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DOES LIPOSUCTION FOR LYMPHEDEMA WORSEN LYMPHATIC INJURY?

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ABSTRACT

Liposuction for treatment of lymphedema is an effective and time-tested treatment. However, as there is a fear regarding further lymphatic damage caused by liposuction, we objectively compared lymphatic function pre- and post-liposuction. All patients with solid-predominant lymphedema who were treated during the study period of June 2014 and November 2018 were included. Patients were assessed using patient-reported baselines/outcomes, lymphedema-specific quality of life scale (LYMQOL), limb circumference/volume measurements, and indocyanine green lymphography (ICGL) preoperatively and at predefined postoperative time intervals. Fifty-seven limbs from 41 patients were included. Mean lipoaspirate volumes were 2035 mL, 5385 mL, and 3106 mL for the arm, thigh, and leg, respectively with a mean adipose fraction of the lipoaspirate of 71%. All patients underwent redundant skin excision with the "flying squirrel" technique. The mean follow-up was 10.7 months (range 3 – 48 months) with a mean limb volume reduction of 32.2% and all patients reporting satisfactory relief of symptoms. All showed statistically significant improvement in LYMQOL in symptoms, appearance, and function. On ICGL, none showed worsened lymphatic drainage, rather, all showed improved lymph drainage. Furthermore, the improved lymph drainage was found to be progressive during the study period in all patients. Our study results demonstrate that treating extremity lymphedema with liposuction does not worsen lymphatic function and in fact, paradoxically, it induces progressive improvement in lymph drainage.

Keywords: liposuction, lymphedema debulking, lymphedema, lymphatic injury, ICG, indocyanine green, lymphography, lymphatic dysfunction.

Removal of the pathologic, lymphedema-induced fibrotic lipodystrophy (1-3) using liposuction is an effective and time-tested treatment (4). One of the presumed disadvantages of the technique is injuring lymphatics while removing the lymphedema bulk. The literature shows evidence both supporting (5) and refuting (6,7) this assumption. Despite the evidence for liposuction-associated lymphatic injury remaining preliminary and circumstantial, it has already prompted surgeons to develop creative solutions including "lymph-sparing liposuction" (8,9). In this study, we further investigate the hypothesis that liposuction, when performed to treat lymphedema-induced lipodystrophy, causes worsening of lymphatic function.

PATIENTS AND METHODS

The Institutional Review Board of the University of Iowa Hospital and Clinics approved the study and it was conducted per the Helsinki Declaration (version 2013). All patients consented in writing to the procedures conducted during this study period, including photograph acquisition and distribution. All patients who underwent liposuction for extremity lymphedema during the study period of June 2014 to November 2018 were included.

Preoperative Workup

Solid-predominant state of lymphedema was suggested by patient's report of non-reversible bulk in the arm/leg and confirmed by physical examination. In select cases, bioimpedance spectroscopy and MRI aided in the diagnosis (*Fig. 1*). Patients were optimized on their lymphedema therapy, including compression, preoperatively. All patients underwent standardized assessment protocol (SAP) including patient-reported baselines/outcomes (PRBO), lymphedema-specific quality of life (LYMQOL) score, limb circumference/volume measurements, and indocyanine green (ICG) lymphography to establish disease baseline (10,11).

ICG lymphography (ICGL) was performed using a standardized protocol. All patients removed their compression garment just before the study and were positioned supine. 0.1 mL of 0.25% ICG (Akron Pharmaceutical, Lake Forest, IL) was injected intradermally in two web spaces and at the medial malleolus (leg) or the wrist (arm). Imaging was performed using SPY Elite System (Novadaq, Mississauga, Canada) in a dark room, at 2 minutes and at 6 hours post-injection. The lymphatic transit time, orientation of channels, and presence, distribution, and size of dermal backflow were recorded. The same operator consistently conducted and interpreted the exam.

Limb circumference measurements were taken at 5 cm (upper extremity)/ 10 cm (lower extremity) using the antecubital fossa and popliteal crease as reference points, respectively. Limb volumes were derived from circumference measurements using truncated cone formula (12).

