Lipoplasty in the Overweight Patient

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KEYWORDS

• Body contouring • Large volume liposuction • VASER liposuction • Ultrasonic-assisted liposuction • Renuvion • Radiofrequency-assisted liposuction • Liposuction safety • Synchronous energy-assisted liposuction

KEY POINTS

- Large volume liposuction (LVL), performed by board-certified plastic surgeons using energy-assisted liposuction devices, is safe with improved aesthetic outcomes and minimal complications.
- Utilizing synergistic energy-based devices, VASERLipo and Renuvion, can achieve substantial retraction following LVL.
- Evidence-based protocols, including hypothermia prevention, deep vein thrombosis (DVT) prophylaxis, and perioperative antibiotics, reduces complications.
- For optimal patient safety and high-quality care, LVL should be performed in accredited hospitals or certified ambulatory surgery centers with overnight admission for hemodynamic monitoring for prompt identification and management of complications.
- While the use of advanced devices like VASERLipo and Renuvion has shown promising results, surgeons must exercise caution to avoid seroma, pneumomediastinum/pneumoperitoneum, and subcutaneous emphysema.

INTRODUCTION

The prevalence of obesity has increased for most countries since the 1980s. This global obesity epidemic has contributed directly to the increased incidence of cardiovascular risk factors, such as type 2 diabetes, hypertension, dyslipidemia, and sleep disorders. Despite the ever-changing ideal of feminine and masculine body types, and constantly changing beauty standards imposed throughout the past decade, the increased rates of obesity and the growing pursuit of a slender body contributed to the growing desire for liposuction. Suction-assisted lipectomy remains one of the most common body contouring procedures in the United States.[1] During the last decade, liposuction has undergone significant improvement with regards to technique, technology, safety, and outcomes. This advancement in techniques and energy-based devices has improved the postoperative skin retraction as well as reduced complications, such as blood loss. With the improvement of surgical outcomes and reduction of potential complications, large volume liposuction becomes a viable alternative in body contouring.

HISTORICAL BACKGROUND

The modern technique of liposuction was initially introduced in 1975 by a father and son who were cosmetic surgeons. Arpad and Giorgio Fischer (Rome, Italy) first described the crisscross suctioning of fat of the outer thighs using a blunt hollow cannula attached to a suction source.[2]

Yves-Gerard Illouz[3] and Pierre Fournier (Paris, France) popularized the Fischer technique in 1977 by performing liposuction to the whole body by introducing smaller blunt cannulas of different diameters. In order to reduce bleeding and trauma to the surrounding tissues, Illouz[4] later developed the "wet technique" by injecting saline

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solution with hyaluronidase into the localized adipose tissue. Fournier subsequently introduced the use of lidocaine in liposuction as well as the concept of compression techniques during the postoperative period.[5]

The reduction of blood loss associated with suction-assisted lipectomy was further improved when Jeffrey Klein (Southern California, USA),[6,7] a dermatologic surgeon, introduced the Klein tumescent technique, which involved the infusion of a solution consisting of 0.05% lidocaine, 1:1,000,000 epinephrine, and 10 mL sodium bicarbonate per liter of saline into the adipose tissue before the liposuction procedure. A safe upper limit for lidocaine dosage was determined by Klein to be 35 mg/kg with minimal toxicity and was later proven to be safe at 55 mg/kg by Ostad and colleagues.[8,9] The peak plasma level of lidocaine was found to be present around 4 to 8 hours after the infiltration of the tumescent fluid.[9] The large volume of dilute epinephrine also afforded the additional benefit of avoiding tachycardia and hypertension during and after the procedure.[8]

The introduction of ultrasonic liposculpturing by Michele Zocchi[10] (Italy) in 1992 further revolutionized liposuction based on the surgical use of ultrasonic energy.

This liposuction method required a two-stage process involving the emulsification of fat with a solid probe followed by aspiration of fat. Selective lipolysis occurs secondary to cavitation and cellular fragmentation at frequencies in excess of 16 kHz with the vibration of the ultrasonic probe.[11,12] With the benefit of a reduced physical workload on the surgeon, this selective destruction of adipose tissues enhanced the ease of fat extraction as well as facilitated the retraction of skin by the application of ultrasonic heat. This ultrasound-assisted liposuction technique has undergone multiple refinements from a solid probe to a hollowed cannula that allowed simultaneous emulsification and lipoaspiration.[13] Vibration Amplification of Sound Energy at Resonance (VASERLipo; (Solta Medical, Bothell, WA, USA) supplanted the 2 previous generations of ultrasonic liposuction systems that were riddled with seroma and thermal injury complications. The VASER system uses a probe with multiple rings or grooves that redistribute the ultrasonic pulsed energy from the tip to the sides of the probe where the rings are located. This redistribution of ultrasonic energy results in a reduction of applied power and greater fragmentation of adipocytes at a lower-energy setting with either a pulsed or a continuous energy.[14,15]

Further technological advancement in 1998 led to the emergence of power-assisted liposuction that uses a rapidly vibrating cannula reciprocating at 2000 to 4000 cpm with a 2-mm stroke.[16] This rapid oscillating cannula movement allows the breaking up of fibrous fat much more readily, which helps reduce operative time as well as makes liposuction less labor-intensive than the traditional suction-assisted lipectomy.[17]

Several technological advancements contributed further to the improvement of the outcome in liposuction. Whether it is driven by an oscillating tool, ultrasound, laser, or radiofrequency (RF) energy, each of these technologies has its set of benefits as well as its complications.[12,18,19]

LARGE VOLUME LIPOSUCTION

In 1998, the American Society of Plastic Surgery Task Force on Lipoplasty defined large volume liposuction as greater than 5000 cc total aspirate in a single procedure.[11] During this procedure, patients are exposed to a large volume of subcutaneous fluid infiltration, prolonged general anesthesia with hypothermia, and potential higher doses of epinephrine or lidocaine. Profound hemodynamic alterations occur during large volume liposuction. Because of the epinephrine from the infused tumescent fluid, there is an increase in heart rate, cardiac index, mean arterial pressure, and right ventricular stroke work index.[20] A diminished mean arterial pressure and systemic vascular index, however, also occur during large volume liposuction, which may be attributed to the vasodilation effects of general anesthesia.[20]

