Review Article | Clinical Studies

Outcomes of liposuction techniques for management of lipedema: a case series and narrative review

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Background and Objective: Lipedema is a commonly underdiagnosed chronic condition. This study aimed to evaluate liposuction techniques for lipedema by conducting a systematic review and presenting our experience. A case series study and a comprehensive review were conducted.

Methods: We assessed surgical outcomes among patients with lipedema who underwent liposuction. Descriptive and inferential statistics were implemented. In our case series, we used tumescent liposuction, vibration amplification of sound energy at resonance (VASER) liposuction, and waterjet-assisted liposuction (WAL). We also performed a literature review of current concepts and state-of-the-art treatment for lipedema.

Key Content and Findings: Twenty-four female patients were included in this study with a median age of 37 years [interquartile range (IQR), 10 years]. A statistically significant difference between preoperative (29.65 kg/m^2) and postoperative body mass index (BMI) (26.95 kg/m^2; P<0.05) of patients was evidenced. The amount of total fat removal between surgical techniques was statistically different (P<0.001). A statistically significant difference in the amount of total fat removal between surgical techniques was found (P=0.0015). Post-hoc analysis with Dunn's test evidenced a significant difference only between tumescent suction-assisted lipectomy and WAL (P<0.001). Nineteen studies were included in this review. Low complication rates, improvement in patient-reported outcomes, and reduction in conservative therapy requirements were found when evaluating multiple studies in this review.

Conclusions: Liposuction has been shown to be a safe and effective alternative in patients with lipedema. It positively impacts clinical and patient-reported outcomes.

Keywords: Lipedema; case series; liposuction; lipectomies; suction

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Introduction

Lipedema (lipohyperplasia dolorosa) (1) is an underdiagnosed chronic condition known as "painful fat syndrome" or "fatty deposition syndrome" due to the pain and discomfort generated by disproportional subcutaneous fat distribution (2,3). It is usually presented as a circumscribed, bilateral, symmetrical disorder that mainly affects the limbs' fatty tissue, sparing the hands, feet, and trunk (3-5). It predominantly affects women; nonetheless, a few cases have been described in male patients (6,7).

This symmetrically disfiguring condition is associated with poor quality of life (QoL) and overall mental health afflictions (7-9). The major reasons for these issues are the lack of clear diagnosis and treatment indications, as well as related complications such as hematoma, edema, concomitant lymphedema development, and arthralgia (2,4,10,11). Additionally, patients have an increased risk of developing depression and anxiety secondary to the disappointment generated by the poor physical improvements despite diet and exercise (3,5,8).

To improve QoL, decrease morbidity, and ameliorate the psychosocial burden generated by this disease, an interdisciplinary approach is fundamental, including psychologists, physiotherapists, nutrition and obesity experts, lymphedema/lipedema nurses, and physicians for conservative and surgical treatments (4,5). Debulking surgery via liposuction has been proposed for lipedema management in the setting of no improvement with conservative treatment (12). Liposuction or suction-assisted lipectomy has been shown to improve QoL and reduce pain in this population (5,10,13,14). Wet, tumescent, and supertumescent techniques with or without vibration-assisted systems or waterjet-assisted systems have been described as potential methods with promising outcomes for the treatment of lipedema (3,5,10,15). On the other hand, dermato-fibro-lipectomy has been described mainly in highly advanced stages of lipedema or lipolymphedema, in which the tissue is very fibrotic (4).

Although most healthcare providers believe liposuction has been the most common therapeutic alternative for patients with lipedema, liposuction is chosen as a treatment option in less than 15% of patients (16). Instead, more frequently used treatments include diet and exercise (52%), compression therapy (45%), and manual lymphatic drainage (MLD) therapy (43%) (16). Despite advances in lipedema surgery, there is limited knowledge about the differences between various surgical techniques (16). This study aimed to evaluate the different surgical methods used in treating lipedema and assess their impact on clinical and patient-reported outcomes through a comprehensive review. Additionally, we share our own experience with lipedema reduction surgery. We present this article in accordance with the Narrative Review and the AME Case Series reporting checklists (available at https://atm.amegroups.com/article/view/10.21037/atm-24-165/rc).

Methods

Case series—study design and settings

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committees and with the Helsinki Declaration (as revised in 2013). A retrospective chart review of patients' medical records was performed. All patients with lipedema who underwent liposuction from February 2018 to December 2022 were included in this study. Informed consent was obtained from all patients. All surgical procedures were performed by the same surgeon (P.C.). Surgical indications were as follows: patients aged 18 years or older, more than 5 years with the diagnosis, at least 2 months with complex decongestive therapy (CDT). Only patients with at least 12 months of follow-up were included. Patients with a history of thromboembolic disease, hypercoagulable state, and rheumatologic diseases were excluded from this study.

Case series—variables

Sociodemographic data were extracted. The stage of lipedema (*Table 1*) (17,18), extremity involvement, conservative therapy time, surgical indications, type of surgical technique, solution infiltration volume, average surgical time, and body mass index (BMI) variations were extracted. Patient-reported outcomes were also collected using a 5-point Likert scale and a 10-point visual analogue scale (VAS) (e.g., spontaneous pain, sensitivity to pressure, edema, bruising, restriction to movement, cosmetic reduction in QoL, and general impairment).

The surgical techniques performed in this cohort were tumescent liposuction, vibration amplification of sound energy at resonance (VASER) liposuction, and waterjet-assisted liposuction (WAL). All solutions infiltrated were based on NaCl and adrenaline. The tumescent local anesthesia liposuction (TLAL) technique was performed

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Table 1 Stages of lipedema (17)

Stages	Description
Stage 1	The skin surface remains normal over the enlarged hypodermis, which contains palpable, pea-sized nodules within the fat. These nodules indicate enlargement and fibrosis in the extracellular matrix and the connective tissue surrounding the fat lobules
Stage 2	The skin appears uneven with dimples, resembling cellulite, due to the thickening and contraction of underlying connective tissue fibers over areas of increased fat, accompanied by small to larger hypodermal masses
Stage 3[†]	Marked loss of elasticity in the adipo-fascia severely limits mobility. This impairs blood flow into and lymphatic drainage out of the fat lobules, leading to inflammation and subsequent fibrosis. The fibrosis becomes pronounced and easily palpable, potentially affecting the skin, which may exhibit thinning and a weakened attachment to the underlying hypodermis

[†], lymphedema can develop at any stage, but it is more commonly seen in women with stage 3 lipedema, where it is frequently referred to as lipo-lymphedema or stage 4.

Table 2 The search strategy summary

Items	Specification
Date of search	August 24th, 2024
Databases searched	PubMed and MEDLINE
Search terms used	((lipedema) OR (lipoedema)) OR (lipedema[MeSH Terms])) OR (lipoedema[MeSH Terms])) AND (liposuction[MeSH Terms]); and (((((lipedema) OR (lipoedema)) OR (lipedema[MeSH Terms])) OR (lipoedema[MeSH Terms])) AND ((debulking) OR (dermo-fibro-lipectomy))
Timeframe	January 1996 through August 2024
Inclusion and exclusion criteria	Inclusion: all articles that included patients with lipedema who underwent any lipedema reduction surgery and reported their surgical technique and outcomes. Observational or interventional studies in English and Spanish were included
	Exclusion: letters to editors, animal studies, review articles, video submissions, and social media observations
Selection process	V.P.B. and J.M.E. performed independent search of articles throughout databases. Conflicts were solved by O.J.M.

by providing local anesthesia to the subcutaneous fat tissue before liposuction. VASER liposuction combines ultrasound technology's power to disrupt the union of fat cells with liposuction. Lastly, the WAL technique employs a dual-purpose cannula that delivers pulsating, fan-shaped jets of tumescent solution, while simultaneously suctioning both the adipose tissue and the injected fluid.

