Evidence-Based Patient Safety Advisory: Liposuction

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Summary: Liposuction is considered to be one of the most frequently performed plastic surgery procedures in the United States, yet despite the popularity of liposuction, there is relatively little scientific evidence available on patient safety issues. This practice advisory provides an overview of various techniques, practices, and management strategies that pertain to individuals undergoing liposuction, and recommendations are offered for each issue to ensure and enhance patient safety. (*Plast. Reconstr. Surg.* 124 (Suppl.): 28S, 2009.)

Liposuction is a highly effective surgical intervention designed to treat superficial and deep deposits of subcutaneous fat distributed in aesthetically unpleasing proportions, thereby improving body contour. Although liposuction was originally intended to treat minor contour irregularities, advances in liposuction surgical techniques and a better understanding of the physiologic consequences of liposuction have enabled recontouring of large regions and multiple body areas. These advances have changed the nature of liposuction, taking it from the realm of a minor surgical procedure to that of major surgery. Liposuction may be performed in the hospital or in one of three outpatient settings: hospital-based ambulatory surgical units, freestanding ambulatory surgery centers, or office-based surgery facilities. As a testament to its success, liposuction is considered to be one of the most frequently performed plastic surgery procedures in the United States.[1,2] Yet despite the popularity of liposuction, there is relatively little scientific evidence available on patient safety issues; the research and published materials available focus more on liposuction techniques and complications rather than on the provision of safe care.

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In an effort to ensure the safety of patients undergoing liposuction in the hospital and ambulatory surgery setting, the American Society of Plastic Surgeons (ASPS) Patient Safety Committee sought to develop a liposuction practice advisory to assist physician decision-making. This advisory serves to update and expand on a prior practice advisory on liposuction issued by the ASPS.[3] The current practice advisory provides an overview of various techniques, practices, and management strategies that pertain to individuals undergoing liposuction, and recommendations for each issue are offered to ensure and enhance patient safety.

This patient safety advisory was developed through a comprehensive review of the scientific literature and a consensus of the Patient Safety Committee. The supporting literature was critically appraised for study quality according to criteria referenced in key publications on evidence-based medicine.[4–8] Depending on study design and quality, each reference was assigned a corresponding level of evidence (I through V) with the ASPS Evidence Rating Scales (Table 1),[9] and the evidence was synthesized into practice recommendations. The recommendations were then graded (A through D) with the ASPS Grades of Recommendation Scale (Table 2)[10]; grades correspond to the levels of evidence provided by the supporting literature for that recommendation. Practice recommendations are discussed throughout this document, and graded recommendations are summarized in Appendix A.

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Table 1. Evidence Rating Scale for Studies Reviewed

Level of Evidence	Qualifying Studies
I	High-quality, multicentered or single-centered, randomized controlled trial with adequate power; or systematic review of these studies
II	Lesser quality, randomized controlled trial; prospective cohort study; or systematic review of these studies
III	Retrospective comparative study; case-control study; or systematic review of these studies
IV	Case series
V	Expert opinion; case report or clinical example; or evidence based on physiology, bench research, or "first principles"

DISCLAIMER

Practice advisories are strategies for patient management, developed to assist physicians in clinical decision-making. This practice advisory, based on a thorough evaluation of the present scientific literature and relevant clinical experience, describes a range of generally acceptable approaches to diagnosis, management, or prevention of specific diseases or conditions. This practice advisory attempts to define principles of practice that should generally meet the needs of most patients in most circumstances. However, this practice advisory should not be construed as a rule, nor should it be deemed inclusive of all proper methods of care or exclusive of other methods of care reasonably directed at obtaining the appropriate results. It is anticipated that it will be necessary to approach some patients' needs in different ways. The ultimate judgment regarding the care of a particular patient must be made by the physician in light of all the circumstances presented by the patient, the diagnostic and treatment options available, and available resources.

This practice advisory is not intended to define or serve as the standard of medical care. Standards of medical care are determined on the basis of all the facts or circumstances involved in an individual case and are subject to change as scientific knowledge and technology advance, and as practice patterns evolve. This practice advisory reflects the state of knowledge current at the time of publication. Given the inevitable changes in the state of scientific information and technology, periodic review and revision will be necessary.

LIPOSUCTION TECHNIQUES

Over the years, a variety of terms have been used to describe liposuction techniques. These techniques are typically classified in the following way.

Suction-Assisted Liposuction

This technique removes adipose tissue from the subcutaneous space by means of a blunt-tip hollow cannula attached to high-powered suction, usually 1 ATM of negative pressure.

Dry Technique

The dry technique, the first liposuction method developed, involves insertion of the liposuction cannula without the infiltration of subcutaneous solutions in patients under general anesthesia. Common consequences of the technique include substantial swelling and discoloration, along with suction aspirate containing 20 to 45 percent blood. These sequelae dramatically limit the amount of fat that can be removed without transfusion or hospitalization, thereby resulting in abandonment of this approach,[11] except in limited applications.

Table 2. Scale for Grading Recommendations

Grade	Descriptor	Qualifying Evidence	Implications for Practice
A	Strong recommendation	Level I evidence or consistent findings from multiple studies of levels II, III, or IV	Clinicians should follow a strong recommendation unless a clear and compelling rationale for an alternative approach is present.
B	Recommendation	Levels II, III, or IV evidence and findings are generally consistent	Generally, clinicians should follow a recommendation but should remain alert to new information and sensitive to patient preferences.
C	Option	Levels II, III, or IV evidence, but findings are inconsistent	Clinicians should be flexible in their decision-making regarding appropriate practice, although they may set bounds on alternatives; patient preference should have a substantial influencing role.
D	Option	Level V: Little or no systematic empirical evidence	Clinicians should consider all options in their decision-making and be alert to new published evidence that clarifies the balance of benefit versus harm; patient preference should have a substantial influencing role.

