Magnetic resonance lymphangiography (MRL), though not yet widely available, is being increasingly explored, as it can reveal a more complete picture of the lymphatic system and has become Becker's central mode of work-up. Neligan uses MRL to detect the presence of discreet lymphatic vessels. If there are identifiable lymphatic vessels present, he will perform an LVA, if not, the patient is offered a lymph node transfer.

FUNCTIONAL IMAGING

LYMPHOSCINTIGRAPHY

We routinely perform a standardized four-limb lymphoscintigraphy to provide a baseline for both donor and recipient sites. This allows us to determine whether or not the patient has a complete versus partial obstruction, and if complete, what level of obstruction. Ming-Huei Cheng will go straight to performing a VLNT if a complete obstruction is visualized on lymphoscintigraphy. If partial obstruction is visualized, the patient is referred to lymphedema therapy for a trial of conservative treatment (Ming-Huei Cheng, pers. comm., January 2015). This may also determine where to place the lymph nodes in the future, although this is currently under study. One question we are asking is, if the patient has a complete obstruction at the level of the elbow, should we be placing the lymph nodes distally in the wrist or forearm as opposed to the axilla? Comprehensive imaging evaluation and prospective study will answer many of the questions this chapter may prompt. One-year postoperative four-limb lymphoscintigraphy is used to assess both the recipient site and determine if there is any subclinical impaired lymphatic transport at the donor site.

INDOCYANINE GREEN LYMPHANGIOGRAPHY

Indocyanine green lymphangiography (IGL) provides the most detailed view of the superficial lymphatics and allows the surgeon to evaluate lymphatic pumping function. The only limitation is that lymphatics deeper than 5 or 10 mm cannot be visualized with current technology, in comparison with lymphoscintigraphy, which provides a view of the entire lymphatic system but at a much lower resolution, limited to only major lymphatic collectors. All of our patients receive a four-limb IGL preoperatively and at 1 year postoperatively for comparison and evaluation of the recipient and donor sites. IGL appears to be more sensitive at detecting impaired lymphatic function compared with lymphoscintigraphy.

In Koshima's group, preoperative IGL is used to determine if a patient is likely to respond to LVA (and may also relate to their response with a VLNT).[14,46–48] On a histologic level, early-stage lymphedema begins with dilation of obstructed lymphatic vessels, followed by vessel contraction, and ultimately sclerosis. Koshima et al. observed that preoperative IGL findings demonstrating a "linear" pattern with functioning lymphatic vessels correlate with dilated lymphatics intraoperatively, while more advanced findings of dermal reflux on IGL correlate with sclerosed lymphatics. The best outcomes in their experience were in patients with early stage lymphedema, while those with the most advanced level of dermal reflux ("diffuse" pattern) are now seen as poor candidates (Fig. 8.6). Lymph node transplantation is considered in this subset of patients.

Masia contends that sclerosed lymphatics have long lost their smooth muscle peristaltic function, which may render both LVA and VLNT ineffective. There is still discussion as to whether or not passive forces may allow these physiologic procedures to work in LVA and VLNT in the more advanced stages of lymphedema. It seems to be a trend now that earlier intervention, even with VLNT, may lead to a more favorable result. Finally, Chang's experience with LVA has shown best success with upper extremity lymphedema as opposed to the lower extremity.[49–51]

In summary, MRA demonstrates the fluid-to-fat ratio very clearly and we can explain more precisely what to expect in terms of volume reduction if the fluid component of the limb is mostly reduced by a physiologic procedure. For example, if 50% of the limb is fat hypertrophy, this patient will never have normalization in limb size with a physiologic procedure alone, and their expectations can be tailored to their scan results. Lymphoscintigraphy and IGL provide a physiologic assessment, and while there are few data to go by at this time, it appears that earlier stage lymphedema with some form of functional lymphatics may respond more favorably to LVA or VLNT. Late stage fat-hypertrophied limbs with no pitting may not respond well and may be better served with liposuction provided constant compression is something the patient will adhere to. Combinations of these two procedures are still being explored at this time. If the patient is a candidate for LVA or VLNT, it is generally in the realm of surgeon preference in terms of which

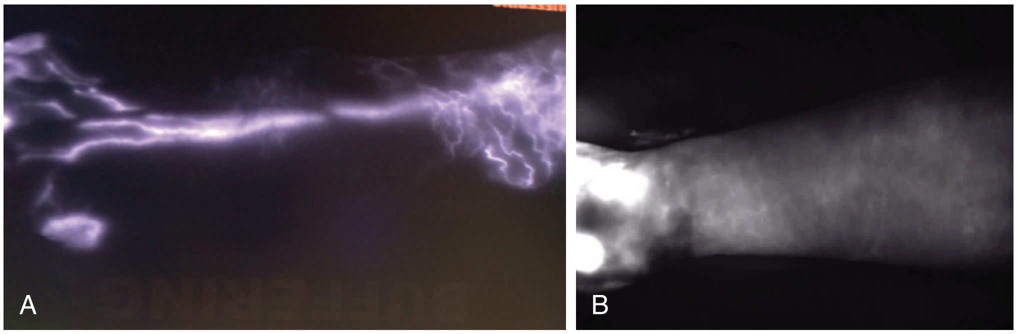

Figure 8.6 (A) Indocyanine green lymphangiography (IGL) in a lymphedema patient with some dermal backflow but a single functional lymphatic vessel. Potential candidate for LVA. (B) IGL of a patient with advanced lymphedema and diffuse dermal backflow.

procedure to proceed with. Nonetheless, these imaging studies provide useful information for both patient and surgeon and may present us with keys to improved patient selection in the future.

