Lymphovenous Anastomosis Bypass Surgery

Edward I. Chang, MD, FACS¹ Roman J. Skoracki, MD² David W. Chang, MD³

¹Department of Plastic Surgery, University of Texas MD Anderson Cancer Center, Houston, Texas

²Department of Plastic Surgery, Ohio State University, Columbus, Ohio

³Section of Plastic Surgery, Department of Surgery, University of Chicago, Chicago, Illinois

Address for correspondence Edward I. Chang, MD, FACS, Department of Plastic Surgery, University of Texas MD Anderson Cancer Center, 1400 Pressler Street, FCT 19.5001, Houston, TX 77030 (e-mail: eichang@mdanderson.org).

Semin Plast Surg 2018;32:22–27.

Abstract

Keywords

- lymphedema surgery
- lymphovenous bypass
- lymphaticovenular anastomosis

The field of lymphedema surgery has witnessed tremendous advancements over the years and has been coupled to the rapid growth of supermicrosurgical techniques. A lymphovenous bypass or lymphaticovenular anastomosis is a new technique that requires identification of patent, residual lymphatic channels and performing an anastomosis to a recipient venule, thereby allowing outflow of lymphatic fluid and improvement in a patient's lymphedema. This article provides a summary of the maturation of the technique, as well as the technical aspects of the approach and the current outcomes in the treatment of postmastectomy lymphedema.

Lymphedema is a chronic debilitating condition that most commonly results from treatment of cancer in the industrialized modern world. While lymphedema can certainly affect the upper and lower extremities, this article focuses on the surgical treatment of lymphedema following the treatment of breast cancer (► **Fig. 1**). Several studies have aimed to examine the risk factors for developing postmastectomy lymphedema syndrome and have identified the most dangerous risk factors to be axillary lymph node dissection, radiation therapy, chemotherapy, and obesity, typically reported as body mass index.^{1–4} While lymphedema can certainly result from even a sentinel node biopsy reported in up to 3 to 8% of patients, the greatest risk factor is associated with the number of nodes removed.^{5–7} However, the risk of lymphedema is not stagnant but can change over time.

Historically, lymphedema was treated with debulking, ablative procedures where the excess volume consisting of fat and fluid was directly excised or removed through liposuction.^{8,9} However, these approaches are far from physiologic and are often disfiguring and barbaric or can only achieve temporary improvement. Although it was first described in the 1960s, the field of lymphedema surgery and supermicrosurgical treatment of lymphedema through a lymphovenous bypass (LVB) or lymphaticovenular anastomosis (LVA) has only recently become more common and is considered one of the gold standard treatments for lymphedema.¹⁰

The field of lymphedema surgery and supermicrosurgery is rapidly expanding since its original description, and recent studies have demonstrated promising results.^{11–14} The technique depends on the identification of lymphatic channels, most commonly through imaging with indocyanine green (ICG) and fluorescent imaging. These devices use an infrared camera to detect the ICG dye that is absorbed into the lymphatic channels.^{15–19} However, there are several different techniques that have been employed for the identification of the lymphatic channels. Computed tomography (CT), lymphoscintigraphy, and magnetic resonance lymphangiography have also been used for the identification of the lymphatic vessels in preparation of LVBs.^{20–22} Unfortunately, these imaging modalities have been used in limited studies, and the use of ICG remains the gold standard for the identification of the lymphatic vessels.²³

Once a suitable channel is identified, a recipient vein is necessary and supermicrosurgical techniques are used to create an anastomosis between the two. The identification of the recipient vein, however, poses another challenge to the supermicrosurgeon. With the use of ICG lymphangiography, the lymphatics are readily visualized; however, the recipient veins and venules can also be identified not by fluorescence but as a shadow crossing over the lymph vessels (► **Fig. 2**). Other techniques that have been described for localization of the veins include ultrasonography or echography, which can

Issue Theme Lymphedema Management; Guest Editors: Edward I. Chang, MD, FACS, Mark V. Schaverien, MBChB, MD, MSc, MEd, FRCS (Plast), and Jesse C. Selber, MD, MPH, FACS

Copyright © 2018 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662.

DOI <https://doi.org/10.1055/s-0038-1636510>. ISSN 1535-2188.

