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Water-jet-assisted liposuction for the treatment of lipedema: Standardized treatment protocol and results of 63 patients

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Summary *Background:* Lipedema is a condition of painful increase in subcutaneous fat affecting almost exclusively women. Several studies have examined the effectiveness of liposuction in the treatment of lipedema, but none has focused on water-jet-assisted liposuction technique.
Methods: A standardized treatment protocol for liposuction in lipedema, which was established over the course of 15 years, is presented. Patients received questionnaires preoperatively and after operative treatment assessing characteristics and symptom severity on visual analog scales in a prospective manner.
Results: Pre- and postoperative questionnaires were available for 63 patients. Median age was 35 years and mean (body mass index) BMI 28.4 ± 0.6, all patients had stages I or II lipedema diagnosed by two separate specialists. After a mean follow-up of 22 months after operative treatment, all assessed symptom had decreased significantly in severity. All patients wore compression garments and/or received manual lymphatic drainage preoperatively; this could be reduced to only 44% of patients needing any conservative treatment postoperatively.

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Conclusion: Liposuction in water-jet-assisted technique using the presented treatment protocol is an efficient method of operative treatment of early-stage lipedema patients leading to a marked decrease in symptom severity and need for conservative treatment.

Introduction

Lipedema was first described by Allen and Hines as a condition with pathological increase in subcutaneous fat and edema in the lower limb.[1]

Literature on the incidence is rare and inconsistent. Studies suggest 10–20% of women who present in lymphologic centers with swelling of the lower limb suffer from lipedema.[2,3] Obviously, this does not allow conclusions on the incidence of the general population.

Lipedema almost exclusively affects women and typically begins in puberty;[4] an onset after pregnancy or menopause suggestive of hormonal factors has been described.[5]

Lipedema shows familial clustering and about 60% of patients with lipedema; a genetic predisposition has been described.[5–7]

Lipedema is a chronic and progressive disease that characteristically leads to an abnormal deposition of subcutaneous fat in the lower extremity by means of hyperplasia and hypertrophy. In addition, in about 30% of the cases, the upper extremity is likewise affected. [8,9] In our experience, predisposition for lipedema is mostly located in both lower and upper extremity. Hands and feet are typically spared leading to an excess of fat at the ankle, also known as the "inverse-shouldering effect" or "cuff sign."

In addition to the abnormal quantitative fat deposition, recent studies have demonstrated a significant higher number of adipose derived stem cells in the stromal vascular fraction of lipedema patients but impeded adipogenesis in vitro.[10,11]

An increase in capillary permeability and fragility has been described, resulting in both extravasation of fluid and easy bruising.[12,13] Subsequently, inflammatory changes with macrophage invasion and adipocyte death have been described.[14,15]

Unlike primary lymphedema, the lymphatic system is unimpaired in the initial stages of lipedema albeit increased amount of interstitial fluid.[9] In accordance with this, lymphoscintigraphy showed increased lymphatic transport in some lipedema patients.[16] At the same time, there has been evidence of morphologic changes in the lymphatic system like microaneurysms with unclear pathophysiological significance.[17] In advanced stages, the amount of fluid produced exceeds the transport capacity of the lymphatic system and excess fat tissue itself can cause impaired lymphatic vessel function, leading to secondary lymphedema, which has also been shown in mice receiving a high-fat diet.[18,19]

Subsequently, the deposition of protein-rich edema results in fibrosis of the tissue, thus further impairing lymphatic drainage. The term "lipo-lymphedema" is used to describe the combined pathology in this most advanced stage.