Narrative review

A comprehensive search across PubMed and MEDLINE was conducted from January 1996 through August 2024. The search strategy was as follows: ((lipedema) OR (lipoedema)) OR (lipedema[MeSH Terms])) OR (lipoedema[MeSH Terms])) AND (liposuction[MeSH Terms]); and (((((lipedema) OR (lipoedema)) OR (lipedema[MeSH Terms])) OR (lipoedema[MeSH Terms])) AND ((debulking) OR (dermo-fibro-lipectomy)). From the selected studies of this search strategy, relevant citations were identified and included in the study (*Table 2*).

Study selection and inclusion criteria

Inclusion criteria were as follows: all articles that included patients with lipedema who underwent any lipedema reduction surgery and reported their surgical technique and outcomes. Observational or interventional studies in English and Spanish were included. Exclusion criteria

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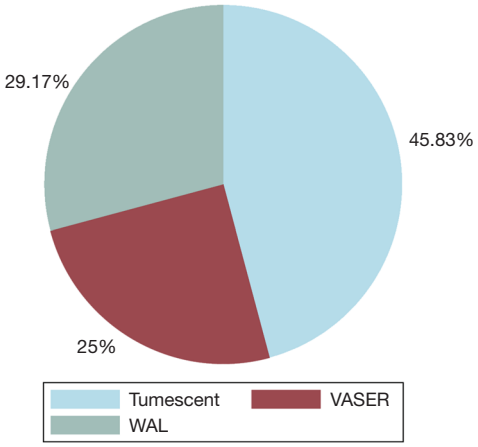

Figure 1 Surgical techniques used in case series (frequency). VASER, vibration amplification of sound energy at resonance; WAL, waterjet-assisted liposuction.

were letters to editors, animal studies, review articles, video submissions, and social media observations. We extracted data on the reference (authors' name), year of publication, country of origin, sample size, gender, and mean age. Surgical outcomes such as circumference, weight, and BMI were identified. Also, pre- and postoperative patient-reported outcomes were extracted (spontaneous pain, sensitivity to pressure, edema, bruising, restriction to movement, cosmetic reduction in QoL, and general impairment). The rest of the variables were the same as the case series.

Statistical analysis

A narrative synthesis of the medical literature was performed. For our case series, inference analysis was performed to assess the mean differences between two groups and three groups with the Wilcoxon matched-pairs signed-rank test and the Kruskal-Wallis rank test, respectively. If a difference was found, post-hoc analysis with Dunn's test was performed. Statistical significance was set at P value <0.05. Stata IC-Version 16.1 was used for the analyses. Discrete variables were presented as mean and standard deviation (SD) or as median and interquartile range (IQR).

Results

Case series

Twenty-four female patients were included in this study with a median age of 37 years (IQR, 10 years). The median follow-up was 19 months (IQR, 13 months). Eleven and thirteen patients presented with stage III and stage II lipedema, respectively. All patients displayed lower extremity involvement. However, five patients had concomitant upper extremity involvement. Tumescent suction-assisted lipectomy, VASER, and WAL surgical procedures were performed in 11 (45.83%), 6 (25%), and 7 (29.17%) patients, respectively (*Figure 1*). In *Table 3*, sample characteristics are depicted based on the type of surgery. Conservative therapy with CDT was performed preoperatively in 18 patients (75%) for 2 months and for 1 month in 6 patients (25%).

Overall, the median preoperative BMI was 29.65 kg/m^2 (IQR, 2.55 kg/m^2), and postoperative BMI was 26.95 kg/m^2 (IQR, 1.8 kg/m^2). Average preoperative and postoperative BMI for different surgical procedure evaluated are shown in *Figure 2*. A statistically significant difference between preoperative BMI and postoperative BMI was found (P<0.05); however, no significant difference regarding the postoperative BMI between surgical techniques was determined (P=0.074). The median solution infiltrated was 4,500 mL (IQR, 1,850 mL), and the median volume of total fat removed was 9,200 mL (IQR, 4,600 mL). A statistically significant difference in the amount of total fat removal between surgical techniques was found (P=0.0015). Post-hoc analysis with Dunn's test evidenced significant difference only between tumescent suction-assisted lipectomy and WAL (P<0.001). In *Figure 3*, the aforementioned variables by type of surgical technique are shown.

The median operative time was 68 min (IQR, 22 min). No significant difference in the average intraoperative time was found between the three surgical techniques (P=0.3674). Regarding the operative times, 11 (45.83%), 9 (37.50%), and 4 (16.67%) patients underwent surgery once, twice, and thrice, respectively. There was no difference regarding the surgical re-interventions between surgical techniques (P=0.0916) and requirement of post-operative CDT (P=0.2003). Lastly, a low rate of complications was evidenced. One patient (4.2%) presented seroma treated with aspiration, 1 patient (4.2%) had infection treated with antibiotics, and 1 patient (4.2%) presented epidermolysis. Preoperative and postoperative patient reported outcomes are reported in *Table 4*.

Summary and discussion

Lipedema is usually a misdiagnosed chronic condition that

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Table 3 Sample characteristics

Variables	Tumescent	VASER	WAL
Total, n (%)	11 (45.8)	6 (25.0)	7 (29.2)
Age (years), median [IQR]	41 [46]	27 [49]	35 [26]
Follow-up (months), median [IQR]	22 [24]	20 [17]	16 [12]
Stage, n (%)			
Stage II	6 (54.5)	3 (50.0)	4 (57.1)
Stage III	5 (45.5)	3 (50.0)	3 (42.9)
BMI (kg/m^2), mean [SD]			
Pre-operative	29.3 [3.6]	29.9 [4.4]	31.5 [15]
Post-operative	26.4 [2.2]	27.7 [3.3]	28.2 [5.5]
Solution infiltrated (mL), mean [SD]	4,918 [744]	5,400 [901]	3,443 [571]
Volume of total fat removed (mL), mean [SD]	11,268 [2,296]	10,450 [2,886]	6,800 [847]
Average surgical time (min), median [IQR]	72 [38]	63.5 [40]	64 [94]
Operative times, n (%)			
One	3 (27.3)	4 (66.7)	4 (57.1)
Two	4 (36.4)	2 (33.3)	3 (42.9)
Three	4 (36.4)	0 (0.0)	0 (0.0)
Post-operative time with CDT (months), mean [SD]	75.9 [13.3]	69.5 [15.4]	66.9 [29.5]
Complications, n (%)			
Infection	1 (9.1)	0 (0.0)	0 (0.0)
Epidermolysis	1 (9.1)	0 (0.0)	0 (0.0)
Seroma	0 (0.0)	1 (16.7)	0 (0.0)

VASER, vibration amplification of sound energy at resonance; WAL, waterjet-assisted liposuction; IQR, interquartile range; BMI, body mass index; SD, standard deviation; CDT, complex decongestive therapy.