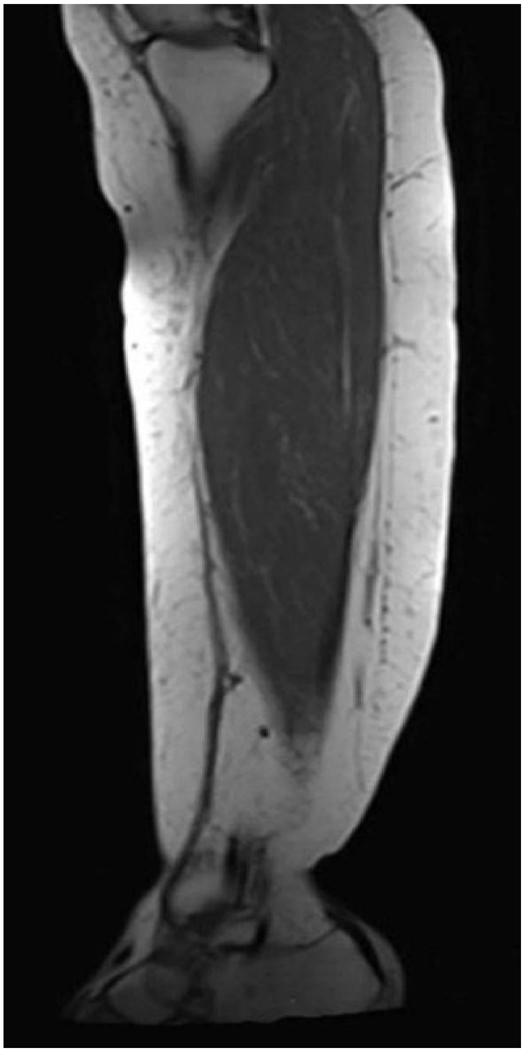

Fig. 1. MRI aids in diagnosis of solid-predominant lymphedema. Adipose tissue under T2-weighted MRI appears white. In this patient, the leg bulk can be seen to be caused by adipose tissue deposit instead of from fluid edema.

Surgical Technique

Liposuction was performed using the tumescent technique. The tumescent solution consisted of 1 mg of epinephrine in 1 liter of normal saline. Under tourniquet control, liposuction was performed circumferentially with

Fig. 2: Positive "flying squirrel" sign. Following liposuction, excessive skin redundancy put patients at risks of seroma, hematoma, and skin necrosis. The patient shown demonstrated a positive "flying squirrel" sign, or undulating skin mobility with ability to traction 4cm or more from the deep fascia. This patient underwent skin excision to reduce risks of complications.

a 5-mm Mercedes cannula using a power-assisted liposuction (PAL) device (Microaire Surgical, Charlottesville, VA, USA). Liposuction concluded either when 1) normal anatomic contour had been achieved, or 2) the dense fibrosis prevented further tissue retrieval. Following liposuction, those with excessive skin redundancy, or positive "flying squirrel" sign (13,14) underwent immediate contouring skin excision *(Fig. 2)*. Excess skin was outlined as an ellipse and anterior incision was given first followed by skin undermining and posterior committing incision. The dimensions and the surface area of the excised skin was measured. No drain was used. The treated limb was immediately compressed after the surgery with a short-stretch compression bandage.

All procedures were performed under general anesthesia. The whole upper extremity was treated at once but in the lower extremity, thigh and leg were treated at different times. In our experience liposuction is more painful in the lower than the upper extremity. Hence, a femoral nerve block or sciatic nerve block was given for thigh and leg cases, respectively.

Postoperative Care

All patients were admitted postoperatively for 1-3 days for pain/fluid management. During the first postoperative month, all patients applied short-stretch bandage for limb compression. Foam paddings were applied to bony prominences such as medial/lateral malleolar regions to create even compression. The bandages were rewrapped/replaced by the patients daily. They transitioned to circular-knit 30-40 mmHg garment at 1 - 2 months post-surgery. Patients were allowed to shower from postoperative day 3.

