater understanding of the biochemical and physiological properties of liposuction has also greatly improved

the blood loss and overall safety of liposuction. Still, liposuction is a procedure that is not without risks. Significant morbidity and adverse outcomes can occur

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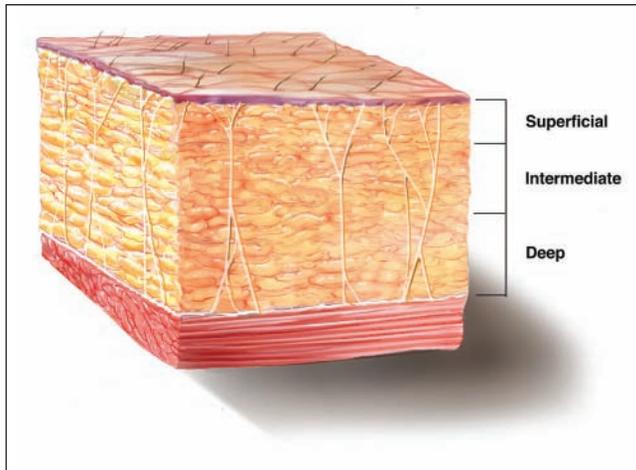


Figure 1. Surgical layers of fat: superficial, intermediate, and deep.

when undertaken by untrained hands. Aesthetic body contouring with liposuction requires a complete knowledge of the anatomic, biochemical, and physiological basis of liposuction. It also requires a thorough understanding of patient needs and knowledge of the many treatment modalities, the benefits and limitations of each, and the potential adverse outcomes and methods of correcting them should they occur. Using a coordinated, thorough approach, liposuction can be performed safely with predictable results and outcomes.

ANATOMIC CONSIDERATIONS

Anatomy texts divide subcutaneous fat into layers separated by Scarpa's fascia or the superficial fascial equivalent. However, for the purposes of liposuction and body contouring, subcutaneous fat is arbitrarily divided into three layers: superficial, intermediate, and deep (Figure 1).^{3,4} Anatomically, the properties of these layers allow a surgeon to know which can be safely suctioned and which require extreme caution to prevent contour irregularities and possible skin injury. In general, the deep and intermediate layers are suctioned and the superficial layer remains undisturbed.³

Additional anatomic considerations include the fatty and fibrous nature of the layers in different areas of the body. The consistency and thickness of each of these fatty layers is specific to the anatomic area. For example, the fat of the back has a more fibrous, compact superficial and intermediate layer, with an underlying loose, areolar layer. This contrasts with the fat of the inner thigh, which is not as fibrous and is less compact.³ The variation in fat consistency and depth will be discussed further as it relates to safe suctioning techniques and which modalities may be preferred for most effective treatment. Finally, the anatomic "zones of adherence," which are present in both men and women, are important to identify preoperatively. These are areas of relative dense fibrous attachment to underlying deep fascia, and they help define the natural shape and curve the body.⁵ Gender-specific variation occurs with respect to these zones (Figure 2). It is

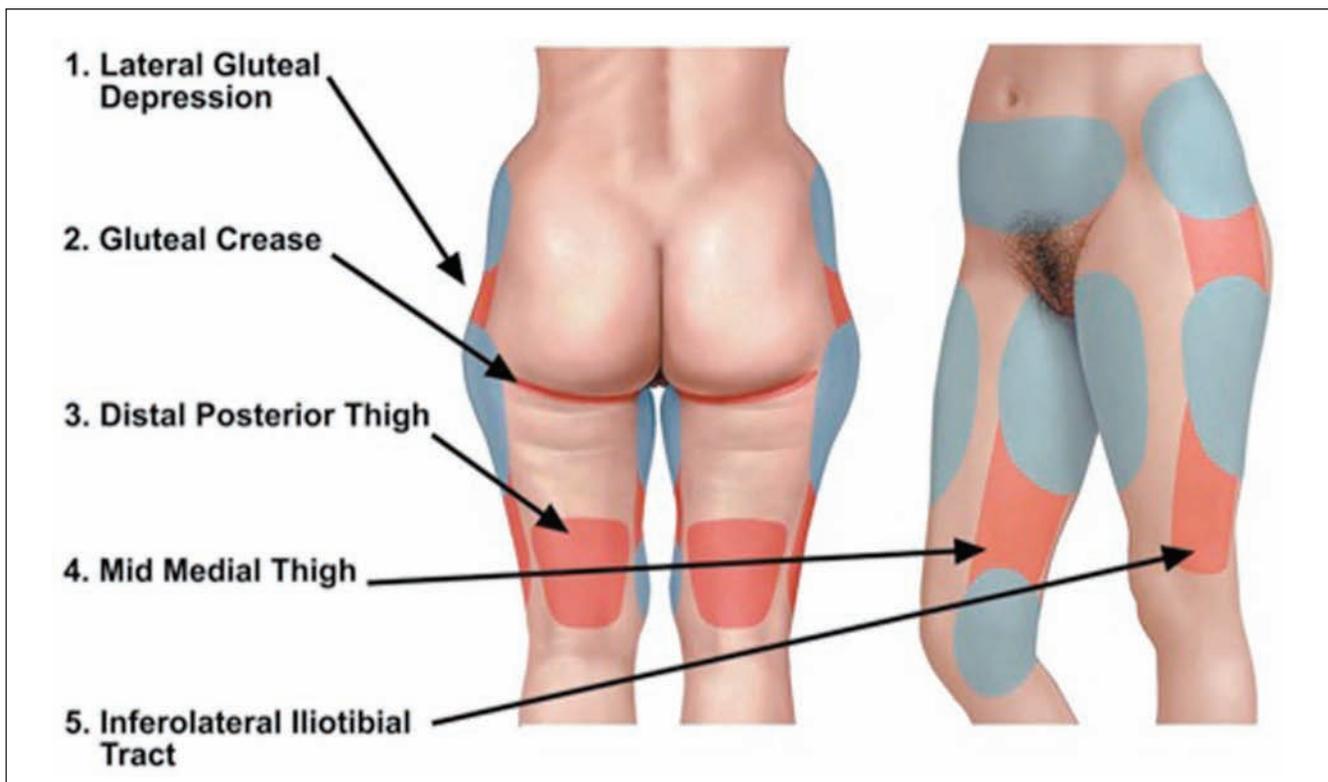


Figure 2. Anatomic zones of adherence, which are areas of relative dense fibrous attachment to underlying deep fascia that help define the natural shape and curve the body. These exist in both men and women and are important to identify. Reprinted with permission from Rohrich RJ, Smith PD, Marcantonio DR, Kenkel JM. The zones of adherence: role in minimizing and preventing contour deformities in liposuction. *Plast Reconstr Surg* 2001;107:1562-1569.

important to recognize these zones, as they are at high risk for contour irregularities after surgical intervention if not properly respected.

