INTRODUCTION
Chronic lymphedema is a debilitating condition that has tormented human beings since time immemorial. For the better part of history, conservative management had been the mainstay of lymphedema treatment with varying success rates. 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.

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.

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 to.
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 mealy vein. 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. 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.

## 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 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.

## 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 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 technique 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.

## 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.

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## Table 1. Relevant Patient Details

| Case No. | Age/ Sex | Cause of Lymphedema | Site of Lymphedema/Site of LVA | Total No. LVAs | 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. Uterus | 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 (+) | NS |
| 8. 55/F | Ca. Uterus | Lower limbs (B/L) | 4 1 (25) | 1+6 | WO(+++), BF(+), ICG (+) Acland test (+) | Leakage sutured |
| 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 (+) | Leakage sutured |
| 11. 44/F | Ca. Breast (R) | Upper limb (R) | 3 2 (50) | 0+3 | WO(+), BF(+), ICG (+) Acland test (+) | NS |
| 12. 71/M | Ca. Prostate | Scrotum | 3 1 (33) | 3+6 | WO(+), BF(+), ICG (+) Acland test (+) | NS |

**Notes:** y+m, years + months; WO, venous washout; BF, lymphatic vessel backflow; ICG, indocyanine green lymphangiogram; NS, nothing significant.
ultrasound findings. 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 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 snugly 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 and an intraoperative ICG based lymphography test (Figs. 3–6).

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, 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. 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”. Presently, a plethora of supermicrosurgical options is available to deal with lymphedema, including LVA, vascularized lymph node transfer, and...
vascularized lymph vessel transfer. Of these options, LVA is the most frequently employed surgical technique because of its relative simplicity and satisfactory outcomes.

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. 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,
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 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. 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. 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. Although this an effective strategy against many mismatch scenarios, 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
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