Stasis of lymphatic tissue, on the other hand, is known to enhance fat disposition and hence a mutual interaction between adipose tissue and the lymphatic system exists.[20,21]

Lipedema is diagnosed based on clinical examination and patient history, ruling out differential diagnoses. Typical clinical complaints include feeling of tension, pain upon pressure, and easy bruising. Many patients have elevated body mass index (BMI) levels which may make the differentiation to obesity difficult. Halk et al. recently published diagnostic criteria in the Dutch guidelines for lipedema adopting initial criteria published by Wold et al. 1951.[22,23]

These guidelines define that patients are required to have disproportionate fat distribution, no or limited influence of weight loss on fat distribution, pain and bruising of the affected limbs, sensitivity to touch or limb fatigue, and no pain improvement upon lifting of the limb.[22] Combined with a physical exam confirming the typical disproportionate fat deposition, the diagnosis of lipedema is regarded certain.[22]

The excess subcutaneous fat can be seen through ultrasound, magnetic resonance imaging (MRI), or computed tomography imaging, but these imaging studies cannot aid diagnosis.[24,25]

Lipedema can be classified in three clinical stages based on morphological appearance:[4,26]

Stage I

Smooth skin surface with homogenous thickening of subcutis.

Stage II

Bumpy, wavelike skin surface with nodular structures in the thickened subcutis.

Stage III

Increase in nodular changes, overhanging masses of tissue.

The condition is a major medical and also psychosocial burden for the majority of patients. Standing for long periods of time and heat are not tolerated well, in severe cases, the condition can cause absence from work or lead to occupational disability.

The widely applied therapy for lipedema is combined decongestive therapy (CDT), which consists mainly of manual lymphatic drainage and wearing compression garments. It aims to reduce orthostatic edema and limit recurrence.

Classic dry liposuction cannot be applied to lipedema patients due to the potential injuries to lymphatic vessels. However, the introduction of the tumescent technique in

the 1980s made the application possible. Cadaver studies showed markedly reduced injury to lymphatic structures when using the tumescent liposuction technique.[27]

In 1994, Rudkin et al. described liposuction in combination with skin and subcutaneous fat excisions as a treatment option for lipedema, contrasting it with lymphedema. In 2002, liposuction alone was presented as a method to reduce the pathologically increased subcutaneous fat surgically.[28–30]

Several studies have since been performed that were able to show liposuction to be an effective treatment modality for lipedema. However, to our knowledge, in no study, water-jet-assisted liposuction (WAL) has been used as the specific liposuction technique.

This study aimed to assess the long-term results of WAL using a standard treatment protocol in the treatment of lipedema, which was established over the last 15 years treating over 5000 patients.

Methods

The study was approved by the local ethics commission (ethics approval nr. 2017329). Patients who were planned to receive liposuction as a treatment for lipedema between December 2016 and June 2017 received a standardized questionnaire with 24 items few days before the first operation. This included assessment of 11 symptoms/impairments on a visual analog scale (VAS) with the range 0–10 and increments of 1. Patients who had been operated on were followed up in January 2019 by an additional questionnaire with 26 items including all 11 VAS score assessments that were performed before. Both questionnaires also assessed weight, manual lymphatic drainage, and wearing of compression garments. Postoperative questionnaires additionally assessed length of inability to work after surgery and VAS scores after surgery. The questionnaires are attached as supplement to this article, questions regarding symptom severity were based on previously published German questionnaires.[31]

Treatment protocol

Decongestive measure such as consequent wearing of class II flat-knit compression garments was applied for at least 6 weeks preoperatively to optimize the results of the operation. In addition, manual lymphatic drainage was needed in cases of severe congestion. The body weight should be approximated to normal BMI ranges as much as possible in patients with coexistent obesity. Therefore, dietary changes under professional counseling and regular physical activity were highly recommended as these habits support maintaining the results postoperatively. Eating disorders or accompanying psychological morbidities required adequate treatment and psychological stability, a premise of any elective surgical procedure.

To reduce the overall perioperative risks, patients with a BMI $>$ 40 (grade III obesity) required preoperative weight reduction. Likewise, varicose veins of the lower extremity required treatment prior to liposuction. Coagulopathies do not constitute general contraindications for lipedema liposuction while they need to be treated perioperatively following hematologic/angiologic guidelines and risk assessment has to be undertaken for each individual case.

