From Theory to Evidence: Long-Term Evaluation of the Mechanism of Action and Flap Integration of Distal Vascularized Lymph Node Transfers

Ketan M. Patel, MD1  Chia-Yu Lin, MSc1  Ming-Huei Cheng, MD, MBA, FACS1

1Division of Reconstructive Microsurgery, Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, College of Medicine, Chang Gung University, Taoyuan, Taiwan

Address for correspondence Ming-Huei Cheng, MD, MBA, FACS, Division of Reconstructive Microsurgery, Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, College of Medicine, Chang Gung University, 5, Fu-Hsing Street, Kweishan, Taoyuan 333, Taiwan (e-mail: minghueicheng@gmail.com).

Surgical treatment of lymphedema utilizing vascularized lymph node (VLN) transfers has becoming increasingly popular in recent years. Despite its popularity, the mechanism by which these flaps provide relief of lymphedema remains unclear. Intrinsic lymphovenous connections have been previously shown to exist in the transferred flap. But, the long-term interaction of the VLN flap and surrounding lymphedematous extremity has not been previously investigated.

Patients and Methods A retrospective review of a prospective maintained database of patients who underwent VLN transfer was evaluated. Patients who underwent distal VLN transfer and had more than 1-year follow-up were identified. Lymphodynamic evaluation was performed using 0.3 to 0.6 mL indocyanine green (ICG) injection at 5 cm proximal to the flap edge on identified patients. Migration direction of dye and latency period was evaluated.

Results In total, 20 patients were identified who met inclusion criteria. Average long-term follow-up was 27.3 months. The average circumference reduction of the affected extremity was 40.5%. ICG appearance within the VLN flap was found in all patients occurring on average in 178.3 seconds. In all cases, flow occurred in the distal direction (toward the flap) with proximal placement of dye. Latency period was found to inversely correlate with circumference reduction ($p < 0.01$).

Conclusions Distal, nonanatomic placement of VLN flaps provide sustained limb circumference reduction in extremity lymphedema patients following a minimum of 1-year postoperatively. Flap integration with the recipient site reliably occurs as witnessed with consistent ICG drainage, and occurs in the gravity-dependent direction. Faster clearance of ICG will result in improved clinical limb circumference reduction.

Abstract

Background Nonanatomic (distal) placement of vascularized lymph node (VLN) transfers have shown efficacy in the treatment of extremity lymphedema, but the mechanism by which these flaps provide relief of lymphedema remains unclear. Intrinsic lymphovenous connections have been previously shown to exist in the transferred flap. But, the long-term interaction of the VLN flap and surrounding lymphedematous extremity has not been previously investigated.

Patients and Methods A retrospective review of a prospective maintained database of patients who underwent VLN transfer was evaluated. Patients who underwent distal VLN transfer and had more than 1-year follow-up were identified. Lymphodynamic evaluation was performed using 0.3 to 0.6 mL indocyanine green (ICG) injection at 5 cm proximal to the flap edge on identified patients. Migration direction of dye and latency period was evaluated.

Results In total, 20 patients were identified who met inclusion criteria. Average long-term follow-up was 27.3 months. The average circumference reduction of the affected extremity was 40.5%. ICG appearance within the VLN flap was found in all patients occurring on average in 178.3 seconds. In all cases, flow occurred in the distal direction (toward the flap) with proximal placement of dye. Latency period was found to inversely correlate with circumference reduction ($p < 0.01$).

Conclusions Distal, nonanatomic placement of VLN flaps provide sustained limb circumference reduction in extremity lymphedema patients following a minimum of 1-year postoperatively. Flap integration with the recipient site reliably occurs as witnessed with consistent ICG drainage, and occurs in the gravity-dependent direction. Faster clearance of ICG will result in improved clinical limb circumference reduction.