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Superwet Technique

The superwet technique, introduced in the mid 1980s, uses larger volumes of subcutaneous infiltrate, whereby 1 to 2 cc of solution is infused for each 1 cc of fat to be removed.[12] The infiltrate solution consists of saline or Ringer's lactate solution with epinephrine and, in some cases, lidocaine. Using this method, blood loss generally decreases to less than 1 to 2 percent of the aspirate volume.[11,13,14]

Tumescent Technique

Introduced in 1985, the tumescent technique uses the largest volume of infiltrate: 3 to 4 cc of infiltrate solution is used for each planned milliliter of aspirate.[14,15] Drug concentrations in the tumescent infiltrate solution vary but typically consist of 0.025% to 0.1% lidocaine and 1:1,000,000 epinephrine in a Ringer's lactate or normal saline solution.[16,17] Estimated blood loss with the tumescent technique is approximately 1 percent of the aspirate, which is comparable to the superwet technique.[11,14]

Ultrasound-Assisted Liposuction

Two different ultrasound techniques, one internal and one external, are available for use with superwet or tumescent liposuction.

Internal Ultrasound Assistance

Introduced in the late 1980s, internal ultrasound-assisted liposuction uses a cannula or probe to deliver fat-liquefying ultrasonic waves subcutaneously, enabling fat to be removed with less physical effort by the surgeon.[18–20] This technique permits the removal of fat from fibrous areas such as the upper abdomen, back, and flanks with greater ease, especially during secondary procedures.[21] Studies have shown that internal ultrasound-assisted liposuction results in slightly higher, although insignificant, blood loss than suction-assisted liposuction performed using the superwet technique.[22] To prevent thermal injury while performing ultrasound-assisted liposuction, two recommendations regarding the technique are of critical importance.[20] First, the ultrasound probe or cannula must be kept in motion. Second, an infiltrate solution must be used to facilitate fat emulsification. Pulsed VASER (Sound Surgical Technologies, LLC, Louisville, Col.) ultrasound technology, which uses a small-diameter grooved probe to increase fragmentation efficiency in conjunction with reduced ultrasound energy, may be an effective technology for limiting collateral tissue damage caused by internal ultrasound assistance[23]; however, additional studies are needed to confirm its efficacy. The dry technique should never be used in ultrasound-assisted liposuction regardless of the planned volume of aspirate.[14]

External Ultrasound Assistance

External ultrasound assistance delivers adjunctive ultrasound through the skin by means of an external paddle. The benefits of this technique are disputed. Some researchers report that external ultrasound assistance benefits skin retraction, eases aspirate extraction, and minimizes cellular disruption of adipocytes, which can have adverse effects on hepatic and renal function.[19,24,25] By contrast, others have found no significant clinical benefits to external ultrasound.[19,26,27]

Laser-Assisted Liposuction

This ancillary technique makes use of a neodymium:yttrium-aluminum-garnet laser to target adipocyte membranes to emulsify fat. Use of tumescent infiltrate solutions is required for proper operation of the laser and also to minimize blood loss and potential complications. A case report comparing laser-assisted liposuction with conventional tumescent liposuction demonstrated that the former technique resulted in better hemostasis, better wound healing, and less surgical trauma in targeted tissue.[28] A subsequent prospective randomized study found no major clinical differences in terms of cosmetic results or signs and symptoms between laser-assisted liposuction and suction-assisted liposuction, except for less pain and lower lipocrit levels with the laser-assisted technique.[29]

Power Water-Assisted Liposuction

This investigational liposuction technique is an almost painless procedure that uses a fine high-pressure jet of water to detach adipose cells while sparing anatomical structures such as blood vessels and nerves. Studies show that power water-assisted liposuction produces significantly less tissue trauma than traditional tumescent liposuction.[30] As a result, more than 85 percent of patients are pain free by 4 days after surgery, and any minimal bruising that occurs largely disappears by 6 days after surgery.

Mesotherapy/Injection Lipolysis

Mesotherapy and injection lipolysis are not liposuction techniques and are advertised as nonsurgical alternatives to liposuction. These therapies and the controversies surrounding them are addressed in a separate ASPS document, entitled "ASPS Guiding Principles for Mesotherapy/Injection Lipolysis."[31]

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LIPOSUCTION CANNULAS

A liposuction cannula is a hollow rod with a blunt to sharp tip and an opening(s) through which fat is detached from subcutaneous skin and evacuated into the aspirator. Cannula designs vary by dimension, length, and tip shape. Cannulas with sharp or pointed tips are easier to manipulate but are more likely to damage the surrounding tissue. By contrast, blunt-tipped cannulas require more physical exertion, causing more physician fatigue. Many cannulas have more than one opening, in various configurations, at or near the tip. Multiple openings facilitate fat extraction and reduce tissue damage by minimizing repeated movement over a given area.

The design, size, and length of the liposuction cannula vary greatly, depending on the area(s) to be suctioned, the type of liposuction performed, and the physician's preference.[32] Cannula diameters typically range from 2 to 6 mm and are available in a variety of lengths. No one cannula is appropriate for all procedures, patients, or surgeons.

Specialized Cannulas

Power-Assisted Liposuction

This approach uses a power source to manipulate the cannula in action, rather than solely relying on the surgeon's arm, thereby limiting physician fatigue. A small motor, either electrically driven or gas driven (by nitrogen or compressed air), moves the 2- to 4-mm cannula tip in a forward and backward motion. The cannulas are small, flexible, and comparable in length and diameter to standard suction-assisted liposuction cannulas. Power-assisted liposuction is effective for large-volume fat removal, fibrous areas, and revisions. This modality is typically used in conjunction with the tumescent or superwet technique. The main disadvantages of this modality include excessive cannula vibration and noise from the power system.[33]

Ultrasound-Assisted Liposuction

Ultrasound-assisted liposuction probes are designed to deliver ultrasound energy to emulsify fat. Two probe designs are available: either solid with no aspiration port or hollow with a central lumen. The hollow probe design allows a continuous stream of emulsion to be aspirated during the ultrasound phase of liposuction.[34,35] The solid probe is thought to be a more efficient fat emulsification device, but its use requires a two-step process in which the fat must first be emulsified and then separately evacuated.[36] Regardless of the probe design, a sheath or skin protector of some type is required to prevent thermal injury at the incision site.[32,37]

ANESTHESIA

Various types of anesthesia or anesthesia combinations are appropriate for liposuction, depending on the overall health of the patient, the estimated volume of aspirate to be removed, and the postoperative dismissal plan. The surgeon has the primary responsibility for deciding on the type of anesthesia to be used and for providing and/or supervising anesthesia delivery. Parenteral sedation, regional anesthesia, dissociative drugs, spinal anesthesia, epidural anesthesia, and general anesthesia may be administered by a qualified physician or anesthesiologist, a certified registered nurse anesthetist under physician supervision, a certified anesthesia assistant, or another qualified health care provider under the supervision of a qualified physician, depending on the accreditation level of the facility, state or federal law, or facility policy.[38] The responsible physician should be physically present in the operating room throughout anesthesia delivery, except when topical or local anesthesia is administered.

