Evidence-Based Medicine: Liposuction

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Learning Objectives: After studying this article, the participant should be able to: 1. Review the appropriate indications and techniques for suction-assisted lipectomy body contouring surgery. 2. Accurately calculate the patient limits of lidocaine for safe dosing during the tumescent infiltration phase of liposuction. 3. Determine preoperatively possible "red flags" or symptoms and signs in the patient history and physical examination that may indicate a heightened risk profile for a liposuction procedure. 4. Provide an introduction to adjunctive techniques to liposuction such as energy-assisted liposuction and to determine whether or not the reader may decide to add them to his or her practice.

Summary: With increased focus on one's aesthetic appearance, liposuction has become the most popular cosmetic procedure in the world since its introduction in the 1980s. As it has become more refined with experience, safety, patient selection, preoperative assessment, fluid management, proper technique, and overall care of the patient have been emphasized and improved. For the present article, a systematic review of the relevant literature regarding patient workup, tumescent fluid techniques, medication overview, and operative technique was conducted with a practical approach that the reader will possibly find clinically applicable. Recent trends regarding energy-assisted liposuction and body contouring local anesthesia use are addressed. Deep venous thromboembolism prophylaxis is mentioned, as are other common and less common possible complications. The article provides a literature-supported overview on liposuction techniques with an emphasis on preoperative assessment, medicines used, operative technique, and outcomes. (*Plast. Reconstr. Surg.* 139: 267e, 2017.)

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Since the latter half of the twentieth century, there has been an increasing focus on the body as a vehicle for identity and self-expression, with a greater recognition of the role of appearance and the desire for self-improvement.[1] In 2014, liposuction replaced breast augmentation as the most frequently performed surgical procedure, with a 16 percent increase over 2013 and more than $1 billion being spent on the procedure in the United States alone.[2]

PREOPERATIVE ASSESSMENT

It is important for the physician early into the consultation to assess the patients' motivations for surgery and the degree of concern they have about their current physical state so that their expectations may be met. Patients with body dysmorphic disorder will not benefit from surgical intervention and have been observed in aesthetic surgery settings to seek surgical enhancement at a reported prevalence of 6 to 15 percent.[3] The current recommendation is for the patient to be within 30 percent of the ideal body mass index, but whether liposuction can be a contributing factor to weight loss in individuals with a high body mass index is an area of controversy.[4] Massive weight loss patients may have persistent areas of lipodystrophy amenable to liposuction. In a recent study using multivariate regression models incorporating the interaction between liposuction volume and body mass index, the authors' risk assessment model demonstrates that volumes in excess of 100 ml per unit of body mass index confer an increased risk of complications.[5] The

From the Manhattan Eye, Ear & Throat Hospital.
Received for publication August 20, 2015; accepted April 15, 2016.

DOI: 10.1097/PRS.0000000000002859

Disclosure: *Dr. Chia and Dr. Theodorou are consultants for InMode Corporation. Dr. Neinstein has no financial disclosures.*

results of this study may help surgeons in surgical planning and expectation management.

Medical History

Many patients take vitamins, minerals, and supplements and do not report this to their practitioner, as they feel they are inconsequential. Stopping all nonessential agents before surgery can reduce the risk of a bleeding-related complication.[6]

The percentage of the U.S. population using at least one psychotropic medication increased from 5.9 percent in 1996 to 8.1 percent in 2001.[7] First-line antidepressants include selective serotonin reuptake inhibitors. These medications, along with others, can compete with lidocaine for metabolism in the liver, increasing the risk of toxicity.[8] Drugs that potentially interfere with lidocaine metabolism should be discontinued at least 2 weeks before using tumescent technique for local anesthesia when high doses of lidocaine are anticipated. If it is not reasonable to discontinue a drug that might interfere with lidocaine metabolism, the operation should be limited to smaller total doses of lidocaine or be performed under general anesthesia.[9] Smoking is an independent risk factor for wound healing complications. The ameliorating effects of cessation are supported by Level I evidence, which suggests that the optimal duration of preoperative cessation of any form of nicotine is 4 weeks or longer.[10] Diabetes mellitus is an increasingly common medical condition affecting approximately 8 percent of the population of the United States.[11] Infections account for 66 percent of postoperative complications and nearly one-quarter of perioperative deaths in patients with diabetes mellitus. Fortunately, tight glycemic control has been shown to have a profound effect on reducing the incidence of many of these complications in a variety of surgical populations.[12] Complication rates in orthopedic surgery have been shown to be lower in patients whose hemoglobin A1c is less than 6.5 percent.[13]