Fig. 1 Postmastectomy lymphedema syndrome demonstrating lymphedema of the arm following treatment for breast cancer.

certainly enhance and facilitate the LVA procedure.^{24,25} However, while there may be benefits of the use of additional imaging technologies for identifying both the veins and the lymphatics for performing an LVB, the only critical imaging modality that has been agreed upon by surgeons who perform high-volume lymphedema surgeries is ICG.^{26–28}

Surgical Technique

Once the vessels have been identified cutaneously, finding them to perform the actual anastomosis also requires time, meticulous technique, and experience. The ICG lymphangiography only provides guidance as to where the incision is made, but to localize the lymph vessel and the vein can often be tedious. Prior to making the incision, the planned location is infiltrated with local anesthetic containing epinephrine for hemostasis in order to limit bleeding from the dermal edges. Isosulfan blue or Lymphazurin (Covidien) is injected distal to the incision site, which is absorbed into the lymphatic vessel and allows for visualization of the lymphatic during the dissection. While visualization of the blue dye certainly makes the dissection easier, lymphatic channels may be present and suitable for the LVA that does not contain any dye (→ **Fig. 3**).

Fig. 2 Indocyanine green (ICG) lymphangiography mapping of the upper extremity demonstrating the lymphatic channels that have absorbed the ICG.

Fig. 3 Lymphatic channels are identified following indocyanine green injection that dictates the location of the incision. Injection of Lymphazurin or isosulfan blue dye distal to the incision aids in the identification of the lymphatic vessels. However, not all lymphatic channels will absorb the dye, as shown here with two lymphatic vessels adjacent to each other, one with blue dye in the lumen and the other without it. Note the recipient venule in close proximity with the lymphatic vessels.

Once the lymph vessel and the recipient vein are identified, the anastomosis presents unique challenges to the operating microsurgeon. Lymphedema surgery, while considered supermicrosurgery, remains grounded in the basic premises of microsurgery.²⁹ The anastomosis between the lymphatic vessel and the recipient venule still requires careful tissue handling and appropriate placement of sutures with full-thickness bites, making certain that there is no back-walling of the vessels to ensure patency of the anastomosis.³⁰ However, while this is easily achievable in vessels measuring approximately 1 mm in size, the task becomes progressively more difficult and challenging as the vessels decrease in size. Several different approaches have been described to perform the anastomosis; however, microscopes with high magnification optics are paramount in achieving successful bypasses, coupled with surgical technique and skill and experience. However, the precise technique by which the anastomosis is completed is fairly variable and is dependent on surgeon preferences and philosophies.

Given the submillimeter size of the lymphatic vessels and recipient veins, the anastomosis presents unique challenges. The lymphatic channel, in particular, is often smaller than the vein, and the walls of the lymph vessels are especially thin and often collapse on themselves, making it difficult to place the needle into the lumen. One technique that has been described uses a suture to serve as a stent to identify the lumen and maintain its patency while performing the LVA (→ **Fig. 4**). The most commonly used suture is a 6-0 Prolene (Ethicon Inc.) or monofilament suture, which often represents the limit of what is technically achievable with current optics and instruments.^{31,32} In the setting where the recipient vein is much larger in size, the size mismatch can be difficult to overcome. Under these circumstances, an end-to-side anastomosis can be performed, where the lymphatic channel is joined to the recipient vein in an end-to-side orientation rather than an end-to-end fashion. However, aside from the size mismatch,

Fig. 4 A 6-0 Prolene suture is used to stent the lymphatic vessel open in order to make certain that the sutures are full thickness and not back-walling the lymphatic channel. The recipient venule is also dissected in close proximity to the lymphatic vessel.

there is concern that the venous pressure may exceed the lymphatic pressure, which would prevent the drainage of lymphatic fluid into the vein. The stent technique has also been applied to other orientations of the lymphovenous anastomosis. Some proponents of the lymphatic bypasses believe that lymphatic fluid can drain bidirectionally; therefore, the most optimal orientation would be to perform an anastomosis with the end of the vein to the side of the lymphatic channel allowing drainage from the proximal and distal extremity, a so-called side-to-end anastomosis.^{32–34} The side-to-end anastomosis can be performed using a stent as well, or, alternatively, the sutures can be parachuted around the anastomosis with equivalent success rates and again would allow bidirectional drainage of lymph fluid into the venous circulation.³⁵ Another option to allow bidirectional drainage would be to perform two end-to-end anastomoses of both the antegrade and retrograde ends of the lymphatic vessel into a recipient vein, which also allows both the proximal and distal extremities to drain and theoretically maximizes the drainage of fluid from the lymphatic system.³⁶