Intraoperative blood loss in suction-assisted lipoplasty has always been a major concern in the past with blood loss ranging from 20% to 45% in dry lipoplasty when no subcutaneous infiltration was given before liposuction.[21] The introduction of tumescent infiltration in the targeted area of liposuction with dilute lidocaine and epinephrine significantly reduced the blood loss associated with this procedure.[7,8,21] Blood loss diminished from 45% as seen in dry lipoplasty techniques to 1% as seen in tumescent and superwet techniques.[21] With the advent of ultrasound-assisted liposuction using the VASERLipo system (Solta Medical, Bothell, WA, USA), blood loss secondary to liposuction further improved and diminished. A 7.5-fold decrease of blood loss made it more feasible to perform large volume liposuction with the use of the VASERLipo device with 0.61% blood loss of the total aspirate.[22]

The use of the superwet and tumescent techniques in liposuction, as well as the utilization of ultrasonic liposuction devices, has significantly decreased intraoperative blood loss and the potential need for blood transfusion in lipoplasty.

Volume overload resulting in pulmonary edema and acute respiratory distress syndrome, however, can be a potential problem in large volume liposuction because greater volumes of subcutaneous fluid infiltration in addition to the resuscitative fluids are involved in this procedure. Given the lack of randomized controlled clinical studies, controversial debate still surrounds the issues of the optimal fluid strategy in large volume liposuction. Several studies were previously conducted and created guidelines for fluid management in patients who underwent suction-assisted lipectomy using superwet techniques.[23–25] "Intraoperative fluid ratio" as described by Trott and colleagues[23] seemed to be a safe guideline for fluid management in large volume liposuction. Intraoperative fluid ratio was defined as the volume of subcutaneous infiltrated fluid and intravenous fluid divided by the total aspiration volume. Studies have shown that an intraoperative fluid ratio of 1.2 to 1.4 was safe for large volume liposuction.[23–25]

SKIN RETRACTION WITH ENERGY-ASSISTED LIPOSUCTION DEVICES

Lipoaspiration is an excellent tool that can remove excess adipose tissue; however, it cannot remove excess skin, and therefore, techniques are compared based on their ability to contract the skin of the treated area. Approximately 10% of skin retraction occurs after suction-assisted lipectomy.[26,27] There were multiple modalities and technologies used to assist skin retraction in suction-assisted lipectomy, which ranges from the use of ultrasonic energy, LASER, to RF energy. VASER-assisted lipoplasty was shown to cause significant skin retraction of 17% at 6 months in a randomized clinical trial by Nagy and Vanek.[14] This was a 53% improvement in skin retraction relative to suction-assisted lipectomy. LASER-assisted liposuction, however, was reported to have a similar soft tissue contraction of 17.2% as compared with 10.6% skin surface area reduction obtained from suction-assisted lipectomy.[27]

The advent of RF energy-based devices further contributed to the improvement of skin retraction as well as to the contraction of the underlying fibroseptal network underneath the skin.[26,28] A randomized clinical study by Duncan[26] revealed that the subdermal and subcutaneous application of RF energy using BodyTite (InMode Corporation, Toronto, Canada) resulted in a 36.4% skin surface area reduction at 1 year by dermal collagen fiber contraction and neocollagenesis. This RF energy device uses a handpiece that transmits RF energy between 2 electrodes: an external electrode that is in contact with the skin, and an internal electrode that is in contact with the subcutaneous adipose tissue layer and fibroseptal network.[19,29]

The introduction of plasma-converted radiofrequency energy (Renuvion; Apyx Medical, Clearwater, FL, USA) in 2016 as a subdermal coagulation device using RF energy contributed further to the arena of energy-assisted liposuction devices as an alternative to improve soft tissue contraction. This device delivers RF energy at 13.05 MHz to energize a tungsten needle electrode that would ionize helium gas and convert it into cold helium plasma.[30,31] Helium gas is used in this device because of its low electron density, which has a higher thermal conductivity when ionized and uses lower energy than an equipment-operational argon plasma.[30,32] This helium-based plasma RF technology delivers heat to the tissues at temperatures greater than 85°C for 0.040 to 0.080 seconds.[30] This rapid heating in the form of cold helium plasma results in rapid cooling after the application of the RF energy to the surrounding tissues. Thus, soft tissue contraction from the heat generated from the Renuvion device is achieved without overheating the full thickness of the dermis. Because the RF plasma energy is conducted to lower impedance targets, such as the fibroseptal networks that encase the fat globules, the redirection of the flow of energy allows soft tissue contraction without excessive heating.[33] This helium-based plasma RF technology not only had shown to improve skin laxity but also affords a treatment time efficiency advantage because it delivers heat within 0.044 seconds.[18,30]

With all these technological innovations, the ideal liposuction technology would be the ability to remove fat easily with minimal morbidity, and concomitantly tighten skin without the need for excisional surgery. Synchronous energy-assisted lipectomy (SEAL) has recently emerged by combining multiple technologies to improve surgical efficiency as well as improve the aesthetic outcome of lipoplasty. Studies have shown that skin and soft tissue retraction that results from the subdermal application of energy-based liposuction devices is also secondary to contraction of the collagen fibers of the fibroseptal network.[18,31,34]

CURRENT STUDY

A retrospective chart review study was conducted on patients who underwent large volume liposuction (>5 L Liposuction aspirate) using either the ultrasonic-assisted lipectomy (VASER only) or the SEAL technique from a single surgeon's institution

from January 2018 to February 2023. This SEAL technique included 4 stages consisting of tumescent infiltration; emulsification of fat using the VASER probe; suction-assisted lipectomy using a power-assisted liposuction device (MicroAire Surgical Instruments, Charlottesville, VA, USA); and subdermal application of plasma-converted RF energy (Renuvion). Inclusion criteria included male and female subjects greater than 21 years of age who underwent large volume liposuction. The exclusion criteria include any previous abdominal or chest surgery, history of ventral hernia, congestive heart failure, myocardial infarction, deep vein thrombosis (DVT), or any combined procedures, such as abdominoplasty or breast augmentation. All patients were also evaluated for the presence of an umbilical hernia. When an umbilical hernia was present, a concomitant umbilical hernia repair was planned before the lipoplasty procedure.