Cellulite is dimpling of the skin most commonly seen in the lower extremities and buttocks. The exact etiology is poorly understood but is thought to be tied to the relationship between fibrous dermal attachments to the underlying fascia and the surrounding hypertrophied fat.⁶ It does appear to be hormonally mediated. The use of liposuction to treat cellulite is unpredictable and not recommended.⁷

PATIENT SELECTION AND EVALUATION

Liposuction patients often present to the surgeon with a variety of complaints, inquiries, and expectations. It is the physician's responsibility to properly assess a patient, diagnose problem areas, and formulate a treatment plan to provide optimal results, keeping in mind that not all patients are candidates for liposuction. A successful body contouring patient must satisfy four key elements to achieve and maintain optimal results.⁸

1. Lifestyle change
2. Regular exercise
3. Well-balanced diet
4. *Body contouring*

As is evident above, only one of four factors (the final one, in italics) is influenced by the operating surgeon. It is imperative that the patient's motives, expectations, and goals are fully discussed prior to performing liposuction, so that the potential benefits of the procedure may be realistically assessed. As has been shown previously, patients who embrace diet, exercise, and a healthy lifestyle are much more likely to lose weight, be satisfied with results, have higher self-esteem, and have increased productivity.⁸

Once the patient's goals and realistic expectations are set, a thorough history and physical exam should be performed to assess patient suitability for surgery. Especially important are notations in the medical history of diabetes, massive weight loss, previous surgery, previous liposuction, and full detailed list of medications. Any concerns about a patient's medical suitability to undergo anesthesia and/or an operative procedure should result in referral for preoperative clearance with either an internist or cardiologist. It is prudent to notify the consulting physician of expected operative times and the amount of expected aspirate and infiltrate. Often, our medical colleagues view liposuction as a very benign operation with minimal operative time and morbidity when in fact a large-volume liposuction case can have significant fluid shifts and time under general anesthesia.⁹ Of note, massive weight loss patients should undergo the same preoperative evaluation and clearance for liposuction as they would for excisional body contouring (including nutrition, hemoglobin, iron, B12, etc.).¹⁰

With regard to medication review, it is essential that the surgeon identify all medications prescribed to the patient, as well as any supplements or vitamins the patient may be taking. Herbal remedies and supplements are not regulated by

the Food and Drug Administration (FDA) and thus may have unknown or adverse consequences with respect to bleeding complications or hypercoagulability.¹¹ In cosmetic surgery, knowledge of aspirin or nonsteroidal anti-inflammatory drug (NSAID) use, as well as any history of hormone use, can be significant in preventing postoperative complications. It is the authors' policy for patients to discontinue use of all NSAIDs, aspirin products, fish oil, and supplements three weeks prior to surgery. If there is a medical indication for these drugs, consultation with the primary physician or appropriate specialist should be completed before discontinuation. Oral contraceptives and estrogens are discontinued one month prior to the procedure.¹²

A detailed physical exam is performed at the first visit. Specific attention to prior scars, presence or absence of hernias, evidence of venous insufficiency, and presence of pre-existing asymmetry or contour irregularity should be discussed and noted in the chart. At the initial and subsequent visits, height and weight with calculation of body mass index (BMI) is paramount for safety, as well as for observation of long-term trends during follow-up. For liposuction candidates, six key elements should be documented:

1. Evaluation of areas of lipodystrophy and contour deformities
2. Skin tone and quality
3. Asymmetries
4. Dimpling and cellulite
5. Myofascial support*
6. Zones of adherence⁵

The exam is best performed in front of a mirror. This allows an open dialogue between patient and physician, wherein the patient's concerns can be addressed and previously unrecognized problem areas can be assessed. Any areas of cellulite should be pointed out to the patient, and a specific discussion of expected outcome in these areas should be noted.^{6,7} At the initial evaluation, high-quality medical images should be obtained, with anterior, posterior, lateral, and oblique views. This will allow for documentation of results, as well as objective evaluation of outcomes by both patient and physician. When feasible, a medical photographer should be employed to provide consistent, high-quality images.¹³

INFORMED CONSENT

Informed consent is a crucial process required by law to protect both the patient and the operating surgeon. It allows the patient to fully appreciate the risks and benefits of the operation and make informed decisions. This process should detail the procedure itself, as well as the risks,

*A thorough evaluation for hernias should be performed; of particular concern are larger patients with prior abdominal incisions. These patients may require computed tomography [CT] scanning to confirm the presence or absence of an occult hernia.⁴



Figure 3. The authors' preferred preoperative markings and placement of access incisions.

benefits, alternatives, and expected outcomes. The common risks, as well as those specific to liposuction, should be discussed. Risks such as ecchymosis, edema, seroma, volume changes, and fluid overload should be included if ultrasound or other modalities are to be used. Specific additional risks such as thermal injury and paresthesias should also be disclosed. These discussions should occur well before the initial surgery; often, a follow-up visit prior to surgery is scheduled to answer additional questions. The American Society for Aesthetic Plastic Surgery (ASAPS) and American Society of Plastic Surgeons (ASPS) provide useful information regarding informed consent, along with pamphlets for patient information and education.

PREOPERATIVE MARKING

Preoperative marking is paramount to successful liposuction. The patients should be marked in the standing position and in front of a mirror, if possible. This allows the patient to contribute to the process and further confirms exactly what will be addressed during the procedure. The four-position stance noted above is preferred. Areas to be suctioned are marked with a circle; zones of adherence and areas to avoid are marked with hash

marks. Asymmetries, cellulite, and dimpling are marked for their respective treatment. When complete, the marks are once again reviewed with the patient to ensure that all areas of concern are addressed.^{3,4} Access incisions are also marked at this setting.

With liposuction, it is beneficial to choose access points that can treat multiple areas. Incisions should also allow each area to be treated from different directions for optimal contouring. Incisions should be no longer than 3 to 4 mm in length and placed in well-concealed areas. Of note, ultrasound-assisted liposuction (UAL) requires slightly larger incisions (5-6 mm) than traditional liposuction to account for skin protector placement (when utilized), which prevents heat transmission to the skin edge. The surgeon should not hesitate in placing additional incisions if access is insufficient with the existing markings. Figure 3 shows the preoperative markings and preferred placement of access incisions based on areas to be suctioned. Cosmetically, it is preferable to stagger incisions in an asymmetric fashion to camouflage their appearance.^{3,4} It is our opinion that poorly healed scars are undesirable and are a telltale sign of the procedure. We close these as we would any other wound.