As previously noted, a size mismatch often exists between the recipient vein and the lymphatic vessel, which can create an unfavorable pressure gradient where the venous pressure exceeds that of the lymphatic system and can lead to failure of the bypass. Some have proposed the technique of funneling several lymphatic channels into a single larger caliber vein, which will increase the pressure of the lymphatic vessels to overcome any venous hypertension to allow drainage of lymphatic fluid into the venous system.^{37,38} The so-called octopus technique or multiple LVAs have demonstrated some promising results, although most high-volume centers prefer to perform individual anastomoses between a single lymphatic channel and a recipient vein either in an end-to-end or an end-to-side fashion.

Outcomes

Overall, the outcomes following LVBs or LVAs have shown tremendous potential and demonstrated excellent outcomes.

Early studies, while preliminary, were very promising. Koshima et al performed lymphaticovenular bypasses in 12 patients and compared their response to patients who were only treated with compression wrapping and found a significant improvement in patients' lymphedema with an average decrease in arm circumference by more than 4 cm.³⁹ Similarly, Chang demonstrated a 95% subjective improvement with a 35% volume reduction at 1 year following LVBs in a prospective study including 20 patients.⁴⁰ Since their early experience, both experts have developed and described their staging criteria for classifying the severity of lymphedema as well as providing a means to guide surgical treatment and have reported similar findings in larger studies.^{41,42}

The larger follow-up studies by Chang et al again demonstrated a 96% subjective response rate, where patients reported an improvement in the sensation of heaviness in the affected limbs, the incidence of infections and cellulitis, and dependency on compression garments. Despite the overwhelming improvement in subjective symptoms, the volumetric measurements only demonstrated a reduction in limb volume in 74% of patients with an average 42% volume reduction at 12 months.⁴² However, the overall success of the operation is mirrored in other studies, which have also demonstrated a significant benefit to patients who have undergone an LVA and, given their initial successes, have continued to define the field by describing novel techniques and approaches to the treatment of lymphedema.^{43,44} One such modification of the technique involved the distinction between the deep and superficial lymphatic system, where they demonstrated the ability to perform an LVA in patients who have lost the superficial lymphatic system but have preservation of the deep system. In patients with this scenario, an LVA can still be effective if performed properly despite the fibrosis and sclerosis of the superficial lymphatic channels.⁴⁵

Other institutions that perform lymphedema surgery have also demonstrated similar outcomes; however, certainly, the number of institutions with high-volume and long-term outcomes are limited. Studies have demonstrated a certain percentage of thrombosis or sclerosis of the bypasses following an LVA, which can lead to recurrent lymphedema and swelling over time. However, studies with a minimum of 1-year follow-up or longer have still demonstrated promising results confirming the efficacy of this approach for treating lymphedema.^{46–48} This highlights the need for experience and an in-depth understanding of supermicrosurgical techniques, as well as the anatomy and physiology of the lymphatic system. Once the anastomosis is completed, the final outcome and improvement in patient symptoms are obviously dependent on a patent anastomosis. Often times, the isosulfan blue can be seen draining into the recipient venule, but there are often circumstances when there is no dye visualized in the lymphatic and therefore it can be difficult to ascertain whether the anastomosis is patent and functional (► Fig. 5). A gentle strip test can sometimes confirm patency and drainage of fluid through the bypass; however, some microscopes are equipped with an ICG filter that will allow detection of ICG passing through the anastomosis to confirm that the bypass is patent and draining.^{49,50} Regardless of which modality is used, a confirmatory

Fig. 5 A completed anastomosis demonstrating drainage of the Lymphazurin blue dye into the recipient vein, confirming patency of the anastomosis.

test is vital in ensuring a patent anastomosis, which obviously dictates the success of the entire operation.

