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Preoperative ultrasound evaluation for lymphaticovenous anastomosis surgery in advanced breast cancer-related lymphedema

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Abstract

Aim: Lymphaticovenous anastomosis (LVA) is the mainstay for treating breast cancer-related lymphedema (BCRL). Preoperative ultrasonography is useful to assess the locations and characteristics of lymphatics and veins to improve LVA success remarkably even in cases of advanced BCRL. Aim: The aim of the study was to describe the use of ultrasonography to reliably map suitable lymphatics and veins and successfully perform LVA surgery in cases of advanced BCRL.

Method: This retrospective cohort study included 41 cases of BCRL who underwent LVA surgery using preoperative ultrasound to map and characterize lymphatics and veins. Cases were analyzed for the following: (1) whether preoperative ultrasonographic detection of both lymphatics and veins correlate to actual intraoperative findings and (2) improvement in mean limb circumference measurements at 1 and 3 months of follow-up in this patient cohort.

Results: For 155 LVA incisions, 212 LVA procedures were performed. Among them, 133 (62.7%) lymphatics and 196 (92.4%) anti-reflux veins were successfully detected and characterized on preoperative sonography. Mean preoperative circumference at the wrist, 10cm below elbow, elbow, and 10cm above elbow were 18.86 cm, 27.79 cm, 29.75 cm, and 33.77 cm, respectively. The mean measurements improved at 1 month correspondingly to 17.14 cm, 24.86 cm, 26.91 cm, and 30.50 cm (9.12%, 10.54%, 9.54%, 9.70% improvement, respectively), and at 3 months to 16.59 cm, 24.28 cm, 26.55 cm, and 30.05 cm (12.02%, 12.63%, 10.73%, 11.02% improvement, respectively). For each individual patient, their four measured circumferences were also added to obtain the Total Circumference (TC). The TC ranged from 89-135 cm (mean 109.46 cm) preoperatively, 83.5-129.5 cm (mean 98.74 cm) 1-month post-op, and 80.5-128 cm (mean 96.55 cm) 3 months post-op. Compared to the preoperative value, each patient had a TC decrease of 2.79%-20.35% (mean 9.80%) at 1-month post-op and 4.39-28.30% (mean 11.80%) at 3 months post-op. These differences were all statistically significant (P < 0.0001).

Conclusion: Preoperative ultrasonography is a useful adjunct to detect lymphatic vessels and anti-reflux veins, thereby increasing the chances of successfully performing LVA surgery even in cases of advanced upper limb lymphedema. It can contribute to long-lasting outcomes.

Keywords: Advanced breast cancer-related lymphedema, lymphaticovenous anastomosis/bypass, upper limb lymphedema, BCRL

INTRODUCTION

Secondary lymphedema of the upper limb is an unfortunate complication of breast cancer lymphadenectomy and radiotherapy. Statistics from the World Health Organization showed that, in 2020, 2.3 million new diagnoses of breast cancer were confirmed in patients worldwide, making it the most prevalent cancer globally. In this huge patient population, the incidence of lymphedema was 21%[1]. Thus, a staggering number of patients are affected by this chronic and debilitating condition.

Supermicrosurgical lymphaticovenous anastomosis (LVA) has emerged in the past two decades as a mainstay of surgical treatment for refractory lymphedema[2-7]. This physiologic procedure attempts to bypass the lymphatic obstruction by draining the engorged lymphatic collectors into subcutaneous veins. LVA surgery is well-tolerated and minimally invasive, requiring a small skin incision. It is crucial to plan the location of this incision preoperatively so that both lymphatic collectors and subcutaneous veins can be assessed.

Various modalities allow the mapping of lymphatic vessels preoperatively, including lymphoscintigraphy, magnetic resonance lymphography, and fluorescence imaging[8,9]. Of these, fluorescence imaging using near-infrared light and indocyanine green (ICG) is arguably the most popular and clinically useful method, allowing real-time imaging and mapping of lymphatics[10,11]. However, its limitations are apparent in severe cases of lymphedema. The presence of stardust or diffuse ICG lymphography patterns in advanced lymphedema may deter the consideration of LVA surgery, despite the potential presence of functional or patent lymphatics in these areas[12]. Furthermore, these overlying dense dermal backflow patterns mask the lymphatics underneath and impair efforts to locate them accurately[13].