Anesthetic Infiltrate Solutions

Anesthetic agents are typically added to liposuction wetting solutions to provide preemptive and prolonged postoperative local analgesia. In small-volume liposuction cases, anesthetic infiltrate solutions alone may provide adequate pain relief. However, in large-volume liposuction cases, the superwet and tumescent techniques are often accompanied by oral or intravenous sedation, general anesthesia, or epidural anesthesia to ensure adequate patient comfort.[14] It should be noted that when infiltration methods such as the tumescent technique are used, they should be regarded as regional or systemic anesthesia because of the potential for systemic toxic effects.[39,40]

Lidocaine

Lidocaine is the most common anesthetic agent selected for use in wetting solutions. Historically, the recommended dose of lidocaine is less than 7 mg/kg.[41,42] However, this dose does not take into consideration the slow absorption from fat, the persistent vasoconstriction from epinephrine, and removal of the agent in the liposuction aspirate, all of which contribute to a reduced risk of systemic toxicity from the lidocaine.[11,14,43] It is generally accepted that an infiltrate solution containing up to 35 mg/kg of lidocaine is safe

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when injected into subcutaneous fat, provided that epinephrine is also included in the solution, although lidocaine doses up to 64 mg/kg have been safely used.[15,16,44–49]

Although lidocaine is safe when administered at an appropriate dose and when the patient is appropriately monitored, toxicity can present as cardiac and neurologic complications. Signs and symptoms of lidocaine toxicity include light-headedness, restlessness, drowsiness, tinnitus, a metallic taste in the mouth, slurred speech, and numbness of the lips and tongue. These signs can be seen at plasma levels between 3 and 6 μg/ml. Shivering, muscle twitching, and tremors can occur when plasma levels reach 5 to 9 μg/ml. Convulsions, central nervous system depression, and coma follow at plasma levels greater than 10 μg/ml. At levels of 20 μg/ml and above, respiratory depression and cardiac arrest can occur.[37,50] It is important to note that plasma lidocaine levels peak 10 to 14 hours after infiltration into most fatty (i.e., poorly vascularized) body areas when epinephrine is present in the wetting solution.[14,15,45,49,51] In more highly vascularized areas such as the neck, plasma lidocaine levels peak approximately 6 hours after injection of a tumescent lidocaine solution and at higher levels.[52] As such, clinicians using tumescent anesthesia in the head and neck or other well-vascularized areas should be aware that lidocaine toxicity may occur sooner and at lower lidocaine doses compared with tumescent anesthesia solutions infiltrated in the trunk and lower extremities. The pressure and rate of infusion of the wetting solution does not affect the rate of lidocaine absorption.[47,51]

Various factors affect the likelihood of lidocaine toxicity, including the level and rate of drug absorption, drug interactions, fluid management, prothrombogenic factors, and volume of the wetting solution and aspirate. To decrease the risk of lidocaine toxicity in large-volume liposuction cases, two options are available. The first is to decrease the concentration of lidocaine in the wetting solution. The second is to use smaller volumes of infiltrate by applying the superwet technique rather than the tumescent technique. If there is concern about lidocaine toxicity, the practitioner may consider other forms of anesthesia that do not require the use of lidocaine.[17]

Other Analgesics

Select analgesics aside from lidocaine have been used in infiltration solutions, including bupivacaine and prilocaine. In the early stages of the wet technique, low-dose bupivacaine was occasionally added to the wetting solution; however, its use for this purpose has not been clinically studied or assessed. Bupivacaine should be used with caution if added to infiltrate solutions because of its slow elimination and reversal and its potential for severe side effects involving the cardiovascular, neurologic, and hematologic systems.[41,53] For patients who cannot tolerate lidocaine, prilocaine may be substituted. Limited data recommend a maximum prilocaine dose of 8 mg/kg for small-volume liposuction (aspirate volume $<$ 2000 cc), although doses up to 15 mg/kg have been used safely without adverse consequences.[54] If prilocaine is used in the infiltrate solution, patients should be monitored closely for 12 hours after administration to watch for signs and symptoms of methemoglobinemia (e.g., headache, dyspnea, lightheadedness, weakness, confusion/delirium, palpitations, chest pain, cyanosis, dysrhythmias, seizures, coma, acidosis, and cardiac or neurologic ischemia).

Epinephrine

Epinephrine is a critical additive in the infiltrate solution. Advantages of its use include vasoconstriction resulting in hemostasis and delayed absorption of the anesthetic agent, which prolongs its effect, decreases the amount of anesthetic needed, and reduces the risk of lidocaine toxicity.[51] The epinephrine dosage used in infiltrate solutions varies and may range from 1:100,000 to 1:1,000,000, depending on such variables as the liposuction technique, the volume of infiltrate infused, and the type of alkalinized fluid used in the infiltrate mixture.[55] It is recommended that epinephrine doses not exceed 0.07 mg/kg, although doses as high as 10 mg have been used safely.[46,55] It should be noted that if the dose of vasoconstrictor (i.e., epinephrine) is high, its systemic absorption can affect hepatic blood flow and modify the rate of disposition of the local anesthetics (i.e., lidocaine) that are metabolized by the liver.[40] In large-volume liposuction cases, staged infiltration of multiple anatomical sites may provide a wider safety margin.