Keywords

► vascularized lymph node transfer
► lymphedema
► lymphatic microsurgery
► lymphedema surgery
► indocyanine green
flow. In addition to anatomic placement of VLNs, our center and others have previously published on nonanatomic (distal) placement of VLN flaps for obstructive lymphedema.\cite{7,9,13} Despite studies reporting clinical success, the mechanism by which nonanatomic placement of VLNs improve lymphedema is far less understood. We have previously proposed the concept that the main mechanism of action is based on intrinsic lymphovenous connections within the VLN, which provides lymphovenous shunting at the level of the flap.\cite{13} Indocyanine green (ICG) venous clearance can be witnessed at the time of flap inset with injection at the flap periphery, thus validating the presence of these intrinsic lymphovenous connections.\cite{7,13} Despite the proven presence of this shunting mechanism, long-term evaluation of these intrinsic connections and the interaction of the flap and surrounding lymphedematous tissue have not been evaluated. To better understand the process of lymphatic drainage following these procedures, we investigated lymphatic flow patterns in patients who have previously undergone distal, nonanatomic VLN transfers.

**Patients and Methods**

**Study Design**

An institutional review board–approved review of a prospectively maintained database was performed at Chang Gung Memorial Hospital in Linkou, Taiwan. All patients who underwent VLN flap transfers for symptomatic obstructive upper and lower extremity lymphedema between 2008 and 2012 were identified. Patients were selected for inclusion in the study if the patient (1) had follow-up more than 12 months, and (2) had distal, nonanatomic placement of a VLN flap. Patients’ demographic, surgical treatment, and outcomes were evaluated. Patients were excluded if additional surgery related to the affected extremity was performed before ICG evaluation.

Circumference reduction was evaluated at standardized office visits. In the postoperative period, patients were instructed to eliminate compression therapy if they were previously using compression. In addition, measurements before revision surgery were used for the evaluation of changes related to VLN transfer and calculation of correlations.

**Lymphodynamic Evaluation**

In patients selected for evaluation, subdermal ICG injections (0.3–0.6 mL) were performed proximal to the VLN flap with the patient lying in the supine position. A custom-made device activated infrared signal 760 nm and integrated with a camcorder (Sony HD Handycam CM05; Sony Corp., Tokyo, Japan) filtering out wavelengths below 820 nm was used for real-time evaluation of lymphatic flow. An injection site 5 cm proximal to the flap edge was performed. Flow directionality and the time to appearance of the ICG dye within the flap (latency period) were specifically evaluated. Time zero was calculated following the first injection of ICG dye proximal to the flap. The appearance of dye within the subdermal lymphatic system of the flap marked the second time point used to calculate the latency period. Reported latest follow-up time and latest circumference reduction rates are represented to demonstrate long-term follow-up results. Statistical analysis using Pearson correlation was performed to investigate the relationship of flow characteristics to clinical outcomes.

**Results**

A total of 20 patients were identified for study inclusion (\textit{► Table 1}). The average patient age and body mass index were 54.9 years and 27.1 kg/m², respectively. The average follow-up time to lymphodynamic evaluation was 27.3 months (range, 12–128 months). Of the 20 patients, 13 (65%) had received VLN flaps for breast cancer–related lymphedema, whereas 7 patients (35%) had treatment for postsurgical lower extremity lymphedema. The average duration of symptoms before VLN transfer was 51.2 months. Distal, nonanatomic recipient sites included the wrist (55%) and elbow (10%) in upper extremity lymphedema, and the ankle (35%) in lower extremity cases. Groin (9 patients) and submental (11 patients) VLN flaps were used for all procedures. At long-term evaluation, the average circumference reduction of the affected limb was 40.5%.

All evaluated patients (100%) had distal ICG migration to flap periphery and into the VLN flap (\textit{► Video 1}). The average latency period of ICG was 178.3 seconds (range, 38–420 seconds). When assessing the impact of the latency period in relation to the clinical improvement, an inverse relationship was found between this time and degree of circumference reduction in the affected extremity ($p < 0.01$).

