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ORIGINAL ARTICLE

Free lymph node flap transfer and laser-assisted liposuction: a combined technique for the treatment of moderate upper limb lymphedema

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Abstract Upper limb lymphedema following breast cancer surgery is a challenging problem for the surgeon. Lymphatico-venous or lymphatico-lymphatic anastomoses have been used to restore the continuity of the lymphatic system, offering a degree of improvement. Long-term review indicates that lumen obliteration and occlusion at the anastomosis level commonly occurs with time as a result of elevated venous pressure. Lymph node flap transfer is another microsurgical procedure designed to restore lymphatic system physiology but does not provide a complete volume reduction, particularly in the presence of hypertrophied adipose tissue and fibrosis, common in moderate and advanced lymphedema. Laser-assisted liposuction has been shown to effectively reduce fat and fibrotic tissues. We present preliminary results of our practice using a combination of lymph node flap transfer and laser-assisted liposuction. Between October 2012 and May 2013, ten patients (mean 54.6±9.3 years) with moderate (stage II) upper extremity lymphedema underwent groin or supraclavicular lymph node flap transfer combined with laser-assisted liposuction (high-power diode pulsed laser with 1470-nm wavelength, LASEmaR 1500-EUFOTON, Trieste, Italy). A significant decrease of upper limb circumference measurements at all levels was noted postoperatively. Skin tonicity was improved in all patients. Postoperative lymphoscintigraphy revealed reduced lymph stasis. No patient suffered from donor site morbidity. Our results suggest that combining laser liposuction with lymph node flap transfer is a safe and reliable procedure, achieving a reduction of upper limb volume in treated patients suffering from moderate upper extremity lymphedema.

Keywords Breast cancer · Breast cancer-related lymphedema · Laser · Laser lipolysis · Liposuction · Lymphedema · Lymph node · Lymph node transfer · Lymph node flap · Lymph · Lymphedema treatment · Quality of life

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Introduction

Breast cancer is the most common cancer in women. One of every eight women will suffer from the disease at some stage in life [1]. Breast cancer-related lymphedema (BCRL) of the upper limb is a well-recognized medium to long-term complication related to breast cancer surgery, particularly when axillary lymph node clearance and irradiation are included as part of the treatment. The incidence of postmastectomy lymphedema is reported to be as high as 9–41 % following axillary dissection [2–5] and 4–10 % following sentinel lymph node biopsy for breast cancer [5–7]. The affected patients develop chronic accumulation of interstitial fluid (lymph) resulting in fibro-adipose tissue proliferation and deposition as well as nonpitting edema. The excess of tissue and fluid causes pain and anxiety, affects the patient's daily activities, decreases function due to heaviness, leads to body image disturbance, and has significant, measureable effects on quality of life [8]. Conventional treatment for chronic lymphedema includes exercise and elevation, manual lymphatic drainage, and static compression garments. Conservative treatment aims to alleviate symptoms and is potentially most effective in early-stage lymphedema (International Society of Lymphology stages I and II) but can also be uncomfortable, restrictive, and time-consuming [9]. Patients with late-stage, pronounced, nonpitting lymphedema do not respond to conservative treatment because of the significant fat hypertrophy and fibrosis; thus, surgical procedures are necessary [10]. Liposuction of lymphedematous tissue was introduced in 1989 [11] and has been shown to be effective in the treatment of late-stage disease but can be a laborious procedure. Laser lipoplasty using a pulsed Nd:YAG laser has routinely been used for cosmetic body contouring. Histological analysis indicates that laser causes small vessel coagulation, destruction of fat cells, and subsequent reorganization of collagen in the dermis [12, 13].

With the advancement of microsurgical techniques, restoration of lymphatic channel continuation can be achieved. Although lymphatico-venous anastomoses have produced good results for early-stage disease in carefully selected lymphedema patients, long-term results are less promising, probably due to vessel re-obstruction [14]. Lymph node transfer was first tested in the canine model [15], and more recent clinical studies in humans have demonstrated good early results as well as long-term postoperative activity of the transplanted nodes [16, 17].

The purpose of this study is to demonstrate the effectiveness of laser liposuction in combination with lymph node flap transfer to treat moderate-stage upper limb lymphedema. We advocate the combination of both a debulking procedure (laser liposuction) to reduce tissue load as well as a physiologic, reconstructive procedure (lymph node flap transfer) to restore lymphatic absorption and channeling.