Informed consent was obtained on every patient before each procedure to be included in a potential clinical research study and informed of the potential risks of the surgical devices used. All patients provided informed consent for the procedure to be performed, as well as authorization for the usage of photographs for research purposes. Deidentified information was collected on the following patient demographics: sex, age, race, body mass index (BMI), and comorbidities. The following surgical variables were included: tumescent infiltration volume, liposuction aspirate volume, concomitant procedures, and intraoperative complications.

EVALUATION

All patients were clinically screened for cardiovascular and blood pressure disorders by obtaining a cardiology clearance from a board-certified cardiologist. It is imperative to evaluate cardiac function of patients undergoing this procedure to determine that their compliant right ventricles can accommodate large fluid shifts during surgery.[35]

Attempts to reduce hypothermia during the procedure were obtained by prewarming the patient with forced warm air using the Bair Hugger before surgery; raising the temperature of the operating room to at least 74°F with a relative humidity of 30% to 60%; using warmed forced air intraoperatively; warmed intravenous and tumescent fluids using a fluid warmer at $\leq$104°F (40°C); and warmed blankets.[36]

Caprini score was calculated by the surgeon in all patients. An intermittent sequential compression device was used before induction of general anesthesia for DVT prophylaxis in all patients. Heparin 5000 units was given subcutaneously at the end of the procedure, and the patients were then prescribed an oral anticoagulant (rivaroxaban) for 10 to 14 days for chemothromboembolic prophylaxis.

Perioperative intravenous antibiotics were given within 30 minutes of the procedure. A Foley urinary catheter was placed, and urine output was monitored throughout the case in all patients. No invasive hemodynamic monitoring was performed.

Intravenous fluids were maintained based on vital signs and urine output of the patient during the entire procedure and postoperatively. All patients were admitted overnight at an accredited hospital or accredited outpatient ambulatory surgery center. Fluid boluses were given if needed under the discretion of the anesthesiologist and surgeon, but maintenance intravenous fluids were administered postoperatively during the 23-hour observation period.

OPERATIVE TECHNIQUE

The patients were marked in the standing position in the preoperative recovery room area and were reevaluated for the presence of umbilical hernia and other hernias. They were then prepared in the standing position using 2% Chlorhexidine gluconate in 70% Isopropyl alcohol (ChloraPrep).

After general anesthesia was induced, surgery was then initiated by performing a simple umbilical hernia repair with a 2-0 nonabsorbable suture if an umbilical hernia was present. It is crucial to repair any umbilical hernia before suction-assisted lipectomy in order to avoid any iatrogenic bowel or intraabdominal organ injuries. Umbilical hernia repair may also mitigate the risk of pneumoperitoneum secondary to the diffusion of helium gas during the Renuvion application phase of the procedure.

Liposuction was then performed by either VASER-assisted liposuction or using a four-stage SEAL technique consisting of tumescent infiltration; emulsification of fat using the VASER probe (Solta Medical); suction-assisted lipectomy using a power-assisted liposuction device (MicroAire); and subdermal application of plasma-converted RF energy (Renuvion).

The superwet technique for infiltration and liposuction was used with 1:1 volume of infiltrate/volume of aspirate. The infiltration solution consisted of 20 mL of 1% lidocaine, 1:1000 (1 mg) of epinephrine, and 8.45% sodium bicarbonate in 1 L of lactated Ringer solution. The author continued to use lidocaine in the wetting solution even though some investigators suggested that lidocaine can be completely eliminated from the infiltration fluid

if liposuction is performed under general anesthesia.[37] The reasoning to continue its usage in wetting solutions is that lidocaine affords better postoperative pain control and reduced systemic anesthesia requirements.[38] Although the safe dosage of lidocaine for tumescent liposuction had been shown to be safe at 55 mg/kg,[9] the author selected the maximum lidocaine dosage in his institution to be less than 35 mg/kg in all patients.

Skin protection using the VASERLipo designed skin ports as well as wet towels adjacent to the port locations was used. The emulsification process was performed using a 5-ring VASER probe at 50% amplitude using the VASER-mode (pulsed energy) at a maximum of 1 minute of treatment time per 100 mL of infused wetting solution. The 5-ring VASER probe was used to achieve more fragmentation of the surrounding tissues/fat and to deliver a higher ultrasonic energy parallel to the probe.

Extraction of the fat was performed using a 3.7-mm Vent-X cannula and a power-assisted liposuction device (MicroAire). Standard manual suction-assisted lipectomy using a 3.0-mm and 3.7-mm Vent-X cannula was performed for the lipoplasty of the abdomen and thighs to minimize contour irregularities. Power-assisted liposuction using a 4.0-mm "candy cane" pattern cannula was performed on the flanks and back. The endpoint of liposuction was when the liposuction aspirate changed from a pure yellow color to a bloody appearance.

The Renuvion device was used at 80% power and 2.0 L of helium flow. The RF-helium plasma was applied subdermally with up to 5 subcutaneous passes applied at the same point of location at different levels. Aspiration of the residual helium gas was performed using a 3.7-mm Vent-X cannula. The small stab incisions were left open to allow egress of the remaining tumescent fluid infused.