PATIENT POSITIONING

Intraoperative patient positioning will vary based on the location to be treated and whether any additional procedures are planned. In general, the prone and supine positions are preferred for liposuction because patients can be treated bilaterally, and the surgeon can visualize each side to confirm symmetry. We prefer to avoid the lateral decubitus position, as access is limited and there is no ability to compare sides for symmetry. In our experience, up to 75% of the liposuction procedure can be performed in the prone position.⁴ The arms, back, hips/flanks, lateral/posterior areas, and partial medial thighs can be treated from this position. Appropriate padding of the hips, breasts, neck, and face/orbits is crucial to preventing avoidable intraoperative or postoperative complications. The supine position is utilized for the remainder of thighs and abdomen. Figure 4 shows a diagram of prone positioning.

ANESTHESIA TECHNIQUE/LOCATION OF OPERATION

The choice of anesthesia technique for liposuction varies based on multiple factors: operating surgeon preference, anesthesiologist preference, amount of expected lipoaspirate, length and extent of procedure, patient positioning, and overall health of the patient. Descriptions of local anesthesia, various forms of sedation (mild, moderate, heavy), and general anesthesia are present in the literature. No single technique of anesthesia has proven superior over another. However, the practice advisory on liposuction does recommend avoiding epidural and spinal anesthesia in office-based settings because of potential hypotension and volume overload issues.¹⁴



Figure 4. Prone positioning. In the authors' experience, up to 75% of the liposuction procedure can be performed in this position. Appropriate padding of the hips, breasts, neck, and face/orbits is crucial to preventing avoidable intraoperative or postoperative complications. Reprinted with permission from Rohrich RJ, Beran SJ, Kenkel JM. *Ultrasound-Assisted Liposuction*. St. Louis, MO: Quality Medical Publishing; 1998.

Small-volume liposuction cases can be performed with local anesthesia, with or without mild sedation. Complex, large-volume liposuction and combined cases should be performed under general anesthesia. Our institutional preference has been to perform the majority of cases under general anesthesia. Deep-sedation cases and general anesthesia procedures are performed under supervision of board-certified anesthesiologists in licensed surgery centers or hospitals. All prone cases are performed with general endotracheal anesthesia for airway control. It is ultimately up to the operating physician and the anesthesiologist to choose the most effective modality for treating the patient, but the ultimate goal should be patient safety.

Operative location should be determined after careful patient evaluation, assessment of the complexity of operation, and appropriate evaluation of medical comorbidities. The anticipated postoperative course and the need for possible overnight observation both factor into choice among inpatient, observation, or outpatient hospital settings. Special importance should be given to medical comorbidities such as obstructive sleep apnea.¹⁵ Current American Society of Anesthesiology recommendations are that, for patients with signs or symptoms suggestive of moderate to severe obstructive sleep apnea, surgery be performed in a hospital setting with extended recovery and observation to prevent postoperative respiratory complications.¹⁶ It is recommended that liposuction procedures, whether inpatient or outpatient, be performed in an accredited facility with the capability to manage the unique postoperative issues that sometimes arise with these patients.^{14,17} Ultimately, it is the operating surgeon's decision, but the risks and benefits of the proposed operation should thoroughly be weighted and a location chosen that best suits patient needs and safety.

WETTING SOLUTIONS

Initially, liposuction was performed without any wetting solutions. This led to blood loss of up to 45% of aspirate

Table 1. Common Formulas for Wetting Solutions, as Described by Rohrich et al³

Klein's Formula	Hunstadt's Formula
Normal saline solution, 1000 mL	Ringer's lactate, 1000 mL at 38°C to 40°C
1% lidocaine, 50 mL	1% lidocaine, 50 mL
1:1000 epinephrine, 1 mL	1:1000 epinephrine, 1 mL
8.4% sodium bicarbonate, 12.5 mL	
	University of Texas Southwestern Medical Center Formula
Fodor's Formula	
Ringer's lactate, 1000 mL	Ringer's lactate, 1000 mL at 21°C
Aspirates < 2000 mL	Aspirates < 5000 mL
1:500 epinephrine, 1 mL	1% lidocaine, 30 mL
Aspirates 2000-4000 mL	Aspirates ≥5000 mL
1:1000 epinephrine, 1 mL	1% lidocaine, 15 mL
Aspirates > 4000 mL	1:1000 epinephrine, 1 mL
1:1500 epinephrine, 1 mL	

in some areas.^{18,19} Liposuction has evolved over time to include the addition of wetting solutions prior to suctioning to improve hemostasis and pain control. Some authors have popularized different variations of these solutions,¹⁸⁻²¹ but all of the formulations include some variant of fluid (NS/LR), epinephrine, and lidocaine. Marcaine should be avoided because of its potential cardiac effects and duration of action; it has yet to be proven clinically as a suitable anesthetic in wetting solutions.¹² The most common solution mixtures are shown in Table 1.

The current options for wetting solutions are dry, wet, superwet, and tumescent (Tables 2 and 3). The dry technique actually employs no wetting solution and has few indications in liposuction.¹⁴ The wet technique involves instillation of 200 to 300 mL of solution per area to be treated, regardless of the amount aspirated. The superwet technique employs an infiltration of 1 mL per estimated mL of expected aspirate, and this is the technique practiced at our institution.^{18,19,22} Tumescent infiltration, popularized by Klein, involves infiltration of wetting solution that creates significant tissue turgor and results in infiltration of 3 to 4 mL of wetting solution per mL aspirated.^{20,21} Regardless of technique, the infiltrate should be allowed to take effect for seven minutes prior to suctioning.^{19,20} Areas to be treated should not be infiltrated more than 30 minutes in advance to allow full effect of solutions.