Epinephrine use should be avoided in patients who present with pheochromocytoma, hyperthyroidism, severe hypertension, cardiac disease, or peripheral vascular disease.[56,57] In addition, cardiac arrhythmias can occur in predisposed individuals or when epinephrine is used with halothane anesthesia. Alterations in the rate and force of contraction or cardiac irritability and hypertension can occur, particularly in hyperthyroid patients.[55–57]

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Type of Anesthesia

Several types of anesthesia are used during liposuction procedures, including general anesthesia, epidural anesthesia, spinal anesthesia, moderate sedation/analgesia, and local anesthesia. Plastic surgeons recognize the definitions of the American Society of Anesthesiologists regarding the types and levels of sedation and analgesia. These definitions comprise a continuum of levels ranging from minimal sedation (anxiolysis) to general anesthesia (Table 3).[58]

Data from the few anesthesia studies that have specifically assessed patients undergoing liposuction confirm the safety of general anesthesia,[59–61] epidural anesthesia,[62] spinal anesthesia,[63] moderate sedation,[60,64] and local anesthesia[48] for this procedure. It should be noted, however, that epidural anesthesia and spinal anesthesia can cause vasodilation and hypotension, thereby necessitating the administration of excess fluid and increasing the risk for fluid overload.[62] For a more thorough discussion of the safety and effectiveness of various anesthesia options in general plastic surgery procedures, see Haeck et al., "Evidence-Based Patient Safety Advisory: Patient Selection and Procedures in Ambulatory Surgery," in this issue.

Duration of Anesthesia

Liposuction at times may be combined with other procedures, thereby increasing the total duration of the surgery. Although no data were found regarding duration of anesthesia and liposuction procedures, studies in ambulatory surgery settings have reported duration of anesthesia to be associated with minor complications (e.g., postoperative pain, bleeding, fever), delays in discharge, and/or unplanned admissions[65–69]; however, it is unclear whether these risks are attributable to the duration of anesthesia or to the complexity of the surgical procedure. Some states have imposed surgery time limits for ambulatory settings; limits range from 2 to 8 hours (e.g., Florida, Pennsylvania, and Tennessee). Surgeons should consult their individual state regulations on this matter. For a more thorough discussion on duration of surgery, see Haeck et al., "Evidence-Based Patient Safety Advisory: Patient Selection and Procedures in Ambulatory Surgery," in this issue.

PATIENT SELECTION

One of the most important aspects in the success of any surgical procedure is the physical condition of the patient at the time of surgery. For a general discussion of patient selection criteria for ambulatory surgery facilities, see Haeck et al., "Evidence-Based Patient Safety Advisory: Patient Selection and Procedures in Ambulatory Surgery," in this issue. Patient selection considerations that specifically pertain to liposuction candidates are discussed below.

Localized Adiposity

Liposuction is a very effective treatment for recontouring localized fat deposits of the trunk, abdomen, and thighs. It has also been used to a more limited extent to correct areas on the upper arms and breasts as an adjunct to reduction mammaplasty or treatment for gynecomastia.[45,70–75] Facial aesthetic surgery has also used liposuction for recontouring the neck and localized areas of the face, and it has even been used in some reconstructive procedures, such as flap defatting, to advantage.

Obesity

Large-volume liposuction has become a technique for addressing contour irregularities, but preliminary studies also suggest improvement in cardiovascular risks, blood pressure reduction,

Table 3. Continuum of Depth of Sedation: Definition of General Anesthesia and Levels of Sedation/Analgesia*

	Minimal Sedation (anxiolysis)	Moderate Sedation/ Analgesia (conscious sedation)	Deep Sedation/Analgesia	General Anesthesia
Responsiveness†	Normal response to verbal stimulation	Purposeful response to verbal or tactile stimulation	Purposeful response following repeated or painful stimulation	Unarousable even with painful stimulus
Airway	Unaffected	No intervention required	Intervention may be required	Intervention often required
Spontaneous ventilation	Unaffected	Adequate	May be inadequate	Frequently inadequate
Cardiovascular function	Unaffected	Usually maintained	Usually maintained	May be impaired

*Source: http://www.asahq.org.
†Reflex withdrawal from a painful stimulus is not considered a purposeful response.

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and reduced levels of fasting insulin after liposuction.[21,76,77] Although liposuction may provide some physiologic benefit to the obese patient, there are inherent risks in these patients that must be considered, such as poor wound healing, increased risk of infection, deep vein thrombosis, and sleep apnea.[78] This is particularly true with respect to the severely obese patient, defined as a patient with a body mass index of 35 kg/m^2 or higher. The relative risks and benefits of surgery can be estimated based on the body mass index of the patient, which can be determined using the reference chart in Table 4.[79] Liposuction is not considered a standard treatment for obesity.

Special Considerations

Some patients may be unsuitable for liposuction, including patients with minimal localized adiposity, patients with existing medical conditions that preclude surgical intervention (e.g., certain blood dyscrasias, risk for hernia), patients with unrealistic expectations, and youths and adolescents.[80–82] For these patients, exercise, diet, medical consultation, and even psychological intervention are still viable options. For more information on the safety of surgery in individuals with blood dyscrasias, see the article by Haeck et al., "Evidence-Based Patient Safety Advisory: Blood Dyscrasias," in this issue.

LIPOSUCTION VOLUME

After determining that the patient is an appropriate liposuction candidate, the surgeon must determine the appropriate volume of fat to remove. Advances in liposuction equipment and technique, along with reduced intraoperative blood loss, have made it possible for skilled surgeons to safely remove larger volumes of fat. Large-volume liposuction is defined as the removal of 5000 cc or greater of total aspirate during a single procedure. A review of the scientific literature shows that there are no scientific data available to support a specific volume maximum at which point liposuction is no longer safe, especially when performed in the inpatient setting.[12,21,34,76,83,84] However, the risk of complications may be higher as the volume of aspirate and the number of anatomical sites treated increase, and occasional deaths have been reported for patients undergoing large-volume liposuction.[85] The patient's body mass index and the potential physiologic consequences of tissue loss should be considered to ensure that the volume of aspirate removed is proportional to the patient's overall size and medical condition. In some instances, it may be best to perform large-volume aspirations as separate serial procedures and to avoid combining additional procedures with large-volume liposuction.[86]