Ultrasonography for preoperative lymphatic mapping in LVA surgery is a new approach. Literature on the pioneering works of surgeons in Japan details the ultrasonographic visualization of lymphatics of the lower limb[14-17]. However, to our knowledge, there is no article available on ultrasonographic evaluation of lymphatics in upper limb lymphoedema, where the lymphatics are smaller and more difficult to detect with conventional means, especially in cases of advanced lymphoedema. Ultrasonography has the additional benefit of being able to map subcutaneous veins, which is evident in its remarkable performance in cases of difficult venous access[18-21].

Preoperative imaging and evaluation is crucial. Having a single modality that can accurately assess both lymphatics and subcutaneous veins in real time can allow pertinent placement of skin incisions at the most suitable locations, thus greatly improving the chances of success of LVA. The aim of this study is two-fold: (1) to describe the use of ultrasonography, with ICG lymphography as an adjunct, to reliably map suitable lymphatics and subcutaneous veins and successfully perform LVA surgery, even in cases of advanced upper limb lymphedema and (2) to evaluate the results of LVA surgery in this patient cohort.

METHODS

This was a retrospective study conducted at the Division of Plastic and Reconstruction Surgery, Department of Surgery, E- DA Cancer Hospital, Kaohsiung City, Taiwan, China. Between November 2019 and August 2023, all patients with upper limb lymphedema were identified. Those who did not have breast cancer-related lymphedema (BCRL), who did not undergo LVA surgery, or those with mild disease (International Society of Lymphology grade (1) were excluded from the study.

Patients' demographic data and operative information were collected. Preoperative sonographic detection and characterization of lymphatics and veins were corroborated with intraoperative findings to determine the accuracy of ultrasonography as an imaging modality. For an objective assessment of the effects of LVA, the arm circumferences of patients were measured at four points: at the wrist, 10 cm below the elbow, at the elbow, and 10 cm above the elbow. These circumferences were also added together to obtain a Total Circumference (TC) value for each patient. These measurements obtained preoperatively were compared against those made at 1 month and 3 months after surgery. Statistical analysis of these two sets of results was performed using the paired sample *t*-test.

ICG lymphography

ICG lymphography was performed on the evening before surgery. Briefly, ICG was diluted to a concentration of 2.5 mg/mL, and injected intradermally into the web spaces of each patient's hand and at the wrist. Several minutes after the injection, ICG uptake within functional lymphatic collecting vessels was detected using the Mitaka Hamamatsu pde-neo II® system. As ICG traveled proximally, its course was traced and marked on the skin. ICG lymphography was repeated the next morning before surgery to reaffirm previous markings and chart new tracts that were missed. Areas with dermal backflow patterns were also marked.

Ultrasonography

Ultrasonography was performed preoperatively in all patients using a commonly available ultrasound machine, Sonosite X-Porte ultrasound®, with 18 MHz and a flat probe. The depth of view was adjusted to 3.1 cm to centralize the view on the subcutaneous fat layer. Color Doppler mode was used, with the flow detection level set at 3 to -3 cm/s, corresponding to the average blood flow rate in subcutaneous veins. The probe was placed axially on the lymphedematous limbs, perpendicular to the expected long axis of the lymphatics and veins. Care was taken to minimize the pressure of the probe on the skin to avoid artificial deformation of the underlying vessels. The first regions to be assessed were those where ICG lymphography demonstrated linear patterns. Thereafter, if the limb only revealed dense dermal backflow patterns, attention was turned to areas more commonly showing a higher density of lymphatics, such as the dorsal and ventral surfaces of the wrist, ulnar aspect of the forearm, and medial aspect of the upper arm. Assessment of both lymphatic vessels and subcutaneous veins was performed and the planned skin incisions were placed strategically.

