A Single Institution Multi-disciplinary Approach to Power-assisted Liposuction for the Management of Lymphedema

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Objective: To implement and evaluate outcomes from a comprehensive, multi-disciplinary debulking program in the United States.

Summary of Background Data: Interest in and access to surgical treatment for chronic lymphedema (LE) in the United States have increased in recent years, yet there remains little attention on liposuction, or debulking, as an effective treatment option. In some other countries, debulking is a common procedure for the surgical treatment of LE, is covered by insurance, and has demonstrated excellent, reproducible outcomes. In this study we describe our experience implementing a debulking technique from Sweden in the United States.

Methods: Patients who presented with chronic LE followed a systematic multi-disciplinary work-up. For debulking with power assisted liposuction, the surgical protocol was modeled after that developed by Håkan Brorson. A retrospective review of consecutive patients who underwent debulking at our institution was conducted.

Results: Between December 2017 and January 2020, 39 patients underwent 41 debulking procedures with power assisted liposuction, including 23 upper and 18 lower extremities. Mean patient age was 58 years and 85% of patients had LE secondary to cancer, the majority of which (64%) was breast cancer. Patients experienced excess volume reductions of 116% and 115% in the upper and lower extremities, respectively, at 1 year postoperatively. Overall quality of life (LYMQOL) improved by a mean of 33%. Finally, patients reported a decreased incidence of cellulitis and decreased reliance on conservative therapy modalities postoperatively.

Conclusions: Debulking with power assisted liposuction is an effective treatment for patients with chronic extremity LE. The operation addresses patient goals and improves quality of life, and additionally reduces extremity volumes, infection rates and reliance on outpatient therapy. A comprehensive, multi-disciplinary debulking program can be successfully implemented in the United States healthcare system.

Keywords: debulking, liposuction, lymphatic surgery, lymphedema, suction-assisted lipectomy

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The number of publications on lymphatic surgery have increased by 50% over the last 20 years.[1] In the United States (U.S.), the path to becoming a lymphatic surgeon most often involves completion of a microsurgical fellowship. Therefore, domestically, the literature has disproportionately emphasized microsurgical, or physiologic, treatments for lymphedema (LE) rather than debulking procedures that do not require microsurgery training. This so-called "microsurgeon's bias" relegates debulking to a secondary consideration in the care of a patient with LE. However, internationally, debulking techniques have consistently demonstrated reduced excess extremity volumes, improved quality of life (QOL), and decreased incidence of cellulitis.[2–5] In Sweden and the United Kingdom, debulking is performed routinely for treatment of chronic LE and is reimbursed by insurance.[6] Recently, the Lymphatic Education & Research Networks developed criteria to designate institutions as "Centers of Excellence." The ability to provide debulking interventions is a requisite for this designation and merits additional attention in the care of patients with LE in the U.S.

The most common modern debulking technique was developed and first described in 1997–1998 by Håkan Brorson.[7,8] The basis of his technique is the understanding that LE can be fluid or fatpredominant, and that the fat-predominant phenotype can be treated effectively with debulking utilizing power assisted liposuction.[9-12] In his inaugural technique paper, Brorson reported a mean postoperative excess volume reduction of 106%.[7] Long term results up to 20 years with this technique show no recurrence.[13] Since then, others across the globe have adopted his debulking technique to treat patients with chronic LE. In the Australian experience, postoperative excess volume reductions were comparable, and the authors also demonstrated an improvement in patient function and satisfaction at 6 months postoperatively.[14] Similar volume reductions were reported in the United Kingdom, where excess volume reduction at 1 year follow-up reached 101% and 90% at 5 years in two different studies.[15,16] In addition, reductions in anxiety, depression, and improvements in overall well-being were reported. More recently, in the U.S., Greene et al reported on 15 patients undergoing the Brorson technique, demonstrating an excess volume reduction of 73%, reduced episodes of cellulitis, and improved QOL over 3.1 years follow-up.[17] Uniquely, this patient

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cohort's LE was mostly non-cancer related (60%).[17] In another report by Granzow et al, which included 10 patients who underwent debulking, 111% excess volume reduction was achieved in upper extremities, and 86% in lower extremities.[18]

At our multi-disciplinary lymphatic center, we have implemented a debulking program based on the Brorson technique. Our program includes a standardized preoperative assessment including multiple imaging modalities specific to the lymphatic system, an intraoperative technique adapted from the Brorson technique, postoperative monitoring by certified LE therapists, and a long-term surveillance protocol. In this paper, we report our experience institutionalizing a debulking program for patients with both chronic upper and lower extremity LE in the U.S. We aim to provide a blueprint for the workup, management, and surveillance of patients with a fat-dominant LE phenotype.

METHODS

Identification and Evaluation of Surgical Candidates

Our center's multi-disciplinary approach to the evaluation of a patient with LE has been previously reported.[19] Briefly, this includes an extensive preoperative work-up including baseline measurements using circumferential measurements, perometry, and L-Dex (ImpediMed, California). L-Dex, a specific form of bioimpedance spectroscopy, estimates extracellular fluid using a proprietary formula, and the normal range is –10 to 10. Surveys are also administered as part of the preoperative work-up.[3,20] The LYMQOL is a validated tool for patients with chronic LE, and evaluates QOL both holistically and on a series of domains including function, appearance, symptoms, and mood. These domains are scored 1 to 4 with lower values indicating better outcomes. The LYMQOL separately measures overall QOL on a scale of 0 (poor) to 10 (excellent).[20] There is a different LYMQOL survey administered to evaluate a patient with upper versus lower extremity LE.

An overview of our patient evaluation and workup schema can be found in Figure 1. Our institution uses T2-weighted STIR (short-T1 inversion recovery) images and fat-specific Dixon images to determine whether subcutaneous fat hypertrophy or edema is primarily contributing to extremity enlargement (Fig. 2). Determination of LE phenotype guides ultimate surgical approach. Specifically, patients with magnetic resonance imaging demonstrating moderate to severe fat hypertrophy, identified by high-intensity signal on the fat-specific Dixon images, are offered a debulking procedure. Compression therapy will not improve these patients' extremity volumes. In contrast, patients with mild fat hypertrophy or fluid-predominant LE are not optimal candidates for debulking and may be better candidates for an upfront physiologic procedure.