POSTOPERATIVE ASSESSMENT

All patients were placed in a foam corset garment and a highly compressive garment immediately after surgery. Highly compressive garments are essential to minimize fluid sequestration into the tissues and thus minimize fluid shifts that may result in intravascular fluid depletion postoperatively. Patients were instructed to wear the foam corset garment for 2 months, and the highly compressive garment for 6 months. The foam corset garment was designed to minimize the risk of seroma formation and compression garment ulcers. Furthermore, all patients received lymphatic massage therapy the following day after surgery for 10 consecutive days. All patients were followed up in clinic the following day after surgery, and 1 week, 4 weeks, 8 weeks, and 6 months after the procedure.

Table 1
Patient demographics and operative data

Sex	
Female	63 (71.59%)
Male	25 (28.41%)
Ethnic background	
African American	43 (48.87%)
Asian	1 (1.14%)
Caucasian	21 (23.86%)
Hispanic	22 (25%)
Middle Eastern	1 (1.14%)
Liposuction of trunk	
No	4 (4.55%)
Yes	84 (95.5%)
Liposuction of bilateral arms	
No	14 (15.91%)
Yes	74 (84.09%)
Liposuction of bilateral thighs	
No	25 (28.41%)
Yes	63 (71.59%)
Fat transfer area	
Butt	44 (50%)
Correction of gynecomastia	
No	80 (90.91%)
Yes	8 (9.09%)
Concomitant procedure	
Bilateral medial thigh lift	4 (4.55%)
Excision of right torso lipoma	1 (1.14%)
No	77 (87.5%)
Umbilical hernia repair	6 (6.82%)
Renuvion	
No	63 (71.59%)
Yes	25 (28.41%)
Drains	
No	63 (71.59%)
Yes	25 (28.41%)
23 Hour Observation	
Yes	88 (100%)
History of previous laparotomy or midline incision scar	
No	88 (100%)
Hospitalization after discharge	
No	88 (100%)

STATISTICS

The data were analyzed by an independent academic biostatistician and clinical researcher who had full access to all study data. The results of this analysis were the results reported in this article. Data were verified, coded, and analyzed using IBM-SPSS 27.0. Descriptive statistics: Means, standard deviations, frequency, and percentages, were calculated. Normality of continuous variables was tested using Kolmogorov-Smirnov test/Shapiro-Wilk test as appropriate. Paired *t* test analysis was carried out to compare the means of continuous outcomes. A significant *P* value was considered when it is less than .05.

RESULTS

Eighty-eight patients with BMI greater than 30 kg/m^2, aged 21 to 64 years (mean age, 40.8; median age, 41), who underwent large volume liposuction (>5 L liposuction aspirate) with either the VASER-assisted liposuction alone versus the Synchronous Energy-assisted lipoplasty (VASERLipo and Renuvion) were included in this retrospective chart review (**Table 1**). The average BMI of the patients included in this chart review was 35.4 kg/m^2 with a mean weight of 99.06 kg (218.4 lbs). The average Caprini score for venous thromboembolism was 3.68, and all patients were given thromboembolism prophylaxis with heparin 5000 units

Table 2
Patient demographics, operative characteristics, and metabolic parameters

	N	Range	Minimum	Maximum	Mean	SE	SD	Median
Age, y	88	43.00	21.00	64.00	40.8068	1.05118	9.86094	41
BMI	88	20.00	30.00	50.00	35.4069	0.45493	4.26762	34.39
Weight	88	145.00	155.00	300.00	218.4659	3.74661	35.14631	209.5
Height	88	50.80	149.86	200.66	167.6977	1.31865	12.37005	163.83
Tumescent fluid infused	88	8.50	5.00	13.50	10.1681	0.17435	1.61687	10.29
Liposuction aspirate volume (L)	88	8.10	5.00	13.10	7.2697	0.19871	1.84279	6/85
Duration of surgery (min)	88	410.00	115.00	525.00	337.8295	6.51462	61.11253	330
Initial systolic BP	88	90.00	94.00	184.00	129.7907	1.94142	18.00400	128.5
Initial diastolic BP	88	82.00	31.00	113.00	83.0233	1.37855	12.78416	83
Systolic BP (1st week)	82	84.00	80.00	164.00	121.5854	1.58916	14.39046	120
Diastolic BP (1st week)	82	46.00	60.00	106.00	80.3537	1.05871	9.58699	78
Systolic BP (1st month)	77	76.00	81.00	157.00	124.5195	1.62428	14.25299	122
Diastolic BP (1st month)	77	47.00	54.00	101.00	81.5065	1.04014	9.12721	79
Hb (preoperative)	69	7.90	10.20	18.10	13.4870	0.18731	1.55591	13.3
Hb (postoperative)	13	7	8	15	11.82	0.591	2.129	12.2
Hct (preoperative)	69	55.90	31.50	87.40	41.6838	0.84386	6.95865	40.7
Hct (postoperative)	13	19	28	46	36.65	1.429	5.153	36.8
Glucose (preoperative)	66	90.00	74.00	164.00	95.9682	2.02112	16.41966	93.45
Glucose (postoperative)	8	55	75	130	101.88	6.996	19.788	99.5
HbA_{1c} (preoperative)	32	3.70	4.90	8.60	5.7500	0.14438	0.81676	5.6
HbA_{1c} (postoperative)	2	0	6	6	5.60	0.000	0.000	5.6
BUN (preoperative)	62	19.00	7.00	26.00	13.4726	0.54167	4.26508	12
BUN (postoperative)	8	13	9	22	13.63	1.647	4.658	12.5
Crt (preoperative)	63	1.57	0.30	1.87	0.8333	0.03013	0.23916	0.8
Crt (postoperative)	8	0	1	1	0.80	0.043	0.121	0.775
Caprini score	88	3.00	3.00	6.00	3.6818	0.07326	0.68725	4

Abbreviations: BP, blood pressure; Crt, Creatinine; Hb, Hemoglobin; Hct, Hematocrit; SD, standard deviation; SE, standard error of mean.

subcutaneously perioperatively and an oral anticoagulant postoperatively.

