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Reconstructive

"Double Barrel" Lymphaticovenous Anastomosis: A Useful Addition to a Supermicrosurgeon's Repertoire

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Background: Microsurgical amelioration of lymphedema has gained much traction in recent years and is now an established modality of treatment for this condition. Despite the development of many newer techniques, lymphaticovenous anastomosis still remains the most frequently carried out microsurgical procedure for lymphedema. One of the most common hurdles faced by lymphatic surgeons while carrying out a lymphaticovenous anastomosis is a mismatch in sizes of the vein and the lymphatic vessels.

Method: This article describes a novel but simple "double barrel" technique, developed by the authors for carrying out lymphaticovenous anastomosis in cases of such lymphaticovenous mismatch. Seventeen double barrel anastomoses were carried out in 12 lymphedema patients, over a 4-year period from 2017 to 2021.

Results: The overall success rate was 100%, as measured by clinical observation (venous washout, lymphatic backflow), the Acland vessel strip test, and by means of intraoperative ICG lymphography. Mild leakage was observed in four cases after release of the venous clamp and was corrected by application of additional sutures.

Conclusions: The double barrel technique is a safe and effective tool that can be employed to deal with the bane of size mismatch, a persistent problem faced by lymphedema surgeons universally. Although we do not advocate it as a total replacement for other techniques, it can be a worthy addition to the present set of available options. In specific scenarios of mismatch with additional challenges, the double barrel technique has the potential to be considered as *primus inter pares.*
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INTRODUCTION

Chronic lymphedema is a debilitating condition that has tormented human beings since time immemorial.[1] For the better part of history, conservative management had been the mainstay of lymphedema treatment with varying success rates.[2] Surgical amelioration of lymphedema, till very recently, had been an equally disappointing exercise and comprised of unrefined, debulking procedures, which were done as a last resort in patients who had otherwise exhausted all their conservative options. The results were often suboptimal with less than average cosmetic and functional outcomes but were accepted nevertheless, due to paucity of a better recourse.[3]

With the advent of microsurgery, plastic surgeons started challenging many longstanding quagmires, which had otherwise proved to be "solution-less" in the past era. Similar to the microsurgery-aided revolutions in posttraumatic/postoncological reconstruction, lymphedema surgery also was given a new lease of life by delineation of a relatively simple concept that a robust lymphatic vessel with an obstruction ahead can instead be anastomosed to a patent vein and the flow can be reestablished. All this renewed interest in lymphatic surgery and changing of the surgical paradigm from a macro to a micro level was possible due to the pioneering work of Koshima and others.[4,5]

Although the concept was relatively simple, it was soon apparent that the world of lymphatics at a microsurgical level was a uniquely challenging one and not a mere replica of the conventional microsurgery that we all were used

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to. Besides the relatively smaller size of the lymphatics (vis a vis arteries and veins), there were other predicaments as well. The lymphatics that had been traumatized by long years of edematous abuse resembled none of those glossy photographs that we see in our standard histology textbooks. Instead, the lymphatics found were usually present with degrees of fibrosis, ectasia, or sclerosis in varying combinations.[6]

The practical implications of such predicaments, wherein lymphatics are histologically unconventional, have a direct bearing on the outcome of any lymphatic surgery. The commonest challenges that most lymphatic surgeons encounter in such hostile microsurgical landscapes may include a gross mismatch in size of lymphatics versus the size of veins, wide distances between the veins and lymphatics, as well as the availability of multiple (but battered) lymphatics with a single measly vein.[7] Such a situation can be a nightmare, as techniques employed for reducing any mismatch in conventional microsurgery are not a feasible option with lymph vessels, which lie in the size range of 0.3–0.5 mm.[8] In extreme cases, this makes lymphaticovenous anastomosis (LVA) an extremely difficult proposition, and at times, one may have to abandon the procedure altogether.

We present a simple "double barrel" LVA technique that we have devised and successfully used for many years, to combat the aforementioned undesirable situations. The aim of this article is to share our technique and highlight how it can be effectively used to convert a zero LVA opportunity into two fine LVAs.