Depending on distribution and extent of lipedema, multiple operations are necessary. We operate patients in a standardized order in three to four independent operations: (1) lower legs, (2) upper legs/buttock (one- or two-stage approach, depending on fat volume, see below), and (3) arms, if applicable. This has proven to address the most symptomatic anatomical regions first and enable optimal anatomical shaping during operations.

Operations are performed under tumescent anesthesia (3 l physiological saline solution/prilocaine 1% 50 ml/suprarenin 1:1000 2 ml/sodium hydrogen carbonate 8.4% 40 ml) in combined with an analgosedation with remifentanil and propofol by an experienced anesthesiologist. Compared with classic tumescent local anesthesia (TLA), lower filling volumes are required while extensive infiltration volume has been identified as risk factor for serious complications of liposuction.[32] Risk of toxic dosage is lower in WAL compared with standard liposuction because of immediate aspiration after infiltration and thus reduction of medication concentration.

A broad-spectrum cephalosporin (Cefazolin 2 g) is administered as a single-shot prophylaxis, if no allergies preclude this.

A WAL device (body jet/Human Med AG, Schwerin, Germany) was used for all operations. Infiltration was performed using a 3.5 mm cannula, liposuction was performed using a 4.8 mm cannula in all areas. Frequency and pressure were set to range 2–3. Infiltration volume at the beginning of the operation was 200–400 ml for the lower legs, 400–700 ml for the upper legs and 200–300 ml for the upper limb. Infiltration time was about 10 min, afterwards liposuction could start without waiting time. This helps to minimize contact time of the tumescent solution with the fatty tissue. For liposuction, waterjet was activated continuously. Typically, the amount of infiltrated fluid approximately resembles the amount of removed fat, but the fluid stays in the body only a short time as it is simultaneously aspirated.

Procedure for patients up to approximately 80 kg: operations of the lower limb were started supine and circular decompression is achieved by intraoperative transfer to prone position in order to reach the dorsal aspects of the limbs. Operations of the lower limb began at the level of the ankle and were continued proximally until the medial and lateral fat pads at the knee, which were included. Operation of the thighs extended from the knee to the level of the iliac crest. The buttocks, where typically a large pathologic accumulation of fat tissue is present, were addressed with particular diligence.

Procedure for patients $>$ 80 kg: In patients weighing more than 80 kg, large volume of the thighs often requires more than a single operation. Typically, two operations of the upper legs were performed in these patients. The first was in supine position, addressing anterior, inner, and outer legs, and a second operation in prone position addressing the posterior legs and buttocks.

Operation of the upper limbs was performed from the wrist to the level of the shoulder. Here, also the lower arm was addressed, despite often bearing little symptoms to improve long-term results. The incisions for the liposuction were closed with 5–0 Prolene single stitches, and the

Table 1 Questionnaire results. Significant reduction of all assessed symptoms and need for conservative therapy measures could be observed.

	Preoperatively (mean ± SD)	At postoperative follow-up (mean ± SD)	*p*-value (paired *t*-test)
Biometry			
Weight (kg)	81.9 ± 14.6	76.3 ± 13.4	<0.001
BMI	28.4 ± 4.5	26.1 ± 5.4	<0.001
Visual analog scales			
Pain	6.47±2.05	1.39±1.66	<0.001
Sensitivity to touch	7.14±1.9	1.55±1.79	<0.001
Bruising	7.18±1.93	2.45±2.62	<0.001
Feeling of tension	7.56±1.72	1.42±1.78	<0.001
Feeling of "heavy" legs	8.42±1.8	1.55±1.66	<0.001
Swelling	6.75±2.41	1.52±1.65	<0.001
Itching	4 ± 3.3	0.8 ± 1.3	<0.001
Running impairment	5.28±3.04	0.6 ± 1.1	<0.001
Occupational impairment	4.97±2.63	0.77±1.72	<0.001
General impairment	7.79±2.11	0.95±1.4	<0.001
Aesthetic impairment	8.71±2.26	3.13±2.48	<0.001
Need for conservative therapy			
MLD (% of patients)	88.9%	39.7%	<0.001
Compression garments (% of patients)	95.2%	31.7%	<0.001

most distal incisions were left open to enable excess fluid to drain; these healed by secondary intention after 7–10 days.