Venous thromboembolism is a serious complication with risks for short-term mortality and long-term morbidity. Venous thromboembolism has been shown to be the single largest cause of mortality in patients undergoing high-volume liposuction.[4] The Caprini risk assessment model is a useful and effective tool for stratifying plastic and reconstructive surgery patients for venous thromboembolism risk, even in oral sedation tumescent liposuction cases.[14] Using regional or tumescent anesthesia alone has been shown to have statistically significant lower incidences of postoperative deep vein thrombosis.[15] If patients are on beta-blockers for hypertension, it should be confirmed that they are cardioselective to prevent a hypertensive crisis from an unopposed alpha vasoconstriction.[16] According to the American College of Cardiology/American Heart Association Guidelines, functional status is a reliable predictor of perioperative and long-term cardiac events.[17]

Physical Examination

A carefully directed history and physical examination should look for stigmata and sequelae of chronic disease. When examining the abdomen, the physician should pay particular attention to surgical scars as potential sources of hernias. Visceral perforations are most common in the small intestine in patients with abdominal hernias.[18] Classification and documentation of the extent of diastasis recti and the visceral fat component is essential. Skin quantity and quality should be assessed, and differences between excisional procedures and liposuction should be discussed with the patients.

Informed Consent and Photography

Accurate photographic documentation has become essential in reconstructive and cosmetic plastic surgery for both clinical and scientific purposes.[19] Generally, "informed consent" requires that the patient be informed of the risks of treatment, the prognosis, and alternative treatments before consenting to treatment. Surgical consent has evolved and is not an event or a signature on a form but is an ongoing process of communication that continues throughout preoperative, perioperative, and postoperative care.

Location of Surgery

Most surgical procedures are performed in one of three outpatient settings: hospitals, free-standing ambulatory surgery centers, or office-based surgery facilities.[20] Office-based surgery has several potential benefits over hospital-based surgery, including cost containment, ease of scheduling, and convenience to both patients and surgeons. In a review of 3615 consecutive patients who had undergone office-based plastic surgery with monitored anesthesia care or sedation, there were no deaths, ventilator requirements, deep venous thromboses, or pulmonary emboli. This study helped show that office-based surgery with intravenous sedation, performed by board-certified plastic surgeons and

nurse anesthetists, is safe.[21] Many surgeons still prefer to perform the majority of liposuction cases under general anesthesia.[22] Tumescent anesthesia was initially developed in 1987 by Jeffery Klein in an attempt to perform liposuction procedures with the sole use of local anesthesia.[23] In a review of 4380 consecutive patients undergoing tumescent liposuction by the same surgeon, no serious complications requiring hospitalization were found.[24] It was found that hospital-based liposuction had three times the rate of malpractice settlements compared with office-based liposuction surgery.[25] To promote its members to practice with the utmost safety and integrity, as of July 1, 2002, facility accreditation is a requirement for active membership in the American Society for Aesthetic Plastic Surgery. Physicians should follow state-specific regulations on total aspirate permitted in a surgical setting.

MEDICATIONS IN WETTING SOLUTIONS

Lidocaine

In 1943, lidocaine was the first drug of the amino amide type to be introduced into clinical practice, and its rapid onset and moderate duration of action ensure its widespread use today.[26] Lidocaine is rapidly eliminated by hepatic metabolism.[27] Any drug that inhibits CYP3A4 enzymes, any condition that reduces hepatic blood flow, along with any disease that effects liver function can reduce lidocaine clearance.[28] Not all patients should be treated equally in terms of lidocaine doses. For example, lower limits of lidocaine should be used in thinner patients with smaller volumes of distribution.[29] The maximum recommended doses typically do not take into consideration the site of injection or factors that may influence tissue redistribution, metabolism, or excretion. The lidocaine hydrochloride (Xylocaine; Astra Pharmaceutical Products, Inc., Westboro, Mass.) package insert reads that the dose of lidocaine at any one time should not exceed 3 mg/kg for plain solutions or 7 mg/kg for preparations including epinephrine.[30] By measuring sequential lidocaine blood samples after tumescent infiltration along with graphing the peak plasma concentrations as a function of the lidocaine dosage (in milligrams per kilogram), a safe maximum dosage for tumescent lidocaine was shown to be 35 mg/kg by Klein.[31] Although it is generally accepted that lidocaine doses up to 50 mg/kg[32] and even 55 mg/kg[33] are safe to use in tumescent liposuction, the American Society of Plastic Surgeons guidelines recommends 35 mg/kg as the maximum dose. Lidocaine may also contribute to the extremely low incidence of infection seen in liposuction because of its bacteriostatic effect. Data suggest that, for patients undergoing general anesthesia with the superwet technique, the lidocaine component may be eliminated without an increase in postoperative pain.[34]