Takeaways

Question: Is the "double barrel" technique efficient in combating lymphaticovenous mismatch while performing a lymphaticovenous anastomosis (LVA)?
Findings: Yes, it is effective and its special utility is in scenarios where the two, in addition to being unequal, are also wide apart and there is reduced flow in the proximal lymphatic vessel. We additionally describe the "walrus" and "elephant" LVA variants. Also, its simplicity gives it a possible edge over other available techniques.
Meaning: Double barrel LVA is a useful technique for lymphaticovenous mismatch.

PATIENTS AND METHODS

During a period from August 2017 to August 2021, a total of 279 patients were operated on for lymphedema at our center by means of LVA, with an average of 3.7 LVAs carried out per patient. Of a total of 1032 LVAs, 17 double barrel LVAs were carried out in 12 patients, in scenarios where a conventional LVA (end-to-end/E2E, end-to-side/E2S, side-to-side/S2S) was not possible due to a size mismatch. Additionally, the veins and lymphatics were too far apart, and there was minimal or no lymphatic flow in the proximal limb of the lymphatic vessel. Table 1 describes the complete profile of these patients, including relevant etiologic, clinical, and diagnostic parameters. The technique was developed by senior author JT, who has been using and further refining it since 2017 at our institute, which is one of the biggest centers catering to lymphedema patients from the whole of South-Central Europe. Over a period of time, all members of our surgical team have gained proficiency in executing this technique.

TECHNIQUE

All LVA procedures were carried out under local anesthesia and optical magnification (Zeiss Kinevo 900, Carl Zeiss Meditec AG, Oberkochen, Germany). A didactic interaction was held with the patient during the course of surgery, with an overhead screen transmitting live video feed to the patients, who were encouraged to be an active part of the whole procedure. Standardized localization of the lymphatics and corresponding veins was done with the aid of a high frequency ultrasound preoperatively[9,10] and the same findings were confirmed with the help of an indocyanine green (ICG) dye based lymphangiography, just before commencement of surgery. Impetus was given to the sites where ultrasound and ICG findings overlapped while keeping the pattern and topography of lymphedema in mind. Our cases exhibited various types of lymphatic patterns, including linear, splash, stardust, and diffuse. The lymphatic patterns had no direct bearing on our anastomosis technique, as our primary mode of localizing lymphatics remains ultrasound, and ICG lymphangiogram is done additionally just to corroborate the

Table 1. Relevant Patient Details

Case No.	Age/ Sex	Cause of Lymphedema	Site of Lymphedema/ Site of LVA	Total No. LVAs	No. Double-barreled LVAs (%)	Follow-up (y + m)	LVA Patency	Postoperative Notes
1.	58/F	Ca. Uterus	Lower limbs (B/L)	4	2 (50)	4+0	WO (+++), BF(-), ICG (+) Acland test (+)	Leakage sutured
2.	63/F	Ca. Uterus	Lower limbs (R)	4	1 (25)	2+3	WO (+++), BF(-), ICG (+) Acland test (+)	NS
3.	49/F	Ca. Ovary	Lower limb (R)	3	1 (33)	1+7	WO(+), BF (+), ICG (+) Acland test (+)	NS
4.	71/M	Ca. Prostate	Lower limbs (L)	4	2 (50)	2+1	WO(+++),BF(-), ICG (+) Acland test (+)	NS
5.	46/F	Ca. Breast (L)	Upper limb (L)	4	2 (50)	1+8	WO(+), BF(+/-), ICG (+) Acland test (+)	NS
6.	38/F	Ca. Breast (R)	Upper limb (R)	3	1 (33)	3+4	WO (+), BF (+), ICG (+) Acland test (+)	Leakage sutured
7.	60/M	Ca. Prostate	Lower limbs (L)	3	1 (33)	2+2	WO (+++),BF(-), ICG (+) Acland test (+)	Leakage sutured
8.	55/F	Ca. Uterus	Lower limbs (B/L)	4	1 (25)	1+6	WO (+++),BF(-), ICG (+) Acland test (+)	NS
9.	74/F	Ca. Uterus	Lower limb (L)	5	2 (40)	2+9	WO (++), BF (-), ICG (+) Acland test (+)	NS
10.	41/F	Ca. Breast (L)	Upper limb (L)	3	1 (33)	2+3	WO (+), BF (-), ICG (+) Acland test (+)	NS
11.	44/F	Ca. Breast(R)	Upper limb (R)	4	2 (50)	0+3	WO (+++), BF(-), ICG (+) Acland test (+)	Leakage sutured
12.	71/M	Ca. Prostate	Scrotum	3	1 (33)	3+6	WO (+++),BF(-), ICG (+) Acland test (+)	NS

