Sound liposuction relies on an awareness of the “three-dimensional anatomy of the fat layers.” The majority of liposuction should be performed on the middle or deeper adipose layer. In fact, it is the preservation of the superficial adipose layer that is crucial in preventing skin irregularities including dimpling, waviness, hyperpigmentation, burns, and contour irregularities.

A variety of liposuction techniques have been described. Advantages and disadvantages for each technique have been described. Suction-assisted liposuction (SAL), ultrasound-assisted liposuction (UAL), and power-assisted liposuction (PAL) have the longest track record and are suitable for most applications.

**Suction-Assisted Liposuction**

SAL was the first technique described in liposuction and remains the most commonly used method. SAL removes adipocytes and other tissues through mechanical avulsion. SAL has been described for the treatment of localized fat deposits unresponsive to diet and exercise in virtually all areas of the body. SAL is performed starting with larger diameter cannula in the deeper plane and transitioning to smaller diameter cannula in the superficial plane.

**Ultrasound-Assisted Liposuction**

UAL technique has undergone many refinements since its introduction by Zocchi in 1992. UAL is particularly advantageous in patients with diminished skin tone, in liposuction of fibrous areas, including treatment of gynecomastia, during secondary liposuction, and effectively permits true circumferential body contouring. UAL requires a 3-staged technique. During infiltration, the first of the stages, room temperature wetting solution is infiltrated into the intermediate fat layer in a 1:1 infiltrate to projected aspirate volume ratio. In the second stage, UAL treatment is performed from the deep to superficial planes with the endpoint being loss of tissue resistance and change in the character of the aspirate. Contour should not be assessed due to the abundance of emulsified fat that remains in the treatment.
area. In the third and final stage, evacuation using traditional suction cannulas is performed.

**POWER-ASSISTED LIPOSUCTION**

PAL uses the reciprocating motion of the tip of the cannula to facilitate fat removal. Several studies comparing PAL with SAL have shown that PAL results in less operator fatigue and provides a faster rate of fat aspiration.6–8 PAL is particularly advantageous in large-volume liposuction where it can reduce operator fatigue, with the treatment of fibrous areas including gynecomastia surgery, and in secondary liposuction. Recently, PAL has been applied in difficult secondary cases for release of scarred areas and redistribution of existing fat and in harvesting large volumes of fat for transfer to other areas.9

**PREOPERATIVE EVALUATION AND PLANNING**

In 2004, the Committee on Patient Safety of the American Society of Plastic Surgeons published the first “Practice Advisory on Liposuction” to help guide appropriate selection and treatment of patients seeking liposuction, which was subsequently updated in 2009.10,11 Patients should be generally healthy and demonstrate a commitment to long-term lifestyle changes including both healthy diet and exercise.12–14 Additionally, patient goals and expectations should be appropriate and realistic. Furthermore, patients who are either obese or who have generalized adiposity, adolescents, and patients with certain preexisting medical conditions that place them in preclusive risk may not be suitable candidates. Venous thromboembolism, the most common cause of mortality during suction lipectomy, should be managed with preoperative risk stratification and treatment, as necessary. The American Society of Plastic and Reconstructive Surgeons recently published “Evidence-based Practices for Thromboembolism Prevention” to guide risk stratification and implementation of preventative measures (Fig. 1).15

Physician-patient dialogue is paramount in this evaluation; understanding patients’ goals and setting expectations is key. This can be supplemented with adequate patient education regarding preparation for surgery, the details of the surgery, potential risks and complications (Table 1), and the expected postoperative recovery period.

Physical examination should be conducted with specific attention to skin tone and quality, the presence of scars, hernias, asymmetries, dimpling or cellulite, location of fat deposits, areas of adherence, and perceived deviations from the ideal gender-specific contour.16 Rohrich et al17 have suggested a preoperative data sheet (Fig. 2) to aid in appropriate documentation of examination findings that should be further supported with high-quality medical photography including anterior, posterior, oblique, and lateral views.

In the past, large-volume liposuction (>5000 mL of total aspirate) was more commonplace. However, with recognition of the increased risks of large-volume liposuction related to fluid shifts and lidocaine toxicity, American Society of Plastic and Reconstructive Surgeons recommends that large-volume liposuction be performed in an accredited/licensed facility and that overnight monitoring of postoperative vitals and urine output be performed. Consideration of modifying the lidocaine concentration of the infiltration solution, particularly in the obese (body mass index > 30 kg/m²), should be given. In addition, attention should be paid toward staging procedures or avoiding combining large-volume liposuction with other procedures.11,18,19

**Patient Marking**

Preoperative marking of the patient is paramount for achieving desirable surgical outcomes. This should be performed in front of a mirror, which allows the patient to remain an active participant in the process. Areas that will require treatment are often labeled with circles using an indelible marker, whereas hash marks are used to label the zones of adherence (Fig. 3). Finally, proposed access incisions are placed with care taken so that they may be inconspicuous once fully healed. Often, this can be achieved by placing them asymmetrically, parallel with the relaxed skin tension lines or striae and/or scars. Most importantly, they should be located in a position that allows for complete treatment of all affected areas without having to place undue force or other distortion of the liposuction cannula during aspiration. Significant abnormalities such as scars, hernias, or contour irregularities should also be marked.

