

# **Safety Considerations and Fluid Resuscitation in Liposuction: An Analysis of 53 Consecutive Patients [Cosmetic]**

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There is no agreement as to appropriate fluid resuscitation in patients undergoing liposuction. This has assumed greater significance, as surgeons have undertaken larger volume aspirations ( $\geq 4$  liters) and the potential complications of hypovolemia and fluid overload have materialized. This prospective study of 53 consecutive healthy patients undergoing liposuction using a superwet technique served to develop general guidelines for safe perioperative fluid management, especially in regard to large-volume aspirations. In this context, "aspirate" is defined as the total fat and fluid that is removed during liposuction.

All patients were monitored using standard noninvasive hemodynamic monitoring. Thirty-six patients were monitored perioperatively with Foley catheters. The 53 patients underwent liposuction alone. We did not include patients who underwent concurrent aesthetic surgical procedures because our intention was to establish fluid administration guidelines for the liposuction patient.

There were no significant complications in our series. The intraoperative fluid ratio, defined as (intravenous fluid + infiltrate)/aspirate, was 2.1 for the small-volume group and 1.4 for the large-volume group. These values were significantly different ( $p < .001$ ,  $t$  test). Average urine output in the operating room and recovery room and on the floor was satisfactory ( $> 0.5$  to  $1$  cc/kg/hr) and did not relate to volume aspirated ( $p = 0.21$ ,  $0.91$ , and  $0.6$ , respectively,  $t$  test). Four patients who underwent "large-volume" aspirations ( $\geq 4$  liters) had transient hypotension, which was immediately responsive to crystalloid fluid boluses in the first postoperative hours. All other patients required only maintenance intravenous crystalloid post-operatively until oral intake had been resumed. There were no statistically significant differences in postoperative fluid administration between the small- and large-volume groups. Ninety-three percent of patients were discharged within 24 hours of surgery.

Our suggested guidelines for fluid resuscitation based on this retrospective study are as follows: (1) small volume ( $< 4$  liters aspirated): maintenance fluid + subcutaneous wetting solution; (2) large volume ( $\geq 4$  liters aspirated): maintenance fluid + subcutaneous wetting solution +  $0.25$  cc of intravenous crystalloid per cc of aspirate removed after 4 liters.

This formula has since been used in the care of 94 patients who have undergone liposuction exclusively. All patients have had unremarkable hospital courses. These guidelines do not replace sound clinical judgment. Good communication between the surgeon and anesthesiologist is critical to optimal patient care and safety.

Liposuction is the most commonly performed aesthetic procedure in the United States.<sup>1</sup> Advances in both technique and technology over the past two decades now allow plastic surgeons to accomplish true circumferential body contouring, in distinction to "spot" reductions. The embrace of subcutaneous infiltration in combination with the advent of ultrasound-assisted liposuction has made the removal of larger volumes commonplace. However, these "large-volume" aspirations ( $\geq 4$  liters) require larger volumes of infiltrate and may introduce potential complications, such as hypovolemia and fluid overload (manifested as pulmonary edema and congestive heart failure).<sup>2-4</sup>

Before the use of epinephrine-containing subcutaneous infiltration, the volume of aspirate that could be removed safely by liposuction was limited by blood loss of 20 to 45 percent of aspirate associated with the dry technique<sup>1,5-7</sup> (Table I). The introduction of the "wet" technique in the 1980s by surgeons such as Clayton and Hetter decreased blood loss to 4 to 30 percent of aspirate but did not eliminate the need for autologous blood transfusions or the potential for hypovolemia.<sup>1,5,8,9</sup> To compensate, aggressive fluid resuscitation regimens and "preloading" were used commonly during this period.<sup>5,8,9</sup> Further refining the use of wetting solutions, in 1986, Fodor advocated the "superwet" technique (a ratio of infiltrate to total aspirate of 1:1).<sup>1</sup> In the same year,<sup>10</sup> Klein introduced the "tumescent" technique (a ratio of infiltrate to total aspirate of 2 to 3:1),<sup>7</sup> which is performed totally under local anesthesia.<sup>13</sup> Both of these techniques succeeded in decreasing blood loss to 1 percent of the volume aspirated and led to the safe performance of larger aspirations and improved aesthetic results.<sup>1,7,10-12</sup>

Technique	Estimated Blood Loss (% of volume)
Dry <sup>1,2,3</sup>	20-43
Wet <sup>4,5,6</sup>	9-30
Superwet <sup>7,8,9,10</sup>	1
Tumescent <sup>11,12,13</sup>	1