y+m, years + months; WO, venous washout; BF, lymphatic vessel backflow; ICG, indocyanine green lymphangiogram; NS, nothing significant.

ultrasound findings.[10] A combined clinical judgment was made thereof, regarding the final choice of sites, where LVAs were carried out through short incisions measuring around 2 cm.

The lymphatic vessels and the vein were dissected in preparation for carrying out a tension-free anastomosis and both were brought together and placed over a surgical background (Micro-Grid Green, Medtronic, Jacksonville, Fla.) to assess the size mismatch and to get a tentative idea about the type of double barreling that would be appropriate (Fig. 1A). Most of the time, an 11-0 nylon suture through the mid-point of the vein (11-0, Ethilon, Ethicon, Raritan, N.J.) creates two lumens of adequate size, to which the corresponding lymphatics can be anastomosed. After that, each LVA proceeds in a conventional E2E fashion with placement of a 6-0 nylon stent (6-0, Ethilon, Ethicon, Raritan, N.J.), two corner sutures, interrupted closure of the anterior wall, followed by the closure of the posterior wall (Fig. 1C–E), which finally completes the double barrel anastomosis (Figs. 1E, 2, and 3). However, in cases of a severe mismatch, the vein and the lymphatic vessel are sutured with a continuous bite, thereby creating bespoke venous lumens at two corners of the vein, which snuggly fit the lymphatic lumen while the central portion is closed with multiple stitches, forming a "walrus" anastomosis (Figs. 1F, 4). In cases with still greater mismatch (one large vein and a single microlymphatic), the lymphatic vessel is anastomosed to one end of the vein after creation of a corresponding lumen, and the rest of the venous circumference is sutured with 11-0 nylon (11-0, Ethilon, Ethicon, Raritan, N.J.), forming an "elephant" anastomosis (Figs. 1F, 5). Thereafter, the venous clamp was released, and the anastomosis was visually scrutinized for any technical defects, torsion, backflow, washout, or any leakages. Finally, patency of each anastomosis was checked with the help of an Acland test strip test[11] and an intraoperative ICG based lymphography test (Figs. 3–6).