After surgery, all patients were treated according to a standardized protocol. Compression bandaging of the treated extremities along with a compression corsage for the trunk was applied.

Prophylactic treatment with low-molecular heparin was administered to all patients for 7 days postoperatively. In the presence of additional risk factors (i.e. factor-V-Leiden), prophylaxis was given longer. Patients were hospitalized overnight.

After 2 days, compression bandages and corsages were removed and custom-made class II flat-knit compression garments (Juzo GmbH, Aichach, Germany, medi GmbH & Co. KG, Bayreuth, Germany) for the treated extremities were applied and worn throughout daytime. At night, patients were allowed to change to circular knit garments. Twenty-four-hour compression was required for 6 weeks. Thereafter, the compression protocol was tapered, i.e. only flat-knit garments were required during daytime until the next operation. In addition, manual lymphatic drainage therapy was started at postoperative day 2 with a frequency of two sessions per week. This regimen had to be held in place at least for 8 weeks postoperatively before the decongestive therapy could be adjusted to the preoperative intensity.

Subsequent operations were performed no earlier than 8 weeks after the previous operation.

In patients who have completed operative therapy, 8 weeks after the last operation, a weaning from compression garments was intended, aiming at abandoning any decongestive measures.

Statistics

Data are presented as mean ± standard deviation or median. Statistical analyses were performed with paired *t*-test for continuous variables and McNemar test for binary variables. The tests were two-sided, with $p < 0.05$ considered statistically significant.

Results

In the time interval, a total of 155 patients were operated. Among these, 130 patients enrolled in the study and preoperative questionnaires were available.

A total of 63 patients could be followed up after a median of 21.5 months. Median age at the first operation was 35 years and mean BMI 28.4 ± 0.6. Forty-seven patients (75%) had lipedema of both arms and legs, while only legs were affected in 16 patients (25%). Eighteen patients (29%) had stage I lipedema and 45 patients (71%) stage II lipedema. Fifty-six patients (89%) were receiving manual lymphatic drainage, and 60 patients (95%) were wearing compression garments preoperatively. Fifty-three patients (84%) were receiving both, seven patients (11%) were only wearing compression garments, and three patients (4.8%) were only receiving manual lymphatic drainage as conservative lipedema treatment. Over the course of operative treatment, six patients (10%) had received a single operation, 21 patients (33%) had received two, 24 patients (38%) had received three, and 12 patients (19%) had received four operations.

A mean amount of 12,922 ml (standard deviation 2922 ml) fat was removed per patient over the course of all operations. Results of an example patient with stage II lipedema after the removal of 6.5l of fat are presented in Figure 1.

Questionnaire results are presented in Table 1. Patients had lost a mean of 5.6 kg at their last follow-up compared with their preoperative weight, resulting in a mean decrease of the BMI by 2.3, both changes were significant with $p < 0.001$.