Patients and methods

A consecutive group of ten female patients suffering from moderate BCRL following modified radical mastectomy, axillary lymphadenectomy, and chemo-radiotherapy was treated between October of 2012 and May of 2013, at the Plastic and Reconstructive Surgery Department of China Medical University Hospital in Taichung (Taiwan).

The inclusion criteria for lymph node flap transfer combined with laser liposuction were as follows: insufficient edema reduction following 6 months of conservative treatment, including exercise, diet, arm elevation, and compression garments; stage II International Society of Lymphedema disease (15 % greater circumference than the normal limb) with repeated episodes of cellulitis and lympho-scintigraphically confirmed proximal lymphatic obstruction; previous axillary excisional surgery procedures; no acute cellulitis or unhealed wounds; and no medical or family history of coagulation disorders or on medications affecting coagulation. Exclusion criteria were as follows: regional recurrence of breast cancer, distant metastases, or brachial plexus neuritis. Ten patients (mean age 54.6±9.3 years) with moderate upper extremity lymphedema initially underwent lymph node flap transfer followed by laser liposuction 1 to 3 months later. All patients had significant edema of the forearm and arm. The Declaration of Helsinki protocol was followed, and preoperatively, all patients gave informed consent for surgery. A local ethics committee approved the study as well as data analysis. Data storage was performed in consistence with good clinical practice (GCP) guidelines.

Patient evaluation

Preoperative assessment included photography and serial measurements of limb circumference at 10 cm above and below the elbow of both the normal and lymphedematous arms. All clinical measurements were taken preoperatively, 3 and 6 months postoperatively by the same assistant. Photography was used for comparative preoperative and postoperative clinical assessment.

Skin tonicity was measured using the DermaLab Combo device (Cortex Technology, Hadsund, Denmark). The device measures the amount of skin retraction following the application of negative pressure as an indicator of skin elasticity. Retraction time is defined as the time in seconds that it takes for the skin to retract 1.5 mm from full elevation. This is displayed as an elasticity score ranging from 0 to 99 where a high score represents a very elastic skin. The probe was positioned 10 cm below the cubital fossa.

Preoperatively and at 6 months postoperatively, lymphoscintigraphy was performed using a intradermal injection of technetium-99 m phytate at the second web space of both hands, to demonstrate the postoperative activity of lymph clearance through the transferred nodes. Two physicians interpreted the lymphoscintigrams independently. The histological effects of laser on subcutaneous lymphedema tissue were evaluated comparing biopsy specimens obtained before, during arm liposuction, and at 6 months postoperatively.

Patient satisfaction at follow-up was classified as poor, fair, good, or excellent, using a standardized questionnaire. Measurements were presented as the mean, standard deviation, and range. Differences were assessed using the Student's *t* test for paired observations; $p<0.050$ was considered significant. All calculations were done using SPSS V 20 for Mac OS X (IBM SPSS Statistics).

Donor lymph node flap harvest

The lymph node flap donor site area selected was either the supraclavicular or groin region. We harvested the supraclavicular lymph node flap from the right side of the neck in order to avoid iatrogenic injury to the thoracic duct on the contralateral side. If the right upper limb was involved, we avoided harvesting nodes from the ipsilateral side of the neck and groin nodes were harvested instead. The anatomical landmarks to harvest the supraclavicular lymph node flap are those of the posterior triangle of the neck and include the clavicle inferiorly, the sternocleidomastoid muscle anteriorly, and the trapezius muscle posteriorly [18]. A skin island is marked obliquely to the axis of the sternocleidomastoid muscle, over the posterior triangle, approximately 7×4 cm in size [19]. Following skin incision, the dissection progresses at the posterior border of the sternocleidomastoid muscle and the external jugular vein (EJV) is encountered and included in the flap. A deep dissection is carried out to identify the omohyoid muscle, which is preserved and reflected cephalad. The dissection then proceeds deep to the muscle until the transverse cervical artery (TCA) is visualized. Usually, the artery runs postero-laterally toward the trapezius muscle, deep to the omohyoid muscle, and superficial to the anterior scalene muscle and the brachial plexus within the fibro-adipose tissue of the supraclavicular fossa. After identification of the TCA and its vena comitant (TCV), the dissection progresses posteriorly in a plane superficial to the anterior scalene muscle. A careful dissection will ensure that the artery is not separated from the overlying fibro-adipose tissue, which includes the lymph nodes. Most of the lymph nodes are located deeply in close proximity to the internal jugular vein. The superficial cervical vein (SCV) is also included within the flap, and its location is constant and present postero-lateral and superficial to the TCA.