Epinephrine

Epinephrine causes vasoconstriction, resulting in hemostasis and delayed absorption of the anesthetic agent. This prolongs its effect, decreases the amount of anesthetic needed, and reduces the risk of lidocaine toxicity.[35] It is recommended that epinephrine doses not exceed 0.07 mg/kg, although doses as high as 10 mg/kg have been used safely.[36] The detection of peak levels between 2 and 4 hours after infusion has been found in multiple studies.[37,38] It has been shown that the time when the lowest cutaneous hemoglobin concentration occurs after 1% lidocaine with 1:100,000 epinephrine is injected subcutaneously is 25.9 minutes.[39] This is considerably longer than the frequently quoted 7 to 10 minutes for maximal cutaneous vasoconstriction.[40]

Bupivacaine

Bupivacaine is a long-acting amide local anesthetic which, unlike lidocaine, does not have an active metabolite. Of all the amide local anesthetics, bupivacaine is said to be the most cardiotoxic. This toxicity is seen mostly when there is a sudden increase in the plasma concentration of bupivacaine.[41] However, full recovery has been reported using an intravenous injection of a lipid emulsion, Intralipid 20% (Baxter Healthcare Corp., Deerfield, Ill.). It has been suggested that lipid emulsion may reverse local anesthetic toxicity by extracting lipophilic local anesthetics from aqueous plasma or tissues or by counteracting local anesthetic inhibition of myocardial fatty acid oxygenation.[42] In a prospective study, Swanson[38] found that plasma levels were slower to rise than lidocaine, peaking at 20 hours compared with 8 to 18 hours after infusion. That study also went on to show safety with 550 mg administered and 3.33-μg/ml peak plasma concentrations. An online survey to members of the American Society of Plastic Surgeons revealed that 7 percent of respondents were using bupivacaine in their tumescent solutions, with no reported cases of toxicity.[43]

Sodium Bicarbonate

When lidocaine is used for local, subcutaneous injections, patients often complain of pain thought to be related to the pH (3.5 to 7.0) of most commercial lidocaine solutions.[44,45] Some data suggest that alkalization of lidocaine does in fact reduce the level of pain associated with its injection.

Wetting Solutions

The current options for wetting solutions are dry, wet, superwet, and tumescent. The essential differences between these techniques focus on the amount of infiltrating solution injected into the tissues and the resultant blood loss as a percentage of aspirated fluid. The dry technique involves no infused fluid and results in approximately 25 to 40 percent blood loss of the volume removed. Blood loss has been estimated to represent approximately 1 percent of the liposuction aspirate volume for both tumescent and superwet techniques.[46] Swanson[38] felt that this was a gross underestimation and has shown that there is substantial extravascular "third-space" blood loss into the interstitial tissues correlating to an approximate 2 percent decrease in hemoglobin for every 2500 cc of aspirate. "True" tumescent anesthesia is considered a 3:1 infiltrate to aspirate under pure local anesthesia. Most plastic surgeons report using a wetting solution that is a variation of superwet anesthesia (1:1 infiltrate to aspirate). Tissue blanching and moderate tension are considered clinical endpoints of infiltrate.[47]

OPERATIVE CONSIDERATIONS

Cannulas

In general, blunt-tip cannulas are used to minimize perforation risk, and smaller diameter cannulas are used to minimize contour irregularities. Non–blunt-tip cannulas are typically used for breaking up scar or discontinuous undermining. Aspiration has been found to be directly proportional to cannula and suction-tubing diameter and inversely proportional to cannula and suction-tubing length.[48] Beck et al.,[49] with a proprietary manufacturing process, found multiport and dual-port cannulas to be significantly more efficient at aspiration compared with the standard Mercedes tip cannula.

Operative Techniques

Specific depths of subcutaneous fat should be suctioned, which vary from different body locations and patient-specific goals. For example, the deep and/or intermediate fat layer should be suctioned primarily,[22] but in rare cases, superficial or subdermal liposuction may be appropriate.[50] Anatomical "zones of adherence," present in both men and women, are important to identify preoperatively. These are areas with relatively dense fibrous attachments running to the underlying deep fascia where they help define the natural shape and curve of the body. These areas are not to be suctioned[51] because of the high potential for contour deformities. Small-volume procedures or procedures primarily for harvesting fat can be performed with syringe liposuction. The syringe technique used blunt-tip suction cannulae connected to a syringe. Drawing back the syringe plunger generates the negative pressures needed to remove fat during liposuction and replaces the electric vacuum pump and connecting tubing traditionally used for this procedure.[52]

ADJUNCTIVE LIPOSUCTION TECHNOLOGY/TECHNIQUES

Power-Assisted Liposuction

Power-assisted liposuction is a commonly used technology that uses a variable-speed motor to provide reciprocating motion to the cannula which, in combination with the reciprocating action of the surgeon's arm, facilitates removal of adipose tissue. The principal advantages of power-assisted liposuction is treatment speed, economy of motion, and reduced operator fatigue.[53]