It is important for physicians, health policymakers, and state regulators to note the distinction between total fat removed and total aspirate removed. Total aspirate is defined as the combination of total fat and fluid that is removed during liposuction. When referring to liposuction volume, total aspirate should be the volume re-

Table 4. Body Weight According to Height and Body Mass Index*

	BMI (kg/m^2)													
	19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**35**	**40**
Height (inches)	Weight (pounds)													
58	91	96	100	105	110	115	119	124	129	134	138	143	167	191
59	94	99	104	109	114	119	124	128	133	138	143	148	173	198
60	97	102	107	112	118	123	128	133	138	143	148	153	179	204
61	100	106	111	116	122	127	132	137	143	148	153	158	185	211
62	104	109	115	120	126	131	136	142	147	153	158	164	191	218
63	107	113	118	124	130	135	141	146	152	158	163	169	197	225
64	110	116	122	128	134	140	145	151	157	163	169	174	204	232
65	114	120	126	132	138	144	150	156	162	168	174	180	210	240
66	118	124	130	136	142	148	155	161	167	173	179	186	216	247
67	121	127	134	140	146	153	159	166	172	178	185	191	223	255
68	125	131	138	144	151	158	164	171	177	184	190	197	230	262
69	128	135	142	149	155	162	169	176	182	189	196	203	236	270
70	132	139	146	153	160	167	174	181	188	195	202	207	243	278
71	136	143	150	157	165	172	179	186	193	200	208	215	250	286
72	140	147	154	162	169	177	184	191	199	206	213	221	258	294
73	144	151	159	166	174	182	189	197	204	212	219	227	265	302
74	148	155	163	171	179	186	194	202	210	218	225	233	272	311
75	152	160	168	176	184	192	200	208	216	224	232	240	279	319
76	156	164	172	180	189	197	205	213	221	230	238	246	287	328

BMI, body mass index.
*Source: http://www.consumer.gov/weightloss/bmi.htm.

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corded. Some states have imposed restrictions pertaining to the aspirate volume and surgical facility; these limits range from 1000 to 5000 cc (e.g., California, Florida, Kentucky, New York, Ohio, and Tennessee). Surgeons should consult their individual state regulations; however, it is the position of American Society of Plastic Surgeons that, regardless of the anesthetic method, large-volume liposuction (>5000 cc of total aspirate) should be performed in an acute-care hospital or in a facility that is either accredited or licensed. Postoperative vital signs and urinary output should be monitored overnight in an appropriate facility by qualified and competent staff members who are familiar with the perioperative care of the liposuction patient.

FLUID MANAGEMENT

Profound hemodynamic and metabolic alterations can accompany large-volume liposuction.[56,83,84,87] As such, physicians performing liposuction must understand the physiologic impact of the procedure and how to manage the fluid and electrolyte balance of a patient. Before large preinfiltrates came into common use, predictable responses to intravenous fluid administration made replacement a straightforward task. Large preinjectate techniques, such as the tumescent technique, complicate fluid replacement estimates.

Although the tumescent technique is very safe when administered in appropriate doses and monitored by properly trained personnel, it is not without potential complications, especially when used in large volumes. Because tumescent liposuction relies on high-volume hypodermoclysis, the possibility of fluid overload exists. This, in turn, can result in serious complications, such as pulmonary edema and fluid imbalance.[39,40,88,89]

Because of the increasingly large volumes of infiltrate used in large-volume liposuction, careful attention must be paid to all fluid infused, whether as part of the infiltrate solution or as intravenous fluids administered during the procedure.[12,34,83,87] It is essential that all remaining fluid be accounted for when assessing total output, including the total volume of aspirate, any additional blood loss from concomitant procedures, and urine output. It is estimated that 70 percent of the tumescent volume infiltrated is not aspirated when a liposuction procedure is completed.[83] In light of this information, fluid resuscitation generally entails administration of maintenance fluid (the amount of fluid to be replaced from preoperative, nothing-by-mouth status) and the subcutaneous infiltrate (70 percent presumed to be intravascular[90]).[12,83] Intravenous crystalloid may also be needed, depending on the amount of aspirate removed. Patients with a residual fluid volume outside the range of 90 to 140 ml/kg may require additional intravenous hydration or the use of diuretics, and an extended period of observation is warranted.[34] Signs and symptoms of fluid overload include increased blood pressure, jugular vein distention, full bounding pulse, cough, shortness of breath, and moist crackles on auscultation of the lungs.[37]

MULTIPLE PROCEDURES

The cumulative effect of multiple procedures performed during a single operation may increase the potential likelihood that complications may develop.[91] Although many combined plastic surgery procedures are routinely and safely performed in inpatient and outpatient surgical settings, some combination plastic surgery procedures are more controversial, particularly those involving liposuction. Serious complications have been reported when large-volume liposuction is combined with procedures such as abdominoplasty.[91–93]

Restricting liposuction in combination with multiple unrelated procedures has been the topic of many debates, largely because the actual volume of liposuction aspirate that can be safely removed during a combined procedure is as yet unknown. Given the lack of national consensus on this topic, some states have imposed restrictions pertaining to the aspirate volume and surgical facility when liposuction is combined with other procedures in the ambulatory setting. For example, for combined procedures, Florida restricts the volume of supernatant fat to 1000 cc[94]; the limit in Tennessee is 2000 cc.[95] As such, surgeons should be aware of their individual state's regulations. Some data tend to support these limitations, whereas other data do not.[91,93,96–98] However, these collective data tend to be anecdotal or derived from studies that lack the level of rigor necessary to establish clear standards of practice.

INTRAOPERATIVE CARE

Surgical procedures can be associated with several physiologic stressors, including the development of hypothermia, blood loss, malignant hyperthermia, and deep vein thrombosis. Taking precautions against the development of these specific physiologic stressors (i.e., warming the patient, using non–malignant hyperthermia–triggering anesthetics, and providing deep vein thrombosis/pulmonary embolism prophylaxis) and thoughtful decision-making regarding the type of anesthesia

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used, the safety of combining multiple procedures, and the duration of the procedure(s) are essential for maximizing patient safety during surgery and for enhancing postoperative recovery. For a more detailed discussion of these issues, see Haeck et al., "Evidence-Based Patient Safety Advisory: Patient Selection and Procedures in Ambulatory Surgery," in this issue; and Gurunluoglu et al., "Evidence-Based Patient Safety Advisory: Malignant Hyperthermia," also in this issue.