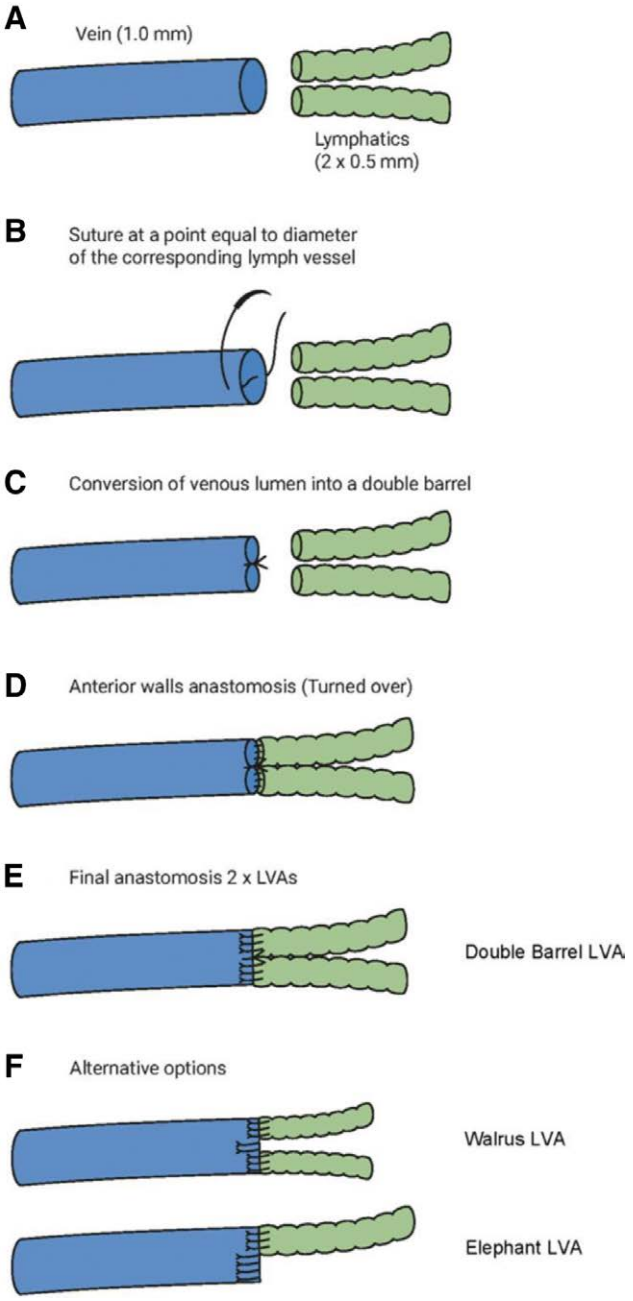

Fig. 1. A diagrammatic representation of the steps involved in carrying out the "double barrel LVA" (A-E). Additionally, Figure 1F shows the two additional possibilities, which may be used in cases of very severe mismatch: walrus anastomosis (upper) and elephant anastomosis (lower).

RESULTS

A total of 17 (10 double barrel/four walrus/three elephant) LVAs were carried out in 12 patients when the conditions were not feasible for a conventional E2E/E2S/S2S LVAs. Overall success rate was 100%, as measured by clinical observation (venous washout, lymphatic backflow), the Acland vessel strip test,[11] and by means of intraoperative ICG lymphography. Mild leakage was observed in four cases after release of the venous clamp and was corrected by application of additional sutures (Table 1). Figures 2–5 are sample representations of our patients, which further elucidate this double barreled anastomosis technique and its variants.

DISCUSSION

In the pre-microsurgical era, surgical options for lymphedema mainly included nonspecific procedures (Charles's procedure, Homan's Procedure) that were employed as a last resort in patients who had become refractory to all other forms of treatment.[3] These procedures paid very little attention to the physiological principles of lymphatic drainage and were mainly debulking exercises, aimed at reducing the mass of a grossly swollen limb, often at the cost of cosmesis and recurrence. The advent of microsurgery and its incorporation into the field of lymphedema treatment gave birth to various revolutionary approaches, which collectively led to coinage of the fancy moniker, "supermicrosurgery".[12] Presently, a plethora of supermicrosurgical options is available to deal with lymphedema, including LVA, vascularized lymph node transfer, and

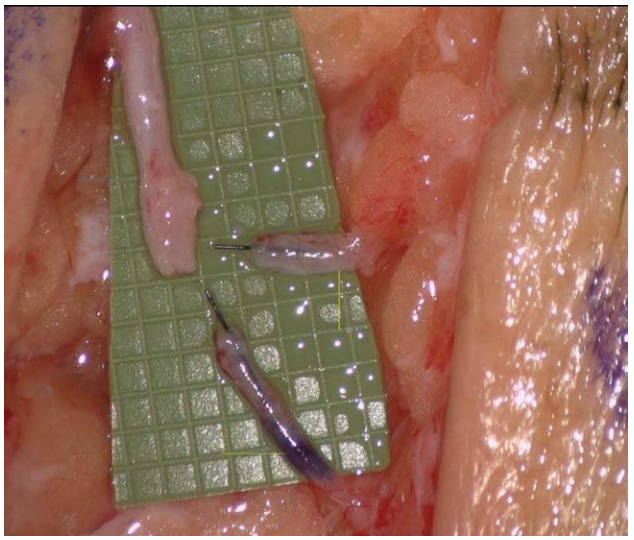

Fig. 2. A single vein (blue pointer) with two mismatched lymphatics (yellow pointers) present at varying distances from each other. (One square of the green surgical background measures 1 x 1 mm.)