**Appropriate Liposuction Technique Selection**

Although SAL, UAL, and PAL may be suitable during primary liposuction, both unique anatomic regions and specific clinical settings arise in which specific modalities are advantageous over other methods of treatment.

**Gynecomastia.** The dense fibroglandular tissue such as that located in the male breast is treated best with UAL although some other have cited increased benefit with the use of PAL.20–22 It is worth mentioning, however, that excisional techniques
do play an adjunctive role in the management of gynecomastia.

**Large Volume/Fat Harvest.** Harvesting fat is particularly suited for PAL as it efficiently removes fat without the use of energy although simple syringe suction is a reliable alternative.

**Revision Liposuction.** UAL and PAL may be beneficial in secondary cases due to their ability to break up...
adhesions between fascia and dermis due to scarring. In many cases, revision liposuction will also involve redistribution of fat and fat grafting to sites that have been previously overtreated.

**INTRAOPERATIVE MONITORING—SAFETY MEASURES**

**Anesthesia**

Liposuction can be performed using general or local anesthesia. However, several key principles exist which should help guide the appropriate choice of anesthetic. Small-volume liposuction (≤1000 mL) can be safely performed with local anesthetic, a proper wetting solution, and additional sedation as needed. However, general anesthesia may be more preferable and comfortable in more complex, large volume or combination procedures with an emphasis on endotracheal intubation if the patient is to be in the prone position. Because of their potential for vasodilation and hypotension, with resultant risk of fluid overload due to aggressive fluid resuscitation, both epidural and spinal anesthesia should be avoided. 

**Positioning**

Body contour surgeons are able to safely perform liposuction from the prone and/or the supine and lateral decubitus positions. As much as 75% of the body can be accessed from the prone position, including the arms, back, hips/flanks, the lateral/posterior areas, and a portion of the medial thigh. Adequate padding of all pressure points must be performed along with routine sterile prepping and draping of the patient. The remaining areas can be addressed with the patient supine. Utmost effort should be made to use sequential compression devices on the lower extremities including placement on the feet when more complete lower body preps are employed. Passive and active warming maneuvers, such as maximizing preoperative warming, increasing ambient room temperatures, minimizing exposed areas, application of cutaneous warming devices or forced air warming blankets, and warming of all fluids, should be employed to prevent hypothermia.

**ROLE OF WETTING SOLUTIONS AND FLUID RESUSCITATION**

**Wetting Solutions**

The use of wetting solutions has enabled liposuction treatment to be performed more safely, in larger volumes, with improved outcomes and, in part, reduced complications. Various types of wetting solutions now exist and can be classified into one of the four categories: dry, wet, superwet, and tumescent (Tables 2 and 3).

Nearly all of the current, commonly used wetting solutions combine a crystalloid (Lactated Ringers or...
normal saline) with epinephrine and lidocaine. Previous research has established guidelines for the safe use of lidocaine in liposuction. Lidocaine concentrations up to 35 mg/kg have been used safely.\textsuperscript{27} Peak serum concentrations of lidocaine occur approximately 6 to 12 hours following infiltration.\textsuperscript{28} Recent work by Hatef et al\textsuperscript{29} studying the effect of varying concentrations of lidocaine on intraoperative anesthesia requirements and postoperative pain when general anesthesia has been administered showed that decreasing concentrations of lidocaine in infiltrative wetting solutions did not significantly affect intraoperative anesthesia requirements or postoperative pain. Peak concentrations of lidocaine and its active metabolite, monoethylglycinexylidide, occur 15.2 hours (range, 8–28 h) post infiltration despite subtherapeutic tissue levels of lidocaine within 4 to 8 hours.\textsuperscript{31} The use of Marcaine should be avoided due to higher potential cardiac toxicity and duration of action.\textsuperscript{11}