Lymphatic vessels

Using ultrasonography, the radio-opaque superficial fascia was first identified at a depth of approximately 1 cm from the skin surface. Lymphatic vessels are often found at the highest density just deep to this fascia. Patent lymphatics appear as round, elliptical, or flat and spiculated hypo-echoic structures, representing the fluid-filled lumen[22,23]. These are surrounded by a hyper-echoic vessel wall of variable thickness[23]. Repeated squeezing and releasing the limb distally to promote lymphatic flow helps distend the vessels for better visualization. While their appearance may be similar to subcutaneous veins to the casual eye, several features distinguish them from veins. For instance, unlike veins, lymphatics are typically non-compressible due to their relatively high intraluminal pressure in patients with lymphedema. Doppler flow in lymphatics is also usually imperceptible at rest, although flow signal may be elicited during sequential squeeze and release of the limb distal to the probe [Figure 1]. Lymphatics may appear more irregular and specular, unlike the smoother, circular veins [Figure 2]. Turbulent flow [Figure 3] can be detected in large lymphatics. When traced proximally, lymphatics often run parallel to each other without joining, and also run across the path of veins, which, in contrast, usually merge and increase in size as they travel proximally[24]. Finally, after identifying and tracing the lymphatic vessels, patent, non-sclerosed lymphatics with lumens denoted by a clearly hypoechoic center were deemed suitable for use in LVA and their locations were marked.

Subcutaneous veins

Subcutaneous veins can be easily detected using ultrasonography. Veins appear as round or elliptical structures with a hyperechoic rim and a hypoechoic center. Compressibility is a hallmark of these vessels, which expediently and easily differentiates them from lymphatics. With the flow detection set at an appropriately low value of 3-4 cm/s, a flow signal is typically observable within the lumen.

Subcutaneous veins and venules are ubiquitous and found easily after incising the skin, making preoperative mapping appear redundant. However, herein lies the main rationale for performing ultrasonography. Rather than just identifying and locating any vein, it is important to check if there is a reflux flow in that vein. The presence of venous reflux flow can retard the antegrade flow of lymph after completion of LVA or may even cause backflow of blood into the lymphatic vessel[25,26]. Under ultrasonography, reflux can be detected by squeezing the limb distally to promote venous flow, and observing if there is any alteration in the color Doppler signal upon the release of the pressure. A color change shows the reverse flow of blood within the vein, indicating reflux. The veins are traced proximally; if a smaller branch joins a significantly larger vein, this usually denotes the presence of a valve at the junction preventing backflow [Video 1]. The detected anti-reflux veins were marked for use in the subsequent LVA surgery.

Lymphaticovenular anastomosis

All LVA procedures were performed by the senior author of this paper. The surgeries were performed under general anesthesia for patient comfort. With the patient in the supine position, the affected arm was placed in an abducted position. Local anesthesia with epinephrine was administered subdermally prior to skin incision. The superficial subcutaneous fat was gently spread and teased apart through a combination of blunt and sharp dissection. Anti-reflux subcutaneous veins were identified corresponding to their preoperative markings and preserved. The superficial fascia was carefully entered and separated. Lymphatics were detected by direct visual identification and confirmed with both correlation to skin markings and intraoperative ICG lymphography using a Leica FL800® microscope. Anastomoses were performed with either 11-0 or 12-0 nylon (Keisei, 50 μ needle, 5R23, 11/12-0N®), by the Intravascular Stenting (IVaS) method with 4/0 nylon as first described by Narushima[27]. After completion of LVA, patency was confirmed with intraoperative ICG lymphography [Figure 4] [Video 2].