Postoperative Management

If the bypass is functional, patients may notice an immediate improvement in their arms following the procedure (► **Fig. 6**). Patients are typically asked to refrain from using any type of conservative measures such as compression sleeves, wrapping, performing manual lymphatic drainage, or using pneumatic pump devices for 4 weeks to allow the bypasses to mature.^{28,51} The overwhelming majority of patients have a significant

Fig. 6 Postoperative photo of patient 6 months after a lymphovenous bypass or lymphaticovenular anastomosis demonstrating improvement of the lymphedema. Patient is no longer wearing compression sleeves and has not noted any increase in the size of the arm with worsening swelling since the operation.

improvement in their quality of life and are able to decrease the amount of time, effort, and resources committed to maintaining their lymphedema. The need to wear compression sleeves, the time wasted in undergoing pneumatic pump therapy, the time spent in traveling and undergoing manual lymphatic drainage and massage with lymphedema therapists, and the risks of infection have all been reported to improve following the LVA.^{42,52}

Discussion

The LVB or LVA procedure is an effective and physiological operation that can have a profound impact on patients suffering from breast cancer related lymphedema. If performed appropriately, the success rates for minimizing the morbidity of lymphedema and improving patients' quality of life is remarkably high and well-documented in the literature. However, while the ability to perform a successful bypass is reminiscent of standard microsurgical reconstruction, the operations are far from identical, and a proficient microsurgeon with extensive skills and expertise in free-flap reconstruction does not guarantee that one can perform lymphedema supermicrosurgery. Success rates are multifactorial and reflect not only the surgeon's skill, expertise, and experience, but also require a multidisciplinary approach involving certified lymphedema therapists as well as the technology enabling the team to diagnose and stage a patient's lymphedema with ICG lymphangiography and the appropriate equipment, instruments, and microscope that allow the operation to be completed.

Although the success rates are truly effective in improving patients' lymphedema using the LVA, the operation does not cure lymphedema. Patients must still be cautioned that they may need to wear their compression garments when they fly or engage in more strenuous activities. Patients are still instructed to be cognizant of risks of infection and should avoid any trauma to the arm that can precipitate worsening swelling or cellulitis. Despite studies demonstrating no increased risks of complications with some of these historic precautions including laboratory draws, blood pressure cuffs, and flying, most surgeons treating lymphedema still maintain these restrictions.⁵³

With the proven benefits of the LVB and LVA procedure, some have even begun performing a lymphatic venous anastomosis at the time of the axillary dissection. Preliminary results have demonstrated significant benefits in reducing the risks of developing lymphedema.^{54,55} In one study including less than 50 patients, a prophylactic LVB performed at the time of the axillary node dissection significantly reduced the incidence of lymphedema from 30.4 to 4.3%, which correlated with a smaller volumetric difference at 3, 6, 12, and up to 18 months follow-up.⁵⁶ The findings have been further reinforced with larger series and longer follow-up, again confirming the efficacy and safety of this approach.^{57,58} However, the long-term patency and efficacy of the LVB/LVA remain to be determined. Whether or not the anastomoses remain patent and provide a permanent benefit for patients is an area of active investigation. While the prophylactic LVB, so-called lymphatic microsurgical preventive healing approach, has demonstrated promising outcomes in

preventing lymphedema in breast cancer patients undergoing axillary dissection, concerns regarding the impact on cancer treatment and metastases remain to be determined. Furthermore, the effect of radiation and chemotherapy on the long-term patency and efficacy of the prophylactic LVA also remains unknown.

Overall, this operation has had a profound impact with a dramatic improvement in the overwhelming majority of patients who have been treated. The widespread implementation of this technique, however, is still limited, and the majority of operations and studies come from a select group of specialized, high-volume institutions across the world. However, as the number of professionals trained to perform the LVA grows, the number of patients who will benefit from this operation and achieve some relief from their debilitating condition will hopefully increase as well.

Conclusion

The LVB or LVA technique is an effective operation and, when performed properly, can provide significant, reproducible benefits in improving the quality of life of patients suffering from breast cancer related lymphedema. The full potential of the LVA remains to be determined, and future studies are needed to optimize the long-term outcomes and applications of this operation for the treatment of lymphedema.

Conflict of Interest

None.