Follow Up

All patients were followed up at 1, 3, 6, and 12 months, and then annually. At each visit, all had an assessment of PRBO, LYMQ-

OL, Limb volume, and ICGL. All complications were recorded. Major complications were those that required surgical interventions while minor complications were ones that resolved conservatively. LYMQOL score for the four domains- appearance, function, symptoms, mood, and overall quality of life, was calculated from the questionnaire responses. ICG lymphographic changes were categorized as improved, unchanged, or worsened based on the change in pathologic patterns (slow ICG transit, abnormally oriented channels, dermal backflow) or appearance of new linear patterns, as compared to the baseline scans.

Statistical Analysis

Data were presented using descriptive statistics and equal variance was checked using Levene test. Pre and postoperative LYMQOL was analyzed with paired t-tests, assuming equal variance. Statistical analysis was performed with Stata 15.1 (StataCorp, College Station, Texas, USA). A $p<0.05$ was considered as statistically significant.

RESULTS

Fifty-seven limbs in 41 patients underwent liposuction during the study period. Twenty limbs were primary lymphedema, and 37 limbs were secondary lymphedema. Twenty-three cases involved arms (upper extremity), 13 cases involved thighs, and 21 cases involved legs (below the knee) (*Table 1*). The mean follow-up duration was 10.7 months (range 3 - 48 months).

Mean lipoaspirate volumes were 2035 mL, 5385 mL, and 3106 mL for the arm, thigh, and leg respectively with a mean adipose fraction of 71%. All patients demonstrated positive "flying squirrel" sign and underwent skin excision. The average dimensions of excised skin were 133.5 cm^2, 399.1 cm^2, and 296.1 cm^2 for the arm, thigh, and leg respectively.

There were no major complications requiring reoperation. Fifteen limbs (26.3%) experienced minor complications (*Table 2*). No patients after liposuction and skin excision experienced seroma/hematoma, skin necrosis,

TABLE 1
Demographic Variables of Study Participants Including Disease Characteristics

Number of Patients	**41**
Females	39
Males	2
Median Age of Patient (in years)	55.8 ± 12.4 (34-73)
Number of Patients with bilateral disease	5/21
Number of Limbs	57
Lower extremity:	
Lower Legs	21
Thighs	13
Upper extremity	23
Average Duration of Disease (years)	13.3 ± 10.7
ISL Stage (Number of Limbs)	
Stage 3	26
Stage 2	31
1° Lymphedema	20
2° Lymphedema	37

TABLE 2
Surgical Outcomes Measurements*

Total number of Limbs	**57**
Average Lipoaspirate Volume	
Lower Leg	3106 ± 824 mL
Thigh	5385 ± 1246 mL
Upper Extremity	2035 ± 488 mL
Average Reduction in Volume	32.2 ± 9.8 %
Complications	
Major	0
Minor	15
Contour Irregularity	5
Paresthesia	3
Dehiscence	7
Seroma/Hematoma	0
Skin Necrosis	0
Infection	0

* Complications were divided into major and minor categories with major complications being defined as those requiring reoperation. Minor complications were managed non-operatively and included wound dehiscence, paresthesia, contour irregularity, seroma/hematoma, skin necrosis, and infection.

or infection.

All patients reported satisfactory relief of symptoms including reduction of pain/paresthesia and improvement in range of motion, function, and exercise tolerance. All also reported improved responsiveness to the preoperative strength of compression therapy or could reduce the strength. The average LYMQOL score at the last follow-up when compared to preoperative baseline, demonstrated statistically significant improvement in appearance (P = 0.019), function (P = 0.046), and symptoms (P = 0.014). An improvement in mood was also observed but did not reach statistical significance (P = 0.052). The overall quality of life was significantly improved (P = 0.033).

At the last follow-up, the average limb volume reduction was 32.2% of the preoperative limb volume. In addition to the expected bulk reduction, all patients showed progressive improvement in skin texture and skin color, suggestive of a decrease in inflammation.

In the post-operative ICGL, no limb showed worsening of lymph drainage. On the contrary, all limbs showed improved lymph drainage, starting at 3 months in 50 (87.7%) limbs and at/after 6 months in the remaining 7 (12.3%) limbs (*Figs. 3,4*). Furthermore, all limbs demonstrated progressive, continuous improvement in serial ICGL performed during the study period (*Fig. 5*). Six (10.5%) limbs exhibited new, previously non-visualized linear lymphatic channels (*Fig. 6*). This finding was noticed at 6 months and continued to evolve beyond one year.