The vascularized groin lymph node flap is harvested with an elliptical skin paddle measuring 6×4 cm [20]. The flap is designed with its long axis parallel and inferior to the inguinal ligament and medial to the sartorius muscle. The skin is incised superiorly, and the dissection proceeds from lateral to medial, just superficial to the sartorius fascia. Most of the lymph nodes harvested (superficial, transverse group) are located in the fibro-adipose tissue in close proximity to the femoral artery. The flap is carefully dissected including the superficial circumflex iliac artery (SCIA) and vein and one more superficial vein. The donor site of the flap is closed primarily resulting in a linear scar, hidden in the supraclavicular or groin area.

Recipient site selection and preparation

There are several reasons for selecting the ulnar and volar side of the wrist as the recipient site for a lymph node flap transfer. As the most dependent site of the upper limb, the wrist is the ideal location for lymph collection by the transplanted nodes. The volar side is selected because flexion of the wrist joint acts as a pump to promote flow within the vessels and also conceals the bulky nodes to a degree, offering an acceptable cosmetic result. The radial artery is anatomically consistent, and its palmar carpal branch or superficial palmar branch is an ideal recipient vessel for the anastomosis. A transverse incision is made on the volar wrist, and fascio-cutaneous skin flaps are elevated. The palmar branch of the radial artery is identified and anastomosed end to end or end to side to the flap artery (SCIA or TCA) [21]. The veins prepared as recipient vessels are usually the concomitant vein of the radial artery and a second superficial vein dissected on the volar region of the wrist. To avoid compression to the pedicle and to cover the exposed fibro-adipose tissue, the lymph node flap can also be covered with a thin split-thickness skin graft, if necessary.

Laser liposuction

The lymph node transfer is performed first, and patients are closely monitored to ensure primary wound healing and avoid flap loss, partial or total. The laser liposuction procedure of the affected limb is planned 1 to 3 months later, according to the patient's desire and hospital stay. Staging treatment allows for a period of time for the transferred lymph nodes to commence filtering and avoids compression of the flap pedicle during solution infiltration for liposuction, at the same time as the anastomosis. A tumescent solution was infiltrated composed of 1000 ml of saline and 1.5 mg/kg of mepivacaine with epinephrine. All patients received cefazolin intravenously at induction and again postoperatively. Following arm exsanguination, an upper arm tourniquet was applied.

Laser-assisted liposuction was performed using a high-power diode pulsed laser with 1470-nm wavelength,

Table 1 Measurements of upper limbs before and 6 months after operation

Measurements of upper limbs before and after operation

Pz *n*	Age (years)	Circumference measurements Controlateral arm	Lymphedematous arm preop	Lymphedematous arm postop (6 months)	Controlateral forearm	Lymphedematous forearm preop	Lymphedematous forearm postop (6 months)
cm, mean							
	54.6	26.9	32.9	30.5	23	28.5	25.7
10							
±SD	±9.3	±1.9	±1.6	±1.6	±1.7	±3	±2.4
Range	35–67	24–30	30–35	28–33	21–26	23–33	22–30
Significance			$p<0.0001$			$p<0.0001$	

LASEmaR 1500 (EUFOTON, Trieste, Italy). The laser light is conveyed through microcannulas with a diameter of 1 mm into which an optical fiber of 300 μm is inserted. A 15 Watt, 10 msON, 20ms OFF microseconds-long pulsed Laser and 150 mJ was used for all cases. A small incision in the skin was made using a no. 11 blade, and the cannula was inserted into the subcutaneous adipose tissue layer. With the laser on, the cannula was repeatedly passed using back and forth movements throughout the deep hypertrophied adipose layers to achieve the required lypolytic effect and in both the supra-fascial and the fibrotic sub-dermal layers to cause dermal tightening and skin retraction (Video 1). Aspiration of the liquefied adipose tissue was performed using a traditional liposuction cannula. The previously transferred lymph node flap was carefully preserved. We used the laser liposuction device with caution in the axillary region to release the scar contracture when present. Special care was taken to deliver laser energy and heat in a homogeneous way within the lymphedematous adipose layer and maintain a constant speed of the cannula's movements along the treated area. This was achieved by controlling motion in a fan-like pattern and by careful depth positioning of the cannula, observing the beam transillumination. We stopped when the required contour enhancement was achieved, and skin incisions were not closed to allow fluid drainage. Patients were instructed to wear an elastic compression garment for 2 to 4 weeks.