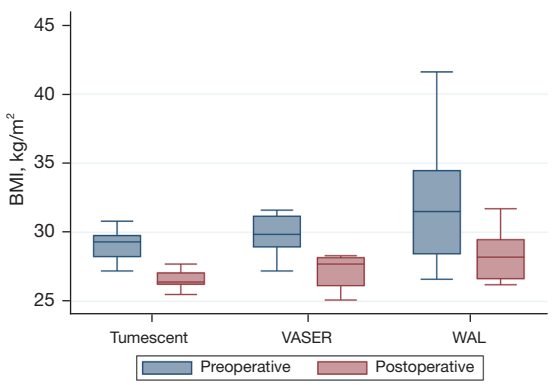

Figure 2 Preoperative and post-operative BMI. BMI, body mass index; VASER, vibration amplification of sound energy at resonance; WAL, waterjet-assisted liposuction.

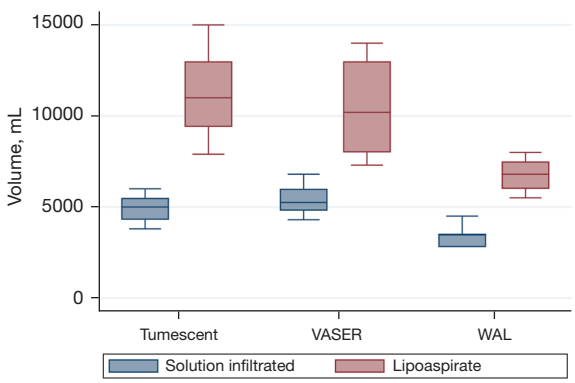

Figure 3 Solution infiltrated and fat removed. VASER, vibration amplification of sound energy at resonance; WAL, waterjet-assisted liposuction.

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Table 4 Case series patient reported outcomes

Clinical effectiveness outcome†	5-point Linkert scale†			10-point VAS		
	Pre-surgery	Post-surgery	Improvement	Pre-surgery	Post-surgery	Improvement
Spontaneous pain	2.00	0.75	1.25	7.10	2.00	5.1
Sensitivity to pressure	2.90	1.20	1.7	7.20	3.10	4.1
Edema	3.20	1.40	1.8	8.50	2.10	6.4
Bruising	3.10	1.60	1.5	7.10	2.10	5
Restriction to movement	3.20	0.70	2.5	–	–	–
Cosmetic impairment	2.80	0.90	1.9	8.80	3.50	5.3
Reduction of QoL	3.20	0.80	2.4	–	–	–
General impairment	2.90	1.20	1.7	–	–	–

†, 0, none; 1, minor; 2, medium; 3, strong; 4, very strong. VAS, visual analogue scale; QoL, quality of life.

afflicts female patients predominantly (7-9). Lipedema reduction surgery remains the sole technique capable of eliminating abnormal lipedema tissue, including adipocytes, nodules, fibrotic extracellular matrix, and other non-adipocyte components (6,11,19-35) (*Table 5*). It is also the only intervention that halts the progression of lipedema and is ideally performed before the onset of complications and disabilities associated with the condition (19,36). The indications for lipedema reduction surgery include a confirmed diagnosis of lipedema, along with evidence of patient compliance with or failure of conservative treatment approaches (36-38). In this context, the decision to proceed with surgery is primarily based on the severity of symptoms, the occurrence of lipedema-related complications, or the progression of symptoms despite conservative treatment, rather than the stage of lipedema itself (20).

Technique

In our case series, three different liposuction techniques were implemented (tumescent, WAL, and VASER liposuction). In this narrative review, four surgical techniques have been used in patients with lipedema. TLAL, WAL, VASER liposuction, and modified suction-assisted lipectomy with microair. The majority of TLAL used vibration-assisted devices (*Table 6*).

Witte *et al.* proposed in 2020 the use of WAL with tumescent anesthesia (3 L physiological saline solution/prilocaine 1% 50 mL/suprarenin 1:1,000 2 mL/sodium hydrogen carbonate 8.4% 40 mL) (28). A WAL device (body jet; Human Med AG, Schwerin, Germany) was used for all operations. Infiltration was performed using a 3.5-mm cannula, while liposuction was performed using a 4.8-mm cannula in all areas. Frequency and pressure were set to range 2–3 (28). Compared to other studies included in this review in which the average solution infiltration and fat removal were similar, Witte *et al.* [2020] reported considerably less infiltration and a large fat removal quantity (28).

Many authors preferred vibration-assisted devices as it causes less shear force and less tissue matrix trauma than traditional cannulas; therefore, non-adipose tissue is preferentially preserved. Schmeller *et al.* [2012] conducted liposuction on the hips and arms utilizing only TLAL with the aid of blunt, vibrating microcannulas, sized 3- and 4-mm in diameter, with a power-assisted approach (20). On average, 7,707 mL of TLAL solution was infiltrated, with a range of 2,564 to 13,450 mL. The average surgical duration was approximately 2 h, varying from 40 min to 3.3 h (20). In a separate study by Dadras *et al.* [2017], a total of 72 liposuction procedures were performed on 25 patients (22). The tumescent technique involved the use of saline containing epinephrine at a dilution of 1:1,000,000 (22). All procedures were carried out as inpatient surgeries under general anesthesia (22). Among these, 41 cases utilized a vibration-assisted device, while 31 employed a WAL device. The average operative time was 116 min, with a range extending from 58 to 251 min (22).

Rapprich *et al.* [2011] described performing liposuction using TLAL and vibrating cannulas measuring 4 mm in diameter, operated with a VibraSat® handpiece (Möller Medical, Fulda, Germany) (25). The tumescent solution employed was adapted from Sattler's formula, consisting of 1% prilocaine (50 mL), suprarenin (1:1,000, 1 mL), sodium bicarbonate (8.4%, 6 mL), triamcinolone (10 mg/mL,

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Table 5 Study characteristics

Authors, year	Country of origin	Sample size	Gender	Age (years), [range] or ± SD	Stage of lipedema		
					Stage I	Stage II	Stage III
Schmeller *et al.*, 2012 (20)	Germany	112	F	Mean 38.8 [20–68]	35	75	2
Wollina and Heinig, 2019 (21)	Germany	111	F	Median 44 [20–81]	7	50	48
Dadras *et al.*, 2017 (22)	Germany	25	F	Median 45 [23–64]	1	11	13
Baumgartner *et al.*, 2021 (23)	Germany	60	F	Mean 41.9 [22–68]	18	42	0
Schmeller and Meier-Vollrath, 2006 (24)	Germany	28	F	Mean 37.7 [22–63]	28		0
Rapprich *et al.*, 2011 (25)	Germany	25	NS	Mean 38.0/median 34.0 [22–65]	NS	NS	NS
Wollina *et al.*, 2014 (11)	Germany	3	F	Mean 68/median 72 [55–77]	0	1	2
Stutz and Krahl, 2009 (26)	Germany	30	F	Mean 33.8 [21–63]	0	5	25
Baumgartner *et al.*, 2016 (27)	Germany	85	F	Mean 40.1 [22–68]	24	61	0
Witte *et al.*, 2020 (28)	Germany	63	NS	Median 35	18	45	0
Peled *et al.*, 2012 (19)	USA	1	F	Mean 21	1	0	0
Chen *et al.*, 2004 (6)	China	1	M	Mean 20	1	0	0
Current study	Peru	24	F	Mean 39.4 [23–73]	0	13	11
Kruppa *et al.*, 2022 (29)	Germany	106	NS	Mean 41 [30–51]	11	61	34
Gensior *et al.*, 2023 (30)	Germany	504	NS	Mean 47.81 [16–78]	NS	NS	NS
Schlosshauer *et al.*, 2021 (31)	Germany	69	F	Mean 50.6±12.8	0	0	69
Sandhofer *et al.*, 2021 (32)	Austria	27	NS	Mean 41.7±12.7	NS	NS	NS
Kirstein *et al.*, 2023 (33)	Germany	34	NS	NS	1	12	21
Klöppel *et al.*, 2024 (34)	Greece	30	F	Mean 32.6 [21–60]	NS	NS	NS
Flores *et al.*, 2024 (35)	Austria	45	F	Mean 38.11±3.74 [19–71]	NS	NS	NS

SD, standard deviation; F, female; NS, not specify; M, male.