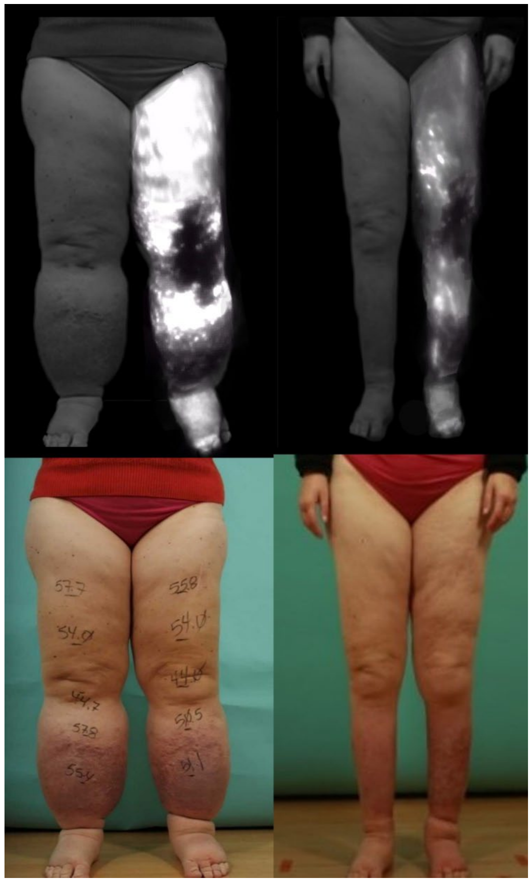

Fig. 3: Improvement in lymphatic function seen on ICG lymphography after liposuction. The patient had lymphedema-induced elephantiasis and gross deformity in bilateral legs (bottom, left). Her clinical presentation correlated well with her preoperative ICGL (top, left), showing diffuse patterns in both left leg and thigh. Following liposuction (bottom, right), ICGL demonstrated striking decrease in dermal backflow suggestive of improved lymphatic function (top, right).

DISCUSSION

To date, the safety of liposuction for lymphedema has not been definitively established. Practices have ranged from aggressive circumferential liposuction (14-17), normalizing liposuction (18), to conservative, selective, "lymph-sparing" liposuction (8,9).

It is not illogical to suspect lymphatic injury from liposuction. In fact, it seems logical to expect that the lymph channels are mechanically excised along with the fibrotic adipose tissue during liposuction. The question is whether this damage to channels translates to worsening of lymphatic function. There are few reports indicating lymphatic injury post-liposuction. A case series of three lipedema patients developing abnormal skin changes with/without swelling post liposuction was reported. All three patients underwent lymphoscintigraphy showing delayed inguinal uptake, but none had preoperative lymphatic function evaluation (5). Furthermore, evidence of injury to lymphatics following dry liposuction