Results

Ten patients with moderate upper limb lymphedema were treated at our institution between October 2012 and May 2013. The mean age of our patient population was 54.6± 9.3 years at the time of surgery (range, 35 to 67 years); all were female. Complete survival was noted for ten lymph node flap transfers. We utilized the groin as a donor site for lymph nodes in six patients and the supraclavicular basin for the other four. At 6 months follow-up, reduction in arm circumference was measured at a mean rate of 30.5 cm (±1.6 cm) range 28–33 cm (90 % improvement compared to preoperatory measurement), and reduction in forearm circumference was a mean 25.7 cm (±2.4 cm) range 22–30 cm (93 % improvement compared to preoperatory measurement). Data are summarized in Table 1. Skin tonicity at 6 months after treatment was a mean rate of 81.5 (±10) range 64–95 (202 % improvement compared to preoperatory measurement). Skin tonicity results are summarized in Table 2. Mean reduction rate of the lymphedematous limb circumference was found to be statistically significant between the preoperative and postoperative groups ($p>0.01$). Indicative clinical results are shown in Figs. 1, 2, and 3. Postoperative lymphoscintigraphy demonstrated minimal to moderate dermal backflow present compared to the preoperative scan, as well as decreased stasis, a clear improvement. A relatively weaker radio-colloid accumulation was evident in the transferred nodes, and a more rapid movement of the tracer was noticed along the arm, indicating improved lymphatic clearance. Indicative images of lymphoscintigraphy are shown in Fig. 3d, e. No wound infections or other short- or long-term donor site complications at either the supraclavicular or groin areas were noted. Both donor site area scars could be well hidden by clothing (Fig. 4a, b). Tissue samples taken from the lymphedematous limb for histological testing preoperatively, immediate postoperatively, and 6 months later revealed a change in histological features (Fig. 5a–c). Most importantly, well-organized adipose cells and collagen fibers similar to those found in healthy tissue were noted postoperatively (Fig. 5c). All patients who underwent lymph node flap transfer and laser liposuction were satisfied with the improvement in limb size and functional outcome. Postoperative physiotherapy was continued as routine in all patients. Compression garments were used for at least 1 month following the liposuction procedure. Five patients (50 %) underwent debulking of the lymph node flap 6 months postoperatively to achieve a better wrist contour and cosmesis [22].

Table 2 Measurement of skin tonicity before and 6 months after operation

Measurements of upper limbs before and after operation

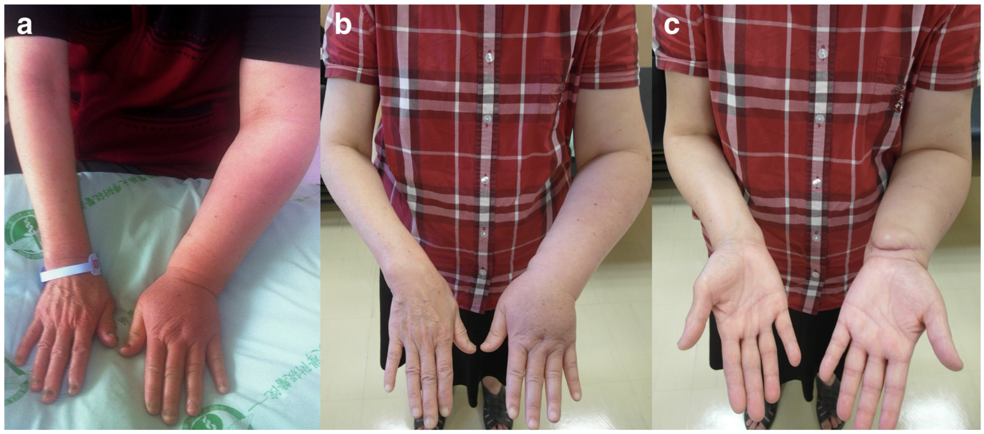
Pz		Skin tonicity		
		Controlateral arm	Lymphedematous arm preop	Lymphedematous arm postop (6 months)
n				
	Mean	96.9	40.3	81.5
10				
	±SD	±0.9	±11	±10
	Range	96–98	23–65	64–95
	Significance	$p<0.0001$		