Laser-Assisted Liposuction

Goldman and colleagues showed histologic evidence of coagulation of small blood vessels, rupture of adipocytes, reorganization of the reticular dermis, and coagulation of collagen in fat tissue with an updated 1064-nm-wavelength neodymium:yttrium-aluminum-garnet laser.[54] In a prospective, randomized, double-blind, controlled clinical trial comparing outcomes between suction-assisted lipoplasty and laser-assisted lipoplasty in patients where the authors randomly allocated half a body part for each modality, no major clinical differences for suction-assisted lipoplasty versus laser-assisted lipoplasty was seen.[55] Although there is no conclusive evidence for the use of lasers in liposuction, the recent adoption of the 1440-nm laser may prove to be efficacious for emulsification. The longer wavelength has 20 times more absorption in adipose tissue than the 1064-nm/1320-nm and 40 times more absorption than 924-nm/980-nm wavelengths.[56]

Ultrasound-Assisted Liposuction

Vibration amplification of sound energy at resonance (VASER; Solta Medical, Inc., Hayward, Calif.) is another modality that was introduced to the United States with great fanfare after early use with mixed results of hollow probe ultrasonic liposuction in the 1990s.[57] Nagy and Vanek[58] compared VASER-assisted lipoplasty and suction-assisted liposuction. They evaluated two objective endpoints: skin retraction, in which VASER showed a 6 percent increase, and blood loss, which also showed a minimal benefit of 3 cc per 100 cc of aspirate. Both surgeons and patients were unable to tell the difference between sides treated with either system.[59] With the growth of autologous fat transfer, the use of ultrasound to selectively target and dislodge fat cells from the fatty tissue matrix may help improve fat viability and retention.[60]

Radiofrequency-Assisted Liposuction

Paul and Mulholland introduced radiofrequency-assisted liposuction and soft-tissue contraction technology, showing that energy could be delivered to the dermis while heating the deep adipose and subcutaneous tissue to much higher temperatures without compromising skin safety.[61] Using the BodyTite (Invasix Ltd., Yokneam, Israel) device in an industry-sponsored in vivo study, linear contraction observed at 6-month follow-up was much more significant than reported with any other technology and varied from 12.7 percent up to 47 percent, depending on patient and treatment variables.[62] Theodorou and Chia,[63] in a study on arm contouring with radiofrequency-assisted liposuction, used three independent plastic surgeons' evaluations of the preoperative and postoperative photographs and showed improvement in arm contouring to be as follows: excellent, 8 percent; good, 72 percent; moderate, 18 percent; and poor, 2 percent. They determined the degree of skin tightening to be excellent in 11 percent, good in 46 percent, moderate in 38 percent, and poor in 5 percent.

Water-Assisted Liposuction

Water-assisted liposuction uses a dual-purpose cannula that emits pulsating, fan-shaped jets of tumescent solution, followed by simultaneous suctioning of the fatty tissue and the instilled fluid. In a single-surgeon study using the Body-Jet (Human Med, Eclipse Ltd., Dallas, Texas), the amount of blood loss was negligible, with lipocrit levels estimated at less than 1.0 percent in both small- and large-volume liposuction cases.[64] There was no comparison to other modalities and, because no thermal energy was applied, there was no discussion of skin tightening or emulsification. In a study of grafted lipoaspirates from water-assisted liposuction compared with suction-assisted lipoplasty, the water-based group had better weight retention, less apoptosis, and greater angiogenesis.[65]

Separation, Aspiration, and Fat Equalization

Separation, aspiration, and fat equalization (SAFELipo) is a three-step process created by Dr. Simeon Wall, Jr., that has been proposed to reduce irregularities and bruising and increase skin retraction. Fat separation is performed without suction, using an angled 5-mm exploded tip (basket) cannula (MicroAire, Charlottesville, Va.). Aspiration of the separated fat is performed with an angled 3-mm or 4-mm Mercedes cannula, to be used in areas with thinner or thicker areas of fat, respectively. Fat equalization (after tunneling) of the previously treated areas is performed with the angled 5-mm exploded tip cannula, without suction. The contour of the areas is assessed by a rolling pinch test while passing the cannula, with the endpoint of a completely smooth rolling pinch test without thick or thin areas of contour. This process leaves behind a layer of separated fat that can be considered local fat grafts.[66]

Markings

Areas to be suctioned are typically marked with a circle in a topographic pattern. Zones of adherence and areas to avoid are marked with hash marks.[67] Some authors advocate grid markings to standardize resection and reduce contour irregularities.[68] Incisions should be placed in natural creases to minimize visibility, and some recommend placing bilateral access incisions asymmetrically to avoid scars that appear planned. It is important to review all markings and access incision locations with patients in front of a mirror before they are medicated.