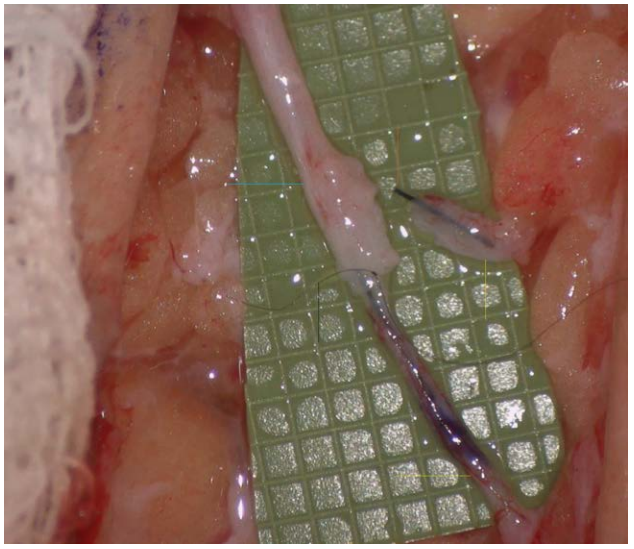

Fig. 3. A single central suture (black pointer) bifurcating the vein (blue pointer) into two lumens, appropriate for the lymphatics (yellow pointers) and reducing the size mismatch. Also seen are the intraluminal stents (brown pointer).

vascularized lymph vessel transfer.[13] Of these options, LVA is the most frequently employed surgical technique because of its relative simplicity and satisfactory outcomes.[14–18]

Long-standing lymphedema not only distorts the external appearance of a patient's affected body parts, but it distorts the microscopic architecture as well. Chronic fibrosis of the soft tissue, sclerosis of the venular wall/lymphatics, and ectasia of the lymphatics are a few of the many factors that wreak havoc at a histological level and complicate things further from a surgical viewpoint.[19] The practical aspects of working in such a distorted histological environment can be frustrating and may manifest as gross mismatches in the size of veins versus the lymphatics, wide distances between the veins and lymphatic vessels,

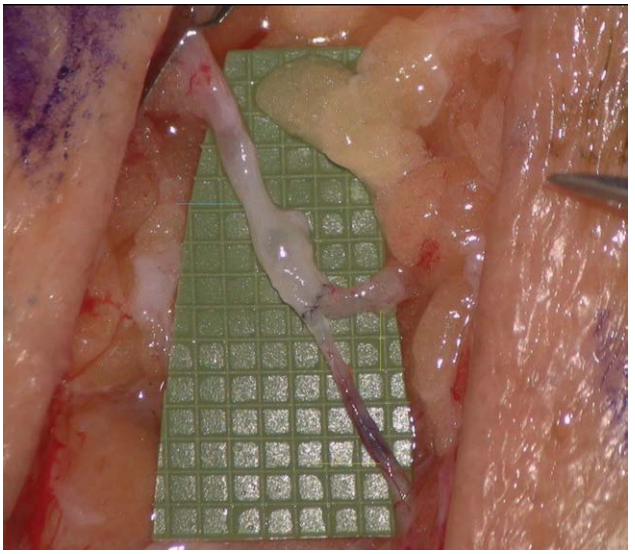

Fig. 4. A double barrel anastomosis done between the vein (blue pointer) and the lymphatics (yellow pointers). Patency of the LVAs confirmed by the Acland test and ICG Lymphangiogram. Significant washout of the veins as well as no backflow of the lymphatics is evident.