Discussion

Recent studies indicate that the pathophysiology of BCRL is more complicated than a simple obstructive event at the axilla and several other pathophysiological features complicate the lymphedema development process [23–25]. This explains the variety of surgical procedures proposed to treat lymphedema and their relative success. The main principles of surgical treatment for extremity lymphedema include excising the scar contracture when present, reducing the lymphatic load, and, most importantly, re-establishing a lymph drainage pathway. Development of microsurgery was crucial to allow the restoration of lymphatic channel continuity. O'Brien et al. [26] first described microsurgical lymphatico-venous anastomoses. Those were proven to be patent and functional initially but, in many cases, occluded eventually due to the elevated subcutaneous and/or intramuscular pressures in the long term [14]. Medgyesi S [27] reported good outcomes using a

Fig. 1 Patient 1. **a** Preoperative photo. **b**, **c** Immediately after laser liposuction. Lymph node flap transfer was performed 1 month before. **d**, **e** Postoperative photo at 6 months follow-up and lymph node debulking. **f** Postoperative photo at 6 months follow-up

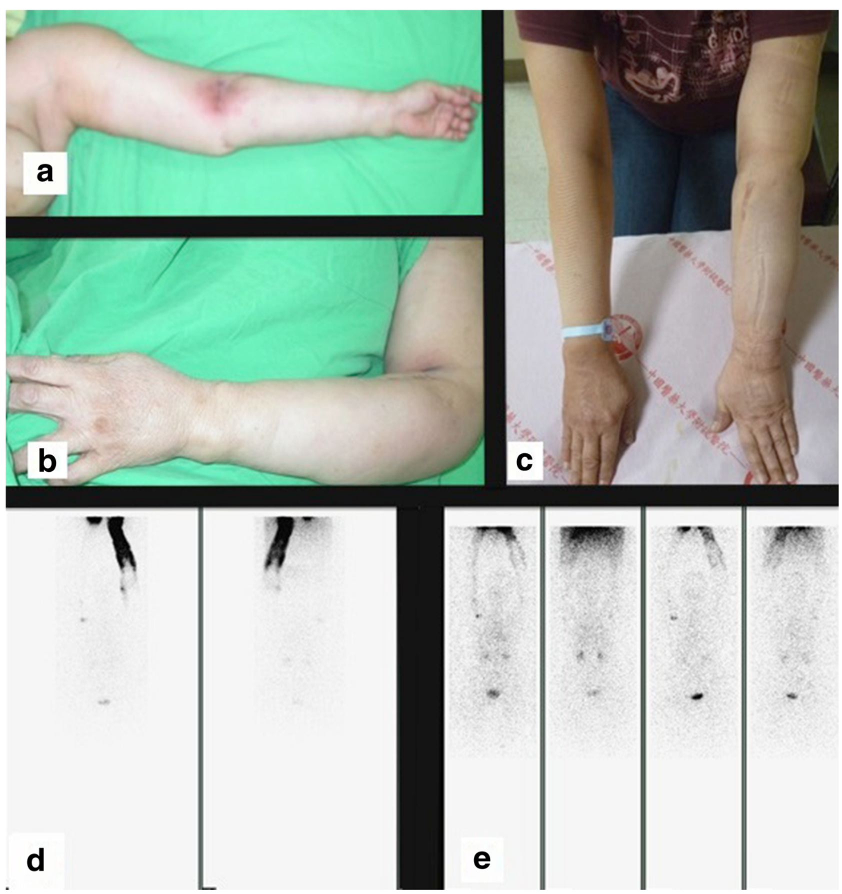
Fig. 2 Patient 2. **a** Preoperative photo. **b** Postoperative photo, volar side at 6 months follow-up. **c** Postoperative photo, dorsal side at 6 months follow-up



myocutaneous flap, Slavin SA et al. [28] investigated treating lymphedema using free tissue transfer, and Chen HC [15, 16, 18, 20] introduced the concept of a free lymph node flap. Among the possible mechanisms explaining the benefit of free tissue transfer is that vascularized tissue has the inherent potential to restore lymphatic flow by promoting angiogenesis and lymphatic regeneration [29]. Evidence exists of the presence of lymphangiogenic growth factors promoting lymphatic vessel regeneration and lymph node function following free lymph node transfer [30].