Fluid Management

Fluid underresuscitation or overresuscitation remains a critical issue with regard to liposuction. Empiric formulas have been suggested. Rohrich et al. suggest intraoperative fluid ratios near 1.8 for small-volume reductions and 1.2 for large-volume aspirations.[69] Pitman et al. recommend that the total volume of fluid administered should equal twice the volume of total aspirate.[70] Matarasso recommends that the total intake of injected, intravenous, and postoperative fluid

is 2 to 3 ml/ml aspirate over the course of the 2 days after surgery.[71] The aim of intravenous fluid administration is to replace the preoperative deficit and provide maintenance fluid. With awake tumescent liposuction, the patient is able to drink normally the night before and the day of surgery, eliminating the need to replace deficits, minimizing the risks of overhydration or underhydration.

Postoperative Care

Traditionally, prolonged use of elastic compression garments was advocated. The general rule of thumb was for patients to wear the garment for 1 week for every decade of life (40-year-old patients would wear garments for 4 weeks). Prolonged compression can cause skin creases, hyperpigmentation, pain, and swelling. Some ways to minimize swelling and postoperative compression include minimally traumatic surgical technique, not suturing the incisions as recommended by Toledo and Mauad and applying bulky absorbent dressings for the first 24 to 48 hours to allow the excess remnant fluid and serous reaction to flow out.[72] Klein[73] advocates for bimodal compression. During the first stage of bimodal compression, a high degree of compression is maintained for as long as drainage persists. The second stage of bimodal compression begins 24 hours after all drainage has ceased, and uses either moderate compression or no compression.

COMPLICATIONS

Local

With appropriate patient selection and minimally traumatic techniques, many complications can be avoided. Overly aggressive liposuction can lead to seromas. The collection of serous fluid in a treated area may lead to extensive breaking of the fibrous tissue network, leading to the formation of a single cavity.[74] The lower abdomen in patients with a high body mass index is a common area for seromas. Infection is extremely uncommon (<1 percent incidence).[75] This may be because of a combination of sterile technique, small incisions, and the antibacterial effects of lidocaine. The most common postoperative complication is contour irregularities, with an incidence of 2.7 percent.[76] Illouz recommends that as a rule the contour should be slightly undercorrected to allow for postoperative fat lysis, which will amplify the result.[77] Using small cannulas, not performing superficial liposuction, turning the suction off when exiting incisions, crisscrossing areas, constantly analyzing areas (visual and tactile), and proper positioning can all help reduce the chance of contour irregularities. Autologous fat transfer at the time of surgery or 6 months postoperatively can be used to help correct deformities. Toledo and Mauad recommend routine harvesting of a few syringes of fat before suction-assisted lipoplasty so that it may be reinjected in cases of inadvertent overliposuctioning in any area.[72] Relatively infrequent skin conditions such as hyperpigmentation, necrosis, and erythema ab igne can be seen. Underlying connective tissue disease, smoking, and superficial aggressive liposuction may contribute to these complications.[78]

Systemic Complications

The most frequent potentially lethal complications associated with liposuction are pulmonary embolism, fat embolism, sepsis, necrotizing fasciitis, and perforation of abdominal organs. Grazer and de Jong[4] in a North American survey of American Society for Aesthetic Plastic Surgery members found a fatality rate of 19.1 per 100,000 liposuction procedures. The major cause of death was pulmonary thromboembolism. Even though dermatologic studies of true tumescent liposuction have reported the risk of death from liposuction procedures to be zero in a series 66,000[79] cases, there are reports of deaths in true-awake tumescent liposuction.[75] Major risk factors for the development of severe complications are poor standards of sterility, the infiltration of multiple liters of wetting solution, permissive postoperative discharge, and selection of unfit patients.[75]

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REFERENCES

1. Honigman R, Castle DJ. Aging and cosmetic enhancement. *Clin Interv Aging* 2006;1:115–119.
2. American Society for Aesthetic Plastic Surgery. ASAPS 2014 statistics on cosmetic surgery. Available at: http://www.surgery.org/media/news-releases/the-american-society-for-aesthetic-plastic-surgery-reports-americans-spent-largest-amount-on-cosmetic-surger. Accessed January 12, 2015.
3. Pavan C, Simonato P, Marini M, Mazzoleni F, Pavan L, Vindigni V. Psychopathologic aspects of body dysmorphic disorder: A literature review. *Aesthetic Plast Surg.* 2008;32:473–484.
4. Grazer FM, de Jong RH. Fatal outcomes from liposuction: Census survey of cosmetic surgeons. *Plast Reconstr Surg.* 2000;105:436–446; discussion 447.
5. Chow I, Alghoul MS, Khavanin N, et al. Is there a safe lipoaspirate volume? A risk assessment model of liposuction volume as a function of body mass index. *Plast Reconstr Surg.* 2015;136:474–483.