POSTOPERATIVE CARE

Immediate postoperative care should include an assessment of fluid and electrolyte balance and the administration of replacement fluids, as needed. In addition, red blood cell loss needs to be assessed and replacement transfusions should be given, if needed. Patients who undergo large-volume liposuction or multiple procedures should be warmed during recovery using appropriate warming methods [e.g., forced-air warming blankets, (Bair Huggers; Arizant Healthcare, Inc., Eden Prairie, Minn.)].

All patients who have received general anesthesia, regional anesthesia, or deep or moderate sedation should receive appropriate postanesthesia management.[99] The physician is responsible for supervising and coordinating the patient's postoperative care. Observation and monitoring using methods appropriate to the patient's condition by qualified and competent staff are essential. Depending on the amount of aspirate removed, the patient needs to be monitored for several hours or, possibly, overnight. Before a patient is discharged, the patient must be alert and oriented, and all vital signs must be stable.

Compression garments and elastic stockings are generally used for several weeks following surgery.[20,100,101] The patient should expect significant bruising and swelling for at least the first 48 to 72 hours postoperatively. Restriction of aerobic and/or high-impact activities should be determined by surgeon preference and experience. Pain management in the immediate postoperative period may require small doses of parenteral narcotics. The patient may be sent home with oral pain medication, which may be needed for several days. The need for pain medication should lessen after that time. The patient should be advised to immediately report any progressively worsening pain to the physician, as it may be indicative of infection or other complications.[102,103] Long-term follow-up care includes assessment of postoperative recovery at regular intervals, depending on the extent of the procedure. This assessment should examine wound healing and scar maturation, and patient satisfaction.

Correction of deformities and/or revisions should generally be undertaken at least 3 to 6 months after the original liposuction procedure to allow for tissue normalization. Deformities may be corrected with repeat liposuction and/or fat grafts.[104]

POSSIBLE COMPLICATIONS

Serious medical complications are rare following liposuction, although their frequency may increase with the number of sites treated and the volume of fat aspirated.[91] Liposuction-related complications range from relatively minor conditions to more serious or life-threatening events. Minor complications that resolve on their own or with little additional treatment include small hematomas, seromas, and minor contour irregularities.[105] More severe complications include skin perforation, major contour defects, skin necrosis, thermal injury, vital organ injury, adverse anesthesia reaction, major hemorrhage, ischemic optic neuropathy, deep vein thrombosis, pulmonary embolism, and fat embolism.[37,39,85,92,103,106–112] Very severe complications may require additional surgery or hospitalization and may result in death.

Infection can be one of the more serious complications of liposuction. Localized wound infection can progress, sometimes rapidly, causing serious to fatal outcomes. The most serious of these complications include toxic shock and necrotizing fasciitis.[103,107,113–117] Aggressive management of the initial infection can forestall more serious complications.[102,118,119] No evidence was found regarding the use of antibiotic prophylaxis in liposuction cases; therefore, the use of prophylactic antibiotics is a decision that is best made by the physician. It is essential that wounds be kept clean and that any change in the wound site is reported to the physician immediately.

Pulmonary embolism results from one or a combination of three mechanisms: venous stasis, activation of blood coagulation, or injury to the vascular endothelium. One of the most important ways of preventing thromboembolism is to adequately assess the patient regarding his or her risk for such events (discussed in detail in Haeck et al., "Evidence-Based Patient Safety Advisory: Patient Selection and Procedures in Ambulatory Surgery," in this issue). In brief, the patient should be assessed for genetic and acquired conditions that predispose him or her to coagulation disorders (e.g., the factor V Leiden mutation, use of oral contraceptives, or hormone replacement therapy).[120–125] Once the

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patient's relative risk is determined, appropriate prophylaxis can be implemented, including preoperative and intraoperative interventions such as graduated compression stockings, intermittent pneumatic compression devices, and prophylactic anticoagulation therapy.[100,101,121,126–130] Signs and symptoms of deep venous thrombosis include calf pain, leg edema, and venous engorgement. Signs and symptoms of pulmonary embolism include chest pain, dyspnea, hemoptysis, tachycardia, tachypnea, altered mental status, rales, rhonchi, and decreased oxygen saturation.[37,89,113]

Fat emboli, although somewhat less common than pulmonary emboli, have been implicated in liposuction deaths.[113,131] There are two theories as to the origin of fat emboli, one mechanical and the other biochemical.[37,89] In liposuction cases, a mechanical blockage can occur when vessel rupture and adipocyte damage allows globules of triglycerides to enter into venous circulation. The fat globules are too large to pass through the pulmonary capillaries, where they become trapped.[132] Symptoms of a fat embolus include tachycardia, tachypnea, elevated temperature, hypoxemia, hypocapnia, thrombocytopenia, and occasionally mild neurologic symptoms. It is essential to distinguish fat embolus from pulmonary embolus because the treatment is different.[37,113] In contrast to a mechanical fat embolism, fat embolism syndrome occurs later and is an inflammatory and biochemical condition. In theory, the syndrome occurs when circulating or hydrolyzed free fatty acids in the pulmonary system damage endothelial cells and pneumocytes. The clinical course of the syndrome can vary from mild dyspnea to adult respiratory distress syndrome. The three classic symptoms of fat embolism syndrome are respiratory distress, cerebral dysfunction, and petechial rash, which usually occur within 24 to 48 hours after surgery.[133] Treatment includes pulmonary support, evaluation of hemodynamics, monitoring of fluid status, and, in some cases, the use of high-dose corticosteroids.[37]

FACILITY SELECTION AND ACCREDITATION

The physician should determine the appropriate surgical technique and surgical facility in which to perform liposuction after considering the patient's overall health and body areas to be liposuctioned. Although a surgeon can safely perform most liposuction procedures in an accredited outpatient or ambulatory surgery facility, hospitalization may be required for some patients. A discussion of patient selection criteria for the ambulatory surgery setting can be found in Haeck et al., "Evidence-Based Patient Safety Advisory: Patient Selection and Procedures in Ambulatory Surgery," in this issue, and should be consulted for that purpose. Plastic surgeons who are members of the American Society of Plastic Surgeons are required to perform ambulatory surgery in accredited facilities and meet their individual state facility regulations. Additional state regulations may require Advanced Cardiac Life Support/Pediatric Life Support certification for procedures performed in office-based facilities.