At our institution, a concern over volume of infiltrated lidocaine and possible toxicity levels has led to a modification in the mixture of wetting solution in large-volume liposuction cases. In large-volume cases with aspirate greater than 5000 mL, the initial five bags of solution are mixed in a standard Southwestern protocol (outlined in Table 1). After 5 L of infiltration, the remaining bags of infiltrate contain lidocaine 1% plain, at a volume of 15 mL

Table 2. Techniques of Liposuction and Infiltrates

Technique	Infiltrate Volume	Aspirate
Dry	No infiltrate	To treatment endpoint
Wet	200-300 mL/area	To treatment endpoint
Superwet	1 mL infiltrate: 1 mL aspirate	1 mL aspirate/ infiltrate (treatment endpoints)
Tumescent	Infiltrate to skin turgor	2-3 mL aspirate/mL infiltrate

Table 3. Estimated Blood Loss With Different Liposuction Techniques¹⁹

Technique	Estimated Blood Loss as % of Volume Aspirated
Dry	20-45
Wet	4-30
Superwet	1
Tumescent	1

Table 4. Endpoints for Ultrasound-Assisted Liposuction (UAL) and Suction-Assisted Liposuction (SAL)

Endpoint	UAL	SAL
Primary	Loss of tissue resistance	Final contour
	Blood in aspirate	Symmetric pinch test
Secondary	Treatment time	Treatment time
	Treatment volume	Treatment volume

per liter.³ Recent data suggest that, for patients undergoing general anesthesia with the superwet technique, the lidocaine component may be reduced and/or eliminated without postoperative sequela of increased pain.^{23,24}

EPINEPHRINE AND LIDOCAINE TOXICITY

Despite the relatively low concentrations infiltrated, the use of lidocaine and epinephrine may result in toxicity in some cases. Lidocaine toxicity has central nervous system and cardiac effects, with the first signs of toxicity being circumoral numbness, tinnitus, and lightheadedness. Intraoperative manifestations may include arrhythmias. Increasing levels cause tremors, seizures, and eventually cardiac and respiratory arrest.²⁵ Klein's data²¹ showed that levels of 35 mg/kg were safe in liposuction; Ostad and colleagues²⁶ increased this to 55 mg/kg. Kenkel et al²⁷ demonstrated that the peak levels of lidocaine and its active metabolite monoethylglycineethylidide (MEGX) occur within eight to 32 hours after initial infiltration. The time to peak systemic levels was greater than initially thought but still below the level of toxicity. Epinephrine has been shown to have increased cardiovascular effects after infiltration and peaks at five hours after infiltration. Caution is warranted in patients with diminished cardiac reserve and/or questionable heart history.^{9,28}

OPERATIVE CONSIDERATIONS: FLUID RESUSCITATION

Body contouring procedures can result in significant fluid shifts and intravascular volume changes for the patient. The operating surgeon should maintain a dialogue with the anesthesia provider, so that patients receive adequate replacement volume and proper fluid resuscitation. Often, a Foley catheter is utilized to guide intraoperative and postoperative volume resuscitation. Awareness of four key elements will guide the intraoperative fluid management of liposuction patients^{3,4}: intravenous (IV) fluid maintenance (body weight dependent), third space losses, volume of wetting solution infiltrated, and total lipoaspirate volume.

Large-volume liposuction patients can present an especially difficult challenge for fluid resuscitation. As previously mentioned by Rohrich et al in 1998 (updated in 2006), the following formula aids in fluid management for these patients.²⁹⁻³¹

1. Replace losses from preoperative oral intake loss as needed
2. Maintain fluid throughout the procedure and manage it based on vital signs and urine output
3. Employ the superwet infiltration technique
4. Administer crystalloid replacements, 0.25 mL for each mL of lipoaspirate over 5 L

Again, these recommendations serve as a guideline for fluid management of these complicated patients and are not meant to replace sound clinical judgment based on specific patient needs.

OPERATIVE CONSIDERATIONS: TREATMENT OPTIONS

Once candidates are identified for liposuction, several modalities exist for treatment. Factors that influence type of treatment include surgeon preference, body area to be suctioned, amount of expected aspirate, and history of previous liposuction. Traditional liposuction, as popularized by Illouz,² is referred to as suction-assisted liposuction (SAL). Other common modalities include ultrasound-assisted liposuction (UAL), vaser-assisted liposuction (VAL), power-assisted liposuction (PAL), and laser-assisted liposuction (LAL).

SAL remains the most common modality for liposuction. As stated above, it is considered "traditional liposuction," in which variable-size cannulas are employed, with an external source of suction for removal of aspirate.

PAL involves an external power source driving the cannula, which are variable in size and flexible, in a 2-mm reciprocating motion at rates of 4000 cycles per minute. Advocates of PAL contend that it is best used for large volumes, fibrous areas, and revision liposuction.^{32,33} Previously, its utility was limited because of noise generation from an external power source (gas or compressed

air) and the mechanical vibration experienced by the operating surgeon. PAL modalities now run on electrical power sources; hence, vibration and noise have decreased significantly.

UAL utilizes ultrasound energy to break down fat and allow removal. Its mechanism of action is primarily mechanical in nature, but cavitation and even thermal effects may occur.³ With this technique, fat is emulsified, which allows removal through traditional liposuction cannulas. Advantages include less surgeon fatigue, as well as improved results in fibrous areas and in secondary procedures.^{29,34} Disadvantages have been reported to include larger incisions, longer operative times, and the possibility of thermal injury.³ UAL requires a superwet environment and cannot be performed without a wetting solution. Also, appropriate management of the UAL probe is essential to preventing thermal injury to the superficial dermis; hence, skin protectors are often employed. Treatment endpoints are highlighted in Table 4 because they differ from those of traditional SAL.

VAL employs a newer generation ultrasound-assisted liposuction device that incorporates less energy with more efficient, solid probes. The probes come in an array of sizes and grooving, depending on tissues in which they will be used. The system uses less energy, decreasing its thermal component to the tissues. The three-stage technique of treatment described by Kenkel et al^{3,34} is utilized in this method. De Souza Pinto et al,³⁵ as well as Jewell et al,³⁶ described their treatment protocol and clinical results from studies utilizing VAL. Garcia and Nathan³⁷ showed the vaser to have significant advantages in blood loss and recommended its use in large-volume liposuction procedures and areas of fibrous fatty tissue where excess blood loss is expected.