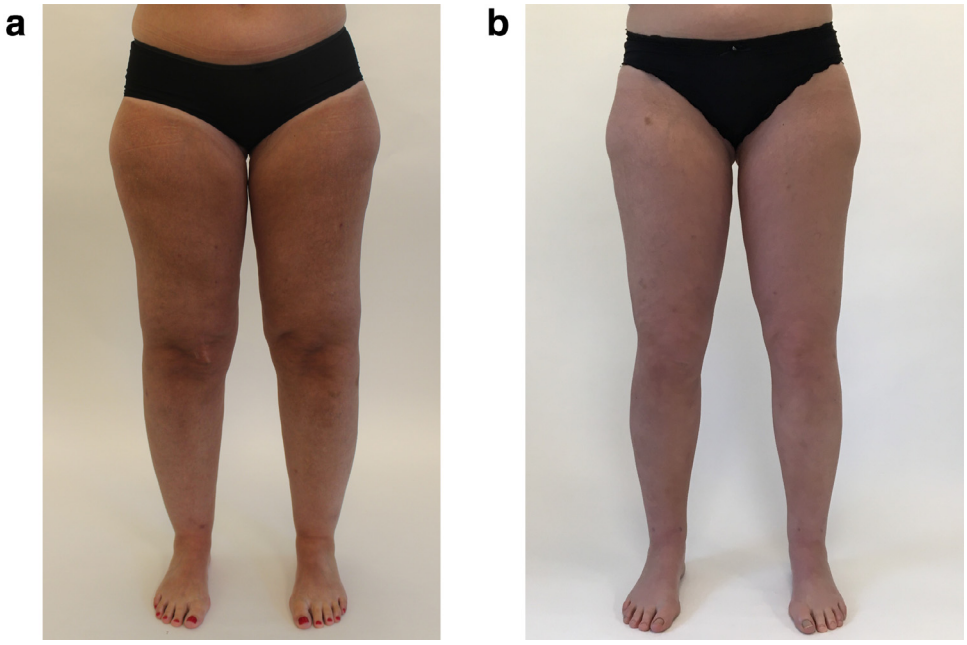

Figure 1 Twenty-five-year-old patient with stage II lipedema.
(a) Preoperative; **(b)** result after two-staged liposuction of the lower extremity removing 6.5 l of fat.

VAS score of all 10 tested items had highly significant decreases in comparison of the postoperative follow-up with preoperatively. Pain as the primary end point was reduced from 6.5 to 1.4. General impairment dropped from 8 to 1 (Figure 2) and esthetic impairment from 9 to 3. Out of the 56 patients (55%), 31 patients, who were receiving manual lymphatic drainage preoperatively, were not receiving it any more at the follow-up presentation. Likewise, 40 out of the 60 patients (67%), who had to wear compression garments preoperatively, did not wear them any longer postoperatively, and additional 10 patients (17%) wore them occasionally. This resulted in 34 patients (55%) not receiving any more conservative treatment. The changes in percentage of patients receiving each type of conservative treatment were highly significant (Figure 3). No significant complications occurred in any of the patients. Postoperative swelling was present for a mean of 4.3 weeks; patients were absent from work for a mean of 2.7 weeks postoperatively.

No recurrence of excess subcutaneous fat was observed in the patients in the follow-up period.

Discussion

Lipedema is a chronic progressive disease. In most guidelines, CDT is considered the standard therapy and consists of physical exercise, manual lymphatic drainage, and flat-knitted compression garments.[22,33]

However, true evidence for the effectiveness of conservative lipedema treatment is lacking.[34]

After evolvement of tumescent technique, liposuction has been applied as an operative treatment for lipedema to decrease subcutaneous tissue. Schmeller and Meier-Vollrath were the first to show successful improvement of lipedema symptoms by vibration-assisted tumescent liposuction in 28 patients after a mean follow-up period of 12 months in 2006 with follow-ups in larger case series in 2012 and 2016.[35]

Subsequent studies could confirm these results, all of which using tumescent liposuction technique.[7,31,36-38]

In a comparison of different lipedema stages, Dadras et al. showed an increased effectiveness of lipedema treatment in stages I and II compared with stage III.[37]

All cited studies treated patients with lipedema stages I-III and used vibration-assisted or regular liposuction in tumescent technique (Table 2).

This is the first study to our knowledge with inclusion of only less advanced stages (I-II) and using a standard treatment protocol for WAL for lipedema treatment.