1 mL), and sodium chloride solution (0.9%, 1,000 mL) (25). The final prilocaine concentration in this mixture was approximately 0.05% (25). On average, about 6,000 mL of the tumescent solution was infiltrated per session, with a maximum volume of 7,000 mL and a minimum of 2,000 mL (25). The mean volume infiltrated was 5,155±1,304 mL. For aspiration, vibrating cannulas with three blunt openings at the tip, arranged in a Mercedes star configuration, were utilized (25).

Some researchers advocate for the use of WAL due to its effectiveness in targeting adipose tissue. This technique involves directing a jet of tumescent solution to dislodge fat lobules while maintaining the structural integrity of blood vessels, lymphatic vessels, nerves, and septa retinaculi cutis. Stutz and Krahl [2009] utilized WAL on both legs to treat lipedema, employing a body jet system (Human Med AG) (26). The procedure involved a reduced volume of Klein's solution (39) (1.0–1.5 L) to avoid significant tissue distension. A 3.5-mm body jet infiltration cannula was used and at range of 2. Sufficient anesthesia was achieved before moving immediately to the aspiration phase (no delay after infiltration) (26). A 3.5-mm irrigation-aspiration cannula was carefully directed along the lymphatic collectors, with a vacuum pressure maintained between 0.6–0.8 bar during the entire process (26). The volume of aspirated fluid ranged from 250 to 2,350 mL (26). The authors noted that WAL mobilized adipose cells in a similar fashion to vibration-assisted liposuction, but with less damage to blood vessels (26). Additionally, they demonstrated that WAL caused minimal

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Table 6 Surgery in lipedema

Authors, year	Type of surgical technique	Solution (if applicable)	Average of solution infiltrated (mL), [range] or ± SD	Average of surgical time, [range] or ± SD	Fat removed (mL), [range] or ± SD
Schmeller *et al.*, 2012 (20)	TLAL with blunt vibrating + PAL	NS	Mean 7,707 [2,564–13,450]	Mean 2 h [40 min–3 h 35 min]	Mean 9,846 [1,000–25,600] per patient Mean 3,077 [450–7,000] per session
Wollina and Heinig, 2019 (21)	TLAL (some patients had 980 nm-diode laser-assisted liposuction) with cannulas connected to a vacuum pump developing negative pressure of 68 mmHg	LR, prilocaine, epinephrine (1:1,000,000)	NS	NS	Median 4,700 [950–14,250][†]
Dadras *et al.*, 2017 (22)	TLAL (41 vibration-assisted device/31 waterjet-assisted device)	Saline, epinephrine (1:1,000,000)	–	Mean 1 h 56 min [58 min–4 h 11 min]	Mean 9,914 [4,000–19,850] per patient Mean 3,106 [1,450–6,600] per session
Baumgartner *et al.*, 2021 (23)	NS	NS	NS	NS	NS
Schmeller and Meier-Vollrath, 2006 (24)	TLAL with vibrating microcannulas (power-assisted liposuction)	NS	Mean 7,881 [2,740–13,500]	[1–2.5 h]	Mean 3,017 [1,060–5,500] per session
Rapprich *et al.*, 2011 (25)	TLAL with vibrating cannulas	Prilocaine, suprarenin, sodium bicarbonate, triamcinolone, sodium chloride[‡]	Mean 5,155 [2,000–7,000]	NS	Mean 1,909±874
Wollina *et al.*, 2014 (11)	TLAL microcannula 980 nm-diode laser-assisted + modified medial thigh lifts 4 months after with lower partial abdominoplasty	Prilocaine	Max 5,000	NS	Range, 4,000–6,000[†]
Stutz and Krahl, 2009 (26)	WAL	Reduced quantities of Klein's solution	[1,000–1,500]	NS	Mean 1,115 [200–2,650][‡]
Baumgartner *et al.*, 2016 (27)	NS	NS	NS	NS	NS
Witte *et al.*, 2020 (28)	WAL with TLAL	Physiological saline solution, prilocaine, suprarenin, sodium hydrogen carbonate in combination with a remifentanil and propofol by an anesthesiologist	Lower legs: [200–400] Upper legs: [400–700] Upper limb: [200–300]	NS	Mean 12,922±2,922

Table 6 (*continued*)

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Table 6 (*continued*)

Authors, year	Type of surgical technique	Solution (if applicable)	Average of solution infiltrated (mL), [range] or ± SD	Average of surgical time, [range] or ± SD	Fat removed (mL), [range] or ± SD
Peled *et al.*, 2012 (19)	Modified suction-assisted lipectomy with micro-air	NS	NS	NS	1,400 each limb
Chen *et al.*, 2004 (6)	TLAL	LR, lidocaine, epinephrine	NS	NS	Mean 3,100
Current study	WAL, TLAL, and VASER liposuction	NaCl-adrenaline	Mean 4,608/median 4,500 [2,800–6,800]	Mean 1 h 12 min [11–105 min]	Mean 9,769.4 [5,000–14,650]
Kruppa *et al.*, 2022 (29)	PAL or WAL	Tumescent solution with saline and epinephrine (1:1,000,000)	NS	NS	Mean 6,355±2,797
Gensior *et al.*, 2023 (30)	PAL	Tumescent local anesthesia	NS	NS	NS
Schlosshauer *et al.*, 2021 (31)	NS	NS	NS	NS	Mean 1,868±885.5
Sandhofer *et al.*, 2021 (32)	PAL—MicroAire	Tumescent solution with 0.7–1.0 mg/L epinephrine	Mean 11,404±3,067	Mean 118±17.7 min	Mean 6,111±2,029
Kirstein *et al.*, 2023 (33)	NS	NS	NS	NS	Mean 3,831±1,971.08
Klöppel *et al.*, 2024 (34)	PAL	NS	NS	NS	Mean 8,700±1,280 [5,900–10,600]
Flores *et al.*, 2024 (35)	VAL	Modified Klein's solution with 1,000 mL LR containing 1 mL of 1:1,000 epinephrin	NS	NS	Mean 6,615.33±3,884.25

†, median amount of removed lipoaspirate. Does not specify if it was pure fat component. ‡, correspond to supernatant fat aspirate. SD, standard deviation; TLAL, tumescent local anesthesia liposuction; PAL, power-assisted liposuction; NS, not specify; LR, lactated Ringer's; WAL, waterjet-assisted liposuction; VASER, vibration amplification of sound energy at resonance; VAL, vibration-assisted liposuction.

disruption of lymphatic tissue, confirmed using the D2-40 immunohistochemical marker (from Zytomed, Berlin, Germany) (26). This method also preserved the collagen-fibrous septal connective tissue framework, which increases postoperative recovery and aids fibrous tissue retraction (26).