LAL has been at the forefront of marketing hype for the past several years. The treatment involves insertion of a laser fiber via a small skin incision. Depending on the manufacturer, the fiber may either be housed within a cannula or stand alone. There are several commercially available lasers on the market under different trade names. The most common available wavelengths in the United States are 924/975 nm, 1064 nm, and 1319/1320 nm.^{38,39} Most companies and physicians utilizing this technique employ a four-stage technique: infiltration, application of energy to the subcutaneous tissues, evacuation, and subdermal skin stimulation. The laser fiber acts to disrupt fat cell membranes and emulsify fat. Evacuation then commences via traditional liposuction cannulas. For smaller regions (such as the neck), some vendors suggest skipping the evacuation phase, allowing the body to absorb the liquefied contents.^{38,39} Currently, these devices are being heavily marketed for purported skin-tightening effects. The belief is that the heating of the subdermal tissue may in fact be the contributing factor for LAL's possible skin tightening effect. No large, prospective trials have been undertaken to examine the benefits of LAL over existing technologies, so unfortunately, most of the reports remain anecdotal.^{40,41} A previously published randomized, double-blinded, controlled

study by Prado et al⁴² showed no difference in the outcomes of LAL versus traditional SAL. In that study, each patient served as his or her own control. Factors evaluated included cosmetic result, postoperative pain, length of operation, lipocrit, and free fatty acids. Besides the lack of difference in the cosmetic outcome of LAL versus SAL, the authors also reported a longer operative time with LAL, less early postoperative pain with LAL, and elevated free fatty acids/triglycerides in the laser-treated lipoaspirate. Based on our early experience with UAL, we recognize that subdermal heating may result in not only skin tightening but also skin injury.^{3,29}

TREATMENT AREAS

Arms

Upper arm contouring can be performed with multiple modalities, as listed above. Caution is advised in all instances as the surgeon progresses toward the ulnar aspect of the elbow. The fatty layer is thin and mobile, with the ulnar nerve lying superficially just beneath the investing fascial layer. Overzealous treatment to this area may result in either temporary or permanent nerve injury.^{3,4} The superficial fat in the upper arms is compact, with a more areolar deeper layer. In most patients, the superficial layer must be addressed to achieve a good aesthetic result. Care must be taken to use small cannulas with close monitoring to prevent superficial irregularities. Access incisions are at the elbow on the radial aspect, away from the ulnar nerve, and in the posterior axillary fold for more proximal suctioning (Figure 5). If more anterior suctioning is needed, alternative access sites may be required.^{3,43}

Back

Liposuction of the back begins with the patient positioned prone and the table flexed, as previously described. The anatomy in this region is unique; it has a very thick dermis and a dense, fibrous characteristic to the underlying fat. These qualities make liposuction with traditional SAL difficult in the back region. Modalities such as UAL/PAL tend to work well in the fibrous tissue of the back. The quantity of fat removed can be moderate, but improved results are often seen with release of folds and attachments to deeper tissue. Access incisions will depend somewhat on the distribution of lipodystrophy and can be medial or lateral; the incisions should be placed in the bra/bathing suit line for the best cosmetic result. Because of its fibrous nature, care should be taken while performing liposuction of the back. Forceful excursion of the cannula should be avoided, as fibrous areas may redirect the cannula to an unsafe location. Suctioning from areas off of the thoracic cage (hip region) to the posterior back should be avoided, as the possibility of intrathoracic penetration exists and results are less than ideal because of the dense skin and the fibrous nature of the tissue (see Figure 6).^{3,4,43}

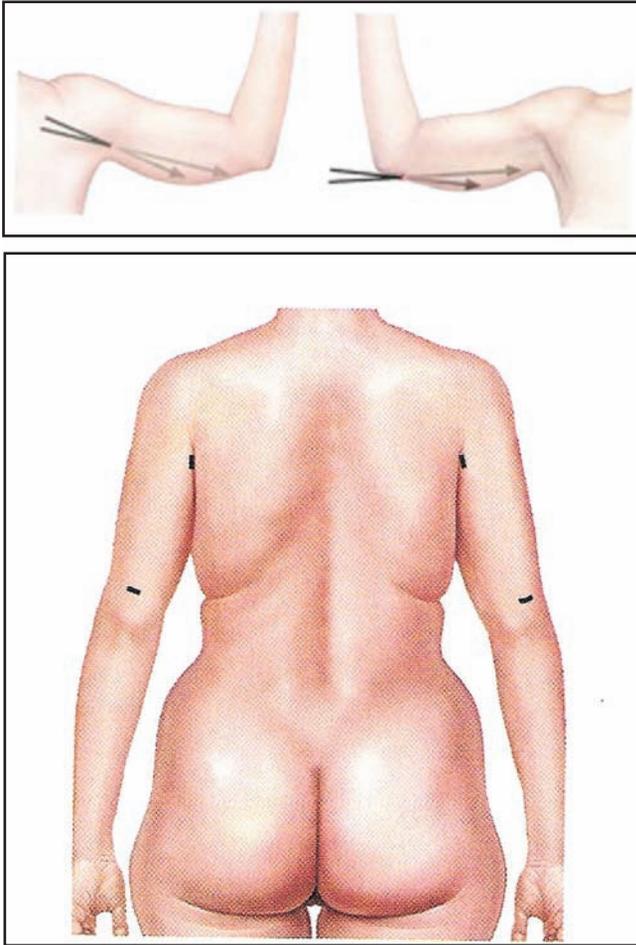


Figure 5. Placement of access incisions for arm liposuction. Access incisions are at the elbow on the radial aspect, away from the ulnar nerve, and in the posterior axillary fold for more proximal suctioning. Reprinted with permission from Rohrich RJ, Beran SJ, Kenkel JM. *Ultrasound-Assisted Liposuction*. St. Louis, MO: Quality Medical Publishing; 1998.

Hips/Flanks

We often treat the hip/flank area in the prone position. Others prefer the lateral decubitus position. This common area of suctioning in males and females is accessible through the bilateral or single midline paraspinous region and/or incision in the lateral gluteal fold. Suctioning in this area can provide excellent results, and all modalities have proven effective. The fat is loose and in some cases fibrous, with thick overlying skin. Significant striae may be seen in patients with weight fluctuations or in postpartum women. Knowledge of the differing aesthetic consideration of the hips and flanks in males and females is crucial to preventing inappropriate masculinization or feminization. In general, males tend to have fullness in this area superiorly and laterally, while females exhibit prominence more inferiorly and posteriorly (Figure 7).

It is essential to mark the lateral gluteal depression prior to liposuction, as violation of this important area can lead to irregular contour and deformity.⁵ Often, this adherent zone is a landmark to which both the hips and lateral thighs are reduced. This creates a favorable silhouette. In others, this area may represent an area of significant depression and may benefit from autologous fat transfer.