PROVIDER TRAINING AND QUALIFICATIONS

Physicians who perform liposuction without having appropriate surgical training may not be as prepared as trained surgeons to recognize and treat an unexpected complication of liposuction when it occurs. Liposuction is a surgical procedure, and as such, physicians performing liposuction must be trained as surgeons.

CONCLUSIONS

Over the past 26 years, liposuction has proven to be a safe, effective, and popular intervention for the surgical removal of adipose tissue. Liposuction techniques have advanced from the treatment of minor contour irregularities to more extensive body contouring. Liposuction patients should be assessed like any other surgical patient. This includes a complete preoperative evaluation, with particular attention to anything that might predispose the patient to complications.

The surgeon can now choose between a variety of liposuction techniques, cannula designs, and anesthesia options. When selecting the most appropriate techniques for each individual patient, the surgeon must consider several factors, including the anticipated liposuction volume, the number of unrelated procedures, the treatment sites, the anesthesia route, the facility type, and the patient's overall health status.

Appropriate postoperative management of the liposuction patient is critical for achieving the best possible outcomes. To this end, a qualified staff is essential for providing the appropriate postanesthesia and postoperative care. Managing the fluid and electrolyte balance, treating pain, and monitoring for complications are important duties, particularly in large-volume cases. When performed by a surgeon with knowledge of the physiologic implications of this surgery, liposuction can be a safe procedure that results in significant patient satisfaction.

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Appendix A. Summary of Recommendations for Liposuction Procedures

	Supporting Evidence	Grade
LIPOSUCTION TECHNIQUE		
• No one single liposuction technique is best suited for all patients in all circumstances. Factors such as the patient's overall health, the patient's BMI, the estimated volume of aspirate to be removed, the number of sites to be addressed, and any other concomitant procedures to be performed should be considered by the surgeon to determine the best technique for the individual patient.	11–16, 18–30, 70, 134–136	B
• Due to the amount of blood loss associated with the dry technique, its use is not recommended except in limited applications with a total aspirate volume ≤100 cc.	11	D
• The dry technique should never be used in conjunction with ultrasound-assisted liposuction.	14	D
• The benefits of performing liposuction while the patient is awake and standing are not currently supported by clinical studies, and this procedure may compromise patient safety.	137	D
LIPOSUCTION CANNULAS		D
• No one cannula is best suited for all patients in all circumstances. Factors such as the patient's overall health, the estimated volume of the aspirate to be removed, the areas of the body to be treated, the number of sites to be addressed, the technique chosen (i.e., suction-assisted, power-assisted, or ultrasound-assisted), and physician preference determine the cannula best suited for the individual patient.	Expert opinion	
ANESTHETIC INFILTRATE SOLUTIONS		B
• In small-volume liposuction, infiltrate solutions containing local anesthetic agents may be sufficient to provide adequate pain relief without the need for additional anesthesia measures. The patient or the surgeon may prefer the use of sedation or general anesthesia even with small volumes of liposuction.	15, 16, 45, 46, 48, 62	
• Insufficient data are available to support the use of bupivacaine or prilocaine in addition to or as a substitute for lidocaine. These agents should be used cautiously if included in infiltrate solutions because of their potential for severe side effects.	41, 53, 54	D
• Lidocaine wetting solutions have the potential to cause systemic toxicity when administered to large or multiple regions of the body. Preventive measures include the following:		
– Limit the lidocaine dose to 35 mg/kg. This level may not be safe in patients with low protein levels and other medical conditions where the metabolic byproducts of lidocaine breakdown may reach problematic levels.	15, 16, 45, 46, 48, 49, 52	B
– Calculate the dose for total body weight.	16	D
– Reduce the concentration of lidocaine when necessary (e.g., depending on the site of infiltration).	52	D
– Use the superwet rather than the tumescent technique.	12	D
– Consider avoiding the use of lidocaine when general or regional anesthesia is used.	Expert opinion	D
• Epinephrine use should be avoided in patients who present with pheochromocytoma, hyperthyroidism, severe hypertension, cardiac disease, or peripheral vascular disease. In addition, cardiac arrhythmias can occur in predisposed individuals or when epinephrine is used with halothane anesthesia. The surgeon must carefully evaluate these types of patients before performing liposuction.	55–57	D
• Consider staging the infiltration of multiple anatomical sites to reduce the possibility of an excess epinephrine effect.	Expert opinion	D
TYPE OF ANESTHESIA		
• A physician should have the primary responsibility for providing and/or supervising anesthesia. All anesthesia should be ordered by a physician. Anesthetics may be administered by either a qualified physician, a certified registered nurse anesthetist under physician supervision, or another qualified health care provider under the supervision of a qualified physician as required by law. The responsible physician must be physically present in the operating room throughout the conduct of the anesthetic. (Refer to the American Society of Anesthesiologists "Guidelines for Sedation and Analgesia"[138] and state law for more specific information.)	Expert opinion	D
• General anesthesia can be used safely in the ambulatory setting for liposuction procedures.	59–61	C
• General anesthesia has advantages for more complex liposuction procedures that include precise dosing, controlled patient movement, and airway management.	Expert opinion	D

(*Continued*)

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Appendix A. (*Continued*)