Most authors have encouraged the use of epinephrine in the infiltration to avoid toxicity with local anesthetics and to offer a better safety profile. Sandhofer *et al.* [2021] examined the serum levels of lidocaine and epinephrine following large-volume liposuction in 27 patients with lipedema (32). The procedure involved administering an average of 11,404 mL of tumescent anesthetic solution (32). The total amount of lidocaine administered averaged 3,061.9 mg, corresponding to 34.23 mg/kg of body weight. The mean dose of epinephrine was 9.7 mg, equating to 0.11 mg/kg of body weight (32). Lidocaine levels in the blood showed a biphasic pattern, peaking first at 4 h post-surgery with an average concentration of 1.65 µg/mL, and then again at 16 h post-operation with a mean concentration of 1.55 µg/mL (32). When patients were categorized by epinephrine concentration in the tumescent fluid, those receiving a lower epinephrine dose (0.7 mg/L) exhibited prolonged elevated lidocaine levels for up to 28 h postoperatively, compared to those who received a higher

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concentration of epinephrine (1.0 mg/L) (32).

Lipoaspirate and procedure

Currently, there is no clear scientific evidence indicating a specific maximum volume for liposuction that could jeopardize patient safety. Patients might be better served by treating large-volume liposuction as a staged procedure rather than attempting it all at once (40). In the context of lipoedema, large-volume liposuction exhibits notable differences from cosmetic liposuction, primarily because the risks and complications associated with limb surgeries are significantly greater compared to those in the central body regions (40). As a result, stringent selection criteria have been proposed, including the presence of persistent symptoms for over a year, considerable functional limitations, a stable body weight maintained for at least 12 months, and a BMI of less than 35 kg/m^2 (40-42).

Debulking lipedema tissue often necessitates larger suction aspirate volumes than traditional liposuction, as well as multiple surgeries spaced at appropriate intervals (36). Unlike cosmetic liposuction, this procedure provides significant benefits in terms of mobility, pain relief, and overall health by removing lipedema tissue (36). Schmeller *et al.* [2012] documented a series of 112 patients undergoing suction-assisted lipectomy (20). Of 112 patients, 12 patients were operated on once, 29 patients twice, 28 patients three times, 23 patients four times, 12 patients five times, four patients six times, and four patients seven times (20). The minimum time between the operations was 1 month (20). The average amount of fat removed was 9,846 mL per person (range, 1,000–25,600 mL per person) or 3,077 mL per session (range, 450–7,000 mL per person), depending on the size and number of operated areas (20). Wollina and Heinig [2019] reported on 111 patients who underwent a total of 334 liposuction procedures at their department, averaging 3.01 sessions per patient (21). The median volume of lipoaspirate was 4,700±7,579 mL, with a range from 950 to 14,250 mL (21).

In our series, we found that the volume of fat removed differed significantly between surgical techniques, particularly when comparing tumescent liposuction with the WAL technique. This disparity may be attributed to WAL's mechanism, which involves the use of a controlled, high-pressure water spray to gently dislodge fat cells while simultaneously performing suction. Using a WAL device (body jet; Human Med AG), Witte *et al.* [2020] noted that 6 patients (10%) underwent a single procedure, 21 patients (33%) had two procedures, 24 patients (38%) had three, and 12 patients (19%) underwent four procedures. On average, 12,922±2,922 mL of fat was removed per patient across all surgeries (28).

Dadras *et al.* [2017] performed on average 3 suction-assisted lipectomy procedures per patient, with a range of 1 to 7 procedures (22). The mean volume of removed fat per liposuction procedure was 3,106 mL (range, 1,450–6,600 mL) and the mean volume of total removed fat per patient was 9,914 mL (range, 4,000–19,850 mL) (22). Likewise, Rapprich *et al.* [2011] indicated that patients were treated in 1 to 5 sessions (mean, 2.5±1.1 sessions; median, 2 sessions) usually at 4-week intervals (25). For each session, the aspiration volume was an average of 2,482±968 mL and the pure fat component was on average 1,909±874 mL or 77% (25).

Kruppa *et al.* [2022] recently evaluated 106 patients who underwent a total of 298 liposuction procedures. A tumescent solution composed of saline and epinephrine (1:1,000,000) was used for tissue infiltration, with a maximum of 6,000 mL administered per session (29). The primary surgical goal was to remove an amount of fat corresponding to approximately 6% of the patient's body weight (29). This often required mega-liposuction, defined as the removal of at least 4 L of pure fat or 5 L of total aspirate (29). On average, patients completed a three-stage surgical regimen, with a mean lipoaspirate volume of 6,355±2,797 mL per procedure. The total cumulative lipoaspirate per patient across the stages averaged 17,887±10,341 mL, with the highest recorded volume reaching 66,200 mL (29). For patients undergoing multistage treatments, the median time span of the surgical process was 8 months (IQR, 4–14 months) (29). Kruppa *et al.* [2022] indicated that they did not find a significant correlation between the primary endpoint (reduction in CDT score) or secondary endpoints (improvement in lipedema-associated complaints) and the amount of total lipoaspirate or aspirate per liposuction, which indicated that the amount of volume aspirated should be individualized and tailored to each patient (29).

Anthropometric outcomes

Suction-assisted lipectomy for lipedema reduction surgery results in a significant decrease in limb circumference measurements (*Table* 7). Schmeller *et al.* [2012] reported that the removal of subcutaneous fatty tissue led to a reduction in the circumference of the hips, legs, and/or arms, ultimately producing a more proportionate body after

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Table 7 Anthropometric outcomes and complications after surgery

Authors, year	Reduction of limb circumference (cm), [range] or ± SD	Weight change (kg)†	BMI change (kg/m^2)†	Complications
Schmeller *et al.*, 2012 (20)	Mean T: 8 [1–23]/LL: 4 [1–11]	Mean (–) 0.4	NS	1.4% wound infections (4 erysipelas and 1 abscess)
				0.3% bleeding
Wollina and Heinig, 2019 (21)	Median 6±1.6	NS	NS	100% temporary met-hemoglobinemia
				98% bruising
				82% temporary burning sensation
				0.6% mild arm-vein phlebitis
				0.3% seizure during meta-hemoglobinemia
				0.3% postoperative anemia requiring blood transfusion
				0.3% pulmonary fat embolism
				0.3% pneumonia
Dadras *et al.*, 2017 (22)	NS	NS	Mean (–) 1.4	1.39% erysipelas
Baumgartner *et al.*, 2021 (23)	NS	Mean (+) 0.5	NS	NS
Rapprich *et al.*, 2011 (25)	NS	NS	NS	4% DVT
Wollina *et al.*, 2014 (11)	NS	Mean (–) 1.8/ median 0	NS	None
Witte *et al.*, 2020 (28)	NS	Mean (–) 5.6	Mean (–) 2.3	NS
Peled *et al.*, 2012 (19)	NS	Mean (+) 9	NS	NS
Chen *et al.*, 2004 (6)	Mean T: 9/RC: 5/LC: 6	NS	NS	NS
Current study	NS	NS	Mean (–) 2.8	4.2% seroma
				4.2% infection
				4.2% epidermolysis
Kruppa *et al.*, 2022 (29)	NS	NS	Mean 2.7 (IQR, 1.1–5.2)	1.3% wound infections
				0.7% seroma
				0.3% postoperative bleeding
Gensior *et al.*, 2023 (30)	NS	NS	NS	1.79% infection
				0.79% seroma
				0.28% erysipelas
				0.14% dry necrosis
				0.07% DVT
Kirstein *et al.*, 2023 (33)	NS	NS	Mean 2.47±3.2	75% had complications