References

- Erdogan Iygun Z, Duymaz T, Ilgun AS, et al. Preoperative lymphedema-related risk factors in early-stage breast cancer. *Lymphat Res Biol* 2017 (e-pub ahead of print). Doi: 10.1089/lrb.2016.0045
- Card A, Crosby MA, Liu J, Lindstrom WA, Lucci A, Chang DW. Reduced incidence of breast cancer-related lymphedema following mastectomy and breast reconstruction versus mastectomy alone. *Plast Reconstr Surg* 2012;130(06):1169–1178
- De Groef A, Van Kampen M, Tieto E, et al. Arm lymphoedema and upper limb impairments in sentinel node-negative breast cancer patients: a one year follow-up study. *Breast* 2016;29:102–108
- Voss RK, Cromwell KD, Chiang YJ, et al. The long-term risk of upper-extremity lymphedema is two-fold higher in breast cancer patients than in melanoma patients. *J Surg Oncol* 2015;112(08):834–840
- Boughhey JC, Hoskin TL, Cheville AL, et al. Risk factors associated with breast lymphedema. *Ann Surg Oncol* 2014;21(04):1202–1208
- DiSipio T, Rye S, Newman B, Hayes S. Incidence of unilateral arm lymphoedema after breast cancer: a systematic review and meta-analysis. *Lancet Oncol* 2013;14(06):500–515
- McLaughlin SA, Bagaria S, Gibson T, et al. Trends in risk reduction practices for the prevention of lymphedema in the first 12 months after breast cancer surgery. *J Am Coll Surg* 2013;216(03):380–389, quiz 511–513
- Garza R III, Skoracki R, Hock K, Povoski SP. A comprehensive overview on the surgical management of secondary lymphedema of the upper and lower extremities related to prior oncologic therapies. *BMC Cancer* 2017;17(01):468
- Carl HM, Walia G, Bello R, et al. Systematic review of the surgical treatment of extremity lymphedema. *J Reconstr Microsurg* 2017;33(06):412–425
- Nielubowicz J, Olszewski W. Experimental lymphovenous anastomosis. *Br J Surg* 1968;55(06):449–451
- Chang DW, Masia J, Garza R III, Skoracki R, Neligan PC. Lymphedema: surgical and medical therapy. *Plast Reconstr Surg* 2016;138(3, Suppl):209S–218S
- Silva AK, Chang DW. Vascularized lymph node transfer and lymphovenous bypass: novel treatment strategies for symptomatic lymphedema. *J Surg Oncol* 2016;113(08):932–939
- Suami H, Chang DW. Overview of surgical treatments for breast cancer-related lymphedema. *Plast Reconstr Surg* 2010;126(06):1853–1863
- Kung TA, Champaneria MC, Maki JH, Neligan PC. Current concepts in the surgical management of lymphedema. *Plast Reconstr Surg* 2017;139(04):1003e–1013e
- Suami H, Chang DW, Yamada K, Kimata Y. Use of indocyanine green fluorescent lymphography for evaluating dynamic lymphatic status. *Plast Reconstr Surg* 2011;127(03):74e–76e
- Burnier P, Niddam J, Bosc R, Hersant B, Meningaud JP. Indocyanine green applications in plastic surgery: a review of the literature. *J Plast Reconstr Aesthet Surg* 2017;70(06):814–827
- Narushima M, Yamamoto T, Ogata F, Yoshimatsu H, Mihara M, Koshima I. Indocyanine green lymphography findings in limb lymphedema. *J Reconstr Microsurg* 2016;32(01):72–79
- Yamamoto T, Narushima M, Yoshimatsu H, et al. Dynamic indocyanine green (ICG) lymphography for breast cancer-related arm lymphedema. *Ann Plast Surg* 2014;73(06):706–709
- Hara H, Mihara M, Seki Y, Todokoro T, Iida T, Koshima I. Comparison of indocyanine green lymphographic findings with the conditions of collecting lymphatic vessels of limbs in patients with lymphedema. *Plast Reconstr Surg* 2013;132(06):1612–1618
- Akita S, Ogata F, Manabe I, et al. Noninvasive screening test for detecting early stage lymphedema using follow-up computed tomography imaging after cancer treatment and results of treatment with lymphaticovenular anastomosis. *Microsurgery* 2017;37(08):910–916
- Visconti G, Yamamoto T, Hayashi N, Hayashi A. Ultrasound-assisted lymphaticovenular anastomosis for the treatment of peripheral lymphedema. *Plast Reconstr Surg* 2017;139(06):1380e–1381e
- MacLellan RA, Zurakowski D, Voss S, Greene AK. Correlation between lymphedema disease severity and lymphoscintigraphic findings: a clinical-radiologic study. *J Am Coll Surg* 2017;225(03):366–370
- Mihara M, Hara H, Araki J, et al. Indocyanine green (ICG) lymphography is superior to lymphoscintigraphy for diagnostic imaging of early lymphedema of the upper limbs. *PLoS One* 2012;7(06):e38182
- Hayashi A, Hayashi N, Yoshimatsu H, Yamamoto T. Effective and efficient lymphaticovenular anastomosis using preoperative ultrasound detection technique of lymphatic vessels in lower extremity lymphedema. *J Surg Oncol* 2017 (e-pub ahead of print). Doi: 10.1002/jso.24812
- Mihara M, Hara H, Kawakami Y, et al. Multi-site lymphatic venous anastomosis using echography to detect suitable subcutaneous vein in severe lymphedema patients. *J Plast Reconstr Aesthet Surg* 2017 (e-pub ahead of print). Doi: 10.1016/j.bjps.2017.10.004
- Scaglioni MF, Fontein DBY, Arvanitakis M, Giovanoli P. Systematic review of lymphovenous anastomosis (LVA) for the treatment of lymphedema. *Microsurgery* 2017;37(08):947–953
- Ito R, Wu CT, Lin MC, Cheng MH. Successful treatment of early-stage lower extremity lymphedema with side-to-end lymphovenous anastomosis with indocyanine green lymphography assisted. *Microsurgery* 2016;36(04):310–315
- Loh CY, Wu JC, Nguyen A, et al. The 5th world symposium for lymphedema surgery-recent updates in lymphedema surgery and setting up of a global knowledge exchange platform. *J Surg Oncol* 2017;115(01):6–12
- Park JE, Chang DW. Advances and innovations in microsurgery. *Plast Reconstr Surg* 2016;138(05):915e–924e