The average volume of tumescent fluid infiltrated per patient was 10.16 L, and the average volume of liposuction aspirate was 7.27 L (**Table 2**). The mean duration of surgery was 337 minutes (median, 330 minutes). Sixty-eight patients (77.27%) had the SEAL, and 6 patients (6.82%) had a simple umbilical hernia repair performed concomitantly before lipoplasty. Only 25 (28.41%) patients had a drain placed intraoperatively at the end of the procedure. All patients were admitted overnight at either a certified hospital or an accredited ambulatory surgery center.

There were no thromboembolic complications and no cardiac events, such as myocardial infarction or pulmonary edema, in any of the patients. No patient required any blood transfusions. There were no pneumoperitoneum or mediastinal emphysema on any of the patients who underwent either the VASER liposuction alone or synchronous energy-assisted lipoplasty with VASERLipo and Renuvion. However, there were 2 patients who developed a seroma postoperatively requiring aspiration (n = 2; 2.27%), and both patients had Renuvion during their procedure (**Table 3**). One patient developed blister formation and subcutaneous emphysema (1.47% of Renuvion patients) on the left forearm the day after surgery secondary to migration of helium gas from the left arm where the Renuvion device was applied (**Fig. 1**). Moreover, there were 3 patients who developed mild cellulitis that resolved with oral antibiotics (n = 3; 3.34%).

Analysis of systolic/diastolic blood pressure, hemoglobin, hematocrit, glucose, blood urea nitrogen (BUN), and creatinine was also performed. Using a paired *t* test for statistical analysis, postoperative outcomes were compared with baseline (**Table 4**). The analysis shows that, after liposuction, systolic blood pressure measurements were significantly lower after 1 week ($P<.001$) and after 1 month ($P = .015$). However, diastolic BP measurements were not significantly reduced ($P = .063$ after 1 week and $P = .421$ after 1 month). Hemoglobin and hematocrit levels were significantly reduced ($P = .001$ and $P = .006$, respectively) with an average decrease of hemoglobin of 1.23 g/dL and hematocrit of 3.02% after large volume liposuction. Regarding glucose, BUN, and creatinine levels, the analysis revealed a nonsignificant difference between baseline and postintervention values ($P = .621$, $P = .595$, and $P = .09$, respectively).

Table 3
Postoperative complications

Thromboembolism	0 (0.00%)
Pulmonary edema	0 (0.00%)
Pressure garment sore	1 (1.13%)
Seroma	2 (2.27%)
Brachial plexus neuropraxia secondary to prone positioning	2 (2.27%)
Infection (cellulitis)	3 (3.34%)
Burn injury	0 (0.00%)
Bullae formation & subcutaneous emphysema	1 (1.13%)
Wound dehiscence (thigh lift)	1 (1.13%)
Pneumomediastinum	0 (0.00%)
Return to operating room	0 (0.00%)
Any return to hospital	0 (0.00%)
Mortality	0 (0.00%)

DISCUSSION

Because of concerns regarding patient safety, the volume of fat to be aspirated in one session of suction-assisted lipectomy is limited. The volume of fat to be aspirated is limited owing to 2 factors: (1) the volume of fat that can be extracted without causing significant blood loss, and (2) the amount

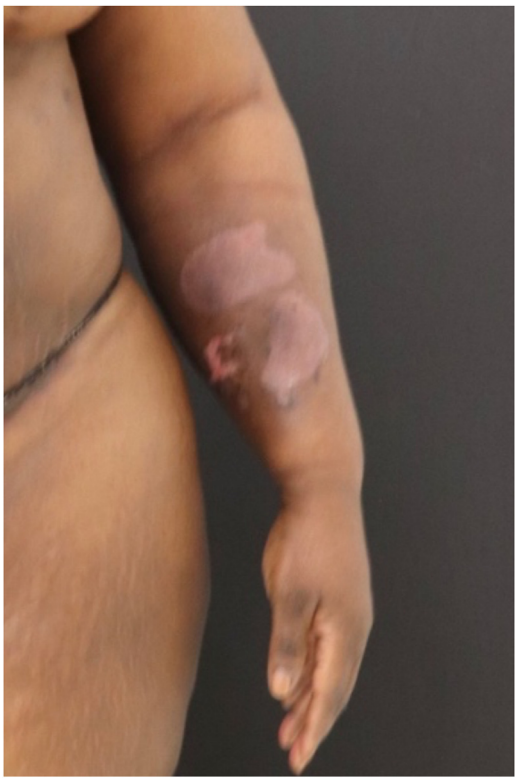

Fig. 1. Subcutaneous emphysema and blister formation of the forearm secondary to helium gas migration from the arm 2 days after Renuvion subdermal coagulation.

Table 4
Postoperative outcomes compared with baseline

	Mean Difference	SD Difference	SE Difference	Lower 95% CI	Upper 95% CI	t	*df*	*P* Value[a]
Systolic BP after 1 wk	−8.82500	20.03843	2.24036	−13.28433	−4.36567	−3.939	79	.000
Systolic BP after 1 mo	−5.33766	18.85444	2.14866	−9.61709	−1.05823	−2.484	76	.015
Diastolic BP after 1 wk	−3.16250	14.97377	1.67412	−6.49475	0.16975	−1.889	79	.063
Diastolic BP after 1 mo	−1.40260	15.21016	1.73336	−4.85488	2.04969	−0.809	76	.421
Hb	−1.23847	1.06578	0.29560	−1.88251	−0.59441	−4.190	12	.001
Hct	−3.02308	3.28815	0.91197	−5.01009	−1.03607	−3.315	12	.006
Glucose	−4.20000	17.55563	7.85111	−25.99819	17.59819	−0.535	12	.621
BUN	1.80000	6.97854	3.12090	−6.86500	10.46500	0.577	4	.595
Crt	0.07600	0.07635	0.03415	−0.01881	0.17081	2.226	4	.090

[a] Results were calculated using the paired *t* test.

of infiltration and intravenous fluid that can be infused during liposuction without causing fluid overload.