TABLE I Blood Loss Estimates in Different Subcutaneous Infiltration Solutions<sup>1</sup>

Despite the acceptance of wetting solutions in liposuction, there remains controversy concerning the fluid resuscitation requirements in these patients. This spectrum of opinion is typified by the stances of Klein and Pitman. Klein, using a tumescent technique, administers *minimal or no supplemental intravenous fluid*. Instead, he relies on the principle of hypodermoclysis, in which the subcutaneously injected fluid enters the intravascular space and contributes to the plasma volume.<sup>7,13,14</sup> A true tumescent technique may provide a ratio of infiltrate to aspirate ranging from as high as 3:1 to 7:1.<sup>15</sup> In contrast, Pitman advocates a 2:1 ratio of total fluid administered [(infiltrate and intravenous in the perioperative period): amount aspirated].<sup>16-20</sup> Neither author reports complications of fluid overload. To date there has been only one such report in the medical literature.<sup>4</sup> In addition, although the specific causes are predominantly unknown, there has been a series of reports in the lay literature and media describing complications and even death in liposuction patients.<sup>2-4</sup>

This study was designed to analyze and define resuscitation parameters in liposuction patients, specifically those undergoing removal of large volumes. Conclusions were based on a review of intraoperative and postoperative clinical outcomes. The guidelines and recommendations serve as a basis for the management of these patients but do not replace sound surgical judgment, diligent patient monitoring, and communication between surgeon and anesthesiologist.

## Patients and Methods [TOP](#)

This prospective study examined 53 patients who underwent liposuction over a 13-month period from October of 1996 to October of 1997. Ages ranged from 15 to 68 years. There were 16 male and 37 female patients. Patients were evaluated preoperatively and postoperatively by clinical examinations and standardized medical photography. Patients with significant medical problems or morbid obesity were not considered for liposuction. All operations were performed under general anesthesia. Intraoperative and perioperative fluid administration was based on our initial guidelines:

1. replacement of preoperative fluid deficits when applicable;
2. crystalloid intravenous maintenance fluid adjusted to vital signs and urine output; and
3. intravenous replacement of 1 cc of crystalloid for each cc aspirated after 4 liters of aspirate.

The delivery of this replacement fluid was completed in the recovery room if necessary. All patients were monitored using noninvasive hemodynamic monitoring including a blood pressure cuff, pulse oximeter, and cardiac monitor. In addition, urine output was monitored with Foley catheters in 27 patients who underwent large-volume aspirations and in nine patients who underwent small-volume aspirations. No invasive hemodynamic monitoring was performed.

Liposuction was performed using a superwet technique of subcutaneous infiltration, i.e., a 1:1 ratio of infiltrate to estimated aspirate.<sup>1</sup> The solution consisted of 30 cc of 1% lidocaine and 1 cc epinephrine 1:1000 per 1 liter of room temperature lactated Ringer's solution. Lidocaine was withheld from any infiltration fluid given beyond the first 4 liters to avoid toxicity. Seven to ten minutes were allowed between infiltration and treatment of each area. A three-stage ultrasound-assisted liposuction technique was used for treatment (Table II). After completion of infiltration, stage II (ultrasound treatment) was performed in an intermediate-to-deep plane with a Lysonix 2000 ultrasound generator (at 23 kHz with an average power setting of 5 to 6), using either a 5-mm hollow "square end" or "round end" titanium cannula and a standard surgical aspirator (Wells-Johnson) operating at 50 percent of maximum. Stage III, evacuation and final contouring using traditional suction-assisted lipoplasty, was performed with traditional liposuction cannulae, 3.0 or 3.7 mm, in a deep to superficial fashion. Hospital records were examined for the volume of fluid administered (subcutaneous and intravenous), urine output and vital signs (as indicators of volume status), and lidocaine and epinephrine dosages. The level of postoperative discomfort (as measured by pain medication requirements) and length of hospital stay were also assessed. Statistical techniques used to analyze the

data include Pearson correlation, chi-square or Fisher's exact test, analysis of variance with Student-Newman-Keuls multiple comparisons, and *t* tests as performed by the University of Texas Southwestern Department of Academic Computing. Results of statistical tests were considered significant with  $p < 0.05$ ; no additional adjustments were made for multiple testing.