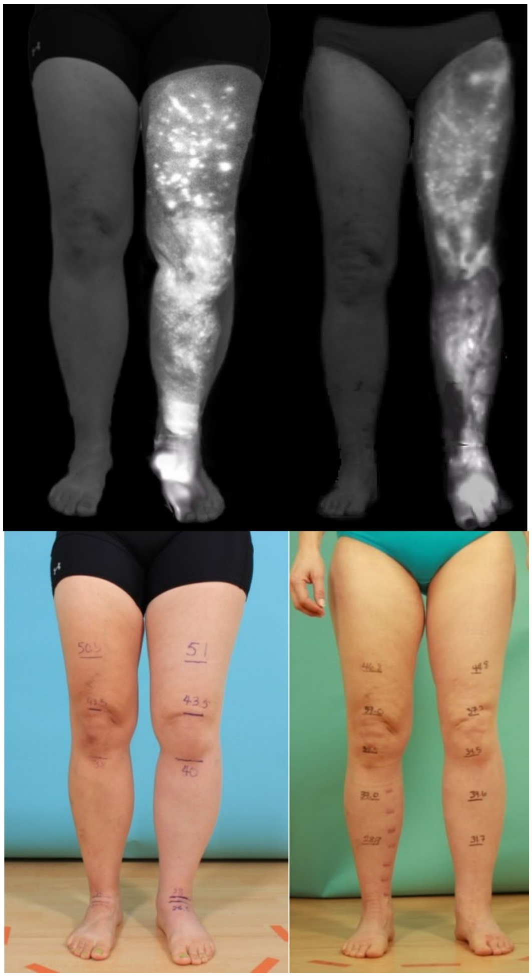

Fig. 4. Patient demonstrating improved lymphatic function post-liposuction. The patient (bottom, left) underwent liposuction for solid-predominant lymphedema of left thigh. ICGL at 12-month postoperatively (top, right) demonstrated decreased stardust patterns at knee and thigh and increased linear patterns in the leg and thigh compared to pre-liposuction image (Top, left).

and transverse cannula movements was shown in an experimental setting in a cadaver model (19). The injury reduced when using tumescent technique in the cadaver (20).

Above observations and logical assumptions have not been validated by actual long-term studies on liposuction for lymphedema. Despite the liposuction thoroughly treating the limb, several studies, including those by Brorson et al (4,6) and others (7,16,21) did not observe evidence of damaged lymphatics following the procedure. On the contrary, they found improved lymphedema-related symptoms and function. The findings from these surgical studies directly contradict the viewpoints that liposuction has an adverse effect on lymphatics.

The above-mentioned conflicting opinions and equivocal literature prompted the conception of our study. In recent years, indocyanine green lymphography (ICGL) has emerged as a simple and easy imaging modality for superficial lymphatic imaging (11,22-24). ICGL has sensitivity surpassing that of the conventional technetium-based lymphoscintigraphy (25). By using a fluorophore instead of a radioactive isotope, it spares patients from deleterious radiation and making the modality suitable for repeated performance required for longitudinal outcome tracking. On ICGL, healthy, functioning lymphatic channels emerge as a "linear" pattern while areas with lymphatic obstructions and/or unfavorable lymphatic pressure gradient manifest as dermal backflow patterns (26-28). The distribution, the extent of, and the specific type of dermal backflow pattern (splash, stardust, diffuse) denote disease severity.

With ICGL, we did not find any evidence of worsened lymphatic drainage following liposuction. No patient had increased dermal backflow and none showed up-staging of the pre-existing dermal backflows (e.g., splash turning into stardust/diffuse, stardust turning into diffuse). This lymphographic finding correlated well with PRBO and LYMQOL – none reported worsened pre-existing lymphedema symptoms or decrease in appearance/function/mood/overall quality of life.

Interestingly, in addition to not finding liposuction worsening lymphatic function on ICGL, we found lymphographic evidence of improved lymph drainage post-liposuction. All patients showed lymphographic changes suggestive of improved lymph transit. These changes included the emergence of previously non-existing linear pattern, an extension of pre-existing linear pattern, shrinkage of dermal backflow patterns, and down-staging