LYMPHATICOVENULAR ANASTOMOSIS VERSUS VASCULARIZED LYMPH NODE TRANSFER

Most microsurgeons are now exploring both LVA and VLNT and even combining these techniques – a sign that no single approach has been completely satisfactory. Unfortunately, there are no data comparing these two techniques. One of the major hurdles is that outcomes are difficult to assess in lymphedema. Limb volume or circumference has dominated outcome measures, yet can be easily manipulated postoperatively by aggressive compression and physiotherapy. This has led to skepticism and a broad spectrum of opinion on surgical management.

While there is currently no consensus on which procedure is most appropriate for a given patient, both procedures have shown both success and disappointment, and future study will clarify the indications. Lymph node transfer is conceptually appealing as it replaces the lymph nodes that were removed during surgery, providing not only an exit for lymph but also restoring a major immunologic organ. VLNT does not require specialized instrumentation and applies techniques familiar to all microsurgeons. Most reports demonstrate increased benefit over time, presumably as lymphangiogenesis progresses. However, the potential risk of donor site lymphedema has been the largest barrier to its use.[42–45] Reverse lymphatic mapping (RLM), described later in this chapter, has addressed this issue in reducing potential morbidity.[19]

On the other hand, one of the most compelling arguments for LVA is that it is minimally invasive, is apparently low-risk, and can be performed under local anesthesia. Limitations of LVA are that it depends on the status of the lymphatic vessels of the patient, it requires specialized instrumentation, and it is technically demanding. Questions regarding the long-term patency and efficacy of the tiny anastomoses have also come into question, although there are long-term successes reported. While many surgeons in the microsurgical community have adopted Koshima's supermicrosurgical technique of LVA, it is important to note that the term "LVA" is often used interchangeably with Campisi's technique. Campisi's vast experience with anastomosis of larger deep lymphatic vessels to larger proximal veins has also shown good results, and is a very different procedure from Koshima's, which is the subject of the following section.[15,52–54]

LYMPHATICOVENULAR ANASTOMOSIS

OPERATIVE TECHNIQUE

Lymphaticovenular anastomosis was first described by O'Brien and has since been through periods of enthusiasm, skepticism, and now resurgence.[14,50,55–57] Two significant reasons for the renewed popularity is the development of IGL in identifying lymphatics and progress in supermicrosurgical technique and instrumentation. Indocyanine green lymphangiography involves intradermal injection of 0.1 mL of dye into the web spaces of the affected extremity. Using a near-infrared detector, the superficial lymphatics can be visualized and used to map out intact lymphatic vessels. Dark areas, which cross the lymphatics are typically veins that Chang uses as a guide to determine where to make the incisions. Koshima's group uses a device that detects veins in addition to IGL to plan the incisions in areas where veins and lymphatics are in close proximity.[47] Previous strategies involved injecting blue dye intradermally but the dye cannot be visualized deeply through the skin, and in more advanced cases, is not always taken up by the lymphatics. However, patent blue or Lymphazurin dye is still commonly injected distal to the planned incision to facilitate identification of lymphatic vessels and confirm patency of the anastomosis. The location and number of incisions is still a subject of controversy. Koshima's group advocates as many anastomoses as possible, pointing out that their results correlate directly with number of bypasses.[13,46,48,57–63] Others such as Chang, limit the number of anastomoses to only a few at most, with the incision placed at the most proximal terminal end of the visualized patent lymphatic vessel.[50] He will also avoid a major lymphatic collector if it is traversing the entire limb and entering the proximal lymph node basin in a patient with a partial lymphatic obstruction. The concern is that dividing a lymphatic in continuity that is contributing to drainage of the affected limb may actually worsen the lymphedema, although no reports of this have yet surfaced in the literature.

Based on the patient's anatomy and IGL findings, a series of 2 cm transverse incisions are planned along the medial aspect of the extremity; 1% lidocaine with 1:100 000 epinephrine is injected into these markings and the entire procedure can be performed under local anesthesia if desired. The incision and dissection are performed under a high-powered microscope (at greater magnification than an average operating microscope provides) where the target lymphatic vessel(s) and neighboring vein(s) are identified in the subcutaneous layer using superfine instruments.

At this point, a decision is made regarding the various potential anastomotic combinations that can be performed. The goal is to allow for a favorable pressure gradient from the lymphatic system flowing into the venous system. When the vein is divided, ideally there should be minimal to no back bleeding, as excess venous back pressure would prevent lymph from flowing into the vein. The lymphatic vessel does not need to be clamped, but if there is some venous back bleeding, a microvascular clamp is placed proximally on the vein.

The anastomotic arrangement depends on the number and size of the lymphatics and veins. Koshima has previously illustrated a number of arrangements, the most convenient of which is a lymphatic vessel in proximity to a bifurcated vein.[57,59–63] The lymphatic is divided and both the proximal and distal ends are anastomosed to each vein branch, allowing for antegrade venous outflow. If such a configuration is not possible, the second best scenario is a side-to-end arrangement. A window is cut into the sidewall of a lymphatic using a microscissor, and this aperture is then