Because postoperative protocol dictates 24/7 compression therapy, patients must also demonstrate adequate compliance with compression therapy at the grade they will be wearing postoperatively. Compliance that indicates readiness for surgery is at the discretion of the treating certified LE therapist. Patient garments are customized 3 weeks before surgery using the non-lymphedematous extremity to estimate postoperative volume. For lower extremity garments, patients require 2 sets of custom fabricated (flat knit) class III (34–36 mm Hg) closed toe, waist high garments, and open-toed thigh-high class II (23–32 mm Hg) stockings. For upper extremity garments, patients require two sets of a class II compression sleeve and glove (Essity Corp, Stockholm, Sweden). In cases of bilateral involvement, magnetic resonance imaging is used to guide postoperative volume estimations. Financial coverage for garments is also addressed before operative intervention to ensure there will be no financial limitations to postoperative compliance. Insurance coverage for compression garments is entirely dependent on the patient's individual insurance plan, and patients often must pay out-of-pocket.

At our institution, only patients who have been pre-approved for coverage undergo surgery. We do not accept out-of-pocket payment. When patients are not pre-approved, we partner with them through an appeals process.

Surgical Technique

The surgical technique used in our center, although adapted for use in the U.S., aims to replicate the Brorson technique. The key components of the procedure include power-assisted liposuction (MicroAire Surgical Instruments, Virginia) utilizing custom-made 3 and 4 mm cannulas (MD Resource, California) under tourniquet control for the limb up to the distal edge of the tourniquet, which is placed proximally.[21] Custom garments are brought into the operating room and placed onto the patient before tourniquet release. Subsequently, the proximal limb, unable to be controlled by tourniquet, is infiltratd with 1 (upper extremity) or 2(lower extremity) liters of tumescent solution (50 mL 2% (20 mg/mL) lidocaine, 1 mL (1 mg/mL) epinephrine in 1L Lactated Ringers) before liposuction. After completion of proximal limb liposuction, the custom garment is unfurled to provide compression proximally. Liposuction is not performed on the hand nor dorsum of the foot because there is no buildup of excess adipose tissue in these locations.

Aspirate Collection and Volume Determination

Intraoperative debulking aspirate is collected and stored for further analysis. Aspirate obtained while on tourniquet are collected in separate containers from aspirate collected after tourniquet release. The total volume of the debulking aspirate collected and tumescent used is recorded at the time of the procedure. The specimens are then stored for 24 hours post-procedure to allow for separation of the fat from the aspirate. After the components have separated, the volumes of fat and fluid from containers collected while on tourniquet are added to the volume of fat from the container obtained off tourniquet to total the volume removed from the patient (Fig. 3). The fluid collected is primarily tumescent solution that was instilled during the procedure, and therefore not included.

Postoperative Protocol

Patients are admitted to the hospital for postoperative monitoring. During this time, patients work closely with physical therapy regarding garment and skin care. Patients with upper extremity LE are educated on the management of hand swelling. To be discharged, a patient must be medically cleared and demonstrate the ability to apply and change their compression garments independently which universally requires an Easy Slide (Arion Group, Re Heerlen, Netherlands), a donning aid. Any complications starting in the immediate postoperative hospital admission to final clinic followup were recorded.

Postoperative garment protocols differ for upper and lower extremity patients. Patients with lower extremity LE are instructed to wear both waist-high (class III) and thigh-high (class II) garments on top of one another during the day and only the bottom layer (class III) at night. The upper extremity protocol requires the compressive sleeve and glove during the day and night. For both upper and lower extremities, garments must