- 30 Chang EI. My first 100 consecutive microvascular free flaps: pearls and lessons learned in first year of practice. *Plast Reconstr Surg Glob Open* 2013;1(04):e27
- 31 Baltzer HL, Winocour S, Harless C, Saint-Cyr M. Lymphaticovenous bypass: adaptations and lessons learned. *Plast Reconstr Surg Glob Open* 2017;5(06):e1328
- 32 Yoshimatsu H, Yamamoto T, Narushima M, Iida T, Koshima I. The guide wire method: a new technique for easier side-to-end lymphaticovenular anastomosis. *Ann Plast Surg* 2014;73(02):231–233
- 33 Narushima M, Mihara M, Yamamoto Y, Iida T, Koshima I, Munding GS. The intravascular stenting method for treatment of extremity lymphedema with multiconfiguration lymphaticovenous anastomoses. *Plast Reconstr Surg* 2010;125(03):935–943
- 34 Yamamoto T, Yoshimatsu H, Yamamoto N, Narushima M, Iida T, Koshima I. Side-to-end lymphaticovenular anastomosis through temporary lymphatic expansion. *PLoS One* 2013;8(03):e59523
- 35 Yamamoto T, Chen WF, Yamamoto N, Yoshimatsu H, Tashiro K, Koshima I. Technical simplification of the supermicrosurgical side-to-end lymphaticovenular anastomosis using the parachute technique. *Microsurgery* 2015;35(02):129–134
- 36 Mihara M, Hara H, Iida T, et al. Antegrade and retrograde lymphatic-venous anastomosis for cancer-related lymphedema with lymphatic valve dysfunction and lymphatic varix. *Microsurgery* 2012;32(07):580–584
- 37 Chen WF, Yamamoto T, Fisher M, Liao J, Carr J. The “octopus” lymphaticovenular anastomosis: evolving beyond the standard supermicrosurgical technique. *J Reconstr Microsurg* 2015;31(06):450–457
- 38 Campisi CC, Ryan M, Boccardo F, Campisi C. A single-site technique of multiple lymphatic-venous anastomoses for the treatment of peripheral lymphedema: long-term clinical outcome. *J Reconstr Microsurg* 2016;32(01):42–49
- 39 Koshima I, Inagawa K, Urushibara K, Moriguchi T. Supermicrosurgical lymphaticovenular anastomosis for the treatment of lymphedema in the upper extremities. *J Reconstr Microsurg* 2000;16(06):437–442
- 40 Chang DW. Lymphaticovenular bypass for lymphedema management in breast cancer patients: a prospective study. *Plast Reconstr Surg* 2010;126(03):752–758
- 41 Yamamoto T, Yamamoto N, Doi K, et al. Indocyanine green-enhanced lymphography for upper extremity lymphedema: a novel severity staging system using dermal backflow patterns. *Plast Reconstr Surg* 2011;128(04):941–947
- 42 Chang DW, Suami H, Skoracki R. A prospective analysis of 100 consecutive lymphovenous bypass cases for treatment of extremity lymphedema. *Plast Reconstr Surg* 2013;132(05):1305–1314
- 43 Mihara M, Murai N, Hayashi Y, et al. Using indocyanine green fluorescent lymphography and lymphatic-venous anastomosis for cancer-related lymphedema. *Ann Vasc Surg* 2012;26(02):278.e1–278.e6
- 44 Mihara M, Hara H, Hayashi Y, et al. Upper-limb lymphedema treated aesthetically with lymphaticovenous anastomosis using indocyanine green lymphography and noncontact vein visualization. *J Reconstr Microsurg* 2012;28(05):327–332