Table 7 (*continued*)

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Table 7 (*continued*)

Authors, year	Reduction of limb circumference (cm), [range] or ± SD	Weight change (kg)†	BMI change (kg/m^2)†	Complications
Klöppel *et al.*, 2024 (34)	NS	NS	NS	53% swelling
				43% hardening or loosening of skin
				40% sensory disturbances
				20% dents

†, before and after surgery. SD, standard deviation; BMI, body mass index; T, tights; LL, lower legs; NS, not specific; DVT, deep venous thrombosis; RC, right calf; LC, left calf; IQR, interquartile range.

surgery. Average reductions were 8 cm (range, 1–23 cm) in the thighs (inguinal region) and 4 cm (range, 1–11 cm) in the mid-calves (20). Likewise, Wollina and Heinig [2019] reported a median 6±1.6 cm-limb circumference reduction at the level of the thighs in 111 patients (21). Similarly, using Image-3D-system (Fa. Bauerfeind, Zeulenroda-Triebes, Germany) and a digital camera to take photos of the leg at different angles, Rapprich *et al.* [2011] achieved an average reduction of leg volume of 6.9 % after liposuction (range from 0.9% to 19.8%) (25).

In our case series, a significant reduction in BMI was observed between the pre- and post-operative periods, highlighting that liposuction not only enhances patient-reported outcomes but also contributes to a measurable decrease in BMI. Comparably, Witte *et al.* [2020] also documented significant reductions in both BMI and weight following liposuction (28). Kruppa *et al.* [2022], after a median follow-up of 20 months, noted a significant decrease in BMI (by 2.7 kg/m^2; IQR, 1.1–5.2 kg/m^2) and a reduction in the size of the affected areas by two European clothing sizes (IQR, 2–4) after liposuction (P<0.001) (29). Similarly, Kirstein *et al.* [2023] used a mixed regression model to analyze 56 patients and found a notable reduction in BMI after surgery, with BMI being 1.65 times higher prior to liposuction [95% confidence interval (CI): 0.67–2.64, P=0.002] (33).

Interestingly, several studies have found no significant reduction in BMI following suction lipectomy. For instance, Flores *et al.* [2024] analyzed 45 liposuction procedures performed on 36 patients, including 35 procedures targeting the lower extremities and 10 on the upper extremities. The average volume of fat removed was 6,615.33±3,884.25 mL, and the mean preoperative BMI was 32.18±7.26 kg/m^2 (35). Despite the large volumes of fat aspirated, no significant changes in BMI were observed postoperatively (35). Notably, a larger proportion of patients underwent suction lipectomy exclusively on the upper limbs, which may have less impact on BMI compared to liposuction of the lower limbs. Other studies have demonstrated that not all patients achieve a sustained weight reduction. Baumgartner *et al.* [2021] reported post-surgical weight gain in 43.3% of their patients, 7.9 kg on average (range, 0.5–39.5 kg) (23).

Symptom control

Pain reduction is a primary goal of liposuction, while body contouring and weight modification are secondary objectives. Suction-assisted lipectomy for lipedema reduction surgery results in a significant improvement of symptoms associated with lipedema. Using a Likert scale from 0 to 5, Schmeller *et al.* [2012] reported that the removal of subcutaneous fatty tissue led to improvement or amelioration of spontaneous pain (P<0.001), pain because of pressure (P<0.001), edema (P<0.001), bruising (P<0.001), and restriction of movement (P<0.001) following liposuction (20). Likewise, Wollina and Heinig [2019] reported that suction-assisted lipectomy resulted in a significant reduction in pain scores, as measured on the 10-point VAS, decreasing from a preoperative value of 7.8±2.1 to 2.2±1.3 postoperatively in 111 patients (21). Also, they noted that 20.9% and 29.1% of patients felt that bruising after minor trauma improved somewhat or completely resolved following liposuction, respectively (P<0.5) (21). Large-scale studies have not established a clear association between pain reduction and volume loss (14). In other series using a WAL device (body jet; Human Med AG), Witte *et al.* [2020] indicated a significant reduction in pain, sensitivity to touch, bruising, feeling of tension, feeling of "heavy" legs, swelling, itching, running impairment, occupational impairment, general impairment, and aesthetic impairment after surgery

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(P<0.001) (28).

Suction-assisted lipectomy for lipedema significantly improves patients' subjective perception of mobility. Wollina and Heinig [2019] reported that all patients (100%) experienced some degree of improvement in mobility after liposuction. Notably, 86% of patients reported marked improvement or complete resolution of impairment, while 14% experienced minor to moderate improvements (21). In a recent study by Kirstein *et al.* [2023], involving 56 patients, the authors assessed symptoms both before and after surgery (33). The mixed-model analysis revealed that preoperative pain was 2.67 times higher compared to postoperative levels (95% CI: 2.09–3.25, P<0.001) (33). Similarly, preoperative pressure sensitivity was 1.97 times greater than after surgery (95% CI: 1.21–2.71, P<0.001). Additionally, walking limitations were found to be 2.26 times higher before surgery than postoperatively (95% CI: 1.49–3.03, P<0.001) (33).

While the cosmetic improvements from liposuction may not be permanent, the functional benefits often persist over time, especially when the procedure is performed for lipedema. Dadras *et al.* [2017] evaluated symptom improvement following liposuction at two different time points during the postoperative period [first postoperative value (postOp-T_1) and second postoperative value (postOp-T_2)] (22). Bonferroni-corrected P values showed significantly improved values comparing preoperative values and postoperative values at the two different time points for spontaneous pain, bruising, sensitivity to pressure, feeling of tension, cosmetic impairment, and general impairment (P<0.001) (22). Remarkably, cosmetic impairment scores aggravated comparing the postOp-T_2 to the postOp-T_1 (22).

The amount of volume aspirated at the time of surgery may not strongly correlate with the degree of symptom improvement. Evaluating 15 symptoms like muscle cramps, lower limb heaviness, itching, and pain, Rapprich *et al.* [2011] were able to reduce 58% symptomatologic burden at 6 months after surgery with suction-assisted lipectomy (P<0.001) (25). In a scale from 0 to 150, the average score before liposuction was 92.0±21.3, and 6 months after surgery was 39.0±23.2 (25). The authors found that the reduction in measured volume did not statistically correlate with the degree of improvement of symptoms (25).