**Fluid Resuscitation**

During liposuction, fluid shifts can manifest in both extremes of fluid status: hypovolemia due to under resuscitation or pulmonary edema and/or congestive heart failure due to over resuscitation. Monitoring urine output with a Foley catheter and constant dialogue between the anesthesia provider and the surgeon should be maintained throughout the procedure to ensure optimal fluid resuscitation. Four crucial elements should guide intraoperative resuscitation: intravenous fluid maintenance (body weight dependent), third space losses, volume of wetting solution infiltrated, and the total volume of lipoaspirate.\textsuperscript{17}

Even higher regard for fluid management is required for large-volume liposuction. In 2006, Rohrich et al\textsuperscript{31} proposed guidelines to aid in this management:

1. Preoperative fluid losses should be repleted as needed and at the discretion of the surgeon and anesthesiologist.
2. Maintenance fluids and fluid boluses should be administered during surgery based on the patient’s vital signs and urine output.
3. Superwet technique should be employed.
4. An additional 0.25 mL of lactated Ringer’s solution should be given intraoperatively for every 1 mL of aspirate.

**CIRCUMFERENTIAL CONTOURING AND COMPLICATION PREVENTION**

**Systematic Use of Body Contouring**

To achieve the best results from currently available techniques, one must employ a specific sequence of techniques, the goal of each being to complement the next. For example, during UAL, the surgeon should begin by infiltration with the wetting solution using a 1:1 superwet technique. Next, large-volume ultrasound liposuction is performed using a 3-mm round tip cannula, approximately 35 cm in length, working in a superficial to deep direction. Finally, during the evacuation phase, SAL is performed working in a deep to superficial plane with consecutively smaller (3.7-3.0) diameter tip cannula used as one works more superficially. Pertinent volumes and other data collected...
during this time are recorded onto an intraoperative data sheet (Fig. 4).

Prevention of Contour Irregularities

Surgical technique is the key to safety and patient outcomes. Variations in surgical approach exist and are dependent on the type of liposuction being performed. For example, during UAL, the skin should never be grasped or held around the cannula while maintaining the depth of the cannula at least 1–1.5 cm deep to the dermis. However, regardless of the liposuction modality, the employment of smooth, uniform, radial pattern gestures is paramount to preventing contour irregularities. Depth of the cannula is of critical importance as liposuction in the superficial subcutaneous tissues is more likely to result in a contour deformity. Liposuction is a dynamic process that requires constant reevaluation. Familiarity with primary and secondary clinical endpoints of liposuction is critical to guiding treatment (Table 4).

Other key technical considerations include not overtreating areas adjacent to access incisions as they have a potential to be overtreated due to the frequency of cannula passes they may be exposed to and turning off the suction when inserting and withdrawing the cannula. It is the senior author’s experience that when encountering contour irregularities, the best course of action is to proceed with immediate fat grafting into the area of deficit with a 50% overcorrection. Users should be warned that attempting to suction the periphery of the contour depression only worsens the irregularity.

Appropriate Instrument Selection and Optimal Cannula Size and Shape

Site-specific treatment includes choosing the appropriate instruments, namely, length and diameter of cannula with appropriate tip and vacuum settings. Numerous cannulas are commercially available ranging in length and diameter (2–5 mm) as well as tip configuration (blunt to sharp). Each cannula has particular advantages and should be implemented with regard to the specific technique being used. Such examples of modality-specific variations in tip design include the 2-probe design of UAL in which either a solid or a hollow probe may be used. The latter allows for continuous aspiration of emulsion during the ultrasound phase but considered to be of poorer design in the emulsion of fat.

Cannula Position

Using the nondominant hand to gently palpate the skin is necessary to maintain constant awareness of tip position. When treating areas on the trunk, it is important to carefully control the depth and direction of the cannula to avoid intrathoracic or intra-abdominal injury. One must be extremely conscientious for any encountered resistance which should be managed by adjusting the direction of cannula.

Regard for Avoidance of the Zones of Adherence

When treating the lower extremities, the 5 zones of adherence—where the superficial subcutaneous tissues are adherent to the fascia of the underlying muscle—should be avoided. These include the lateral gluteal depression, the gluteal crease, the distal posterior thigh, the middle medial thigh, and the inferolateral iliobibial tract (Fig. 3). Of these, the most important is the gluteal crease, which should never be violated. The key element is that you can go through the zone of adherence but never directly suction them to prevent deformity. However, as described by Rohrich et al., treatment during large-volume liposuction cases may involve treatment of the other zones of adherence, albeit with a small (<3.0 mm) cannula and a low pressure vacuum.

Incision Closure and Dressing

At the conclusion of the liposuction, any readily encountered fluid should be massaged out from the access incisions. A single 5-0 absorbable suture is used to close these incisions with a single interrupted knot, this allows for further fluid to egress out. Next, a single layer of topiFoam (Byron Medical, Tucson, Ariz.) is placed after which the patient is placed in compression garments.