Blood loss had been a major factor limiting surgeons from performing large volume liposuction. The advent of tumescent and superwet techniques a few decades ago led to the increase in the amount of fat to be removed from suction-assisted lipectomy. Despite the fact that the Klein formula described in 1987 contributed to a significant reduction of blood loss from 45% to 1% of the liposuction aspirate, there is still apprehension with regards to performing large volume liposuction of more than 5 L of fat.[7,8]

Minimizing blood loss during surgery had always been the objective of many surgeons in the past few decades. In a meta-analysis involving 3583 patients who had large volume liposuction, the most common complication was blood loss requiring blood transfusion with an incidence of 3.35%.[39] In pursuit of mitigating perioperative hemorrhage, plastic surgeons have started to incorporate the usage of tranexamic acid in suction-assisted lipectomy.[40–42] Hoyos and colleagues[41] had shown in a double-blind randomized clinical trial that the use of intravenous tranexamic acid was associated with a decrease in postoperative bleeding from liposculpture procedures. In the author's retrospective study, they found that the mean decrease of hemoglobin and hematocrit using the superwet technique and ultrasonic-assisted liposuction (with or without the use of Renuvion) in large volume liposuction (>5 L lipoaspirate) was 1.23 g/dL and 3.02%, respectively.[41] Although they did not use tranexamic acid in their patients, the use of tranexamic acid is very promising in large volume liposuction and may lead to a further increase in the amount of fat that can be aspirated.

The volume of tumescent or infiltration fluid, however, may still be a limiting factor to the amount of fat that can be aspirated without causing significant hemodynamic shifts and fluid overload. Fluid overload occurs when there is more than 20% gain of total body fluid.[43] In healthy individuals who do not have a history of renal or cardiopulmonary disorders, the amount of excessive fluid administration that may lead to pulmonary edema occurs when the Net Fluid Retention (NFR) Index exceeds 67 mL/kg/d or an NFR of 7 L over the initial 27 postoperative hours.[44] Thus, the NFR volume in a patient undergoing liposuction would be the total amount of fluids received minus the liposuction aspirate and urine output [Net Fluid Retention Volume = (IVF + Infiltration Fluid) – (Total Liposuction Aspirate Volume + Urine Output)]. Total liposuction aspirate volume as opposed to total aspirated wetting solution as suggested by Commons and colleagues[45] in 1999 is used in the calculation because most lipoaspirate is pure fat. This modified calculation correlates more with the safe upper limit of an NFR index of 67 mL/kg/d. The total volume of intravenous and infiltration fluids given during suction-assisted lipectomy, and the occurrence of major postoperative complications are correlated in a parabolic distribution curve [$f(X) = a(X-1)^2 + 3$)] (**Fig. 2**).[46,47] This parabolic distribution curve is the reciprocal of the Frank-Starling curve. Although the mathematical formula is not precise because the time factor is not considered in the equation, knowledge of the potential NFR Volume during the lipoplasty perioperative period may be helpful in managing and mitigating the risks and postoperative complications associated with fluid overload.

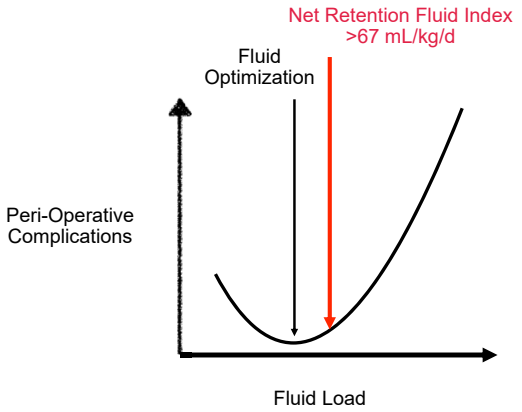

Fig. 2. Correlation between fluid load and perioperative complications in large volume liposuction with a parabolic distribution curve [$f(X) = a(X-1)^2 + 3$)]. Pulmonary edema occurs when net retention fluid exceeds 67 mL/kg/d. NFR Volume = [(IV Fluid + Infiltration fluid) – (Total Liposuction Aspirate Volume + Urine Output)].

Further technological advancements in liposuction, such as the ultrasonic-assisted liposuction using the VASERLipo and power-assisted liposuction device, made large volume liposuction a viable alternative for body contouring in the overweight patient. The emulsification of fat using ultrasonic energy further reduced bleeding in addition to the blood loss reduction from the Klein formula. The power-assisted liposuction device, however, contributed to the ease of fat extraction in the massively obese patient.

Major strides have been made with regards to the innovation of the ideal liposuction device. The optimal liposuction technology should exhibit efficient fat removal; minimal bleeding and contour irregularities; and simultaneous enhancement of