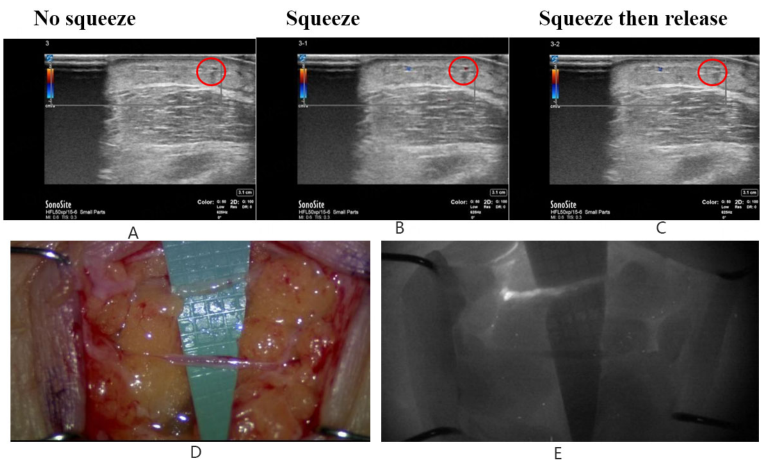

Figure 1. Dynamic changes in appearance during sonography when the limb was squeezed and then released distal to the probe. A: No Doppler signal at rest; B: Doppler signal detected when the limb was squeezed; C: Signal disappeared upon release of the squeeze; D: Intraoperative microscopic finding of an ectasic lymphatic vessel corresponding to the preoperative sonographic location; E: ICG fluorescence confirmed the identification of a lymphatic vessel (images shown in Figure 1D and E were captured using a Leica microscope FL800®; each square of the green background represents a distance of 1 mm).

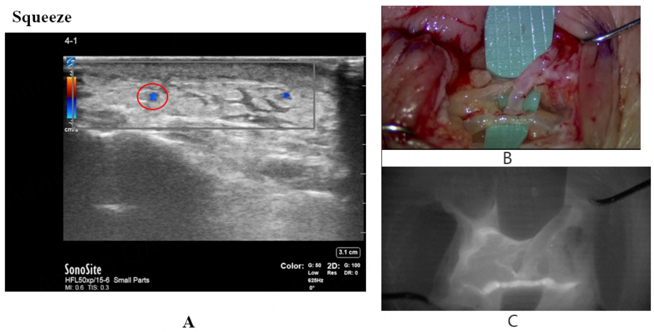

Figure 2. A: A lymphatic vessel with a spicular cross-section detected on a preoperative sonogram (marked with a red circle); B: This correlated with intraoperative microscopic finding of an ectasia lymphatic vessel; C: Intraoperative ICG fluorescence confirmed the identification of the lymphatic vessel (Images in 2B and 2C were captured using a Leica microscope FL800®).

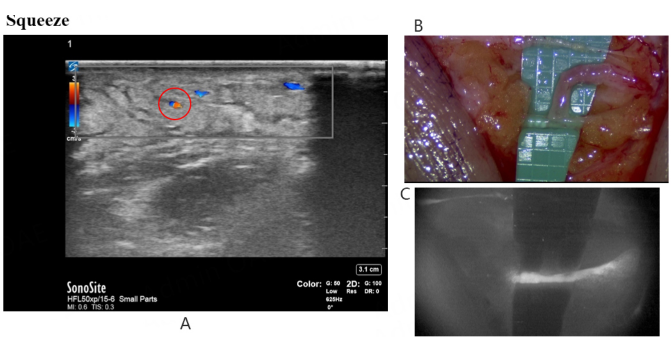

Figure 3. A: Turbulent flow within the lymphatic vessel upon squeeze and release of the limb; B: Intraoperative microscopic finding of an ectasia lymphatic vessel corresponding to the sonographic location; C: ICG fluorescence confirmed the identification of a lymphatic vessel.