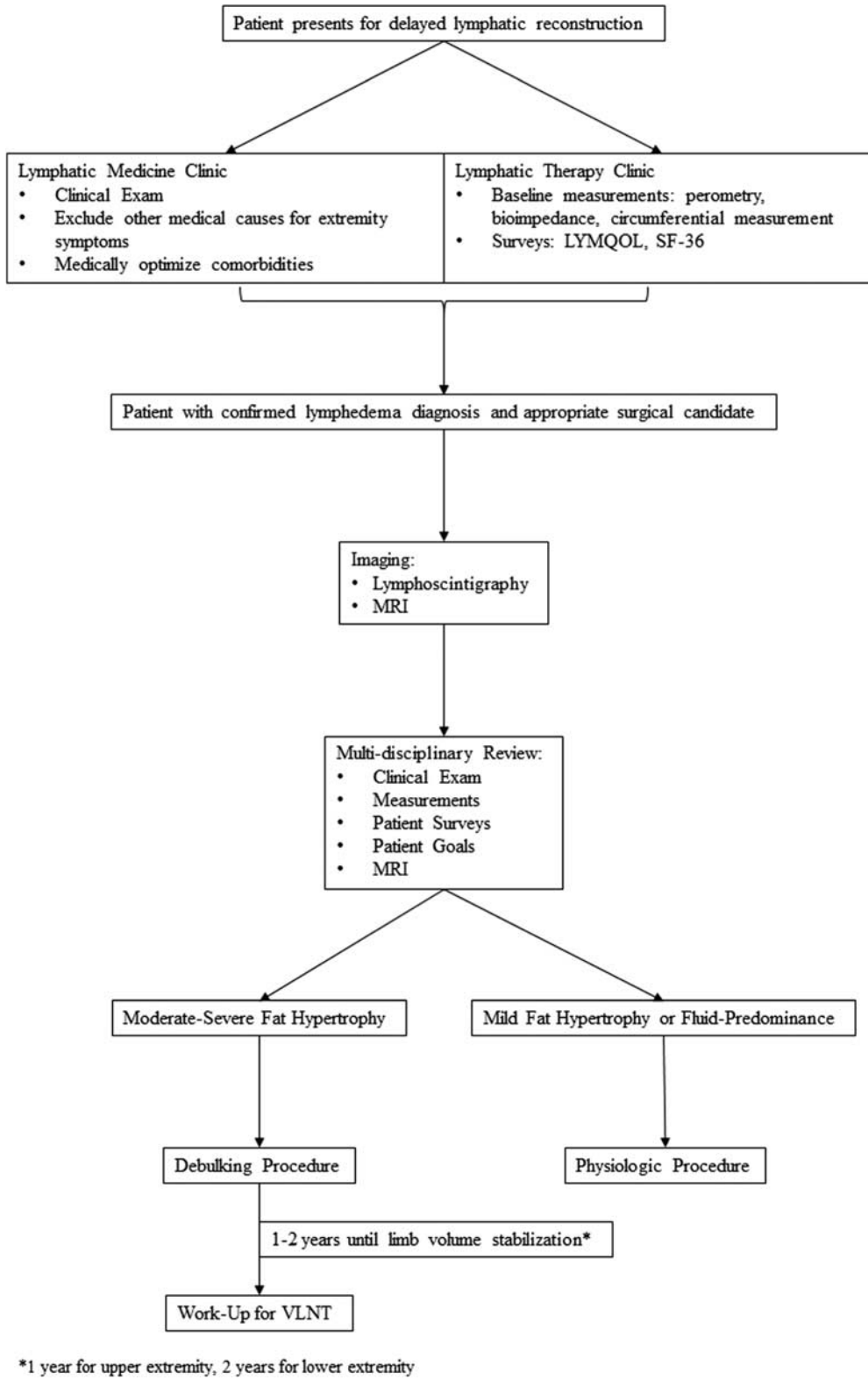

FIGURE 1. Patients with chronic lymphedema: flow and work-up through the lymphatic center.

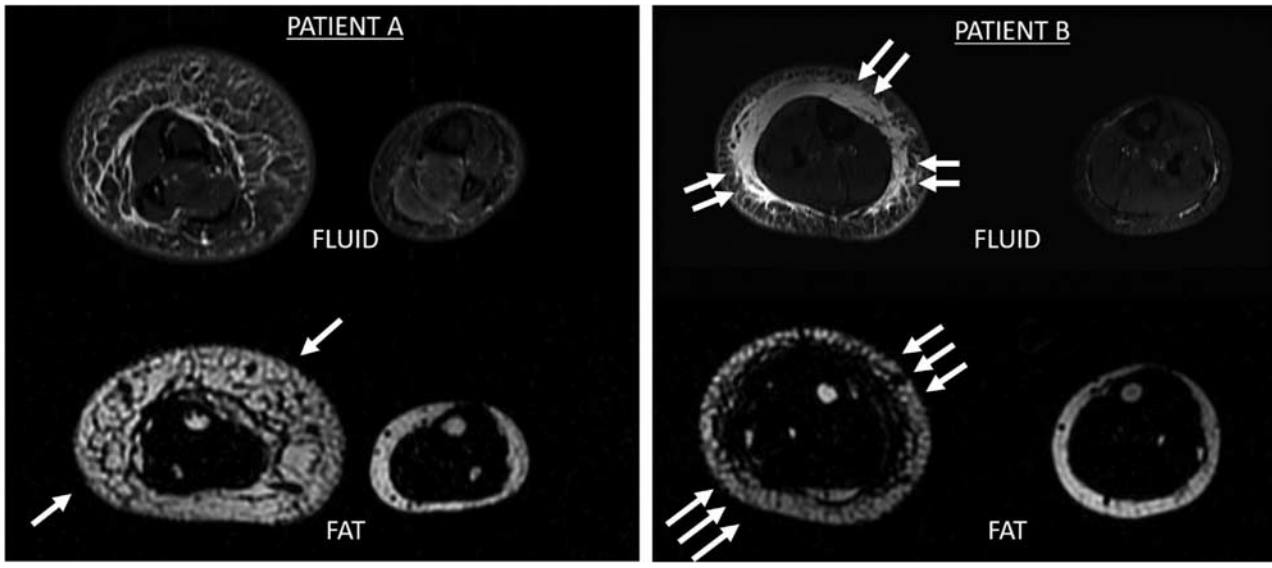

FIGURE 2. Examples of fat-dominant versus fluid-dominant soft tissue swelling in lower extremity lymphedema demonstrated on MRI. T2-weighted STIR (short-T1 inversion recovery) images (top row) and fat-specific Dixon images (bottom row) are shown across the mid-calf of two different patients with unilateral right lower extremity lymphedema. A, In Patient A's imaging, severe circumferential subcutaneous fat hypertrophy throughout the right calf is the primary contributor to asymmetric enlargement of the limb, as demonstrated by a relatively greater amount of high signal intensity on the fat-specific image (single arrows). B, In Patient B's imaging, on the other hand, the bulk of the relative enlargement of the calf is due primarily to extensive subcutaneous edema (double arrows). Fat hypertrophy is also present in the left calf, but only to a mild degree (triple arrows). MRI indicates magnetic resonance imaging.

be exchanged for the alternate set every other day for the first 2 weeks after surgery, and then exchanged daily. In addition, garments must be washed every night to shrink stretching that occurred during daytime use for both upper and lower extremity patients.

Patients are seen for surgical follow-up at 2 weeks, 3 months, 9 months, and 1 year. Patients are seen for measurement and garment follow-up with a certified LE therapist at 4 weeks, 3 months, and then every 3 months. At each postoperative surveillance visit, our previously published objective and subjective measures are taken.[19] Excess volume of unilateral LE is calculated as:

Volume of Affected Extremity – Volume of Unaffected Extremity

Excess volume reduction is reported as a percentage of the preoperative excess volume:[22]