Stage	Combined UAL/SAL	Rationale
Stage I	Subcutaneous infiltration	Decrease blood flow, decrease tissue density
Stage II	UAL treatment	Enlarge fat
Stage III	SAL treatment	Evacuation of emulsification fluid containing

TABLE II The Three-Stage Model of Ultrasound-Assisted Liposuction<sup>21</sup>

## Results [TOP](#)

Fifty-three healthy patients at the University of Texas Southwestern Medical Center underwent liposuction over a 12-month period from September of 1996 to September of 1997. None of the patients underwent concurrent procedures. There were 16 male and 37 female patients. The average age of patients was 37 years with a range from 15 to 68 years. The average anesthesia time was 227 minutes, with a range of 55 to 515 minutes. The average volume aspirated per patient was 4587 cc with a range from 300 to 15,500 cc (standard deviation of 3192). Twenty-five patients (47 percent) had small-volume (<4000 cc) and 28 had large-volume ( $\geq 4000$  cc) aspirations ([Table III](#)). The average ratio of infiltrate to aspirate was 0.97 with a range of 0.56 to 2.3. (standard deviation 0.31).

Volume Aspirated (cc)	No. of Patients (%)
<3000	8 (7)
3000-4000	21 (40)
4000-7000	19 (36)
>7000	5 (11)
Total	53 (100)

TABLE III Aspiration Volumes

Thirty-six patients were monitored with Foley catheters in the operating room; 27 had undergone large-volume aspirations and 9 had undergone small-volume aspirations. Two of these catheters were removed—one from a small-volume patient and one from a large-volume patient—before transfer to the recovery room. Five more were removed from large-volume patients before transfer to the floor. As depicted in [Figure 1](#), the average urine output in the operating room and recovery room and on the floor was more than 1.5 cc/kg/hr for both large- and small-volume patients. There were no statistically significant differences in urine output between patients who had undergone large- and small-volume aspirations ( $p = 0.21, 0.91, \text{ and } 0.6$  for the operating room, recovery room, and floor, respectively, *t* test). The majority of patients who were monitored with Foley catheters had urine outputs greater than or equal to 1 cc/kg/hr in the operating room and recovery room and on the floor ([Fig. 2](#)).

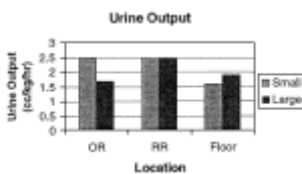


Fig. 1. Urine output averages for small-volume patients (operating room,  $n = 9$ ; recovery room,  $n = 8$ ; floor,  $n = 7$ ) and large-volume patients (operating room;  $n = 27$ ; recovery room,  $n = 26$ ; floor,  $n = 21$ ).

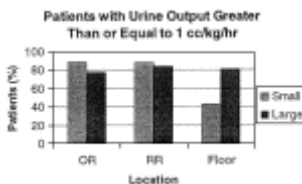


Fig. 2. Percentage of patients with urine outputs greater than 1 cc/kg/hr. Small-volume patients: operating room,  $n = 9$ ; recovery room,  $n = 8$ ; floor,  $n = 7$ . Large-volume patients: operating room,  $n = 27$ ; recovery room,  $n = 26$ ; floor,  $n = 21$ .

The intraoperative fluid ratio, defined as the ratio of intraoperative intravenous fluid + subcutaneous infiltrate to total aspirate, ranged from 1.03 to 3.7, with averages of 2.1 for the small-volume group (range 1.2 to 3.7, standard deviation 0.67) and 1.4 for the large-volume group (range 1.0 to 2.0, standard deviation 0.23) ([Fig. 3](#)). This average value was significantly different between the large- and small-volume groups ( $p < 0.001, t$  test). It also correlated positively with the rate of urine output in the recovery room ( $p = 0.03$ , Pearson correlation).

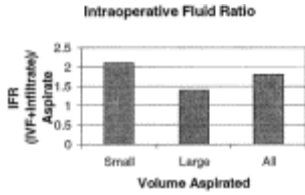


Fig. 3. Average intravenous fluid delivery for small-volume patients (operating room,  $n = 25$ ; recovery room,  $n = 25$ ; floor,  $n = 17$ ) and large-volume patients (operating room,  $n = 28$ ; recovery room,  $n = 28$ ; floor,  $n = 27$ ).