Furthermore, the lymph nodes transferred are thought to function as an internal pump and suction mechanism offering a new pathway for lymphatic drainage for the limb. The hand instead of the axilla is usually at the dependent position of the upper extremity. Free node flap transfer placement on the volar site of the wrist offers an ideal position for this potential "pump action" to be enhanced, as a result of the continuing movements of the joint. Relatively high-pressure flow from the arterial anastomosis at the palmar branch of the radial artery provides a strong hydrostatic force into the lymph node

Fig. 3 Patient 3. **a**, **b** Preoperative photo. In evidence of the pitting lymphedema. **c** Postoperative photo, at 6 months follow-up. **d** Preoperative lymphoscintigraphy. **e** Postoperative lymphoscintigraphy at 6 months follow-up



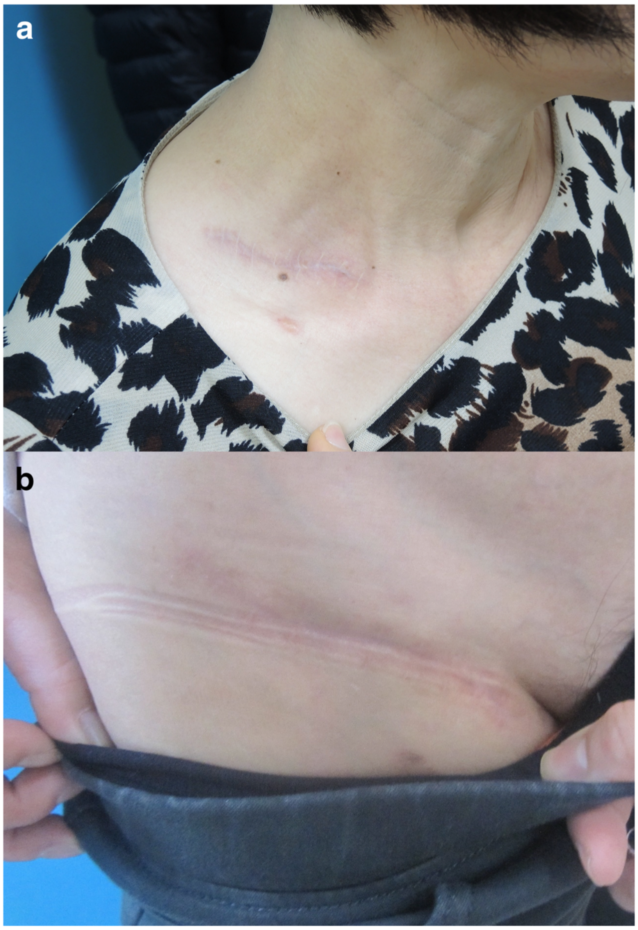


Fig. 4 Donor site closure. Both donor site area, supraclavicular **a** and groin **b**, resulted in a well-hidden scar

flap. This "suction effect" is supported by the low-pressure venous drainage provided by the vein, further enhancing lymphatic flow [20].

Furthermore, we usually perform two vein anastomoses, one of the deep system and one of the superficial system, in order to maintain a connection of the two circulatory systems and to achieve better drainage. There is published evidence that free lymph node flap transfers improve postmastectomy lymphedema by reducing the lymph overload and by stimulating the regeneration of lymphatic vessels [17, 18, 20]. However, it has been our experience that the transfer of a lymph node flap alone is not particularly effective in advanced stage lymphedema which is characterized by an element of fibrosis. Liposuction has been used to remove the nonfunctional, impaired fibro-fatty tissue accumulated, to reduce the lymphatic load, and to debulk the lymphedematous arm [11, 31, 32]. It is an effective method to remove the hypertrophied fibro-adipose tissue and accumulated lymph fluid with good cosmetic and functional results but remains controversial due to the risk of disruption of residual lymphatic channels [31, 33]. There is some evidence that the diffuse superficial (near dermal) lymphatic activity observed in early disease stages indicates a collateral route of enhanced drainage along the skin/subcutis while the cutaneous collateral lymphatic channels increase in capacity to drain the swollen limb [24, 26, 33]. The eventual disruption of dermal and subcutaneous lymphatic channels may contribute to established, large volume, postmastectomy lymphedema.