Due to the earlier stages in our collective, median patient age with 35 years was lower than in aforementioned studies. Also, initial pain level was 6.47 and thus lower than in the studies by Wollina et al. (7.8), Dadras et al. (7.2), or Rapprich et al. (7.2).

The applied treatment protocol was highly effective and significantly reduced all assessed lipedema symptoms. General impairment was reduced from 7.8 to below 1 representing a very mild impairment.

Before treatment, 89% of patients received manual lymphatic drainage and 95% of patients wore compression garments, this fraction could be reduced to 40% and 32%, respectively. All patients received some form of CDT preoperatively; this could be reduced to 44% postoperatively translating into 59% of patients not needing any CDT after operative treatment. Although a reduction of CDT by liposuction has been reported in other studies, the rate of patients not needing CDT postoperatively was higher than in any study before, likely due to the early stage of disease in the patients.[7,31,37,38] As such, in a recent study of Wollina et al.

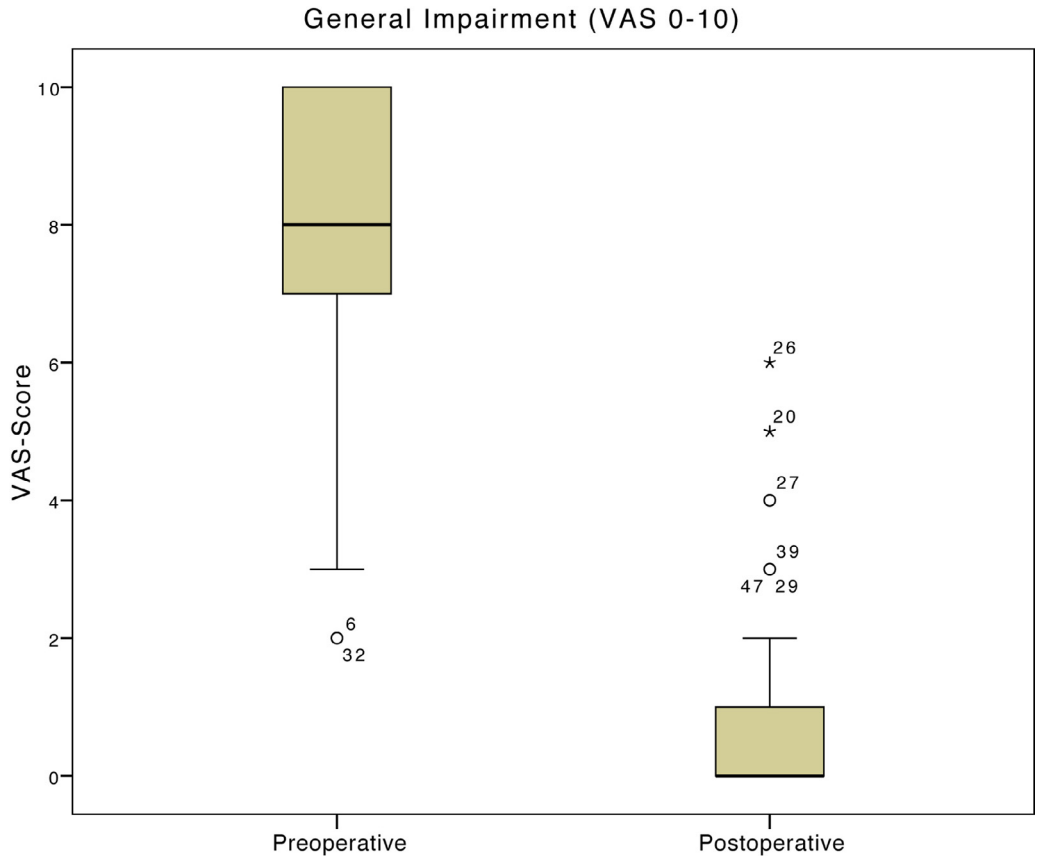

Figure 2 Pre- and postoperative assessment of general impairment by lipedema. The change was significant with $p<0.001$ (paired *t*-test).