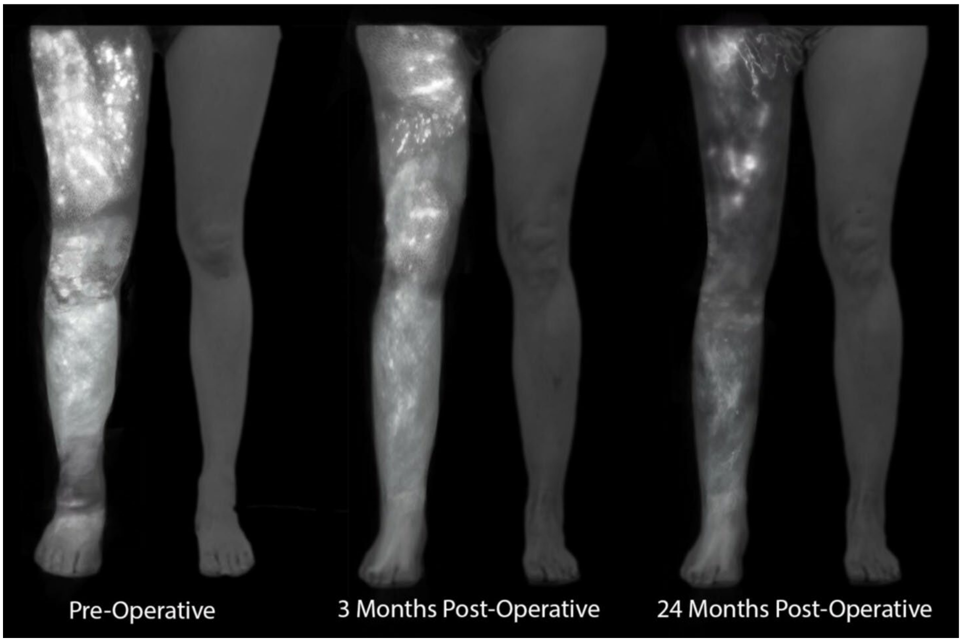

Fig. 5. Serial ICG lymphographic improvement seen in this patient over two years. At 3-months (middle), improved lymphatic function can be seen as reduced stardust and partial down-staging from stardust to splash pattern. Further improvement was evident in the 24-month study (right), showing dissipation of stardust and emergence of linear patterns.

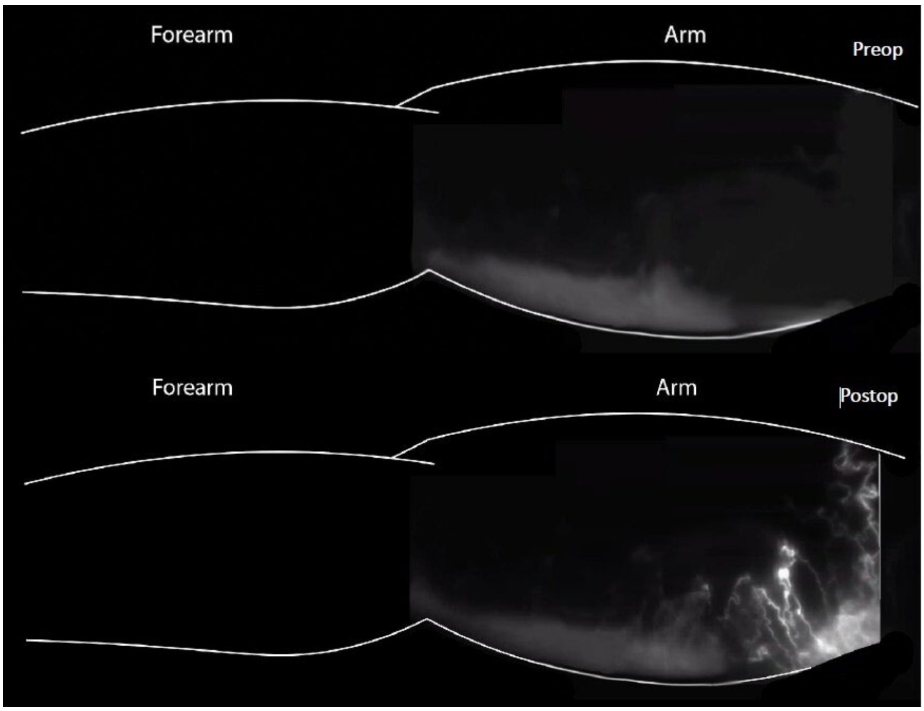

Fig. 6: Newly emerged lymphatic precollector signals seen in 6-month ICGL (bottom) after liposuction compared to pre-operative image (top).

