INTRODUCTION
Lymphedema is a chronic condition inflicting a significant burden, both physically and psychologically, on up to 250 million people worldwide. Vascularized lymph node transfer (VLNT) is the most common physiological procedure indicated for severe lymphedema. We describe a new physiological treatment strategy for lymphedema, lymphatic system transfer (LYST), which comprises transfer of the vascularized afferent lymphatic vessels along with their draining lymph nodes.

METHODS
All patients undergoing LYST for treatment of lymphedema from 2017 to 2018 were identified. Patient demographics, intraoperative factors, and postoperative outcomes were reviewed.

RESULTS: Three patients underwent LYST. Average patient age and body mass index were 65.3 years and 23.6 kg/m², respectively. Indications for LYST were upper extremity lymphedema following mastectomy, radiation, and lymphadenectomy (2) and unilateral lower extremity lymphedema following total hysterectomy and bilateral pelvic lymphadenectomy (1). In all patients, lymphatic vessels could not be visualized by preoperative lymphoscintigraphy. All LYST flaps were procured from the groin region. A superficial circumflex iliac artery perforator flap, including the afferent lymphatic vessels and their draining lymph nodes, was elevated. A large portion of the skin paddle was deepithelialized, and the LYST flap was inset into a subcutaneous tunnel made in the lymphedematous limb. All LYST flaps survived completely. No donor site complications were observed. The average rate of estimated volume decrease in the patients at eighth month follow-up was 21.9%. Average follow-up was 11 months.

CONCLUSIONS: Because the afferent lymphatic vessels are transferred with the lymph nodes, a presumably lesser degree of lymphangiogenesis is required for a LYST flap to commence its physiological function. Its real-time physiological lymphatic drainage is demonstrated in a video. (Plast Reconstr Surg Glob Open 2020;8:e2721; doi: 10.1097/GOX.0000000000002721; Published online 23 April 2020.)
demographics, intraoperative factors, and postoperative outcomes were reviewed. Circumference of the affected limb was measured preoperatively and every month at anatomical sites as shown in Table 1. For consistent measurement, compression garments were taken off 3 hours before taking measurements. The average rate of decrease was defined as follows: (Preoperative value) − (Postoperative value)/(Preoperative value). Estimated limb volume was obtained by the frustum formula mentioned by Casley-Smith, which is as follows: \( V = \frac{h}{3} (C^2 + Cc + c^2) / 12 \pi \), where “\( C \)” is the girth measurement of distal section, “\( c \)” is the girth measurement of the proximal section, and “\( h \)” is the distance between distal and proximal section.19

Surgical Technique

All LYST flaps were harvested from the groin region. Reverse mapping is performed using technetium as described in previous reports.20 Indocyanine green (ICG) is locally injected in the flank, and the afferent lymphatic vessels and the lymph nodes (1 or 2) at the end of the afferent lymphatic vessels are marked using an infrared camera system (Fig. 1 and see Video 1 [online], which demonstrates ICG injection in the flank and visualization of the afferent lymphatic vessels and the lymph nodes thereafter using an infrared camera system).

The superficial branch of the superficial circumflex iliac artery (SCIA) is found and dissected via an incision made between the anterior superior iliac spine and the pubic tubercle, as described in our previous report.21 After locating the branches to the lymph node, a skin paddle is designed to include the marked afferent lymphatic vessels. Before flap harvest, appropriate recipient vessels are prepared in the affected limb. After microsurgical anastomoses, a large portion of the skin paddle is deepithelialized, leaving only a small skin paddle for postoperative monitoring, and the LYST flap is inset in a subcutaneous tunnel made in the affected limb. The donor site is closed primarily over a drain.

RESULTS

Three patients underwent LYST. Average patient age and body mass index were 65.3 years and 23.6 kg/m², respectively. All patients were women. Indications for LYST were upper extremity lymphedema following mastectomy, radiation, and lymphadenectomy in 2 cases [one with International Society of Lymphology (ISL) stage 3 and the other with ISL stage 2B] and unilateral lower extremity lymphedema following total hysterectomy and bilateral pelvic lymphadenectomy in 1 case (with ISL stage 2B). All patients had received at least 3 years of complete decongestive therapy before the surgical intervention. In all patients, lymphatic vessels could not be visualized by preoperative lymphoscintigraphy. The details of the patients are presented in Table 1.

For the upper extremity cases, the proximal region of the upper arm was chosen for the recipient site because of expectation to reconstruct both the resected lymph nodes in the axilla and the lymphatic vessels in the upper arm. For the lower extremity case, most severe objective and subjective symptoms manifested in the lower leg. Thus, the lower leg was chosen as the recipient site. The SCIA, its vena comitans, and the superficial circumflex iliac vein were anastomosed to the axillary artery and the axillary vein in an end-to-side fashion, respectively, in upper arm lymphedema cases. In the lower extremity lymphedema case, the SCIA was anastomosed to a perforator found in the medial region of the lower leg, and the vena comitans of the SCIA and the superficial circumflex iliac vein were anastomosed to the subcutaneous vein of the lower leg and the great saphenous vein in an end-to-end fashion, respectively. The lymph node end of the LYST flap was inset to the axilla, and the afferent lymphatic vessels extended to the upper arm in upper extremity lymphedema cases. In the lower extremity lymphedema case, the LYST flap was inset to the lower extremity, with the lymph node end placed cephalad.