- 45 Yamamoto T, Yamamoto N, Hayashi A, Koshima I. Supermicrosurgical deep lymphatic vessel-to-venous anastomosis for a breast cancer-related arm lymphedema with severe sclerosis of superficial lymphatic vessels. *Microsurgery* 2017;37(02):156–159
- 46 Winters H, Tieleman HJP, Hameeteman M, et al. The efficacy of lymphaticovenular anastomosis in breast cancer-related lymphedema. *Breast Cancer Res Treat* 2017;165(02):321–327
- 47 Tourani SS, Taylor GI, Ashton MW. Long-term patency of lymphovenous anastomoses: a systematic review. *Plast Reconstr Surg* 2016;138(02):492–498
- 48 Lee KT, Park JW, Mun GH. Serial two-year follow-up after lymphaticovenular anastomosis for the treatment of lymphedema. *Microsurgery* 2017;37(07):763–770
- 49 Chen WF, Zhao H, Yamamoto T, Hara H, Ding J. Indocyanine green lymphographic evidence of surgical efficacy following microsurgical and supermicrosurgical lymphedema reconstructions. *J Reconstr Microsurg* 2016;32(09):688–698
- 50 Yamamoto T, Yamamoto N, Azuma S, et al. Near-infrared illumination system-integrated microscope for supermicrosurgical lymphaticovenular anastomosis. *Microsurgery* 2014;34(01):23–27
- 51 Masia J, Olivares L, Koshima I, et al. Barcelona consensus on supermicrosurgery. *J Reconstr Microsurg* 2014;30(01):53–58
- 52 Cornelissen AJM, Kool M, Lopez Penha TR, et al. Lymphaticovenous anastomosis as treatment for breast cancer-related lymphedema: a prospective study on quality of life. *Breast Cancer Res Treat* 2017;163(02):281–286
- 53 Asdourian MS, Skolny MN, Brunelle C, Seward CE, Salama L, Taghian AG. Precautions for breast cancer-related lymphoedema: risk from air travel, ipsilateral arm blood pressure measurements, skin puncture, extreme temperatures, and cellulitis. *Lancet Oncol* 2016;17(09):e392–e405
- 54 Jørgensen MG, Toyserkani NM, Sørensen JA. The effect of prophylactic lymphovenous anastomosis and shunts for preventing cancer-related lymphedema: a systematic review and meta-analysis. *Microsurgery* 2017 (e-pub ahead of print). Doi: 10.1002/micr.30180
- 55 Yamamoto T, Yamamoto N, Yamashita M, Furuya M, Hayashi A, Koshima I. Efferent lymphatic vessel anastomosis: supermicrosurgical efferent lymphatic vessel-to-venous anastomosis for the prophylactic treatment of subclinical lymphedema. *Ann Plast Surg* 2016;76(04):424–427
- 56 Boccardo FM, Casabona F, Friedman D, et al. Surgical prevention of arm lymphedema after breast cancer treatment. *Ann Surg Oncol* 2011;18(09):2500–2505
- 57 Boccardo F, Casabona F, De Cian F, et al. Lymphedema microsurgical preventive healing approach: a new technique for primary prevention of arm lymphedema after mastectomy. *Ann Surg Oncol* 2009;16(03):703–708
- 58 Boccardo F, Casabona F, De Cian F, et al. Lymphatic microsurgical preventing healing approach (LYMPHA) for primary surgical prevention of breast cancer-related lymphedema: over 4 years follow-up. *Microsurgery* 2014;34(06):421–424