Table 2 Studies assessing effectiveness of liposuction for lipedema treatment. VAS_ visual analog scale, WAL: water-jet-assisted liposuction, TLA: tumescent local anesthesia, CDT: complex decongestive therapy.

	Technique	*n*	Median follow-up	Pain pre-/postoperative (VAS)	% patients needing postoperative CDT
Present study	WAL	63	21.5 months	6.5/1.4 (0-10	44%
Wollina and Heinig, 2019[38]	TLA	111	2 years	7.8/2.2 (0-10)	84%
Dadras et al., 2017[37]	TLA	25	16/37 months	7.2/3.7 (0-10)	N/A
Schmeller et al., 2012[7]	TLA	112	4 years	1.86/0.37 (0-4)	77%
Baumgartner et al., 2017[36]	TLA	85	8 years	1.86/0.37 (0-4)	70%
Rapprich et al., 2011[31]	TLA	25	6 months	7.2/2.1 (0-10)	N/A

on 111 patients including 48 patients with stage III lipedema receiving microcannular tumescent liposuction, only 16.4% of patients did not need CDT after liposuction treatment.

We were able to show that the weight of the patients was reduced by a mean of 5.6 kg and the BMI by 2.3 kg/m^2 from the preoperative to the postoperative follow-up suggesting a sustainable loss of removed fat tissue, and possibly, more healthy lifestyle. Relatedly, occupational impairment was estimated at 4.97 preoperatively with imaginable significant impact economically. This impairment could be reduced to 0.77 postoperatively.

All patients of this study were treated by the presented standardized protocol by a total of four surgeons. We believe that this protocol enables achievement of reliable results by trained surgeons after a certain learning curve.

Few studies have used WAL as liposuction technique for the treatment of lipedema. In comparison with classic tumescent liposuction, less volume is infiltrated reducing risk of local anesthesia overdose and facilitating visual control of contour and symmetry. WAL has been shown to be a safe procedure, and as such, no severe complications were recorded in our study collective. This is comparable with studies with application of regular liposuction techniques for lipedema treatment reporting serious complications in roughly 1% of cases.[7,37,38]

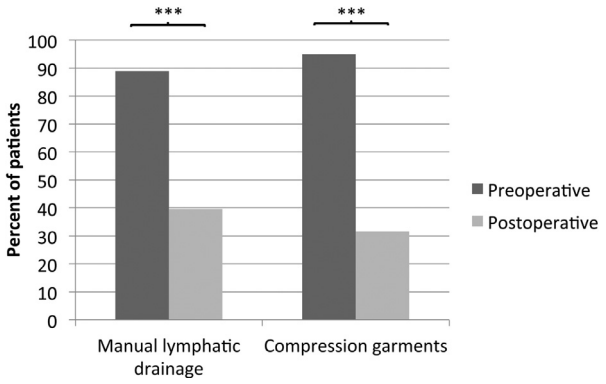

Figure 3 Pre- and postoperative assessment of conservative therapy need. Operative treatment resulted in significantly less patients in need of manual lymphatic drainage or compression garments (McNemar test).

Conclusion

Liposuction using the WAL technique is highly efficient in the treatment of lipedema and yields sustaining reduction of fat tissue and disease-associated complaints. A standard treatment protocol is essential for predictable operative results and low rate of complications. Timing of treatment at early stages should be aimed for to avoid progression of the disease to a lipo-lymphedema with associated irreversible damage to the lymphatic system.

Declaration of Competing Interest

TW and FCH are counselors for Human Med GmbH, the producer of the WAL device used. This affiliation had no impact on the content or writing of this study.

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Ethics

The study was conducted according to the Declaration of Helsinki, approval by the local ethics committee was given (approval number 2017329). The STROBE guidelines were adhered to where applicable.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2020.03.002.

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