There were three instances of transient hypotension immediately responsive to crystalloid fluid boluses in the recovery room and three on the floor (Table IV). This occurred in a total of four patients (two patients experienced these brief episodes both in the recovery room and in the first few hours on the floor). "Hypotension" in this setting is defined as systolic blood pressure that was low, relative to the patient's previously recorded blood pressures; in all cases systolic blood pressures were 80 to 89 mmHg. Adequate blood pressure in all patients was restored with crystalloid boluses. All patients who experienced these episodes had undergone large-volume aspirations. However, the incidences of hypotension in the large- and small-volume aspiration groups, 11 percent and 0 percent, respectively, were not significantly different ( $p = 0.238$ , Fisher's exact test). Similarly, the hypotensive group of patients did not have a significantly lower average intraoperative fluid ratio than did the normotensive large-volume patients ( $p = 0.38$  for the recovery room and  $p = 0.25$  for the floor,  $t$  test) (Table V). Furthermore, none of these patients had tachycardia (sustained heart rate  $>100$  bpm)<sup>22</sup> or urine output below 0.5 cc/kg/hr.

Location	Number of Patients	Number of Episodes
Operating Room	0	0
Recovery Room	3	3
Floor	3	3
Total	6	6

TABLE IV Patients Who Had Episodes of Transient Hypotension

Location	Average Intraoperative Fluid Ratio		p Value
	Normotensive	Hypotensive	
Recovery room	1.5	1.3	.38
Floor	1.5	1.3	.25

TABLE V Comparison of Aspiration Volumes and Intraoperative Fluid Ratios of Hypotensive and Normotensive Patients

The average intravenous fluid administered in the operating room and recovery room and on the floor is depicted in Figure 4. Aside from the previous cases, all patients received only maintenance fluid postoperatively until oral intake was adequate. There was no statistically significant difference in the postoperative fluid delivery per kilogram between the small- and large-volume aspiration groups ( $p = 0.33$  for the recovery room and  $p = 0.21$  for the floor,  $t$  test).

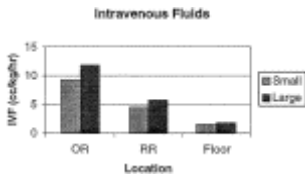


Fig. 4. Average intraoperative fluid ratio in small-volume ( $n = 25$ ) and large-volume ( $n = 28$ ) patients.

Lidocaine dosages ranged from 1.1 to 33.3 mg/kg, with an average of 16.1 mg/kg (Table VI). Epinephrine dosages ranged from 0.3 mg to 12 mg, with an average of 3.9 mg (Table VII).

Volume Aspirated (cc)	Average Lidocaine Dosage (mg/kg)	Range of Lidocaine Dosage (mg/kg)
$<4$ liters	11.5	1.1-29.4
$\geq 4$ liters	26.5	11.3-33.3
All	16.1	1.1-33.3

TABLE VI Average Lidocaine Dosages Given to Patients ( $n = 53$ )

Volume Aspirated (cc)	Average Total Epinephrine Dosage (mg)	Range of Epinephrine Dosage (mg)
$<4$ liters	3.9	0.3-19
$\geq 4$ liters	6.3	3.6-22.9
All	5.9	0.3-22.9

TABLE VII Average Total Epinephrine Dosages Given to Patients ( $n = 53$ )

Large-volume aspiration patients spent an average of 96 minutes (range 50 to 150 minutes) in the recovery room, whereas the small-volume patients spent an average of 80 minutes (range 40 to 120). This difference of recovery room length of stay was not significant ( $p = 0.063$ ,  $t$  test). The percentage of patients who required parenteral narcotics for control of discomfort in the recovery room was not significantly different between the two groups ( $p = 0.523$ , chi-square) (Fig. 5, above). However, the average large-volume

aspiration patient required postoperative parenteral narcotics for a significantly longer time period than did the average small-volume patient (9.2 vs. 2.8 hours,  $p = 0.0006$ ,  $t$  test) ([Fig. 5](#), below).

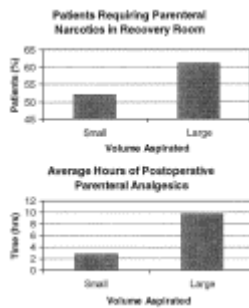


Fig. 5. (Above) Percentage of small-volume ( $n = 25$ ) and large-volume ( $n = 28$ ) patients who required parenteral narcotics for pain control in the recovery room. (Below) Length of time postoperatively (in hours) that small-volume ( $n = 25$ ) and large-volume ( $n = 28$ ) patients required parenteral narcotics (total,  $n = 53$ ).