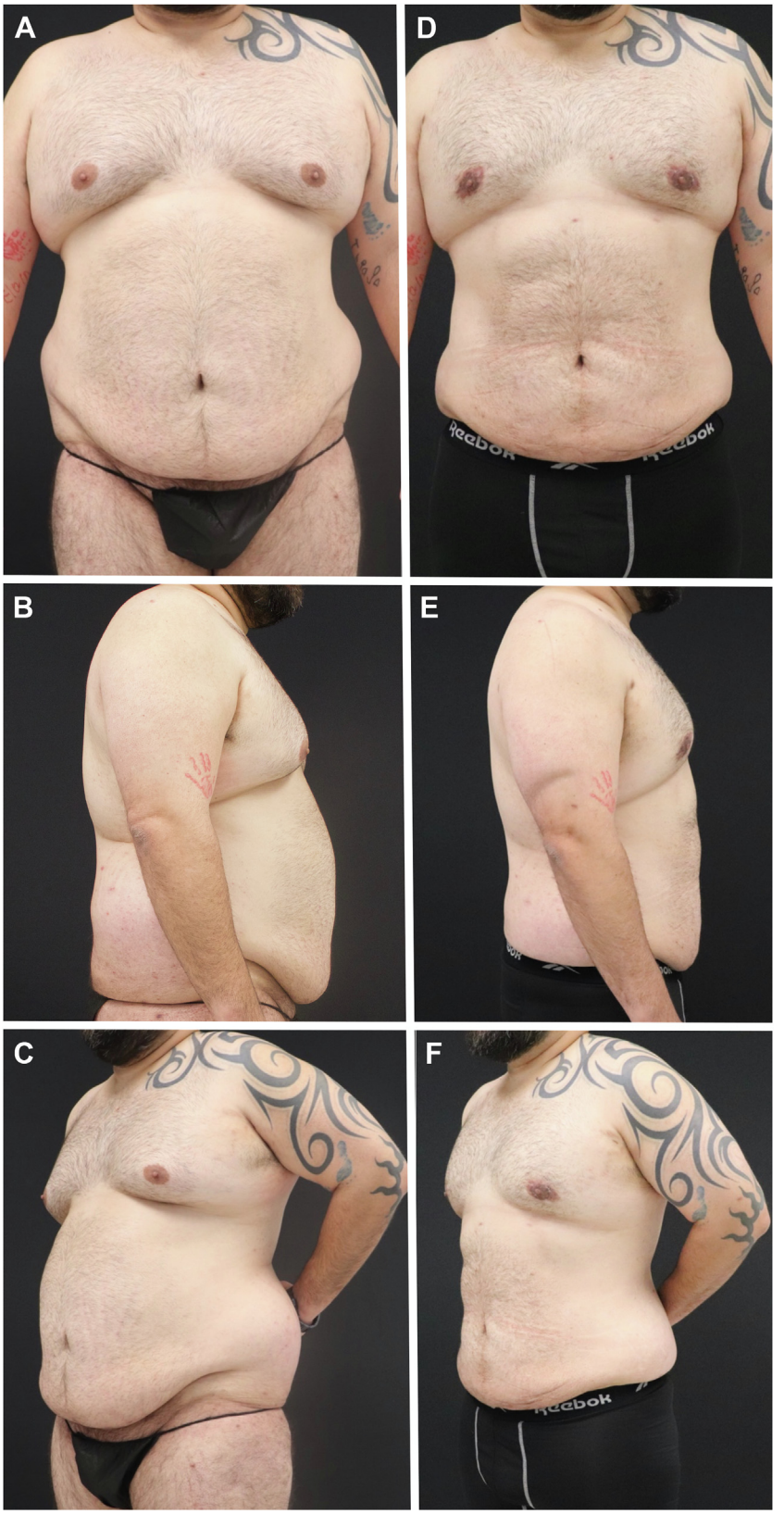

Fig. 3. A 41-year-old man who underwent synchronous energy-assisted lipoplasty of the abdomen, flanks, and back with Renuvion. He also underwent gynecomastia surgery. A total of 6500 mL of fat was removed. The patient lost 18.14 kg 3 months after surgery. (*A–C*) Preoperative views of the front, side, and oblique, respectively. (*D–F*) Postoperative views of the front, side, and oblique at 3 months.