### Table 2. Infiltration to Aspiration Ratios of Wetting Solutions Used in Liposuction

| Technique      | Infiltrate Volume                  | Aspirate                                      |
|----------------|-----------------------------------|-----------------------------------------------|
| Dry            | No infiltrate                      | To treatment endpoint                         |
| Wet            | Symmetrical pinch test results     | To treatment endpoint                         |
| Superwet       | 1 mL infiltrate: 1 mL aspirate     | 1 mL aspirate/infiltrate (treatment endpoints) |
| Tumescent      | Infiltrate to skin turgor          | 2–3 mL aspirate/mL infiltrate                 |

### Table 3. Estimated Blood Loss of Wetting Solutions Used in Liposuction

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

Postoperative Care and Prevention of Complications

Compression garments are worn at all times for the first 2 weeks followed by nightly for an additional 2 weeks. The majority of small-volume patients can be counseled that they may return to work in 3–5 days, whereas, generally, 7–10 days is needed for patients undergoing larger volume procedures. Most patients will return to regular activities in 3 to 4 weeks.

Safe lipectomy depends not only on the intended action of the surgeon but also on the management of risk and prevention of complications. Gargan and Courtiss, broke these risks into 2 distinct subgroups: undesirable sequelae include surface contour irregularities, hypesthesia, edema, ecchymosis, and discoloration while potential complications include excessive blood loss, hematoma, seroma, infection, thrombosis, fat emboli, and skin necrosis. Notably, hypesthesia of the treatment area is to be expected rather than considered an avoidable consequence to suction lipectomy. Typically, a 3- to 6-month waiting period will allow for normal sensation to return.

Contour irregularities that are evident during the operation should be immediately addressed by fat grafting. Postoperatively, contour irregularities that arise should be treated conservatively for at least 6 months during which time they should be treated with massage therapy. Depending on the severity of the irregularity, methods of correction include liposuction of areas of prominence or adjacent to areas of depression, fat grafting, or even dermolipectomy.

More severe consequences of lipectomy include not only morbidity but also mortality. In a review by Grazer and de Jong of 1200 active board-certified plastic surgeons, there were 95 fatalities in nearly 500,000 lipectomy procedures, producing a mor-
tality rate of 19 in 100,000 with 23% attributable to pulmonary embolism. In a discussion of these findings, Rohrich and Muzaffar suggested the following Safety Guidelines in Liposuction:

1. Appropriate patient selection (American Society of Anesthesiologists class I, within 30% of ideal body weight)
2. Use of superwet technique
3. Meticulous monitoring of volume status (urinary catheterization, noninvasive hemodynamic monitoring, constant communication with anesthesiologist)
4. Judicious fluid resuscitation
   a. For aspirate < 5 L: maintenance of fluid plus subcutaneous infiltrate
   b. For aspirate > 5 L: maintenance of fluid plus subcutaneous infiltrate plus 0.25 mL of intravenous crystalloid per 1 mL of aspirate > 5 L.
5. Overnight monitoring of large-volume (>5 L total aspirate) liposuction patients in an appropriate healthcare facility
6. Use of pneumatic compression devices in cases performed under general anesthesia or lasting longer than 1 hour
7. Maintaining total lidocaine doses below 35 mg/kg (wetting solution)

Outcomes

Follow-up studies, although limited in quantity, have sought to characterize the long-term results of patients undergoing liposuction. In work derived from a survey distributed to 600 liposuction patients, several key findings were discovered. Notably, a responder’s opinion of their appearance was the pivotal determinant in their satisfaction with their liposuction procedure. This, in turn, influenced whether they would have the procedure again or recommend it to another. Other factors, including weight gain, revision rate, the return of fat, and the level and duration of postoperative pain, did not have a statistical effect on these decisions. However, weight gain has been shown to have a direct negative impact on appearance, which, in part, impacts their satisfaction, willingness to continue therapy, and, ultimately, outcomes. These findings reiterate what has already been emphasized in body contouring, proper patient selection and physician-patient dialogue are crucial given that those patients who were not satisfied with their liposuction treatment were also those with the lowest opinion of their appearance. In a separate publication reviewing the same data, the authors relate the importance of educating patients on postoperative lifestyle changes, including continued exercise and healthy eating, which are paramount to successful liposuction treatment.

CONCLUSIONS

Over the past 30 years, there have been many advances in surgical technique and patient-related standards for liposuction. Applying these 5 principles shown here will lead to consistent and safe results although more level II and III evidence-based research is needed to further improve outcomes and diminish risk.

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