Thighs/Buttocks

Thigh liposuction is one of the more difficult procedures, where overly aggressive treatment may result in unsatisfactory contour. In most instances, patients are best suited for a circumferential approach in the prone/supine position. Although patients may present with an isolated medial/lateral deformity, superior results are obtained with a circumferential approach, which provides the best contour and the most patient satisfaction.^{2,3,7,43} Particular attention should be given to marking the zones of adherence in this region, as the results of overzealous suctioning can lead to significant postoperative deformities.⁵ It is important to place the access incisions asymmetrically, to avoid an operated look. Liposuction of the buttocks can provide excellent results when undertaken in a careful, graded fashion. Avoidance of deep, aggressive suctioning and maintenance of the length and position of the inferior gluteal crease are of critical importance. Special care should be taken when addressing the proximal posterior thigh. Overzealous suctioning in this area may result in skin rolls and redundancy (Figure 8). These can be very difficult to correct, requiring either autologous fat transfer or skin excision. In females, this complication may elongate the gluteal fold, masculinizing the female silhouette.

Abdomen

The boundary of the abdomen is the xiphoid and costal margin superiorly, the pubis and inguinal ligament inferiorly, and the anterior superior iliac spine laterally. Lipodystrophy in the abdomen is predominantly in the deep infraumbilical region.⁴ Careful preoperative evaluation is vital in the abdomen; the distribution of fat, scars, skin laxity, and the presence or absence of hernias should be noted. Abdominal scarring on patients with large pannus or a difficult physical exam should be considered for a CT scan to rule out hernias prior to operation. Patients with diastasis, abdominal wall laxity, or significant intra-abdominal fat should be counseled on the possible need for skin excision, plication, or limited improvement with liposuction alone. Treatment is performed in the supine position, and access incisions are often suprapubic and/or periumbilical. The fat in the abdomen is amenable to all forms of liposuction. Superficial liposuction should be approached with caution and only performed by an experienced surgeon. We reserve superficial liposuction for the linea alba or for the correction of secondary deformities. There have been published reports of superficial sculpting of the abdomen,⁴⁴ but care should always be taken. Overly



Figure 6. Diagram of access and position for liposuction of the back. Access incisions will depend somewhat on the distribution of lipodystrophy and can be medial or lateral; the incisions should be placed in the bra/bathing suit line for the best cosmetic result. Reprinted with permission from Rohrich RJ, Beran SJ, Kenkel JM. *Ultrasound-Assisted Liposuction*. St. Louis, MO: Quality Medical Publishing; 1998.



Figure 7. Differences in female (A) and male (B) hip/flank anatomy. Knowledge of the differing aesthetic considerations is crucial to preventing inappropriate masculinization or feminization. In general, males tend to have fullness in this area superiorly and laterally, while females exhibit prominence more inferiorly and posteriorly.

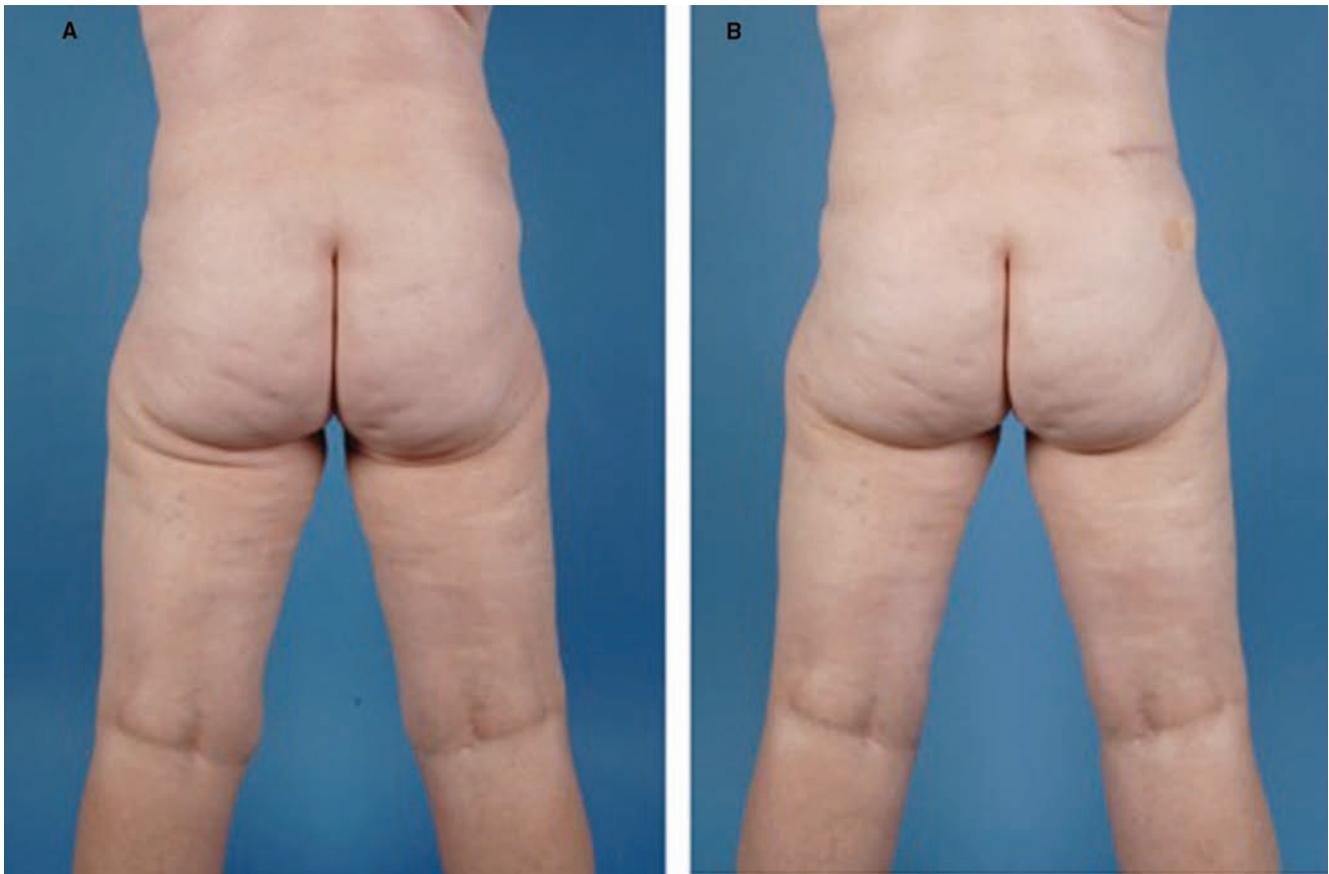


Figure 8. Overaggressive suctioning along the gluteal fold resulted in skin rolls and redundancy for this 55-year-old woman. The patient is shown (A) preoperatively and (B) nine months after liposuction of the buttocks.

aggressive treatment of the abdomen may result in contour irregularities and/or skin injury.