Large-volume aspiration patients required postoperative maintenance fluids for an average of 15.6 hours, at which time oral intake was sufficient without supplementation. Small-volume aspiration patients required an average of 10.6 hours of postoperative maintenance fluids.

Ninety-four percent (34 of 36) of Foley catheters were removed by postoperative day 1, and none later than postoperative day 2. There were no significant differences between large-and small-volume patients ( $p = 0.1$ ,  $t$  test). Thirty-six percent (9 of 25) of the small-volume patients were discharged on the operative day, and the remainder were discharged on postoperative day 1. Ninety-three percent (26 of 28) of the large-volume patients were discharged by postoperative day 1. No patients stayed longer than postoperative day 3.

There were no major complications, specifically pulmonary emboli, fat emboli, deep venous thromboses, or pulmonary edema. There were five complications specific to the use of ultrasound-assisted liposuction: one dysesthesia, three seromas, and one access site superficial skin burn, all of which resolved. No patients received blood transfusions.

## Discussion [TOP](#)

Before the use of subcutaneous infiltration, third space losses, hypovolemia and blood loss were frequent concerns during liposuction. However, the routine use of wetting solutions has largely eliminated these problems. Unfortunately, fluid overload is now an issue and even in the healthy patient, iatrogenic fluid overload can be potentially harmful. The adoption of the superwet and tumescent techniques has led to numerous reports, published and unpublished, of fluid overload and its attendant complications.[2-4](#)

The infiltration of tumescent fluid is comparable to hypodermoclysis, the injection of large volumes of fluid into subcutaneous tissues for hydration. Although no consensus value exists for the speed of absorption of the infiltrate into the intravascular space, this subject has been examined in the past. One early study reported that the average length of time for absorption of 1 liter of isotonic fluid by hypodermoclysis in the medial thigh of 33 patients was 167 minutes.[23](#)

In liposuction, the issue of absorption of infiltrate is complicated by the removal of infiltrate along with fat and/or emulsion during evacuation. Recent studies have demonstrated that most of the infiltrate is *not* removed by suctioning. Samdal reports an aspirate fluid fraction of 29 percent<sup>12</sup> and Pitman implies that roughly 22 percent of the fluid aspirated is infiltrate.<sup>17</sup> Similarly, Klein showed by measuring serial plasma lidocaine levels that liposuction reduces the amount of lidocaine absorbed systemically by approximately 10 to 30 percent<sup>14</sup>; presumably, the same proportion of infiltrate is removed. Ostad et al., in a series of 60 patients, found that only 1 to 10 percent of the lidocaine is removed.<sup>24</sup> Overall, it appears that at least 70 percent of the infiltrate remains after liposuction and, despite fluid egress through the incisions postoperatively, large fluid volumes enter the intravascular space. This is reflected in the positive correlation of the intraoperative fluid ratio with the rate of urine output in the recovery room.

Our initial formula for total intraoperative fluid delivery is based on several assumptions that we made concerning perioperative fluid management in liposuction:

## Preexisting Volume Deficits [TOP](#)

The preexisting volume deficit in the liposuction patient is caused by overnight fasting. Standard anesthesia practice is to replace this with crystalloid (approximately 1 liter), 50 percent over the first hour and 50 percent over the next 2 hours.<sup>25</sup> Current anesthesia guidelines allow patients to consume clear liquids up to 2 hours before surgery.<sup>26-29</sup> Therefore, in the healthy liposuction patient, preoperative volume deficits may not be sufficient to warrant replacement. Replacement is undertaken at the discretion of the surgeon and anesthesiologist.

## Maintenance Fluid [TOP](#)

We categorize liposuction as "moderate" surgical trauma, for which administration of 5 to 6 cc/kg/hr, adjusted accordingly in response to vital signs and urine output, is an adequate rate for intraoperative maintenance fluid.<sup>30</sup>

## Replacement of Intraoperative Losses [TOP](#)

Blood loss using the tumescent or superwet technique is negligible, roughly 1 percent of the aspirate, and should not require replacement.<sup>1,7,10,11</sup> Based on our previous experience and the assumption that approximately 70 percent of the wetting solution reaches the intravascular space in the immediate postoperative period, we believed that additional intravenous fluid replacement was necessary only after removal of more than 4 liters. Replacement was delivered at a ratio of 1 cc for each cc aspirated.