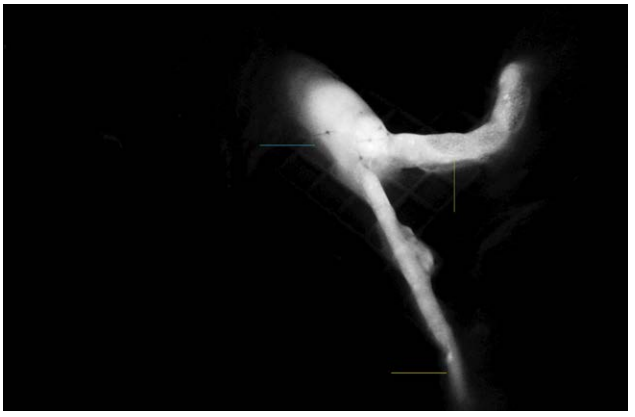

Fig. 5. Post LVA ICG of the patient confirming patency of the anastomosis.

Fig. 6. Two end-to-end anastomoses carried out between a single vein (blue pointer) and two lymphatics (yellow pointers) with a large size mismatch and situated at opposite corners of the incision (double barrel anastomosis).

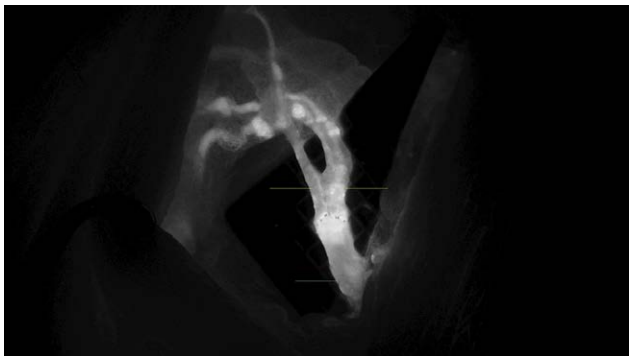

Fig. 7. Post LVA ICG Lymphangiogram confirming the patency and adequacy of the LVA.

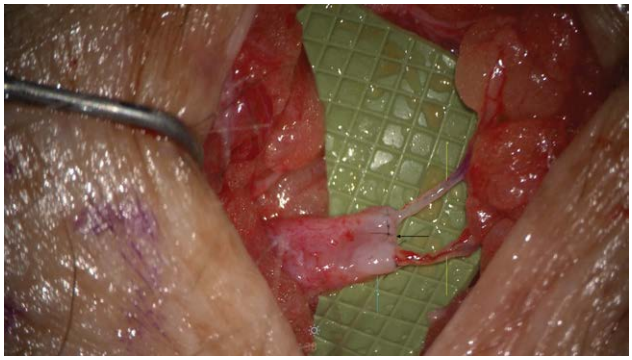

Fig. 8. Two LVAs carried out between a solitary vein (blue pointer) and two super thin lymphatics (yellow pointers) with closure of a large part of the central venous circumference with multiple central sutures (black pointer) (walrus anastomosis).

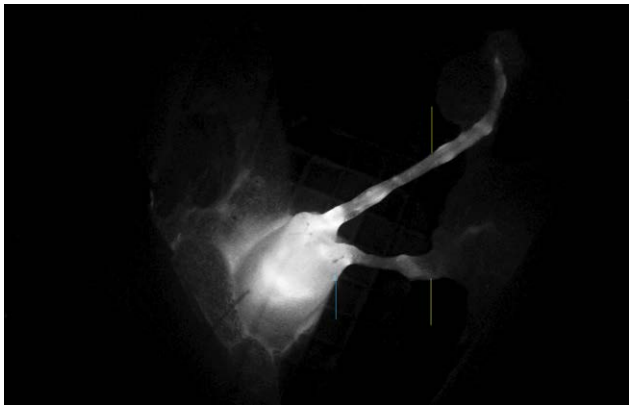

Fig. 9. Post LVA ICG Lymphangiogram confirming the patency and adequacy of the LVA.

and the presence of multiple super thin lymphatic vessels with the presence of a solitary venule.