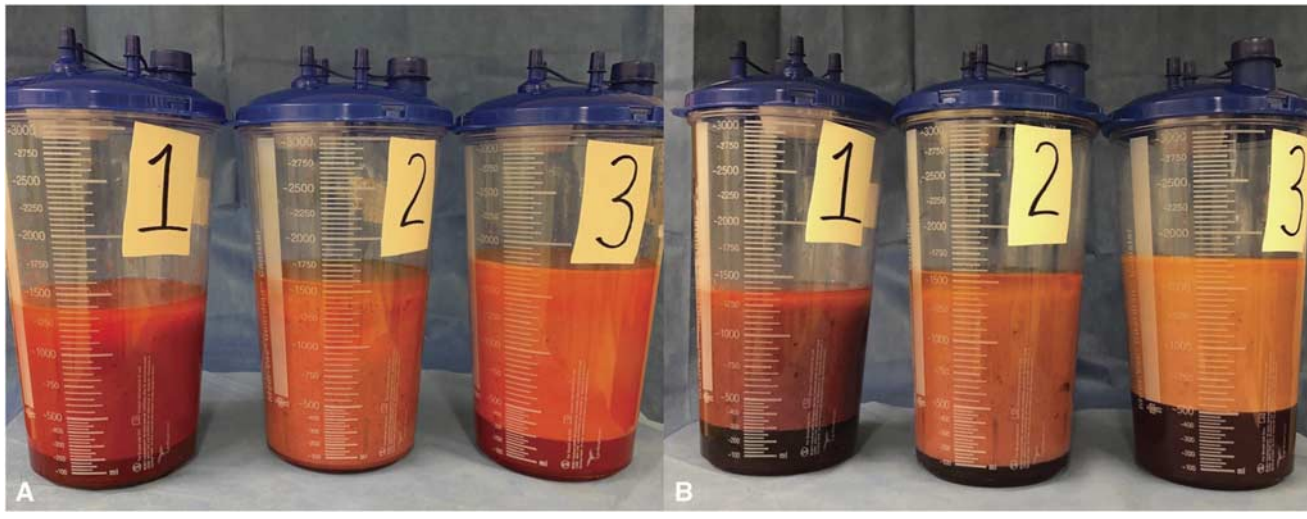

FIGURE 3. Debulking Aspirate. The contents of canisters 1 and 2 were aspirated on tourniquet while canister 3 was aspirated off tourniquet. Debulking aspirate immediately after surgery (A). Debulking aspirate 24 h after surgery. In this example, the 1350cc from canister 1 and 1550cc from canister 2 would be added to 1250cc of fat from canister 3 (note, the fluid in canister 3 is essentially ignored) (B). Therefore, the total volume removed from this patient is 4150cc.

$$\frac{\text{Pre} - \text{Operative Excess Volume} - \text{Present Excess Volume}}{\text{Pre} - \text{Operative Excess Volume}} * 100$$ [22]

Of note, all data is entered into an institutional REDCap Lymphedema Quality Improvement (QI) database by designated staff.[23] If there is pitting edema, a volume increase, or if the garment seems loose, new garments are recommended.[24] The pitting test is performed by applying pressure sufficient to blanch the thumbnail over a bony surface, most commonly over the radius at the mid-forearm or tibia at the mid-lower leg, for 1 minute. The depth of the resulting divet is measured by estimation. Patients requiring increased compression can either increase compression class, make the garment smaller, add an additional layer of compression, replace the garments more frequently to prevent stretching out, or add to their set of 2 garments so that they alternate among more garments.[21,24]

If patients are compliant with daily compression therapy and extremity volume stabilization is achieved (1 year for upper extremity, 2 years for lower extremity), they may then initiate work-up for a staged vascularized lymph node transplant (VLNT).[19]

Retrospective Review: Clinical Characteristics and Surgical Outcomes Evaluation

A retrospective review of consecutive patients with chronic LE who underwent a debulking procedure at our institution was performed. Institutional Review Board approval was obtained for this study (Protocol # 2020P-000273). Patient demographics, clinical characteristics, intraoperative details, and surveillance data were obtained for analyses. Continuous variables were reported as means [standard deviations (SD)] or medians [1st quartile (q1), third quartile (q3)] for normally distributed and skewed data, respectively. Categorical variables were reported as counts and percentages To compare excess volume and L-Dex measurements at pre-specified intervals (preoperative measurement versus month 1 measurements and month 1 measurements versus year 1 measurements), we performed paired Wilcoxon signed-rank tests. Patients with bilateral LE were excluded from analysis for excess volume and L-Dex. All analyses were performed using Excel and R v 4.0.0 (R Development Core Team, 2020). *P*-values < 0.05 were considered statistically significant.

RESULTS

Preoperative Characteristics

From December 2017 through January 2020, 39 consecutive patients with LE underwent 41 debulking procedures with power assisted liposuction. The majority of patients were female (87.2%). Mean patient age was 58 years (SD 14) at the time of surgery and mean body mass index (BMI) was 25.9 kg/m^2 (SD 9). The main etiology of LE was cancer-related (84.6%), 63.6% of which was secondary to breast cancer, 33.3% to gynecologic cancer, and 3.0% to Hodgkin Lymphoma. Of LE cases that were not secondary to cancer (15.4%), the primary etiology was congenital (66.7%). Our patient cohort lived a mean of 8.9 years with LE before undergoing a debulking procedure (Table 1).

Upon initial surgical evaluation, the most common primary goal was to decrease symptoms (48.7%) (see Supplemental Digital Content 1, http://links.lww.com/SLA/C696). The mean overall QOL from the LYMQOL reported at the preoperative visit was 6.3 out of 10.

TABLE 1. Patient Demographics and Preoperative Lymphedema Characteristics

(n = 39)	
Age at surgery, mean (SD)	58.1 (13.5)
Sex – female, n (%)	34 (87.2)
BMI, mean (SD)	25.9 (9.1)
Etiology of LE	
Cancer, n (%)	33 (84.6)
Breast, n (%)	21 (63.6)
Gynecological, n (%)	11 (33.3)
Endometrial, n (%)	2 (18.2)
Cervical, n (%)	4 (36.4)
Uterine, n (%)	2 (18.2)
Ovarian, n (%)	3 (27.3)
Hodgkin Lymphoma, n (%)	1 (3.0)
Non-Cancer, n (%)	6 (15.4)
Surgery (non-cancer), n (%)	2 (33.3)
Primary, n (%)	4 (66.7)
Extremity affected	
Upper Extremity, n	23
Lower Extremity, n*	19
Years living with LE, mean (SD)	8.9 (6.9)
Hours/week managing LE preoperatively, mean (SD)	118.8 (49.9)
Use of manual lymphatic drainage (MLD), n (%)	36 (92.3)
Use of compression, n (%)	39 (100)
Use of pneumatic device, n (%)	29 (74.4)

*1 bilateral lower extremity patient awaiting contralateral procedure.BMI indicates body mass index; LE, lymphedema; SD, standard deviation.

Preoperatively, patients reported a mean of 119 hours of LE-related therapy per week. All patients used compression, and 92% performed manual lymphatic drainage (MLD). The majority also used targeted LE exercises (72%) and pneumatic devices (74%).