Neck

Liposuction in the neck region is often performed with traditional SAL and small cannulas or hand syringe suctioning. Access is typically via a submental incision and often is just posterior to the lobule on either side. Suctioning should proceed in a controlled fashion, and the superficial dermis should be avoided. Continuous assessment of contour is important. Overzealous treatment of this area may result in contour irregularities or neuropraxia of the marginal mandibular nerve.^{43,45} Fortunately, this often resolves within a few weeks.

POSTOPERATIVE CARE

At the conclusion of surgery, patients are placed in the appropriate compression garment; some type of compression foam may be used. Depending on the volume of lipoaspirate and other concomitant procedures, patients are

either discharged home or remain overnight in a surgical hotel suite/hospital. In general, patients who have undergone any large-volume procedure (more than 5000 mL aspirate), liposuction of multiple areas, or liposuction in addition to abdominoplasty are kept overnight for 23-hour observation. Patients are asked to ambulate the night of the surgery, and sequential compression devices remain on the patient while in bed until discharge. Patients are allowed to shower beginning one or two days postoperatively and instructed to keep the compression garment on 24 hours a day for two weeks, except while showering.

Initial postoperative visits are scheduled for five to seven days postoperatively; return to activity/work can occur as early as three to four days or at two weeks, depending on the procedure. Walking is encouraged immediately, and light activity is allowed two weeks after surgery, unless the patient underwent associated abdominoplasty. Patients are cautioned that swelling may persist for three to four weeks and that final results can be expected in three to four months. Postoperative lymphatic massage is encouraged to help with swelling and induration. This is often begun prior to surgery and resumed shortly after the procedure.

COMPLICATIONS

Liposuction is not a procedure without risks. Much attention has been directed toward outcomes and prevention in the past few years, with the ultimate goal of improved results while maintaining patient safety. Complications can vary from mild postoperative nausea and vomiting to deep venous thrombosis (DVT)/pulmonary embolism (PE) and even death. Complications can occur in the perioperative period, early postoperative period, and late postoperative period. In a questionnaire to board-certified members of ASAPS, Hughes⁴⁶ reported a significant increase in complications when liposuction was combined with other procedures. This increase in the complication rate was most notable in liposuction combined with abdominoplasty.

Perioperative complications can include anesthesia and cardiac complications, cannula trauma to skin and/or internal organs, and volume loss/overload from bleeding or excess fluid administration. Instances of direct cannula trauma to the bowel, internal organs, or vessels have been reported in the literature.⁴⁸ Although rare, these complications are related to incomplete preoperative examination (hernia) and overaggressive suctioning or penetration by infiltration cannula (see Figure 9 for instance of cannula injury to spleen).

Hypothermia occurs commonly in liposuction cases. Hypothermia is generally defined as a core body temperature less than 36.5°C.⁴⁷ Its risk is amplified in larger volume cases where more of the patient is exposed at one time. The core body temperature can drop up to 2.8°C in the first hours of surgery. This is due to anesthesia effects on autonomic regulation of core temperature, as detailed by Young and Watson.⁴⁷ Warming of the wetting solutions and prep, increase of the ambient temperature, and use of warming devices (Bair Hugger, Arizant, Eden Prairie, Minnesota) all help reduce losses during liposuction. Prewarming the patient with forced air for one hour has also been shown to significantly reduce the incidence of hypothermia.⁴⁷

Fluid management is crucial to the prevention of volume overload and anesthesia-related complications. As stated previously, careful management of intraoperative and postoperative fluids, as well as use of an intraoperative data sheet, helps prevent volume-related complications from liposuction.⁴⁸ The tumescent liposuction technique has been implicated in volume overload and pulmonary edema; however, these can often be attributed to incorrect patient selection and/or poor fluid management.^{49,50} Fluid overload and untoward sequelae from large-volume liposuction (more than 5 L) prompted a warning by the ASAPS that physicians performing liposuction should be trained in comprehensive fluid resuscitation and the physiology of large-volume liposuction.⁵¹

Other early postoperative complications can include venous thromboembolism, infection, and skin slough or loss. Incidence of DVT in liposuction has been reported at <1%,⁴⁰ but a marked increase in this percentage is demonstrated when liposuction is combined with other surgery (abdominoplasty/belt lipectomy).⁵²⁻⁵⁴ Physicians should familiarize themselves with American College

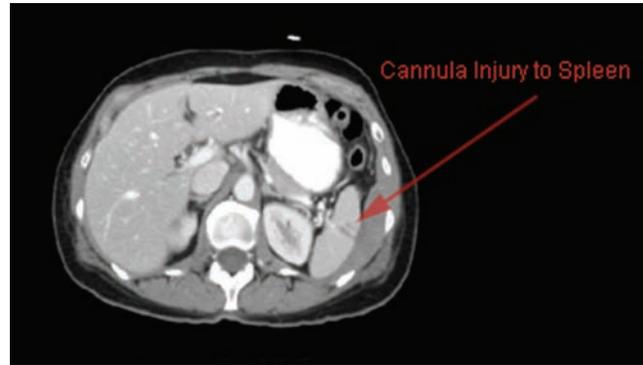


Figure 9. Cannula injury to the spleen resulting from overaggressive suctioning.

of Chest Physicians (ACCP) current recommendations and a model (such as the Georgetown model) for risk assessment when patients are undergoing any type of prolonged surgery, including liposuction and combined procedures.^{12,52,54}

Administration of enoxaparin has resulted in a decreased incidence of DVT, but there may be increased risks of bleeding. A randomized, controlled, multicenter trial is under way to further assess prophylaxis in the plastic surgery patient.^{52,55} Clinical signs of lower extremity swelling, Homans signs, shortness of breath, chest pain, and/or tachycardia should alert the provider to the possibility of DVT/PE and warrant immediate evaluation and treatment. Sequential compression devices are placed on all patients in preoperative holding and remain in place throughout the procedure, as well as postoperatively while the patient is in bed until time of discharge. Chemoprophylaxis is used at the discretion of the provider, based on risk assessment evaluation. See Table 5 for a modified Davison-Caprini model for thromboembolism risk assessment.

Finally, wound infections and necrotizing soft tissue infections are rare but can occur after liposuction.⁵⁶ Persistent postoperative fevers and/or cellulitis should be closely monitored and aggressively treated. First-generation cephalosporins are administered perioperatively at our institution prior to incision unless the patient has a known history of methicillin-resistant *Staphylococcus aureus* (MRSA), in which case vancomycin is administered preoperatively.