All LYST flaps survived completely. No complications were observed at the donor sites. Compression therapy was resumed 4 weeks after the lymphatic flap transfer.

The average rate of estimated volume decrease in the patients at eighth month follow-up was 21.9% (using truncated cone estimation with circumference measurements). Average length of follow-up from surgery to last clinic visit was 11 months. These findings are summarized in Table 1.

CASE REPORT

An 81-year-old woman has had ISL stage 3 lymphedema of the left upper extremity for 20 years after undergoing radical mastectomy (Fig. 2). Lymphatic scintigraphy demonstrated neither functional lymphatic vessels nor draining lymph nodes. A 9 × 3 cm LYST flap was designed in the left groin and was elevated based on the superficial branch of the SCIA. The video demonstrates intradermally injected ICG travelling from the afferent lymphatic vessels to the lymph node and then finally to the vein approximately 5 minutes after the injection (see Video 2 [online], which

---

**Table 1. Summary of the Patient Demographics and Postoperative Results**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Lymphedema Site</th>
<th>ISL Stage</th>
<th>BMI (kg/m²)</th>
<th>15 cm above the Elbow (20 cm above the Knee)</th>
<th>5 cm above the Elbow (10 cm above the Knee)</th>
<th>Elbow (Knee)</th>
<th>5 cm below the Elbow (10 cm below the Knee)</th>
<th>20 cm below the Elbow (20 cm below the Knee)</th>
<th>Decrease Rate of Estimated Volume (%)</th>
<th>Follow-up Length (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>81</td>
<td>Upper limb 3</td>
<td>3</td>
<td>24.2</td>
<td>15.5</td>
<td>18.9</td>
<td>13.1</td>
<td>23.3</td>
<td>15.6</td>
<td>40.8</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>58</td>
<td>Upper limb 2B</td>
<td>2B</td>
<td>29.2</td>
<td>6.0</td>
<td>3.0</td>
<td>2.3</td>
<td>2.7</td>
<td>1.1</td>
<td>13.8</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>57</td>
<td>Lower limb 2B</td>
<td>2B</td>
<td>17.5</td>
<td>13.9</td>
<td>6.7</td>
<td>1.2</td>
<td>2.0</td>
<td>-0.5</td>
<td>11.0</td>
<td>12</td>
</tr>
</tbody>
</table>

Postoperative improvement rate: ((Preoperative value) − (Postoperative value))/(Preoperative value).
demonstrates intradermally injected ICG travelling from the afferent lymphatic vessels to the lymph node and then finally to the vein approximately 5 minutes after the injection). The SCIA was anastomosed to the axillary artery in an end-to-side fashion, and the vena comitans and a subcutaneous vein were anastomosed to the axillary vein in an end-to-side fashion. The flap survived completely, and the affected limb demonstrated a 40.8% decrease in estimated volume 12 months after the operation (Fig. 2).

**DISCUSSION**

Lymphaticovenous anastomosis is not indicated for advanced lymphedema, where no functional lymphatic vessels remain. Though many procedures aimed at improvement of physiological status have been proposed, including VLNT and flap transfers including the lymphatic vessels, none is yet regarded as the gold standard for the physiological treatment of lymphedema.8–18,23,24
We combined VLNT and vascularized afferent lymphatic vessel transfer, hence the name LYST. Because the long afferent lymphatic vessels are transferred with the lymph node, a lesser degree of lymphangiogenesis (at least for the length of transferred afferent lymphatic vessels) is required for a LYST flap to commence its physiological function. The function of the transferred afferent lymphatic vessels is demonstrated in Video 2 (see Video 2 [online], which demonstrates intradermally injected ICG travelling from the afferent lymphatic vessels to the lymph node and then finally to the vein approximately 5 minutes after the injection). It is true that VLNT with a skin paddle includes a certain degree of afferent lymphatic vessels, but not so much attention had been paid to the afferent lymphatic vessels per se. We postulate that the afferent lymphatic vessels play a vital role in the skin paddle; we selectively marked and harvested the afferent lymphatic vessels as long as possible for maximum efficacy of the transfer.

Indications of the LYST are the same as those of the VLNT: for fluid dominant lymphedema patients with no remaining functional lymphatic vessels. For fat dominant lymphedema, LYST after liposuction may be effective, but further study is needed to confirm this hypothesis.

The limitation of this method is that the possibility of donor site lymphedema still remains, although special precautions including reverse mapping can be taken. For more definite assessment of donor site lymphedema, a longer follow-up is definitely required. This was a proof-of-concept study; more clinical cases with longer follow-ups are warranted to evaluate the long-term efficacy of LYST and its donor site morbidity. In addition, different donor sites that can also provide long afferent lymphatic vessels with the lymph nodes should be sought in the future.

CONCLUSION
LYST, including the lymph node and its afferent lymphatic vessels, has potential to become the optimal physiological treatment for severe lymphedema. Its real-time physiological lymphatic drainage, reported here, corroborates its efficacy.

REFERENCES