Postoperative care

The postoperative care was standardized amongst all patients. Decongestion therapy with compression

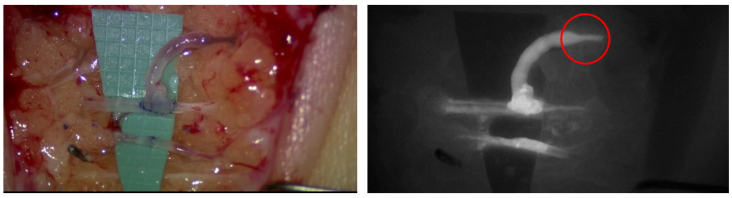

Figure 4. A: Upper (side to end, suture with Keisei 11-0, 50 μ needle, 5R23 11-0N), and lower anastomoses (end to end, suture with Keisei 12-0, 50 μ needle, 5R23 12-0N) showed no blood backflow into lymphatic vessels; B: Intraoperative ICG lymphography shows patency of the microanastomoses with a good flow of lymphatic fluid into the venules. The red circle outlines the valve of the vein.

bandages at pressures of 40 mmHg was performed for the first 3 months. This was subsequently converted to pressure garments that usually apply 25 mmHg of pressure, and these were worn from 3 to 6 months postoperatively. After 6 months, pressure garment use was gradually terminated. Thereafter, the condition of most patients remained stable; some were unable to completely stop wearing pressure garments or wearing them in an on-and-off manner depending on their lifestyle requirements.

RESULTS

Fifty-four patients with upper limb lymphedema were identified, of which 51 had BCRL and fulfilled the inclusion and exclusion criteria. Ten patients were excluded because of incomplete data from missed follow-ups during the COVID-19 pandemic lockdown, resulting in a cohort of 41 female patients. Their background characteristics are summarized in Table 1. The average age of the patients was 62.6 years, with a range of 47 to 80 years. The median body mass index (BMI) of the patients was 24.2 kg/m^2, with a range of 20 to 31 kg/m^2. The average duration of lymphedema was approximately 11.82 years (range: 5-25 years). Of the 41 patients, 40 underwent axillary lymphadenectomy. All 41 patients received adjuvant radiotherapy, and 38 received adjuvant chemotherapy. According to the International Society of Lymphology (ISL) staging system, 5 patients had grade 2a, 33 patients had grade 2b, and 3 patients had grade 3 lymphedema. The average follow-up period for the patients was 12.1 months, ranging from 5 to 24 months.

Among the 41 patients, 155 incisions were made and 212 LVA procedures were performed. Out of these 212 LVAs, 133 underwent preoperative sonographic detection of lymphatic vessels that correlated with intraoperative findings, yielding a success rate of 62.7%. Likely reasons for this low rate include the small size of the upper limb lymphatics and advanced staging of lymphedema in this patient cohort. For anti-reflux veins, 196 out of 212 LVA procedures showed a good correlation between preoperative sonographic detection and intraoperative findings, with a success rate of 92.4%.

For the circumference at the wrist, 10cm below elbow, elbow, and 10cm above elbow, the mean measurements taken preoperatively were 18.86 cm, 27.79 cm, 29.75 cm, and 33.77 cm, respectively. At the 1-month follow-up, the corresponding mean measurements were 17.14 cm, 24.86 cm, 26.91 cm, and 30.50 cm, showing improvements of 9.12%, 10.54%, 9.54%, and 9.70%, respectively. At the 3-month follow-up, the mean measurements were 16.59 cm, 24.28 cm, 26.55 cm, and 30.05 cm, with an improvement of 12.02%, 12.63%, 10.73%, and 11.02%, respectively, compared to preoperative results [Figures 5 and 6]. These differences were all statistically significant ($P < 0.0001$).

To track the relative improvement for each individual patient, their circumferences at the four measurement points were also added to obtain a Total Circumference (TC) figure. Preoperatively, the TC ranged from 89-135 cm (mean 109.46 cm). At 1 month after surgery, the TC ranged from 83.5-129.5 cm (mean 98.74 cm), and at 3 months after surgery, the TC ranged from 80.5-128 cm (mean 96.55 cm). When comparing the

Table 1. Patient demographic characteristics

Age (years)	**Average (range)**	**62.6 (47~80)**
Sex	Female	41
	Male	0
BMI, Kg/m^2, median (IQR)	Average (range)	24.2 (20~31)
Lymphedema duration (year)	Average (range)	11.82 (5~25)
Axillary lymphadenectomy	+	40
	-	1
Adjuvant radiotherapy	+	41
	-	0
Adjuvant chemotherapy	+	38
	-	3
ISL classification	1	0
	2a	5
	2b	33
	3	3
Follow-up (months)	Average (range)	12.1 (5~24)
Preoperative ultrasound character of lymphatic vessel / Total LVA Shunts	133/212	62.7%
Preoperative ultrasound character of vein/ Total LVA shunts	196/212	92.4%