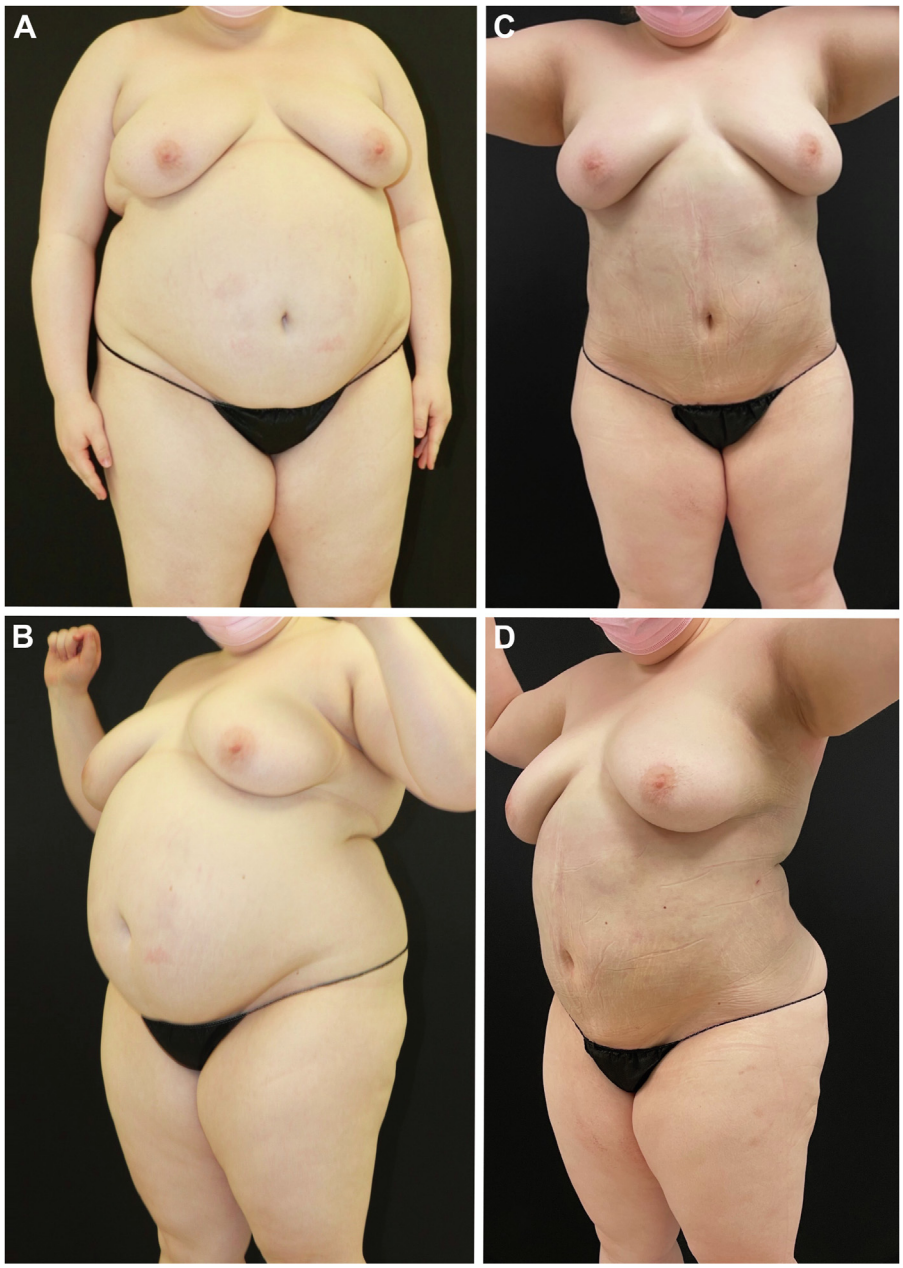

Fig. 4. A 21-year-old woman who underwent large volume liposuction of the trunk and thighs with VASERLipo and Renuvion. A total of 8 L aspirate was removed. (*A*, *B*) Preoperative views of front and oblique, respectively. (*C*, *D*) Postoperative views at 2 weeks.

skin and soft tissue retraction. Regrettably, the current market lacks a device that fulfills all these criteria. However, the recent trend in SEAL has introduced promising advancements. By combining multiple cutting-edge technologies, such as VASERLipo, Renuvion, and MicroAire, surgical outcomes have significantly improved in terms of skin and soft tissue retraction while minimizing complications. Although there is no current study evaluating the amount of skin retraction using the combined-energy devices, clinically there is a significant improvement with regards to skin retraction and the quality of skin postoperatively (**Figs. 3–5**.) Skin and soft tissue contraction varies individually and may be influenced by age, ethnic background, Fitzpatrick scores, and/or history of bariatric surgery. Despite the theoretical advantages of synchronous energy-assisted lipoplasty, new potential

Fig. 5. A 29-year-old woman with a BMI of 44.3 who underwent large volume liposuction of the trunk and thighs with VASERLipo and Renuvion with fat transfer to bilateral buttocks. A total of 11.95 L infiltration fluid was infused, and 11.2 L of liposuction aspirate was obtained. Approximately 700 mL of fat was transferred subcutaneously on each side of the buttocks.

complications may arise from these novel devices, such as Renuvion. Excessive residual helium gas with the usage of Renuvion may potentially result in subcutaneous emphysema, pneumomediastinum, and possibly pneumoperitoneum if the residual helium gas is not aspirated after the procedure.[48] Although the author had no pneumoperitoneum or pneumomediastinum in the retrospective study, they had one patient who developed subcutaneous emphysema and a bullae distal to the treated area of Renuvion (see **Fig. 1**). The use of Renuvion is also associated with an increased seroma rate. Although the seroma rate was minimal (n = 2; 2.27%), all patients who developed seroma

requiring aspiration in the study underwent Renuvion subdermal coagulation.

When combining multiple energy devices, it is essential to reduce the power and amplitude of the VASER device to 50% using the VASER mode in order to reduce the risks of potential burn injury and reduce the seroma formation.[45] Aspiration of the residual helium gas at the end of the procedure, and reduction of the flow rate of the Renuvion device can also dampen the excessive residual helium gas. It is also imperative to evaluate and repair any incidental or occult umbilical hernia to reduce any iatrogenic bowel injury for every liposuction procedure. The repair of an occult umbilical hernia may also mitigate the risk of pneumoperitoneum that may result from the Renuvion device.

SUMMARY

Large volume liposuction using multiple energy-assisted liposuction devices is safe with improved aesthetic outcome and with minimal complications. By using techniques to minimize blood loss, such as the superwet technique and ultrasonic-assisted liposuction, and being cognizant of the maximal volume of infiltration fluid that can be safely infused, large volume liposuction can be safely performed by board-certified plastic surgeons. Evidenced-based surgical protocols for hypothermia prevention, DVT prophylaxis, and perioperative antibiotic prophylaxis should be followed to mitigate the risk of postoperative complications. Large volume liposuction should be performed, and patients should be admitted overnight in an accredited hospital or certified ambulatory surgery center for proper hemodynamic monitoring immediately after surgery. While improving skin and soft tissue contraction, the synergy of multiple devices, such as VASERLipo and Renuvion, is associated with a higher seroma rate formation (2.27%) and risk of subcutaneous emphysema (1.47%). One should exercise caution when using these new medical devices to prevent any untoward events.

CLINICS CARE POINTS

- While adhering to safe infiltration fluid volume limits, superwet technique and ultrasonic-assisted liposuction minimizes blood loss.
- Technological advancements, such as ultrasonic-assisted liposuction and power-assisted liposuction, make large volume liposuction (LVL) a viable option for overweight patients, but should be carefully managed to minimize risks.
- Adherence to evidence-based protocols, including hypothermia prevention, deep vein thrombosis (DVT) prophylaxis, and peri-operative antibiotic prophylaxis, reducesthe incidence of complications.
- Use accredited hospitals or certified ambulatory surgery centers for LVL to ensure the highest standards of care and patient safety.
- Monitoring of fluid administration with overnight stay is crucial to prevent overload in LVL, which can lead to hemodynamic shifts and complications.
- Synchronous energy-assisted liposuction, combining multiple cutting-edge technologies, improves outcomes and skin retraction, but long-term studies are needed.
- Surgeons should be aware of complications associated with novel devices, such as Renuvion, including subcutaneous emphysema and increased seroma rate, and take appropriate precautions.

DISCLOSURE

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