Furthermore, liposuction effectiveness is limited to nonpitting lymphedema and patients need to continue wearing compression garments, as liposuction alone will not reduce the future tendency of recurrent lymphedema and subsequent re-accumulation of subcutaneous fat. The continuous use of compression bandages is one of the major factors limiting the quality of life of lymphedema patients [8]. In our study, patients have worn compression garments continuously for approximately a month following laser liposuction. After that time, they were advised to use a compression garment only at night, in an attempt to compromise garment fatigue with risk of recurrent edema. Recent studies have noted that lymph node transfers promote the regeneration of lymphatic vessels 3 months following the implantation, helping to decreasing the limb circumference [18, 30]. The potential benefit of lymphatic network regeneration could indicate potential for the use of this microsurgical technique in presence of pitting lymphedema and in combination with excisional procedures [34–36].

To improve the effectiveness of liposuction, achieve better results, and reduce complications, the authors used laser lipolysis. To our knowledge, this is the first report of laser lipolysis used to treat chronic lymphedema. Laser liposuction is a well-

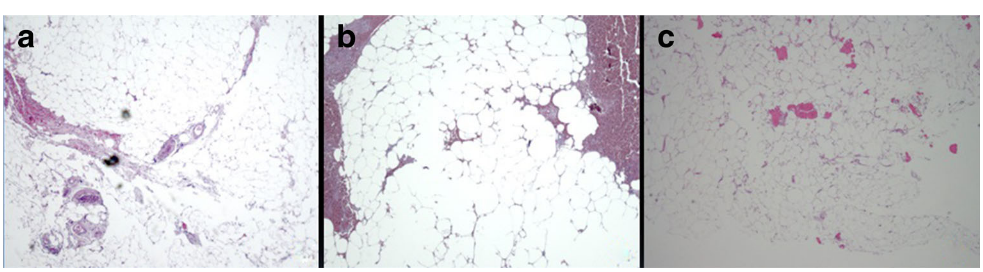


Fig. 5 Histological findings. **a** Specimen harvested during the first treatment. Large quantity of fibrotic tissue and adipocytes. **b** After laser liposuction: coagulation of small vessels, rupture of human adipocytes, and degeneration of collagen. **c** Specimen harvested after 6 months of the second treatment. Subsequent reorganization of fat cells and collagen in the reticular dermis

established technique in aesthetic surgery and less-invasive body contouring procedures. Specifically for lymphedema patients, advantages of this technique over conventional liposuction include the easier penetration of the cannula in the fibro-adipose-lymphedematous tissue (Video 1), a more potent single-stage fibro-lipolysis, and higher heat levels produced. This results in tissue shrinkage, skin tightening and subsequent tissue contraction, concurrent rupture of human adipocytes, degeneration of collagen, and blood vessel coagulation, as shown in the Fig. 5b. Due to its wavelength at 1470 nm, the laser is preferentially absorbed by water and fat. This translates to preferential fat liquefaction using relatively low power with limited thermal diffusion and collateral damage to the surrounding tissues. Furthermore, laser-assisted liposuction produces small channels through tissue measuring less than 1 mm in diameter and results in a less aggressive mechanical tissue penetration. Due to its minimally invasive characteristics, laser liposuction is more likely to avoid damage to any adjacent lymphatics and thus spare the lymphatic drainage still occurring via the superficial dermal route. At long-term follow-up, laser liposuction was shown to have stimulated the production of new healthy tissue by promoting reorganization of adipose cells and collagen in the reticular dermis as shown in Fig. 5c. Laser liposuction treatment can potentially be repeated in severe edema cases or cases of edema recurrence. Finally, we used laser liposuction to release the sometimes significant axillary scar present after axillary dissection. Using a small peri-axillary approach, it is possible to introduce the thin laser cannula into the fibrotic bands of the scar and gently create microchannels to release localized heat, which dissolves the fibrotic contracture.

Conclusion

We present our experience of treating BCRL of the upper limb with free lymph node flap transfer and laser-assisted liposuction in a series of patients. Our preliminary results are very promising. We found that both components of the procedure, lymph node flap transfer and laser liposuction, are safe and reliably improve the lymphedema burden. The strategy to combine these two treatment modalities to improve outcome offers an ideal option for the treatment of patients who suffer from moderate-stage lymphedema after mastectomy and axillary dissection. These patients will be followed up further, and long-term outcomes will be reported.

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Conflict of interest The authors have no relevant financial interest in this article.

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