Late complications of liposuction can include delayed seroma formation, edema and ecchymosis, paresthesia, and contour irregularities. Seromas following aggressive liposuction are rare and thought to be secondary to overzealous treatment of an area, which denudes the fascia. It appears to be technique dependent rather than technology specific.³⁴ A loose closure of cannula sites, postoperative compression garments, and expressing residual fluid over liposuction areas at the end of procedure all reduce the incidence of seroma formation and edema.³⁴ Postoperative edema and ecchymosis occur to a varying extent in all patients. Prolonged edema can occur up to three months from surgery and is best treated with supportive care and lymphatic massage. Postoperative paresthesia/dysesthesia can occur in all forms of liposuction. The sensory changes

Table 5. UT Southwestern Modification of Davison-Caprini Model⁵²

Step I: Exposing Risk Factors			
One Factor	Two Factors	Three Factors	Five Factors
Minor surgery	Major surgery (general anesthesia or time greater than 1 hour)	Previous myocardial infarction/ coronary heart failure	Hip/pelvis/leg fracture
	Immobilization	Severe sepsis	Stroke
	Central venous access	Free flap	Multiple trauma
	Body mass index > 30	Circumferential abdominoplasty	
Step II: Predisposing Factors			
Clinical Setting (Factors)		Inherited (Factors)	Acquired (Factors)
Age 40-60, years (1)		Any genetic hypercoagulable state (3)	Lupus anticoagulant (3)
Age > 60 years (2)			Antiphospholipid antibody (3)
History deep venous thrombosis/pulmonary embolism (3)			Myeloproliferative disorder (3)
Pregnancy (1)			Heparin-induced thrombocytopenia (3)
Malignancy (2)			Homocystinemia (3)
Oral contraceptive/hormone replacement therapy (2)			Hyperviscosity (3)
Total of Step I and Step II: _____			
Step III: Orders			
Number of Factors	Risk Assessment	Recommendations	
One factor	Low risk	Ambulate tid	
Two factors	Moderate risk	Intermittent pneumatic compression device and elastic compression stocking on patient all times while not ambulating	
Three factors	High risk	Intermittent pneumatic compression device and elastic compression stocking on patient all times while not ambulating	
Four factors	Highest risk	Intermittent pneumatic compression device and elastic compression stocking on patient all times while not ambulating + Lovenox 40 mg SQ daily postoperatively	

are usually reversible and can take up to 10 weeks to recover, but recovery is generally felt to be quicker with SAL than with UAL.⁵⁷ Newer technologies have not been investigated in this manner.

The most common postoperative complication from liposuction is contour deformity, which can occur in up to 20% of patients.^{7,58,59} Mild irregularities are often present after suctioning and are treated conservatively as swelling and edema resolve. These can also be treated with lymphatic massage, as discussed above. Once a contour deformity is present, it is best to elucidate the etiology. Treatment can be directed at replacing the fat in the over-resected region and/or suctioning the adjacent regions to reduce the prominence of the concavity. Chang^{58,59} presented his approach to the correction of contour deformities with a multimodality approach, wherein the techniques of correction included liposuction of prominence surrounding a concavity, fat grafting, and dermolipectomy to correct skin sag. UAL has a decreased incidence of contour deformities versus traditional SAL and is often the preferred method for secondary liposuction cases in which fat grafting is not

indicated.^{3,34} Careful preoperative analysis, planning, and proper informed consent all help to minimize the risk of postoperative contour irregularity.

EMERGING TECHNOLOGY

Mesotherapy is an emerging technology, the goal of which is a reduction in fat by dissolution.^{60,61} The concept dates back to 1952 and involves injection of phosphatidylcholine, deoxycholate, and/or other agents with the aim of dissolving fat deposits.⁶⁰ It has gained popularity because of its “noninvasive” nature and the marketing efforts have reached mainstream media and patients.⁶² Park et al⁶¹ showed no discernable difference in the treatment in lower extremities with mesotherapy by measurement or CT evaluation.

Lipodissolve is considered by some, but not all, practitioners to be a variant of mesotherapy. It is the injection of a standardized solution into the subcutaneous fat, rather than the mesoderm. Several studies on safety and efficacy are available for review. Common side effects listed

include hyperpigmentation and persistent pain; 12% of patients had cosmetic outcomes that were less favorable than expected.^{63,64} Further study and evaluation of safety on all forms of mesotherapy are warranted before clinical use can be endorsed.^{65,66}

Focused external ultrasound therapy is currently being evaluated. Depending on the technology, it can be thermally or nonthermally mediated (via cavitation). There is no “evacuation” phase relying primarily on removal by the body’s own phagocytic mechanisms. Preliminary data by Brown et al⁶⁷ have shown it to be effective in treatment in a preclinical porcine model, in which the UltraShape (UltraShape, San Ramon, California) device was target specific for the adipocyte, preserving the surrounding neurovasculature. Two clinical studies have validated its safety.^{67,68} Currently, the company is performing a multicenter, prospective, randomized, blinded study evaluating its safety and efficacy.

LipoSonix (Medicis, Scottsdale, Arizona) technology uses high-intensity focused ultrasound (HIFU) to disrupt fat in a thermally mediated mechanism. The device is currently undergoing clinical trials outside of the United States and also is being marketed in Europe. LipoSonix disrupts fat via a thermocoagulation-mediated mechanism (vs UltraShape, which acts via cavitation, causing disruption of fat cell membrane). Neither the UltraShape nor LipoSonix is FDA approved or available in the United States.

Liposuction combined with radiofrequency ablation of fat cells is currently being investigated under the trade name BodyTite (Invasix, Toronto, Ontario, Canada). The purported benefits are thermal destruction of fat cells, removal via aspiration cannula, and subnecrotic heating of the dermis for skin tightening. This device is not currently approved by the FDA.⁶⁹

Cryolipolysis is a new and vastly different technology currently being evaluated for fat destruction under the trade name Zeltiq (Zeltiq, Pleasanton, California). The concept is a controlled cooling of the subcutaneous fat, with destruction of selective fat cells without epidermal or dermal injury. It has the European EC mark of approval and is currently undergoing US-based evaluation but is not FDA approved.⁷⁰

CONCLUSIONS

Liposuction has evolved tremendously over the years since its initial description by Illouz.² In the past 25 years, there has been significant evolution of the techniques and technologies available, resulting in improved safety and outcomes. As new technology is continually being introduced, we must temper our enthusiasm and base treatment on solid, scientific evidence. Device manufacturers often provide scant, if any, objective data to support claims such as skin tightening, reduced pain, and improved aesthetic results. The authors are confident that liposuction will remain one of the most popular procedures performed in the years to come and we must thus remain committed to the common goals of patient safety and improved aesthetic outcomes.

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