Reduction in conservative

The European Lipedema Forum Consensus in 2020 highlighted significant changes in the understanding, diagnosis, and treatment of lipedema due to advancements in the comprehension of the disease (43). Previously, lipedema was believed to involve "fluid in fat", a concept that gave rise to its name (43). However, there is no scientific evidence to support this hypothesis. Consequently, it is inaccurate to attribute the benefits of MLD to "drainage effects". In fact, improvements in pain following MLD therapy are mainly observed in the initial stages of treatment (43). Compression therapy remains a critical component in lipedema management, although its therapeutic effects are due to its anti-inflammatory properties rather than drainage (43). Additionally, it is incorrect to assert that lipedema is a progressive condition, that weight loss is ineffective, or that lipedema leads to lymphedema, as no scientific evidence currently supports these claims (43).

Recent and most contemporary studies have indicated liposuction for lipedema management only generates minimal reduction in the need for non-surgical treatments or conservative therapies. Schmeller *et al.* [2012] reported that among patients who had undergone lymphatic drainage and compression therapy prior to surgery, 20% required less post-surgery, 13% needed only compression, 6% required only lymphatic drainage, and only 15% no longer required either treatment (20). Thirteen percent of patients still required both lymphatic drainage and compression therapy following surgery (20). In a similar series of 111 patients documented by Wollina and Heinig [2019], only 16.4% were able to completely abandon CDT at a median follow-up of 2.0±2.1 years (21).

Conversely, other reports have indicated that liposuction significantly reduces the need for conservative therapy in the majority of patients. According to Rapprich *et al.* [2011] approximately two-thirds of the patients received MLD and compression therapy prior to undergoing liposuction (25). Six months after the final liposuction session, only 8% of patients reported that they still required MLD, though less frequently (25). Also, only 16% of patients indicated that they occasionally or regularly wore compression stockings post-procedure (25). Witte *et al.* [2020] using WAL, indicated a significant reduction of MLD and compression garments after surgery (28). The percentage of patients requiring MLD after surgery was reduced from 88.9% to 39.7% (P<0.001) while compression garments use was reduced from 95.2% to 31.7% (P<0.001) (28).

Lipedema stage & outcomes

The stage of lipedema influences the clinical outcomes of liposuction. Patients with earlier stages of lipedema tend

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to have better responses to suction-assisted lipectomy than those with more advanced stages. Kruppa *et al.* [2022] determined that patients with stages I and II lipedema exhibited a more significant reduction in their composite VAS scores for QoL (median reduction of 46%; IQR, 24.6% to 60.9%) compared to those with stage III lipedema (20%; IQR, 12.7% to 51.3%; P=0.0107) (29). Additionally, patients with stage I and II lipedema showed a more pronounced decrease in the requirement of CDT scores (50%; IQR, 8.3% to 100%) compared to those in stage III (16.7%; IQR, 0 to 50%; P=0.0019), indicating a better response to liposuction at early stages (29).

Kruppa *et al.* [2022] also showed a reduction in the CDT score with a median of 37.5% (IQR, 0 to 88.8%) following large-volume liposuction in all stages of lipedema (P<0.001) (29). The percentage of patients that were able to stop compression garments postoperatively was higher in stage I and II patients (41.7%) compared to stage III patients (20.6%; P=0.0487) (29). Likewise, a higher proportion of patients with stage I and II (33.3%) did not need any conservative treatment postoperatively compared to stage III patients (8.8%; P<0.008) (29).

Similarly, Dadras *et al.* [2017] assessed the overall impairment in patients with stage II and stage III lipedema both preoperatively and at two postoperative time points (22). Although the general impairment values were significantly improved at postoperative point 1 (mean, 16 months) and point 2 (mean, 37 months) compared to preoperative levels, stage III patients experienced a notable increase in the severity of their symptoms between the first and second postoperative follow-ups (22).

Duration of results

Baumgartner *et al.* [2021] conducted a longitudinal study following 60 patients with stage I and II lipoedema over an extended period (23). Their findings revealed that the improvements in spontaneous pain, pressure sensitivity, swelling, bruising, and restricted movement observed at 4 and 8 years post-lower limb liposuction were maintained even 12 years after the procedure (23). Self-reported measures of cosmetic dissatisfaction, QoL, and overall functional impairment also remained stable 12 years postoperatively (23). Furthermore, the reduction in reliance on conservative treatments, such as decongestive therapy and compression garments, paralleled those seen at the earlier follow-up intervals (23). In this setting, long-term outcomes for patients with stage III lipoedema must be evaluated in future studies (23).

Complications

Patients who undergo suction-assisted lipectomy for the management of lipedema experience minimal complications after surgery and therefore, benefits outweigh risks in most cases (*Table* 7). Schmeller *et al.* [2012] reported a 1.4% rate of infection in which three cases were simple erysipelas and one case had an abscess. The authors also reported a 0.3% rate of postoperative bleeding with significant hemoglobin drop (5.2 g/dL drop) (20). In a series using vibration-assisted device for liposuctions in 57% of the cases and a WAL device for the remaining 43% of the cases, the complication rate was 1.39% (22). Witte *et al.* [2020] using WAL, indicated that they did not encounter significant complications in any of the patients (28). Postoperative swelling was present for a mean of 4.3 weeks; patients were absent from work for a mean of 2.7 weeks postoperatively (28).

Liposuction for lipedema can be safely performed in patients with varying stages of lipedema even in the presence of different comorbidities. In a recent investigation by Kruppa *et al.* [2022], 106 patients were evaluated after undergoing a total of 298 liposuction procedures (29). The study population included patients with varying stages of lipedema: 11 patients (10.4%) with stage I, 61 patients (57.6%) with stage II, and 34 patients (32.1%) with stage III (29). The cohort exhibited a high prevalence of comorbidities, with 37.6% classified as obese (BMI >35 kg/m^2), 36.8% having allergies, 31.1% diagnosed with hypothyroidism, 25.5% experiencing depression, 25.5% suffering from sleep disorders, 24.5% with hypertension, 22.6% with migraines, and 18.9% with skin disorders (29). Despite the fact that 69.1% of the liposuction procedures were categorized as mega-liposuction, the study reported a low incidence of complications (29). The observed complications were minor and included wound infections in 1.3% of cases, seroma formation in 0.7%, and postoperative bleeding in 0.3% (29). Although a subset of patients developed excess skin following multiple liposuction treatments, only 2 patients (1.9%) pursued corrective surgery (29).