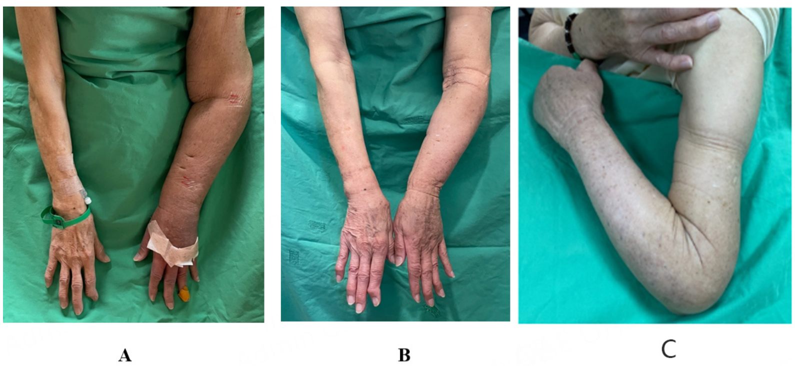

Figure 5. A: A patient with ISL grade 3 BCRL of the left upper limb. Preoperative findings included regional skin fibrosis and limited elbow range of motion due to soft tissue swelling; B: Twelve months post-LVA, the skin texture softened and skin dyspigmentation improved. C. Improved range of motion of the elbow.

preoperative figure to that at 1 month after surgery, each patient's TC had a percentage decrease ranging from 2.79%-20.35% (mean 9.80%). Similarly, comparing their TC values preoperatively to 3 months after surgery showed a percentage decrease of 4.39%-28.30% (mean 11.80%). The differences in TC values were statistically significant ($P < 0.0001$).

DISCUSSION

Supermicrosurgical LVA was first described by Koshima *et al.* in 1999, and its popularity has since remained steadfast and not waned over the years[2]. Treatment of lymphedema is undeniably complex and requires various specialists to participate in a concerted multidisciplinary and multi-modal approach[28]. Newer physiologic procedures have been developed, such as free lymph node transfer that can be done either in isolation or in combination with other procedures[29,30]. Nonetheless, LVA surgery has compelling advantages, making it relevant over the years. It has minimal morbidity and downtime. It can be conveniently done under local anesthesia or as a day procedure. The surgery can be repeated as necessary to

Figure 6. A: Patient with ISL grade 2b BCRL of the right upper limb with dorsal forearm regional skin fibrosis, recurrent eczema of hand webspace, and decreased wrist and elbow range of motion from joint swelling; B: Twelve months post-LVA, the skin texture softened, skin dyspigmentation improved, and eczema resolved fully.

titrate against the patients' clinical course. The effects can be obtained extremely quickly, with both subjective and objective improvements apparent as early as the day after surgery. Nonetheless, despite its strengths, it is not infallible. Its efficacy in advanced lymphedema is debatable, as subcutaneous fibrosis makes it difficult and hazardous to identify and isolate functional lymphatic vessels, especially without accurate prior knowledge of their locations. Thus, it is often relegated to the treatment of patients with early stages of lymphedema, especially in the hands of less experienced surgeons[12,31]. However, if accurate preoperative assessment of lymphatics is made possible, surgical success improves, opening up avenues for performing LVA successfully even in cases of advanced lymphedema[32].

ICG lymphography has emerged as a cornerstone for the preoperative evaluation of lymphatics, making it a standard procedure in most centers. Extensive literature details its use and the classification of lymphography findings corresponding to the stages of lymphedema. Nonetheless, we have previously highlighted its limitations in cases of advanced lymphedema where dense dermal backflow patterns obscure underlying lymphatics and dissuade attempts at LVA surgery. The depth of assessment is also limited to 15 mm from the skin surface, precluding deeper lymphatics in areas of increased adiposity[33,34]. The accuracy of ICG lymphography in predicting the properties of lymphatic vessels can be as low as 20%-33%[13,23]. It cannot be performed in patients with iodine allergy. Specialized near-infrared devices may also not be available in all hospitals.