Surgical and Patient-Centered Outcomes

Upper Extremity

For upper extremities, the mean volume of aspirate removed was 855cc (SD 398). Mean tourniquet time was 113 minutes (SD 27) and mean total operative time was 146 minutes (SD 37). Median excess volume reduction by circumferential measurement was 93% at 1 month (n = 19, p = 0.002), 107% at 3 months (n = 17), 111% at 6 months (n = 16), and 116% at 12 months (n = 8). Median excess volume reduction by perometry was 96% at 1 month (n = 19, $p < 0.001$) and 3 months, 108% at 6 months, and 116% at 12 months. Median excess volume of patients who underwent upper extremity debulking over time are recorded in Figure 4A. Median upper extremity preoperative L-Dex was 55.2 (Q1–Q3 33–65), and postoperative was 52.1 (Q1–Q3 46–67, p = 0.045) at 1 month, 40.4 at 3 months (n = 16, Q1–Q3 32–50), 26.3 at 6 months (n = 15, Q1–Q3 14–32), and 23.2 at 12 months (n = 7, Q1–Q3 17–27) (Fig. 4B). Median hospital length of stay was 2 days (Q1–Q3 2–4).

The mean overall quality of life (QOL) reported at the preoperative visit was 6.5 versus 8.3 at the last point of contact with the patient, which on average was 8.0 months after surgery (SD 4.5 months) (Fig. 4C). LYMQOL sub-scores improved on all metrics for patients with upper extremity LE, with the largest improvement in the Appearance sub-score (44%) (Fig. 4D).

Lower Extremity

For lower extremities, the mean volume of aspirate removed was 2550cc (SD 907). Mean tourniquet time was

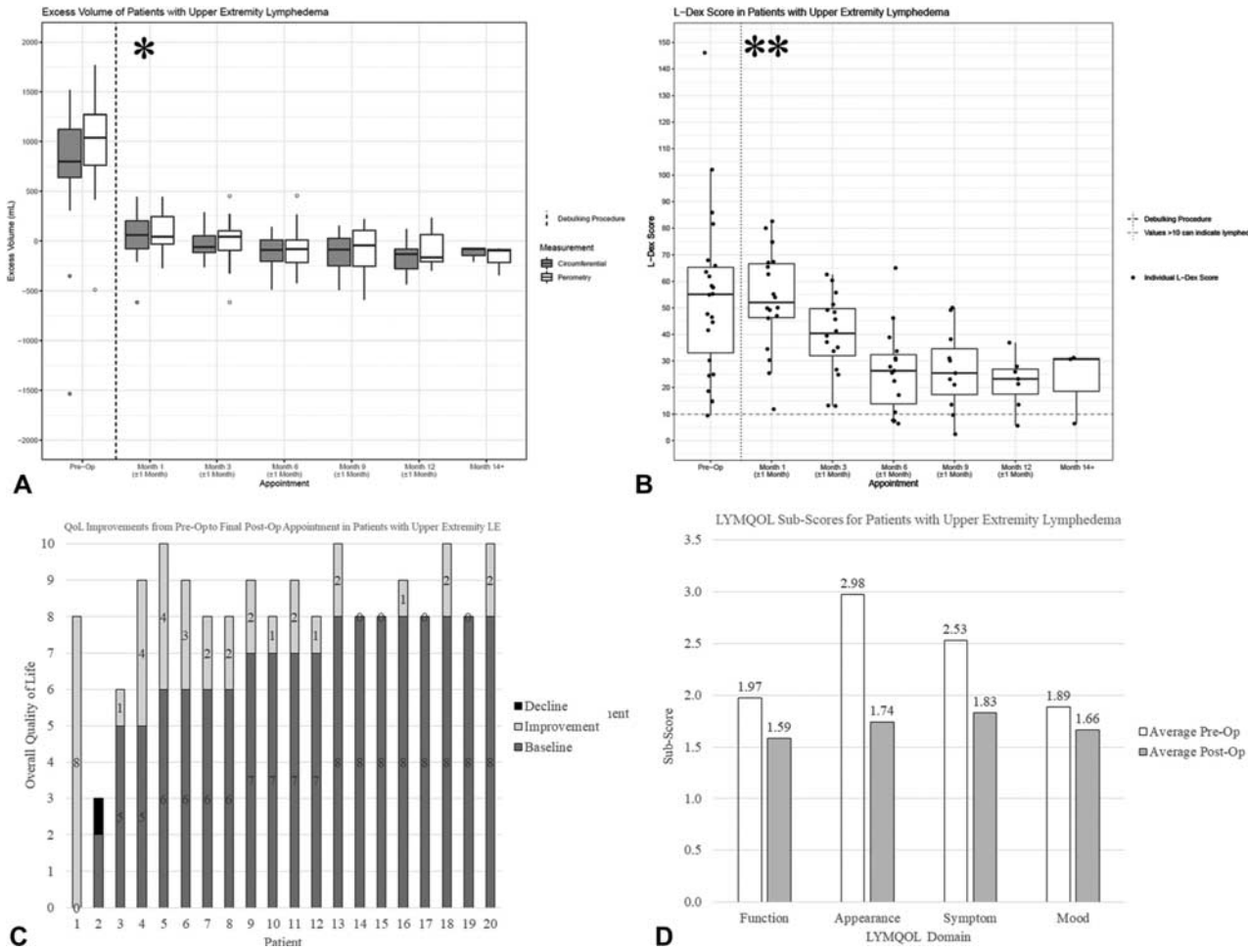

FIGURE 4. Results of patients with upper extremity lymphedema. A. Excess volume of patients with upper extremity lymphedema. A vertical dotted line delineates the debulking procedure. An asterisk indicates statistical significance. B. L-Dex Score in Patients with Upper Extremity Lymphedema. A red dotted line delineates an L-Dex score of 10, above which indicates a diagnosis of lymphedema. An asterisk indicates statistical significance. C. QoL Improvements from Pre-Op to Final Post-Op Appointment in Patients with Upper Extremity Lymphedema. D. LYMQOL Sub-Scores for Patients with Upper Extremity Lymphedema. QoL indicates quality of life.

140 minutes (SD 24) and mean total operative time was 254 minutes (SD 152). Median excess volume reduction by circumferential measurement was 79% at 1 month (n = 12, $P < 0.001$), 78% (n = 10) at 3 months, 82% at 6 months (n = 7), and 115% at 12 months (n = 5). Median excess volume reduction by perometry was 85% at 1 month (n = 12, P < 0.001), 87% at 3 months, 91% at 6 months, and 104% at 12 months. Median excess volume of patients who underwent lower extremity debulking over time are recorded in Figure 5A. Median lower extremity preoperative L-Dex was 68.2 (Q1–Q3 47–87), and postoperative was 29.8 (QI–Q3 29.8, $P = 0.0049$) at 1 month, 28.0 at 3 months (n = 10, Q1–Q3 9–46), 21.5 at 6 months (n = 7, Q1–Q3 15–37), and 20.3 at 12 months (n = 5, Q1–Q3 7–46) (Fig. 5B). Median hospital length of stay was 3.5 days (Q1 –Q3 2.25–5.75).