All of the above scenarios render a conventional LVA nearly impossible to perform, and the surgeon may resort to second rung techniques to gain something out of an otherwise hopeless situation. In the worst cases, a surgeon may be forced to surrender altogether without attempting an anastomosis at all! It was while facing these inclement scenarios ourselves, that our double barrel anastomosis technique took birth. The relative simplicity, less time

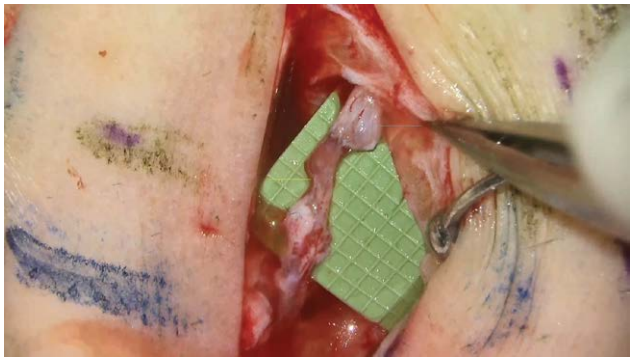

Fig. 10. LVA carried out between a mismatched vein (blue pointer) and a single lymphatic vessel (yellow pointer) with closure of the remaining venous lumen (elephant anastomosis).

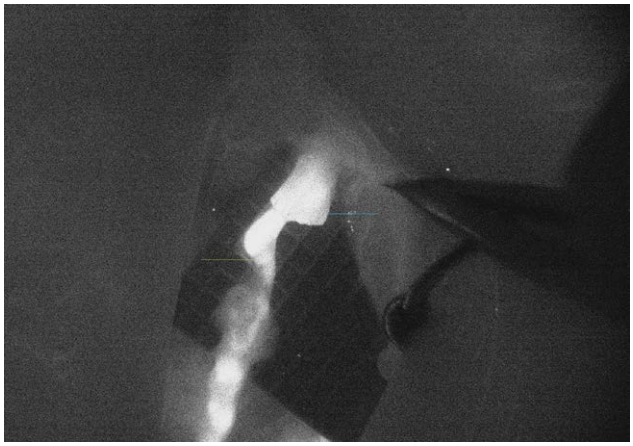

Fig. 11. Post LVA ICG Lymphangiogram confirming the patency and adequacy of the LVA.

consumption, and turning a zero-anastomosis opportunity into two fine anastomoses makes it an effective tool that can be employed by lymphatic surgeons the world over.

Due to its commonality, the topic of vein versus lymphatic mismatch has been dealt extensively in the medical literature.[20] Many solutions have been proposed to combat this difficulty, including traditional beveling of the smaller lymphatic vessels so as to increase their lymphatic caliber and reduce the size discrepancy.[21] Although this technique may be well suited for macroscopic structures or conventional microsurgery, it is not a very fruitful exercise in lymphatic surgery where the vessels in question are in the range of less than 0.5 mm. Also, from our own experience, we have observed that the beveling technique barely provides a solution while dealing with such lymphaticovenous mismatches.

Another measure suggested to tackle this situation is an E2S or a S2S LVA, which is routinely done at many centers, including ours.[22] Although this an effective strategy against many mismatch scenarios,[8] its use was not possible in our cases because of multiple reasons. Firstly, in all our patients, the vein and the lymphatics were too far away from each other. One of the prerequisites for an E2S/S2S LVA is that vein and lymph vessels should be in relative proximity, for the anastomosis to be

tension free. An attempted E2S/S2S in such cases would have led to excessive traction on the anastomosis, which can potentially lead to disastrous consequences in the long run, unless the aid of additional lengthening conduits like vein grafts is taken.[23] Secondly, in most of the cases, we found out that the retrograde lymphatic flow in the proximal limb was nearly nonexistent and hence a potential E2S would not have fetched any added benefit. Also, there have also been concerns raised by many about the significant venous reflux associated with such techniques, which may eventually lead to higher rates of venous thrombosis and a resultant malfunctioning of the LVAs.[24] From our unpublished data, we have also experienced that in some patients, in whom a healthy E2S LVA was done, thrombosis of the LVA from venous side along with a lymphatic fistula developed within the first 12 hours. All of these cases needed revision surgery. One possible reason for this thrombosis can be that when the thick and viscous, slowly moving lymphatic fluid merges with thrombogenic venular blood, it creates a fluid cocktail of still greater viscosity and lesser flow, resulting in thrombosis of the vein along with obstruction of the newly created LVA. Even though the lymphatic fluid is not inherently thrombogenic, its admixture with blood can turn it into such a state. Also, the E2S/S2S variants are technically more challenging and comparatively time-consuming for beginners, as they involve supplementary maneuvers like creation of a microscopic venular window and closure of the posterior wall first, which can be a substantially challenging job for lesser experienced surgeons, while working in the less than 0.5 mm microscopical environment.[25,26]