In contrast, the common ultrasound machine is ubiquitous in every hospital, easily accessible, and readily used. Hara and Mihara first described ultrasonographic lymphatic evaluation for LVA in 2017[14]. Similar to ICG lymphography, ultrasonography is performed in real time by the surgeon, who knows exactly what to look for, what information is needed, and how these correlate to subsequent intraoperative findings. Unlike ICG lymphography, it can be repeated easily and can assess both lymphatics and subcutaneous veins. Hara and Mihara reported 13 successful LVA procedures in four patients with iodine allergy, solely based on preoperative ultrasonography mapping[35]. Rather than a replacement for ICG lymphography, ultrasonography is a valuable adjunct that should be used in conjunction with other available modalities to optimize the surgical outcome. Published reports confirm that routine ultrasound machines with a low frequency of 18 MHz are sufficient for preoperative assessment, and our experience concurs with this finding[16]. High- and ultra-high frequency ultrasonography have also been described[15,36,37]. It offers supreme resolution and clarity but is ultimately unnecessary. These machines are cost-prohibitive, and their rarity and lack of availability counteract one of the main advantages seen in their more common, lower-frequency counterparts.

Mihara *et al.* first described the macroscopic appearance of lymphatics, establishing the NECST classification[38]. Lymphatics can be classified into the following subtypes: normal, ectasis, contraction, and sclerosis, representing a spectrum of severity in ascending order. This macroscopic appearance is correlated to their ultrasonographic appearance[23]. Since normal, ectasis, and contraction subtypes all have patent lumens, these lymphatics are amenable for use in LVA, with ectasis vessels yielding the best results[39-41]. Extrapolating on this pioneering work, we found that, rather than rigidly shoehorning lymphatics into distinct categorical subtypes, for most practical purposes, detecting patent lymphatics denoted by a clearly hypoechoic center is sufficient to successfully perform an LVA. This simplified approach helps reduce the learning curve for surgeons who may be less adept at ultrasonography.

While lymphatic assessment is well documented, preoperative evaluation of the venous system has received less emphasis in literature. Several authors have described the use of vein visualizers to detect venules preoperatively[42-45]. These non-contact and non-invasive devices use infrared and laser light to detect differences in hemoglobin concentrations between subcutaneous veins and their surrounding tissues before superimposing their positions directly on the skin. They can detect venules as small as 0.5 mm in size[44]. However, like most infrared-based technologies, vein visualizers can only image superficial venules up to 1.5 cm below the skin. This depth may be sufficient for use in early lymphedema cases, and even then, only in anatomical sites with thin, soft tissues such as the hand, wrist, foot, and ankle. For more advanced cases or obese patients, this technology is likely unhelpful[46].

Ultrasonography for detecting veins for LVA surgery is scarcely reported. This modality is very sensitive and theoretically capable of imaging blood vessels as small as 0.3 mm in diameter[47]. Mihara reported ultrasonographic assessment of subcutaneous veins for use in LVA surgery of the lower limb, allowing the identification of larger venules, performing more microanastomoses, and achieving a better postoperative reduction in limb circumference[48]. However, we find that ultrasonography serves a purpose beyond merely locating subcutaneous veins; it also aids in determining the presence of reflux. Even in cases of advanced lymphedema, venous pressure remains higher than lymphatic pressure[49-51]. This discrepancy occurs due to competent valves in veins that allow unidirectional flow and maintain a favorable pressure gradient for LVAs to drain lymphatic fluid into the venous system. However, when reflux flow occurs in the recipient vein, lymphatic drainage is retarded, and anastomotic thrombosis can occur, resulting in surgical failure[52-54]. Visconti *et al.* coined the BSO classification, which delineates three patterns of recipient venules after the completion of microanastomoses. Outlet (O) venules showed no backflow of blood and more intense fluorescence compared to the lymphatics in ICG lymphography. Slack (S) venules had initial mild backflow that was washed out and appeared similar in fluorescent intensity. Backflow (B) venules had minimal lymph flow and low fluorescent signal, highlighting an unfavorable pressure gradient. Patients with backflow venules had 3.32 times the odds of having poor surgical outcomes compared with those showing outlet or slack patterns[25]. Bianchi *et al.* analyzed 1,000 LVAs and concluded that LVAs should not be performed on veins showing high reflux, and if no suitable recipient venules are detected, it is recommended to abandon the incision[26].