6. Broughton G II, Crosby MA, Coleman J, Rohrich RJ. Use of herbal supplements and vitamins in plastic surgery: A practical review. *Plast Reconstr Surg.* 2007;119:48e–66e.
7. Zuvekas SH. Prescription drugs and the changing patterns of treatment for mental disorders, 1996-2001. *Health Aff (Millwood)* 2005;24:195–205.
8. Wrighton SA, Stevens JC. The human hepatic cytochromes P450 involved in drug metabolism. *Crit Rev Toxicol.* 1992;22:1–21.
9. Klein J, Kassasjdian N. Lidocaine Toxicity with Tumescent Liposuction: A Case Report of Probable Drug Interactions. *Dermatol Surg.* 1997;23:1169–1174. Available at: http://tumescent.org/lidocaine-toxicity-with-tumescent-liposuction/. Accessed October 22, 2015
10. Rinker B. The evils of nicotine: An evidence-based guide to smoking and plastic surgery. *Ann Plast Surg.* 2013;70:599–605.
11. American Diabetes Association. Diabetes basics. Available at: http://www.diabetes.org/diabetes-basics/. Accessed January 16, 2014.
12. Van den Berghe G, Wilmer A, Milants I, et al. Intensive insulin therapy in mixed medical/surgical intensive care units: Benefit versus harm. *Diabetes* 2006;55:3151–3159.
13. Liu J, Ludwig T, Ebraheim NA. Effect of the blood HbA1c level on surgical treatment outcomes of diabetics with ankle fractures. *Orthop Surg.* 2013;5:203–208.
14. Pannucci CJ, Bailey SH, Dreszer G, et al. Validation of the Caprini risk assessment model in plastic and reconstructive surgery patients. *J Am Coll Surg.* 2011;212:105–112.
15. Prins MH, Hirsh J. A comparison of general anesthesia and regional anesthesia as a risk factor for deep vein thrombosis following hip surgery: A critical review. *Thromb Haemost.* 1990;64:497–500.
16. Kim Y. Interaction between beta blockers and epinephrine on hemodynamics of spontaneously hypertensive rats. *Res Commun Chem Pathol Pharmacol.* 1993;80:3–19.
17. Anderson JL, Antman EM, Harold JG, et al. Clinical practice guidelines on perioperative cardiovascular evaluation: Collaborative efforts among the ACC, AHA, and ESC. *J Am Coll Cardiol.* 2014;64:2371–2372.
18. Lehnhardt M, Homann HH, Daigeler A, Hauser J, Palka P, Steinau HU. Major and lethal complications of liposuction: A review of 72 cases in Germany between 1998 and 2002. *Plast Reconstr Surg.* 2008;121:396e–403e.
19. Persichetti P, Simone P, Langella M, Marangi GF, Carusi C. Digital photography in plastic surgery: How to achieve reasonable standardization outside a photographic studio. *Aesthetic Plast Surg.* 2007;31:194–200.
20. American Hospital Association. Hospital statistics. 2010; Available at: http://www.aha.org/research/rc/stat-studies/Studies.shtml. Accessed October 22, 2015.
21. Bitar G, Mullis W, Jacobs W, et al. Safety and efficacy of office-based surgery with monitored anesthesia care/sedation in 4778 consecutive plastic surgery procedures. *Plast Reconstr Surg.* 2003;111:150–156; discussion 157.
22. Stephan PJ, Kenkel JM. Updates and advances in liposuction. *Aesthet Surg J.* 2010;30:83–97; quiz 98.
23. Klein JA. The tumescent technique for liposuction surgery. *Am J Cosm Surg.* 1987;4:263–267.
24. Boeni R. Safety of tumescent liposuction under local anesthesia in a series of 4,380 patients. *Dermatology* 2011;222:278–281.
25. Coleman WP III, Hanke CW, Lillis P, Bernstein G, Narins R. Does the location of the surgery or the specialty of the physician affect malpractice claims in liposuction? *Dermatol Surg.* 1999;25:343–347.
26. Tetzlaff JE. The pharmacology of local anesthetics. *Anesthesiol Clin North Am.* 2000;18:217–233, v.