The mean overall QOL reported at the preoperative visit was 5.9 versus 8.5 (44% increase) at the last point of contact with the patient, which on average was 9.1 months after surgery (SD 4.9 months) (Fig. 5C). LYMQOL sub-scores improved on all metrics for patients with lower extremity LE, with the largest improvement in the Appearance sub-score (37%) (Fig. 5D).

An example of a patient who underwent lower extremity debulking can be seen in Supplemental Digital Content 2, http://links.lww.com/SLA/C697. Surgical outcomes for upper versus lower extremities are recorded in Table 2.

Upper and Lower Extremities

After the debulking procedure, all patients continued to use compression, as per the standard postoperative protocol, but largely discontinued all other LE management modalities including MLD, pneumatic pumps, and LE specific exercises. (See Supplemental Digital Content 3, http://links.lww.com/SLA/C698).

Complications

One patient who underwent a lower extremity debulking procedure was transfused with 1 unit packed red blood cells for a hematocrit of 19.9 during their hospital course. Three patients (7.7%) developed skin ulcers secondary to garment use on the affected extremity in the postoperative period, which all resolved with modification of their garments.

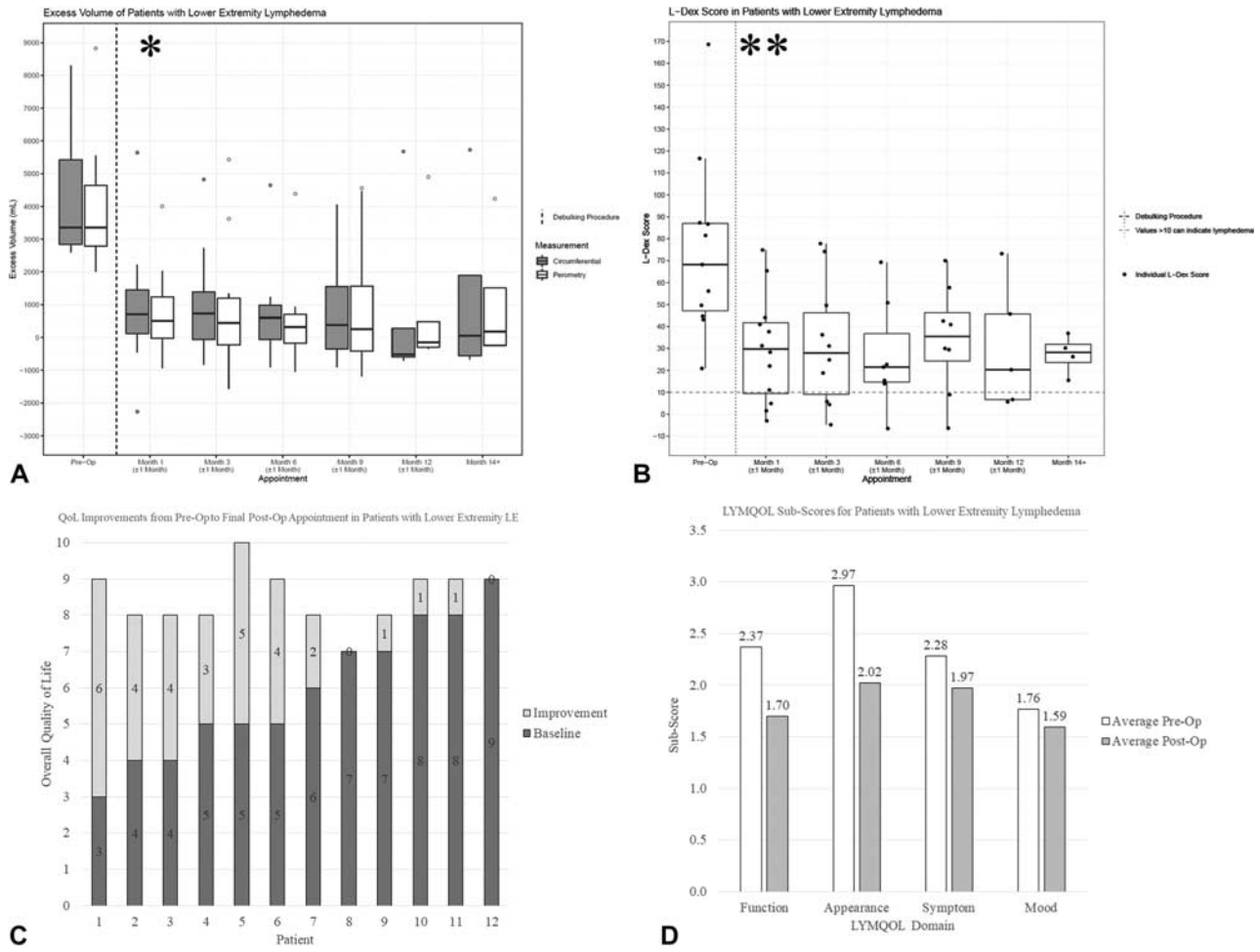

FIGURE 5. Results of patients with lower extremity lymphedema. A. Excess volume of patients with lower extremity lymphedema. A vertical dotted line delineates the debulking procedure. An asterisk indicates statistical significance. B. L-Dex score in patients with lower extremity lymphedema. A dotted line delineates an L-Dex score of 10, above which indicates a diagnosis of lymphedema. An asterisk indicates statistical significance. C. QoL Improvements from Pre-Op to final Post-Op appointment in patients with lower extremity lymphedema. D. LYMQOL sub-scores for patients with lower extremity lymphedema. QoL indicates quality of life.

Cellulitis

Ninety-two episodes of cellulitis were reported in our patient cohort before debulking over a total of 348.5 disease years (0.26 epi-sodes/yr). In comparison, 2 episodes of cellulitis were reported after debulking over the course of 27.4 post-operative years (0.07 episodes/yr). Of note, both patients who developed cellulitis postoperatively did so after traumas to their operative extremity. One patient suffered an oil burn in the kitchen, and developed a cellulitis 7 months after her operation. The second patient developed an early postoperative blister, and then a secondary infection 10 days after the procedure. Both infections were treated with antibiotics and were self-limited.