Preoperative assessment of anti-reflux veins is thus of paramount importance to allow optimized placement of incisions. Several authors have demonstrated the efficacy of detecting reflux by employing vein visualizers and “milking” veins on the skin surface[45,55]. However, based on the images and videos, the veins tested appear to be of large dimensions; the sensitivity of this method may be reduced for the smaller venules more commonly used in LVA. The absence of reflux in main venous trunks may not necessarily imply that the venules are also reflux-free; ideally, reflux testing should be performed directly on the venules to be used for LVA. Wongkietkachorn *et al.* visualized subcutaneous veins using an ICG fluorescence device after intravenous injection of 0.1 to 0.2 mg/kg of ICG[56]. With the veins illuminated, reflux is tested by milking them on the skin. However, using ICG for both venous and lymphatic detection is tricky. Intravenous ICG can quickly migrate to the soft tissues, obscuring the lymphatics during ICG lymphography, and similarly, ICG lymphography patterns can mask the visualization of subcutaneous veins.

Ultrasonography, in contrast, can help visualize both lymphatics and veins independently, along with determining the presence of reflux in both the main subcutaneous vein trunk and its smaller venular branches. Using the color Doppler mode, and through a simple maneuver of alternately squeezing and relaxing the limb distally, reflux venous flow can be detected by a change in the color signal. While positive Doppler findings are definitive, Rodriguez and Yamamoto listed other ultrasonographic features that may be associated with reflux-free veins, namely the presence of a hyperechoic wall, subcutaneous location, and selection of a primary or secondary branch from a larger vein. Conversely, venules with an isoechoic/thin wall, an immediate subdermal location, or concomitant perforator veins usually have a higher risk of reflux[57].

LIMITATIONS

Some limitations of this study warrant further consideration. Data on the preoperative conservative management for the patient cohort were not collected in this study. Long-term postoperative data are not available for every patient due to defaulted follow-ups (especially during the COVID-19 lockdowns) and surgeries performed more recently. The study analyzed patients with BCRL only; inclusion of other causes of upper limb lymphedema, as well as comparison with cases of lymphedema of the lower limb, may further yield results of interest and would be our focus for future research.

CONCLUSION

Preoperative ultrasonography serves as a useful adjunct to detect not only lymphatic vessels, especially ectasic ones, but also subcutaneous veins, and assess the presence of reflux. No other single imaging modality has such versatility. In our study, we achieved 62.7% and 92.4% accuracy in detecting lymphatic vessels and veins, respectively, using preoperative ultrasonography, and our patients showed statistically significant improvements in mean upper limb circumference. The techniques and methods described herein to identify lymphatics and non-reflux veins can increase the chances of successfully performing LVA surgery even in cases of more advanced upper limb lymphedema, which is expected to contribute to better and more long-lasting outcomes.

DECLARATIONS

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Authors' contributions

Conception and design: Chang RCH, Koshima I
Data analysis and interpretation: Chang RCH, Liang WH
Data acquisition, administrative support: Hung CM
Writing: Liang WH, Chang RCH

Availability of data and materials
Not applicable.

Financial support and sponsorship
None.

Conflicts of interest
All authors declare that there are no conflicts of interest.

Ethical approval and consent to participate
This cohort study was approved by the Institutional Review Board (EMRP-112-068). All participants provided written consent for their information to be used in this study.

Consent for publication
Written informed consent for publication was obtained.

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