The octopus technique,[27] with its own set of critics and admirers, wherein a bunch of super thin lymphatic vessels are placed inside the lumen of a large vein with only a few placement sutures holding the entire assembly together, is yet another option to deal with the size discrepancy hurdles while attempting an LVA. At our center, we also employ this technique, albeit sparingly, and in situations where a regular LVA is technically not possible due to size constraints posed by the lymphatic vessels.

Our double barrel technique is a simple measure that can convert an unfavorable, but potentially salvageable situation into an opportunity where two (or theoretically more!), relatively easy, E2E anastomoses can be performed. The sheer simplicity and proven efficacy of an E2E LVA makes it the most widely performed LVA worldwide.[8,28] It is less time-consuming and can be easily mastered by beginners, as there is no need to create an additional venular window or to start with the posterior wall closure first, both of which are additional steps in comparison with an E2E anastomosis.

The technique is best suited for scenarios where the vein and the lymphatics are lying far apart from each other. In such cases, the entire length of the vessels can be used to bridge the gap between the vein and lymphatics, and both ends can be brought together in a tension-free manner toward an area of our choice, deemed as appropriate for the comfortable placement of the LVA. Furthermore, this technique can be customized as per the availability/morphology of lymphatics. In the most common scenario, the vein can be simply bifurcated at the mid-point and the two lymphatics can be joined to the resultant double-barreled lumen in a conventional E2E fashion. In cases of severe mismatch, the two lymphatics can be anastomosed at the two corners of the vein to form a walrus anastomosis (Fig. 1F, Fig. 4). In still severe cases, with the presence of a single vein and a solitary micro lymphatic vessel, the two can be anastomosed to form an elephant anastomosis (Fig. 1F, Fig. 5). Theoretically, there is a possibility of creating more than two LVAs in cases where a single large vein and multiple lymphatics (with a lumen adequate to perform an LVA) are present but we have not yet carried out such a procedure at our center.

We do carry out a meticulous followup of all lymphedema patients who undergo surgery and evaluate the postoperative outcomes on the basis of numerous parameters (including periodic measurements, photography, and patient satisfaction). Although it would have been tempting to include these postsurgery outcomes as a part of this study, we chose not to do so. The primary reason for this decision was that all 12 patients had a mixture of double barrel as well as conventional LVAs (Table 1), and it would not have been possible to attribute outcomes to one specific type of LVA. Perhaps, in the future we may be able to assemble a cohort of patients in whom exclusive double barrel LVAs are done and co-relate the long-term outcomes of such patients.

CONCLUSIONS

In our opinion, the double barrel technique is an effective tool that can be employed to deal with the bane of size mismatch, a common obstacle faced by all lymphedema surgeons. Although we do not advocate it as a replacement for other techniques (E2S, S2S), it can certainly be viewed as a worthy addition to the set of options available to lymphatic surgeons. In specific scenarios of mismatch with additional challenges, our double barrel technique may, in fact, be more suited than other techniques: for example, when the vein and lymphatics are situated far apart from each other and any E2S/S2S LVA, if performed, would be under severe tension and prone to injury, or when the proximal lymphatic vessel has reduced or no retrograde flow and thus carrying out an additional E2S LVA would not be beneficial. Also, for beginners who do not have enough experience of carrying out E2S/S2S LVAs, the technically simpler and less time-consuming E2E double barrel LVA can be a welcoming respite.

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