DISCUSSION

In this study, we review our experience and describe surgical outcomes for debulking with power-assisted liposuction performed in 39 consecutive patients with upper and lower extremity LE. In our patient cohort, we found sustained decreased excess volume, increased QOL, and learned three important lessons in adapting the Brorson technique in the U.S.

In our patients with upper extremity LE, the excess volume reduction was 116% at 12 months by circumferential measurement. This figure is commensurate with that of prior reports utilizing the Brorson technique, which range in reductions from 101% to 118% at 1 year follow-up.[14,15,25] In patients with lower extremity LE, the excess volume reduction was 115% at 12 months by circumferential measurement. This data is similarly consistent with previous reports of excess volume reductions ranging from 86% to 114%.[5,18,21,26] In our 3 patients with unilateral lower extremity LE of primary origin, we noticed significant pitting edema (>3 mm) despite optimized compression therapy. In 2 patients with elevated BMI (>35 kg/m^2), we were only able to achieve excess volume reductions of 23.7% and 31.5%. In the patient with an optimized BMI preoperatively (23.2 kg/ m^2), we were able to achieve a reduction of 115%. The literature suggests that outcomes of the Brorson technique in patients with primary LE are not as impressive as in those

TABLE 2. Upper Versus Lower Extremity Surgical Outcomes

	Upper Extremity (n = 23)	Lower Extremity (n = 18)
Volume of fat debulked in cc, mean (SD)	855 (397.9)	2550.3 (907.3)
Operative time in mins, mean (SD)	145.9 (36.6)	253.7 (151.8)
Tourniquet time in mins, mean (SD)	113.4 (27.1)	140.1 (23.5)
Hospital length of stay in days, median (Q1–Q3)	2 (2–4)	3.5 (2.25–5.75)
Excess volume (circumferential measurement) in cc, median (Q1–Q3)		
Pre-op	799 (638–1125)	3355 (2843–5428)
Post-op		
1 mo	60 (–76–202)*	710 (116–1450)*
3 mo	–58 (–113–50)	727 (–63–1385)
6 mo	–89 (–201–10)	600 (–59–986)
12 mo	–128 (–277–78)	–511 (–591–283)
Excess volume (perometry) in cc, median (Q1–Q3)		
Pre-op	1038 (763–1273)	3360 (2791–4639)
Post-op		
1 mo	44 (–27–246)*	506 (–27–1242)*
3 mo	42 (–90–100)	437 (–229–1196)
6 mo	–78 (–213–9)	314 (–182–702)
12 mo	–165 (–207–65)	–147 (–297–475)
L-Dex, median (Q1–Q3)		
Pre-op	55.2 (33–65)	68.2 (47–87)
Post-op		
1 mo	52.1 (46–67)*	29.8 (9–42)*
3 mo	40.4 (32–50)	28.0 (9–46)
6 mo	26.3 (14–32)	21.5 (15–37)
12 mo	23.2 (17–27)	20.3 (7–46)

*Indicates statistical significance ($P < 0.05$).
SD indicates standard deviation.

patients with secondary LE.[5,27] Our limited cohort of patients with primary LE suggests that preoperative BMI optimization may be an important factor in the postoperative outcomes of these patients.

Our patient cohort demonstrated an overall QOL e improvement (33% increase) as measured via the LYMQOL. This finding is consistent with prior literature on this procedure.[2–4,17,28] Of note, our data suggests a plateau effect in this metric. Specifically, patients with a high preoperative overall QOL score demonstrated less improvement than those with lower preoperative QOL scores. (Figs. 4C and 5C). In the sub-score section of the LYMQOL, which evaluates self-reported improvement in appearance, symptoms, function, and mood as separate domains, all showed improvement in patients with upper and lower extremity LE (Figs. 4D and 5D). The largest improvement in subscore QOL was in the appearance domain (44% upper extremity, 37% lower extremity) (Figs. 4D and 5D). Of note, preoperatively, improvement of appearance was the most commonly reported secondary patient goal. The most common primary goal was improvement of symptoms. The symptom domain improved by 31% in patients with upper extremity LE and 21% in those with lower extremity LE. Our data supports that debulking in patients with LE improves QOL, both overall and specifically with regard to function, appearance, symptoms, and mood.

In adapting the Brorson operative technique to a lymphatic center in the U.S. we confronted three important challenges. First, appropriate instrumentation is critical to safely executing this procedure. The cannulas utilized by Brorson are custom-made and have an aggressive grind taking up 50% of the circumference of the cannula. This grind is critical to allow for adequate liposuction in a short tourniquet time. Although these cannulas were not available in the U.S., we had them custom made by MD Resource and they can now be ordered (we named them the "Brorson Cannulas"). Second, in Sweden, compression garments placed in the operating room before tourniquet release are steam sterilized at 134 degrees Celsius. However, sterilization shortens the life span of these garments to 2 days. In the US, due to the cost of compression garments often falling upon the patient and without a nationalized health system, we needed a solution to this issue that would not shorten the life span of the garment. Ultimately, we worked with OR nursing to develop a draping protocol that allowed us to place the non-sterile garment on the patient while maintaining sterility for debulking of the proximal extremity. Finally, similar to the experience in Sweden, all of our patients who underwent upper extremity debulking developed hand swelling postoperatively. Patients with preoperative hand swelling will not resolve the swelling and will be required to continue the use of a gauntlet. Patients without preoperative hand swelling can be expected to experience resolution of hand swelling with strict compliance to a gauntlet over 6 months postoperatively. However, we found our patients complaining more about the hand swelling than our Swedish counterparts. In Sweden, likely because custom garments are covered by insurance, most patients initially present to clinic already in a custom gauntlet, maintaining better preoperative control of hand swelling. In addition, Swedish patients are generally accustomed to custom high-grade compression preoperatively, which promotes better postoperative compliance with high-grade compression. In contrast, most patients presenting to our clinic either have no gauntlet or a ready-to-wear glove (lower grade compression). Postoperative compliance with hand compression is therefore challenging for our patients. We have incorporated extensive preoperative counseling that includes a discussion on postoperative hand swelling and the importance of compliance with gauntlet compression postoperatively.