The incidence of transient hypotension was not significantly greater in the group of patients who underwent large-volume aspirations. Additionally, it was not associated with a significantly lower than average volume of fluid delivered in relation to volume aspirated (intraoperative fluid ratio). It is true that because such a small percentage of patients experienced hypotension, comparing the intraoperative fluid ratios of these groups of three and four with the relatively much larger group of 28 limits our statistical power. However, the fact that 24 other large-volume patients experienced no hypotensive episodes gives us further evidence that the transient drops in blood pressure were not the result of lower deliveries of fluid volume in relation to aspirate. Furthermore, all of the patients who experienced transient hypotension had normal heart rates and adequate urine output. Therefore, it is unclear if the transient hypotension was actually caused by volume depletion at all, or by other factors such as general anesthesia.

All patients, except for the four described previously, received only maintenance fluid postoperatively until they resumed oral intake, usually by postoperative day 1. More than 90 percent of patients were discharged by postoperative day 1 and none later than postoperative day 3.

Overall, the patients in our series had uneventful hospital courses. Urine output, a well-accepted parameter of hydration status in a patient with normal renal function, is considered adequate if more than 0.5 to 1.0 cc/kg/hr.<sup>31</sup> As depicted in [Figure 1](#), average urine outputs in the operating room and recovery room and on the floor were well above this minimum. We realize that this sample size does not include most of the small-volume patients; our experience has been that they do not require close monitoring of urine output and we do not place Foley catheters in them routinely. However, these numbers do reflect accurately the hydration status of nearly all of the large-volume patients: 96 percent of those in the operating room, 93 percent of those in the recovery room, and 75 percent of those on the floor. The fluid balance in these large-volume patients is the primary concern of this study.

Analysis of our data revealed mild fluid over-resuscitation, manifested by a high average urine output using our initial guidelines. However, it appears from our series that average intraoperative fluid ratios of 2.1 in the small-volume group (compared with the 2:1 ratio of Pitman) and 1.4 in the large-volume group are both safe. No patient manifested clinical signs of pulmonary edema or fluid overload. We believe that the larger ratio of fluid delivered to the small-volume patients is acceptable in aspirations less than 4 liters, because it reflects a small absolute fluid delivery. However, when we are managing larger volumes of fluid, it is prudent to consider the possible complications of fluid overload, such as congestive heart failure and pulmonary edema. The majority of large-volume patients in our series consistently had urine outputs more than 1 cc/kg/hr, indicating more than adequate fluid resuscitation and providing us with a window in which we could modify our formula. Our intraoperative fluid recommendations are the following:

1. preoperative deficits replaced at the discretion of the surgeon and the anesthesiologist;
2. maintenance crystalloid adjusted accordingly to vital signs and urine output;
3. superwet infiltration; and
4. 0.25 cc of intravenous fluid for each cc aspirated over 4000 cc

Foley catheters are placed in all large-volume patients and are usually removed by the first postoperative morning. Patients who have undergone large-volume aspirations benefit from an overnight stay in a hospital or ambulatory nursing care setting, both for parenteral analgesics and for fluid management.

Since we began implementation of this formula, we have had no episodes of hypotension and urine output remains adequate. Postoperative courses have been uneventful and hospital discharge is within 1 to 2 days ([Fig. 6](#)). Maintenance fluid is continued postoperatively until oral intake is adequate and peripheral lines are removed.

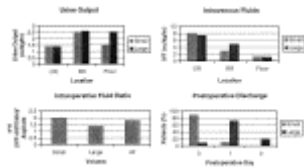


Fig. 6. (Above, left) Average urine output in small-volume (operating room,  $n = 6$ ; recovery room,  $n = 6$ ; floor,  $n = 2$ ) and large-volume (operating room,  $n = 11$ ; recovery room,  $n = 10$ ; floor,  $n = 10$ ) aspiration patients treated with modified fluid resuscitation guidelines. (Above, right) Average intravenous fluid delivery in small-volume (operating room,  $n = 18$ ; recovery room,  $n = 18$ ; floor,  $n = 2$ ) and large-volume (operating room,  $n = 11$ ; recovery room,  $n = 11$ ; floor,  $n = 10$ ) aspiration patients treated with modified fluid resuscitation guidelines. (Below, left) Average intraoperative fluid ratios (IFRs) for small-volume ( $n = 18$ ) and large-volume ( $n = 11$ ) aspiration patients treated with modified fluid resuscitation guidelines. (Below, right) Postoperative discharge days for small-volume ( $n = 18$ ) and large-volume ( $n = 11$ ) aspiration patients treated with modified fluid resuscitation guidelines.