27. Bennett PN, Aarons LJ, Bending MR, Steiner JA, Rowland M. Pharmacokinetics of lidocaine and its deethylated metabolite: Dose and time dependency studies in man. *J Pharmacokinet Biopharm.* 1982;10:265–281.
28. Stenson RE, Constantino RT, Harrison DC. Interrelationships of hepatic blood flow, cardiac output, and blood levels of lidocaine in man. *Circulation* 1971;43:205–211.
29. Pfeifer HJ, Greenblatt DJ, Koch-Weser J. Clinical use and toxicity of intravenous lidocaine: A report from the Boston Collaborative Drug Surveillance Program. *Am Heart J.* 1976;92:168–173.
30. Astrazeneca. Xylocaine and Xylocaine with adrenaline product information 2010. Available at: http://www.astrazeneca.com.au/cs/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobheadername1=Content-Disposition&blobheadername2=MDT-Type&blobheadervalue1=inline%3B+filename%3DXylocaineltsupgt174ltsupgt.pdf&blobheadervalue2=abinary%3B+charset%3DUTF-8&blobkey=id&blobtable=MungoBlobs&blobwhere=1285657394625&ssbinary=true. Accessed October 22, 2015.
31. Klein JA. Tumescent technique for regional anesthesia permits lidocaine doses of 35 mg/kg for liposuction. *J Dermatol Surg Oncol.* 1990;16:248–263.
32. Pitman G. *Operative Planning and Surgical Strategies.* St. Louis: Quality Medical; 1993.
33. Ostad A, Kageyama A, Moy RL. Tumescent anesthesia with lidocaine dose of 55 mg/kg is safe for liposuction. *Dermatol Surg.* 1996;22:921–927.
34. Perry AW, Petti C, Rankin M. Lidocaine is not necessary in liposuction. *Plast Reconstr Surg.* 1999;104:1900–1902; discussion 1903.
35. Iverson RE, Lynch DJ; American Society of Plastic Surgeons Committee on Patient Safety. Practice advisory on liposuction. *Plast Reconstr Surg.* 2004;113:1478–1490; discussion 1491.
36. Matarasso A. Lidocaine in ultrasound-assisted lipoplasty. *Clin Plast Surg.* 1999;26:431–439, viii.
37. Brown SA, Lipschitz AH, Kenkel JM, et al. Pharmacokinetics and safety of epinephrine use in liposuction. *Plast Reconstr Surg.* 2004;114:756–763; discussion 764.
38. Swanson E. Prospective study of lidocaine, bupivacaine, and epinephrine levels and blood loss in patients undergoing liposuction and abdominoplasty. *Plast Reconstr Surg.* 2012;130:702–722.
39. McKee DE, Lalonde DH, Thoma A, Glennie DL, Hayward JE. Optimal time delay between epinephrine injection and incision to minimize bleeding. *Plast Reconstr Surg.* 2013;131:811–814.
40. Larrabee WF Jr, Lanier BJ, Miekle D. Effect of epinephrine on local cutaneous blood flow. *Head Neck Surg.* 1987;9:287–289.
41. Eledjam JJ, de la Coussaye JE, Bassoul B, Brugada J. Mechanisms of the cardiac toxicity of bupivacaine (in French). *Ann Fr Anesth Reanim.* 1988;7:204–210.
42. Corman SL, Skledar SJ. Use of lipid emulsion to reverse local anesthetic-induced toxicity. *Ann Pharmacother.* 2007;41:1873–1877.
43. Paik AM, Daniali LN, Lee ES, Hsia HC. Local anesthetic use in tumescent liposuction: An American Society of Plastic Surgeons survey. *Ann Plast Surg.* 2015;74:145–151.
44. McKay W, Morris R, Mushlin P. Sodium bicarbonate attenuates pain on skin infiltration with lidocaine, with or without epinephrine. *Anesth Analg.* 1987;66:572–574.
45. Burns CA, Ferris G, Feng C, Cooper JZ, Brown MD. Decreasing the pain of local anesthesia: A prospective, double-blind comparison of buffered, premixed 1% lidocaine with epinephrine versus 1% lidocaine freshly mixed with epinephrine. *J Am Acad Dermatol.* 2006;54:128–131.