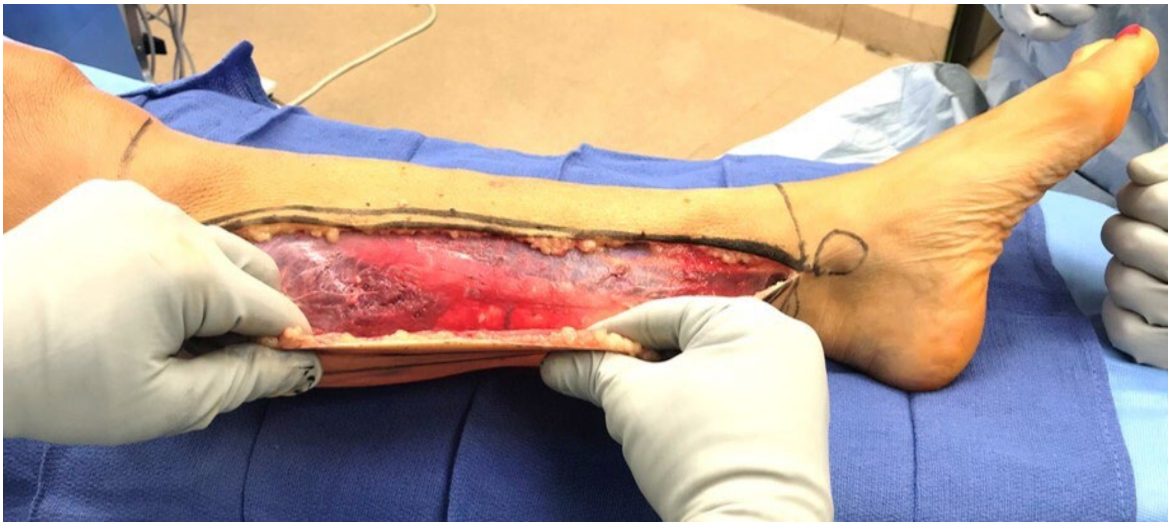

Fig. 7: Surgical endpoint of lymphedema liposuction. We concluded liposuction when 1) normal anatomic contour had been achieved, or 2) the dense fibrosis prevented further tissue retrieval.

of pre-existing dermal backflow patterns. Furthermore, the ICGL improvements in all patients were found to be trends of improvement, instead of being a one-time isolated occurrence. In all patients, following the initial documented ICGL improvement, further ICGL improvements were confirmed during their subsequent follow-ups. The progressive improvement in lymph transport suggested by ICGL was corroborated by PRBO and LYMQOL. Both PRBO and LYMQOL also demonstrated postoperative trends of improvement.

Lymphatic supermicrosurgeons may take advantage of the consistent post-liposuction improvement in lymphatics in treatment planning. The newly emerged linear pattern can be recruited to build lymphaticovenular anastomosis (LVA) later, if needed. The senior author has successfully performed LVA in patients with advanced solid-predominant lymphedema with elephantiasis using this approach (29).

The origin of the newly emerged lymph vessels seen on ICGL is uncertain. It is uncertain whether they represented recanalization of preexisting, previously non-functioning lymph vessels, or whether they were the result of in vivo lymphangiogenesis. One hypothesis we have already refuted is that the newly emerged lymph vessels represented the deep lymph vessels that existed deeper than the 2-cm effective ICGL surveillance range and therefore were not detected by ICGL preoperatively. First, if this were the case, all newly emerged lymph vessels should have been observed at the initial 3-month follow-up. Instead, in all 6 cases, they were observed at 6-months postoperatively. Second, we performed liposuction by removing deeper tissues, preserving 1 - 2 cm of subdermal fat *(Fig. 7*). This means the new linear patterns developed in this thin, superficial layer of fat, which was already adequately evaluated by ICGL prior to surgery.

The finding of our study using PRBO, LYMQOL, and ICGL to assess the lymphatic function pre- and post-liposuction is three-fold. First, liposuction does not worsen lymphatic drainage in lymphedema patients. Second, not only does liposuction not cause observable adverse effects, but it also paradoxically improves lymphatic function. Third, the post-liposuction improvement in lymphatic function was progressive — it got better with time. This three-fold finding is counterintuitive but unequivocally demonstrated. It should help lymphedema surgeons in treatment planning when considering the longstanding controversy of reconstruction-first/debulking-later vs debulking-first/reconstruction-later. It does raise one mildly vexing question — If liposuction, a debulking procedure, improves lymphatic function, then how does it compare to physiologic procedures such as lymphaticovenular anastomosis and lymph node transfer whose sole functions are to improve lymphatic function?

CONFLICT OF INTEREST AND DISCLOSURE

All authors declare no financial interests in any of the products, devices, or drugs mentioned in this manuscript.

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