Although the superwet technique is controversial, we believe that it offers several advantages when used with general anesthesia. These are minimal blood loss, low complication rate, and better regulation of fluid delivery. As Fodor has stated in his 1995 editorial, the superwet technique, when used with general anesthesia, is an approach that lessens the potential danger of fluid overload.<sup>15</sup> In his discussion of Klein's article, "Tumescent Technique for Local Anesthesia Improves Safety in Large Volume Liposuction," Pitman also acknowledges the possibility of cardiac and pulmonary decompensation with large-volume subcutaneous injections.<sup>16</sup> The tumescent technique may result in intraoperative fluid ratios of as high as 3 to 7:1,<sup>15</sup> which we believe may be unnecessary and potentially excessive. Gilliland has reported pulmonary edema in a patient with an intraoperative fluid ratio of approximately 2.6.<sup>4</sup> In support of the tumescent technique, Klein claims that it obviates the need for administration of large volumes of intravenous fluids.<sup>7,13,14</sup> Although patients undergoing the tumescent technique need minimal if any intravenous fluids, we believe that the combination of a superwet technique and intravenous fluid delivery allows better control of fluid resuscitation and produces equal blood loss with consistently excellent aesthetic results from liposuction.

In regard to composition of subcutaneous infiltrate, we believe the critical components to be epinephrine and a balanced isotonic solution, with lidocaine added for analgesia. Burk et al. advocate an upper safety limit of 10 mg of epinephrine based on normal endocrine values.<sup>32</sup> We add 1 cc of epinephrine 1:1000 to each liter of wetting solution for a final concentration of 1:1,000,000. With this formula, none of our patients have manifested clinical evidence of epinephrine toxicity such as tachycardia or hypertension.

Because of the slow absorption that takes place when it is in such a dilute form, lidocaine may be administered in relatively high doses in liposuction. Klein has documented that dosages of up to 35 mg/kg of lidocaine, with peak plasma levels at 12 hours, never reach toxic levels.<sup>14</sup> Ostad reports safe use of an even higher dose, up to 55 mg/kg.<sup>24</sup> Nevertheless, monitoring the patient for lidocaine toxicity remains prudent ([Table VIII](#)). It is important to remember that in the patient under general anesthesia, the first signs of lidocaine toxicity may be manifested as cardiac abnormalities.

TABLE VIII Lidocaine Toxicity<sup>14</sup>

5.0 µg/ml	Subjective toxicity
5.0 µg/ml	Oliguric toxicity
8.0 µg/ml	Severe cardiac depression
12 µg/ml	Coma
20 µg/ml	Respiratory arrest
20 µg/ml	Cardiac arrest

In liposuction, lidocaine has been shown to provide clinical analgesia for up to 18 hours postoperatively, with blood levels detectable at 24 hours.<sup>7,14</sup> However, it is our experience that the majority of patients require supplemental postoperative analgesia and that pushing the limits of lidocaine dosage is unnecessary. Therefore, we have changed our lidocaine dosing, and in cases of anticipated large-volume aspirations (≥4 liters) we add 15 cc of 1% lidocaine to every liter, which we believe still preserves the analgesic effect to a certain extent ([Table IX](#)).

TABLE IX Lidocaine Formulas for Wetting Solution in Small-Volume and Large-Volume Patients

Volume	Volume 75 Lidocaine per Liter Lidocaine (cc)
Small (<=4 liters)	30
Large (>4 liters)	15

The potential for fluid overload in large-volume liposuction draws serious concern. Current recommendations for fluid resuscitation are not well defined and are based on clinical experience rather than experimental data. Overall, the superwet technique combined with judicious intravenous resuscitation and adherence to standard monitoring principles is safe. Based on our experience, we have developed a formula for perioperative fluid resuscitation for use in conjunction with the superwet technique. This formula serves as a general guideline and is not a substitute for sound clinical judgment or close patient monitoring. Good communication between the surgeon and anesthesiologist is the key component for optimal patient care. We encourage further comprehensive experimental studies of fluid resuscitation in large-volume liposuction patients. It is hoped that these will improve our understanding of how the significant fluid shifts involved in subcutaneous infiltration and subsequent fat aspiration affect the hemodynamic status of our patients.

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