46. Rohrich RJ, Beran SJ, Fodor PB. The role of subcutaneous infiltration in suction-assisted lipoplasty: A review. *Plast Reconstr Surg.* 1997;99:514–519; discussion 520–526.
47. Matarasso A. Superwet anesthesia redefines large-volume liposuction. *Aesthet Surg J.* 1997;17:358–364.
48. Young VL, Brandon HJ. The physics of suction-assisted lipoplasty. *Aesthet Surg J.* 2004;24:206–210.
49. Beck DO, Davis K, Rohrich RJ. Enhancing lipoaspirate efficiency by altering liposuction cannula design. *Plast Reconstr Surg Glob Open* 2014;2:e222.
50. Gasperoni C, Gasperoni P. Subdermal liposuction: Long-term experience. *Clin Plast Surg.* 2006;33:63–73, vi.
51. 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.
52. Hunstad JP. Tumescent and syringe liposculpture: A logical partnership. *Aesthetic Plast Surg.* 1995;19:321–333.
53. Fodor PB, Vogt PA. Power-assisted lipoplasty (PAL): A clinical pilot study comparing PAL to traditional lipoplasty (TL). *Aesthetic Plast Surg.* 1999;23:379–385.
54. Goldman A, SD, Blugerman GS. Laserlipolysis: Liposuction using Nd:YAG laser. *Rev Soc Bras Cir Plast.* 2002;17:17–26.
55. Prado A, Andrades P, Danilla S, Leniz P, Castillo P, Gaete F. A prospective, randomized, double-blind, controlled clinical trial comparing laser-assisted lipoplasty with suction-assisted lipoplasty. *Plast Reconstr Surg.* 2006;118:1032–1045.
56. Tark KC, Jung JE, Song SY. Superior lipolytic effect of the 1,444 nm Nd:YAG laser: Comparison with the 1,064 nm Nd:YAG laser. *Lasers Surg Med.* 2009;41:721–727.
57. Rohrich RJ, Beran SJ, Kenkel JM, Adams WP Jr, DiSpaltro F. Extending the role of liposuction in body contouring with ultrasound-assisted liposuction. *Plast Reconstr Surg.* 1998;101:1090–1102; discussion 1117.
58. Nagy MW, Vanek PF Jr. A multicenter, prospective, randomized, single-blind, controlled clinical trial comparing VASER-assisted lipoplasty and suction-assisted lipoplasty. *Plast Reconstr Surg.* 2012;129:681e–689e.
59. Matarasso A. Discussion: A multicenter, prospective, randomized, single-blind, controlled clinical trial comparing VASER-assisted lipoplasty and suction-assisted lipoplasty. *Plast Reconstr Surg.* 2012;129:690e–691e.
60. Fisher C, Grahovac TL, Schafer ME, Shippert RD, Marra KG, Rubin JP. Comparison of harvest and processing techniques for fat grafting and adipose stem cell isolation. *Plast Reconstr Surg.* 2013;132:351–361.
61. Paul M, Mulholland RS. A new approach for adipose tissue treatment and body contouring using radiofrequency-assisted liposuction. *Aesthetic Plast Surg.* 2009;33:687–694.
62. Paul M, Blugerman G, Kreindel M, Mulholland RS. Three-dimensional radiofrequency tissue tightening: A proposed mechanism and applications for body contouring. *Aesthetic Plast Surg.* 2011;35:87–95.
63. Theodorou S, Chia C. Radiofrequency-assisted liposuction for arm contouring: Technique under local anesthesia. *Plast Reconstr Surg Glob Open* 2013;1:e37.
64. Sasaki GH. Water-assisted liposuction for body contouring and lipoharvesting: Safety and efficacy in 41 consecutive patients. *Aesthet Surg J.* 2011;31:76–88.
65. Yin S, Luan J, Fu S, Wang Q, Zhuang Q. Does water-jet force make a difference in fat grafting? In vitro and in vivo evidence of improved lipoaspirate viability and fat graft survival. *Plast Reconstr Surg.* 2015;135:127–138.
66. Wall S Jr. SAFE circumferential liposuction with abdominoplasty. *Clin Plast Surg.* 2010;37:485–501.
67. Rohrich RJ, Broughton G II, Horton B, Lipschitz A, Kenkel JM, Brown SA. The key to long-term success in liposuction: A guide for plastic surgeons and patients. *Plast Reconstr Surg.* 2004;114:1945–1952; discussion 1953.
68. Chang KN. The use of intraoperative grid pattern markings in lipoplasty. *Plast Reconstr Surg.* 2004;114:1292–1297.
69. Rohrich RJ, Leedy JE, Swamy R, Brown SA, Coleman J. Fluid resuscitation in liposuction: A retrospective review of 89 consecutive patients. *Plast Reconstr Surg.* 2006;117:431–435.
70. Pitman GH, Aker JS, Tripp ZD. Tumescent liposuction: A surgeon's perspective. *Clin Plast Surg.* 1996;23:633–641; discussion 642.
71. Matarasso A. Superwet anesthesia redefines large-volume liposuction. *Aesthet Surg J.* 1997;17:358–364.
72. Toledo LS, Mauad R. Complications of body sculpture: Prevention and treatment. *Clin Plast Surg.* 2006;33:1–11, v.
73. Klein JA. Tumescent liposuction and improved postoperative care using tumescent liposuction garments. *Dermatol Clin.* 1995;13:329–338.
74. Dixit VV, Wagh MS. Unfavourable outcomes of liposuction and their management. *Indian J Plast Surg.* 2013;46:377–392.
75. Lehnhardt M, Homann HH, Daigeler A, Hauser J, Palka P, Steinau HU. Major and lethal complications of liposuction: A review of 72 cases in Germany between 1998 and 2002. *Plast Reconstr Surg.* 2008;121:396e–403e.
76. Hanke CW, Bernstein G, Bullock S. Safety of tumescent liposuction in 15,336 patients: National survey results. *Dermatol Surg.* 1995;21:459–462.
77. Illouz YG. Complications of liposuction. *Clin Plast Surg.* 2006;33:129–163, viii.
78. Kim YH, Cha SM, Naidu S, Hwang WJ. Analysis of postoperative complications for superficial liposuction: A review of 2398 cases. *Plast Reconstr Surg.* 2011;127:863–871.
79. Housman TS, Lawrence N, Mellen BG, et al. The safety of liposuction: Results of a national survey. *Dermatol Surg.* 2002;28:971–978.