	Supporting Evidence	Grade
• Epidural and spinal anesthesia is discouraged in the ambulatory setting because of the possibility of vasodilation, hypotension, and fluid overload.	62, 63	D
• Moderate sedation/analgesia augments the patient's comfort level and is an effective adjunct to anesthetic infiltrate solutions.	60, 64	B
PATIENT SELECTION		
• Even though liposuction is generally an elective procedure, the liposuction patient must be assessed using the same standards as those used for anyone who is undergoing any type of surgery, including a complete preoperative history and physical examination. (See Haeck et al., "Evidence-Based Patient Safety Advisory: Patient Selection and Procedures in Ambulatory Surgery," in this issue, for a discussion of patient selection criteria for ambulatory surgery facilities.)	Expert opinion	D
• In some cases, liposuction may be used in the treatment of gynecomastia and breast hypertrophy.	45, 70–75	D
• BMI is a good method with which to assess a patient's relative risks and benefits for liposuction.	21	D
• In obese patients receiving large-volume liposuction, it may be necessary to modify the anesthetic infiltrate solution to prevent lidocaine toxicity.	12	D
• Not all patients are appropriate liposuction candidates, in particular, patients with minimal localized adiposity, patients with existing medical conditions that preclude surgical intervention (e.g., certain blood dyscrasias, risk for hernia), patients with unrealistic expectations, and youths and adolescents.	80–82	D
• Patients who are not liposuction candidates may wish to continue diet and exercise routines, seek medical intervention to treat an existing condition(s), consider bariatric evaluation, or, in the case of patients who have unrealistic expectations about their condition or potential outcomes, be referred for a psychiatric or psychological evaluation.	Expert opinion	D
LIPOSUCTION VOLUME		
• Large-volume liposuction (>5000 cc of total aspirate) should be performed in an acute care hospital or in a facility that is either accredited or licensed, regardless of the anesthetic method.	Expert opinion	D
• For patients undergoing large-volume liposuction, postoperative vital signs and urinary output should be monitored overnight in an appropriate facility by qualified and competent staff members who are familiar with liposuction perioperative care.	12	D
• Under certain circumstances, it may be in the best interest of the patient to perform large-volume procedures as separate serial procedures and to avoid combining them with additional procedures.	86	D
FLUID MANAGEMENT		
• A data sheet should be used to facilitate communication.	Expert opinion	D
• The intake and output of all fluids used in the operative and postoperative periods should be monitored accurately.	34, 87	D
• Communication with the anesthesia care provider about fluid management is critical.	Expert opinion	D
• Fluid management and liposuction surgery must account for preexisting deficits (i.e., created by a fasting state), maintenance requirements (based on vital signs and urine output), and intraoperative losses of aspirated tissue and third-space deficit.	12, 34, 83	D
• Blood loss estimates should be made and confirmed with preoperative and postoperative hemoglobin measurements. However, because of fluid shifts, hemoglobin levels may not be reliable during the first 24 hr postoperatively.	Expert opinion	D
• Calculation of residual fluid volumes after liposuction is helpful in planning postoperative care.	34	D
• Suggested fluid resuscitation guidelines: – For aspirate <5000 cc: maintenance fluid plus subcutaneous infiltrate – For aspirate ≥5000 cc: maintenance fluid plus subcutaneous infiltrate plus 0.25 ml intravenous crystalloid for each milliliter of aspirate	12, 83	D
MULTIPLE PROCEDURES		
• Large-volume liposuction combined with certain other procedures (e.g., abdominoplasty) has resulted in serious complications, and such combinations should be avoided.	91–93	D
• Individual patient circumstances may warrant performing liposuction as a separate procedure.	Expert opinion	D
POSSIBLE COMPLICATIONS		
• Physicians should be aware of the signs and symptoms of the following complications that may arise during or after liposuction (all complications listed below were described in at least one case report).		N/A

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Appendix A. (*Continued*)

	Supporting Evidence	Grade
• Minor complications: – Small hematomas – Seromas – Minor contour irregularities	105	
• More severe complications: – Skin perforation – Major contour defects – Skin necrosis – Thermal injury – Vital organ injury – Adverse anesthesia reaction – Major hemorrhage – Ischemic optic neuropathy – Deep vein thrombosis – Pulmonary embolism – Fat embolism	37, 39, 85, 92, 103, 106–112, 131	
• Most severe complications: – Infection – Toxic shock – Necrotizing fasciitis	102, 103, 107, 113–119	
FACILITY SELECTION AND ACCREDITATION • The physician should determine the appropriate surgical technique and surgical facility in which to perform liposuction after considering the patient's overall health and body areas to be liposuctioned, and state regulations. Hospitalization may be required in select cases to ensure patient safety. (See Haeck et al., "Evidence-Based Patient Safety Advisory: Patient Selection and Procedures in Ambulatory Surgery," in this issue, for a more detailed discussion of patient selection criteria for the ambulatory surgery setting.) • Plastic surgery, including liposuction, performed under anesthesia, other than minor local anesthesia and/or minimal oral tranquilization, should be performed in a surgical facility that meets at least one of the following criteria: – Accredited by a national- or state-recognized accrediting agency/organization such as the American Association for Accreditation of Ambulatory Surgery Facilities, the Accreditation Association for Ambulatory Health Care, the American Osteopathic Association, or the Joint Commission on Accreditation of Healthcare Organizations. – Certified to participate in the Medicare program under Title XVIII. – Licensed by the state in which the facility is located.	Expert opinion	D
PHYSICIAN TRAINING AND QUALIFICATION • Physicians performing liposuction must be trained as surgeons. • Surgeons performing procedures outside of his or her area of training, defined by the surgeon's specialty, must obtain additional education, certification, and experience. The ABMS surgeon must have liposuction and body-contouring training and must operate in his or her area of anatomical expertise. The physician who performs liposuction in any surgical setting must meet *all* of the following minimal formal training requirements: – The physician must have a basic education: M.D. or D.O. – The physician must be qualified for examination or be certified by a surgical board recognized by the ABMS, *and* the physician must: ○ Complete training in liposuction/body contouring during an accredited residency or fellowship, *or* ○ Complete an 8-hr liposuction/body-contouring training course approved for category I Continuing Medical Education credit with at least 3 hr of hands-on bio-skills cadaver training and a comprehensive instructional program on fluid replacement. Observation by a proctor with liposuction privileges for the first three clinical procedures is recommended. – The physician must operate within his or her area of training and area of anatomical expertise, which is defined by his or her ABMS surgical specialty board.	38	D

BMI, body mass index; ASA, American Society of Anesthesiologists; ASPS, American Society of Plastic Surgeons; N/A, not applicable; ABMS, American Board of Medical Specialties.

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