In other series, the rate of complications has been higher with some major complications significantly affecting the postoperative course of patients. For instance, the use of local anesthetics in tumescent anesthesia can lead to a marked production of methemoglobin (21). Certainly, in one of the largest series, the authors indicated that

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Table 8 Patient reported outcomes after surgery treatment

Patient-reported outcomes[†]	5-point Likert scale[‡] (20,23)			10-point VAS		
	Pre-surgery	Post-surgery	Improvement	Pre-surgery	Post-surgery	Improvement
Spontaneous pain	1.86	0.42	1.44	6.86 (22,25,28)	2.16 (22,25,28)	4.7
Sensitivity to pressure	2.90	0.97	1.93	6.99 (22,25)	3.14 (22,25)	3.85
Edema	3.07	1.31	1.76	7.68 (25)	2.71 (25)	4.97
Bruising	3.03	1.34	1.69	7.32 (22,25)	3.5 (22,25)	3.75
Restriction to movement	2.04	0.40	1.80	4.6 (25)	1.6 (25)	3
Cosmetic Impairment	3.30	1.18	2.12	9.05 (22,25,28)	3.26 (22,25,28)	5.80
Reduction of QoL/impairment of QoL	3.38	0.83	2.55	8.7 (25)	3.6 (25)	5.10
General impairment	2.82	0.94	1.88	–	–	–

[†], current case series is included in this calculation, except for restriction to movement, reduction of QoL, and general impairment in VAS. [‡], 0, none; 1, minor; 2, medium; 3, strong; 4, very strong. VAS, visual analogue scale; QoL, quality of life.

the most common complication they encountered was temporary methemoglobinemia (100%) (21). This was treated by intravenous injection of toluidine blue (21). In a number of initial liposuctions, 1 g intravenous vitamin C was administered (21). Also, temporary burning sensations and bruising were noted in 82% and 98% of cases (21). A generalized seizure episode was evident during methemoglobinemia in a 34-year-old female without known comorbidities (0.3%) (21). Significant anemia requiring a blood transfusion was seen in 1 patient (0.3%), two patients presented with mild arm-vein phlebitis (0.6%), microscopic pulmonary fat embolism was seen in one patient (0.3%), and one patient required intensive care unit (ICU) admission for management of pulmonary issues (0.3%) (21). In another series, Rapprich *et al.* [2011] had a patient with lower limb deep vein thrombosis 1 week after surgery (4%) (25).

In another series, the authors conducted 1,400 lymphological liposculpture procedures across 504 patients with lipedema, with 504 procedures targeting the inner half of the limbs, 504 targeting the outer half, and 392 performed on the upper arms (30). Within 30 days after surgery, 43 patients (3.07%) experienced adverse effects (30). Surgical site infections were observed in 25 patients (1.79%), while seroma formation occurred in eleven patients (0.79%) (30). Additionally, erysipelas developed in 4 patients (0.28%), dry necrosis in 2 patients (0.14%), and deep vein thrombosis in 1 patient (0.07%) (30).

QoL

Suction-assisted lipectomy for lipedema reduction surgery results in a significant improvement of QoL (*Table 8*). Multiple authors have reported a statistically significant improvement of QoL using different instruments following liposuction. Using a Likert scale from 0 to 5, Schmeller *et al.* [2012] reported that the removal of subcutaneous fatty tissue led to improvement of QoL from a preoperative score of 3.36±0.86 to 0.76±0.91 postoperatively (P<0.001) (20).

In a recent prospective study assessing QoL following liposuction for lipoedema, 30 female patients with a mean BMI of 27.2±3.7 kg/m^2 were examined (34). The classification of disease severity among these patients was as follows: 7% were categorized as having mild lipoedema, 47% as moderate, 43% as severe, and 3% as very severe (34). Notably, 83% of the participants reported having previously received MLD and/or used compression therapy as part of their treatment regimen (34). During the liposuction procedure, an average of 8.7±1.28 L (ranging from 5.9 to 10.6 L) of adipose tissue was aspirated from the thighs, knees, and calves. The study found no serious postoperative complications (34). Overall satisfaction with the surgical outcomes at 6 months postoperatively was notably high, averaging 7.9±1.82 on a 0 to 10 scale (34), Regarding satisfaction with the treated area, 23% of patients reported being very satisfied, while 63% were fairly satisfied. Furthermore, 93% of patients experienced an improvement in personal well-being following the surgery (34). The Questions on Life Satisfaction Modules (FLZM) (44) results indicated significant enhancements in all three evaluated domains: general life satisfaction, health status, and body image (34). The Patient Health Questionnaire-4 (PHQ-4) (45) assessment revealed notable reductions in

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both anxiety and depression levels, as well as overall mental stress. Additionally, the Rosenberg Self-Esteem Scale (RSES) (46) demonstrated a significant increase in self-esteem postoperatively (34).

Suction-assisted lipectomy appears to have a beneficial effect on mood in patients with lipoedema. According to the PHQ-9 scale, patients who underwent liposuction for treatment of lipedema improved from experiencing moderate to severe depression preoperatively (mean score of 10.84±6.38) to a mild depressive state after surgery (mean score of 8.27±6.45) (33). The World Health Organization Quality of Life-BREF (WHOQOL-BREF) assessment revealed a significant positive correlation between liposuction and improvements in the physical domain scores (95% CI: 12.84–4.86, P<0.001). However, no significant correlations were observed between the surgery and the psychological, social, or environmental domains (33).

Liposuction improves QoL in patients with lipedema, even in patients with severe stage III lipedema. In a retrospective study involving 69 female patients with stage III lipoedema, liposuction was performed as a therapeutic intervention (31). On average, each patient underwent 2.9±1.9 liposuction sessions, with the number of sessions varying between 1 and 12. Of these patients, 20 completed the Freiburg Quality of Life Assessment for lymphatic disorders, Short Version (FLQA-lk) questionnaires (47) both prior to the procedure and 6 months postoperatively (31). The findings indicated a notable enhancement in disease-specific QoL following liposuction treatment, with significant improvements observed across all subscales and the overall score (31).

Kruppa *et al.* [2022] conducted an evaluation of QoL—including spontaneous pain, pressure sensitivity, feelings of tension, bruising, body image perception, and overall impairment—and found substantial improvements across all measured parameters following liposuction as indicated by significant reductions in VAS scores (P<0.001) (29). This study demonstrated high overall patient satisfaction with the multistage surgical treatment, with a median VAS score of 9 (IQR, 7–10). Furthermore, notable enhancements were observed in sexual QoL, demonstrated by a reduction in impairment scores from a preoperative VAS score of 7.5 (IQR, 4.0–8.25) to a postoperative VAS score of 3.0 (IQR, 1–5) (P<0.001) (29).

Malcolm *et al.* [2024] reported a series of forty-seven patients that received tumescent liposuction over 5 years (48). Most patients (77%) were diagnosed with stage 2 (n=16) and 3 (n=20) lower limb lipedema. After liposuction, they evidence a significant reduction of depression and anxiety (P<0.05) using Hospital Anxiety and Depression Scale (48). Using the QoL scores from the LYMQoL questionnaire, the authors demonstrated a significant improvement of QoL overall in patients with lipedema following liposuction, with stage 3 patients achieving the most notable improvement (P<0.001) (48). After surgery, patients also demonstrated a significant improvement in functional ability using the Lower Extremity Functional Scale (LEFS) (P<0.005) (48).

Limitations

Significant limitations arise due to the substantial heterogeneity among studies and the various instruments used to assess patient-reported outcomes. Additionally, all studies included in this review are either case reports or case series, which are observational and inherently lack randomization. As a result, they are more susceptible to confounding bias. Furthermore, the case series in this study are limited by their small sample sizes, reducing the statistical power of the findings. We did not include waist-to-height-ratio in order to evaluate co-incidence of obesity. Only using BMI leads to inaccurate diagnoses overestimating overweight and obesity (1,43).

Conclusions

Liposuction has been shown to be a safe and effective alternative when conservative therapy fails to treat lipoedema. All liposuction techniques used to date have had a positive impact on both clinical and patient-reported outcomes, with these benefits being sustained over time. However, further studies with stronger levels of evidence are needed to support these findings and to evaluate differences between surgical techniques, ideally using standardized assessment tools such as the VAS.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committees and with the Helsinki Declaration (as revised in 2013). Informed consent was obtained from all patients.

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