This study is limited by its short overall follow-up time, and by factors related to it being a retrospective database review rather than prospective trial. Although the data we have suggests

that the excess volume reduction achieved by the debulking surgery persists, only longer-term follow-up can prove lasting volume reduction. We are continuing to monitor these patients closely and look forward to reporting their future longer-term outcomes, especially as these patients return for eventual staged VLNT.

CONCLUSIONS

Although debulking is widely recognized and reimbursed internationally, lymphatic surgery literature in the U.S. largely ignores this procedure, despite its excellent surgical and patientcentered outcomes. Our experience with power-assisted liposuction for debulking of the lymphedematous extremity supports its ability to maintain volume reduction over time, improve QOL, and is utilized as a first stage procedure before VLNT in the fat-dominant patient. As lymphatic centers are formed in the U.S., we strongly encourage them to integrate debulking into their treatment algorithm.

REFERENCES

1. pubmeddev. Home - PubMed - NCBI Available at: https://www.ncbi.nlm.-nih.gov/pubmed/. Accessed April 13, 2020.
2. Brorson H, Ohlin K, Olsson G, et al. Quality of life following liposuction and conservative treatment of arm lymphedema. *Lymphology*. 2006;39:8–25.
3. Hoffner M, Bagheri S, Hansson E, et al. SF-36 shows increased quality of life following complete reduction of postmastectomy lymphedema with liposuction. *Lymphat Res Biol*. 2017;15:87–98.
4. Carl HM, Walia G, Bello R, et al. Systematic review of the surgical treatment of extremity lymphedema. *J Reconstr Microsurg*. 2017;33:412–425.
5. Lamprou D-aA, Voesten HGJ, Damstra RJ, et al. Circumferential suctionassisted lipectomy in the treatment of primary and secondary end-stage lymphoedema of the leg. *Br J Surg*. 2017;104:84–89.
6. Liposuction for Chronic Lymphoedema j Interventional Procedures Guidance [IPG588]. National Institute for Health and Care Excellence (NICE). Available at: https://www.nice.org.uk/guidance/ipg588. 2017. Accessed May 1, 2020.
7. Brorson H, Svensson H. Complete reduction of lymphoedema of the arm by liposuction after breast cancer. *Scand J Plast Reconstr Surg Hand Surg*. 1997;31:137–143.
8. Brorson H, Svensson H. Liposuction combined with controlled compression therapy reduces arm lymphedema more effectively than controlled compression therapy alone. *Plast Reconstr Surg*. 1998;102:1058–1067. discussion 1068.
9. Brorson H, Ohlin K, Olsson G, et al. Adipose tissue dominates chronic arm lymphedema following breast cancer: an analysis using volume rendered CT images. *Lymphat Res Biol*. 2006;4:199–210.
10. Hoffner M, Peterson P, Mansson S, et al. Lymphedema leads to fat deposition in muscle and decreased muscle/water volume after liposuction: a magnetic resonance imaging study. *Lymphat Res Biol*. 2018;16:174–181.
11. LT, PP, HB, et al. Assessment of subfascial muscle/water and fat accumulation in lymphedema patients using magnetic resonance imaging. *Lymphat Res Biol*. 2018;17:340–346.
12. Trinh L, Peterson P, Brorson H, et al. In vivo comparison of MRI-based and MRS-based quantification of adipose tissue fatty acid composition against gas chromatography. *Magn Reson Med*. 2020;84:2484–2494.
13. Brorson H. Liposuction normalizes lymphedema induced adipose tissue hypertrophy in elephantiasis of the leg–a prospective study with a ten-year follow-up. *Plast Reconstr Surg*. 2015;136:133–134.
14. Boyages J, Kastanias K, Koelmeyer LA, et al. Liposuction for advanced lymphedema: a multidisciplinary approach for complete reduction of arm and leg swelling. *Ann Surg Oncol*. 2015;22:1263–1270.
15. Schaverien MV, Munro KJ, Baker PA, et al. Liposuction for chronic lym-phoedema of the upper limb: 5 years of experience. *J Plast Reconstr Aesthetic Surg JPRAS*. 2012;65:935–942.
16. Stewart CJ, Munnoch DA. Liposuction as an effective treatment for lower extremity lymphoedema: a single surgeon's experience over nine years. *J Plast Reconstr Aesthetic Surg JPRAS*. 2018;71:239–245.
17. Greene AK, Maclellan RA. Operative treatment of lymphedema using suction-assisted lipectomy. *Ann Plast Surg*. 2016;77:337–340.
18. Granzow JW, Soderberg JM, Kaji AH, et al. An effective system of surgical treatment of lymphedema. *Ann Surg Oncol*. 2014;21:1189–1194.
19. Johnson AR, Fleishman A, Tran BNN, et al. Developing a lymphatic surgery program: a first-year review. *Plast Reconstr Surg*. 2019;144:975e.
20. Keeley V, Crooks S, Locke J, et al. A quality of life measure for limb lymphoedema (LYMQOL). *J Lymphoedema*. 2010;5:26–37.
21. Brorson H. From lymph to fat: complete reduction of lymphoedema. *Phlebology*. 2010;25 Suppl 1:52–63.
22. Hoffner M, Ohlin K, Svensson B, et al. Liposuction gives complete reduction of arm lymphedema following breast cancer treatment–a 5-year prospective study in 105 patients without recurrence. *Plast Reconstr Surg Glob Open*. 2018;6:e1912.
23. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42:377–381.
24. Ohlin K. Controlled Compression Therapy after Liposuction for Lymphedema - How to Maintain Control Over Time. 2018. Available at: https://lympha-ticnetwork.org/treating-lymphedema/the-lymphedema-symposium-2018/controlled-compression-therapy-after-liposuction-for-lymphedema.
25. Damstra RJ, Voesten H.G.J.M, Klinkert P, et al. Circumferential suction-assisted lipectomy for lymphoedema after surgery for breast cancer. *Br J Surg*. 2009;96:859–864.
26. McGee P, Munnoch DA. Treatment of gynaecological cancer related lower limb lymphoedema with liposuction. *Gynecol Oncol*. 2018;151:460–465.
27. Greene AK, Slavin SA, Borud L. Treatment of lower extremity lymphedema with suction-assisted lipectomy. *Plast Reconstr Surg*. 2006;118:118e–121e.
28. Klernas P, Johnsson A, Boyages J, et al. Quality of life improvements in patients with lymphedema after surgical or nonsurgical interventions with 1-year follow-up. *Lymphat Res Biol*. 2020;18:340–350.