**Video 1**

A patient with symptomatic left lower extremity lymphedema previously underwent vascularized submental lymph node flap to the distal ankle. Before revision surgery, the patient had lymphodynamic evaluation with indocyanine green (ICG). The patient was lying supine during examination. Two ICG injections were placed proximal to the flap edge. The clear migration of ICG can be seen to the flap with fluorescence enveloping the flap. These findings highlight flap integration in the surrounding lymphedematous tissue.


**Case Example**

A 53-year-old female patient had a history of a modified radical mastectomy, axillary lymph node dissection, and postoperative radiotherapy 6 years before evaluation (\textit{► Fig. 1}). She developed symptomatic left upper extremity lymphedema (Stage IV) and underwent submental VLN transfer to the volar distal forearm (\textit{► Fig. 2}). Postoperatively,
## Table 1 Patient demographics and outcomes

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age, y</th>
<th>BMI, kg/m²</th>
<th>Symptom duration, mo</th>
<th>Pre-op lymphedema stage</th>
<th>Flap type</th>
<th>Circumference differentiation</th>
<th>Circumference reduction rate, %</th>
<th>ICG dose, c.c.</th>
<th>ICG latency, s</th>
<th>ICG flow direction</th>
<th>Follow-up, mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63</td>
<td>31.5</td>
<td>72</td>
<td>4</td>
<td>VGLN</td>
<td>Pre-op 103.0, Post-op 14.8</td>
<td>84.5</td>
<td>0.3</td>
<td>148</td>
<td>Distal</td>
<td>128</td>
</tr>
<tr>
<td>2</td>
<td>55</td>
<td>30.0</td>
<td>96</td>
<td>3</td>
<td>VGLN</td>
<td>Pre-op 23.0, Post-op 13.5</td>
<td>43.5</td>
<td>0.5</td>
<td>60</td>
<td>Distal</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>62</td>
<td>30.2</td>
<td>36</td>
<td>3</td>
<td>VGLN</td>
<td>Pre-op 20.0, Post-op 17.7</td>
<td>35.9</td>
<td>0.4</td>
<td>100</td>
<td>Distal</td>
<td>49</td>
</tr>
<tr>
<td>4</td>
<td>46</td>
<td>23.5</td>
<td>120</td>
<td>3</td>
<td>VGLN</td>
<td>Pre-op 20.6, Post-op 9.0</td>
<td>55.1</td>
<td>0.3</td>
<td>45</td>
<td>Distal</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>64</td>
<td>33.6</td>
<td>24</td>
<td>4</td>
<td>VGLN</td>
<td>Pre-op 33.9, Post-op 23.5</td>
<td>29.6</td>
<td>0.3</td>
<td>160</td>
<td>Distal</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>47</td>
<td>24.9</td>
<td>36</td>
<td>4</td>
<td>VGLN</td>
<td>Pre-op 26.6, Post-op 18.5</td>
<td>28.2</td>
<td>0.3</td>
<td>168</td>
<td>Distal</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>46</td>
<td>22.6</td>
<td>24</td>
<td>4</td>
<td>VGLN</td>
<td>Pre-op 29.6, Post-op 28.0</td>
<td>29.4</td>
<td>0.3</td>
<td>233</td>
<td>Distal</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>54</td>
<td>23.0</td>
<td>48</td>
<td>4</td>
<td>VGLN</td>
<td>Pre-op 28.4, Post-op 21.9</td>
<td>35.0</td>
<td>0.3</td>
<td>180</td>
<td>Distal</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>44</td>
<td>22.0</td>
<td>28</td>
<td>4</td>
<td>VGLN</td>
<td>Pre-op 28.0, Post-op 25.8</td>
<td>13.6</td>
<td>0.3</td>
<td>250</td>
<td>Distal</td>
<td>16</td>
</tr>
<tr>
<td>10</td>
<td>53</td>
<td>26.8</td>
<td>48</td>
<td>4</td>
<td>VSLN</td>
<td>Pre-op 30.8, Post-op 14.7</td>
<td>47.3</td>
<td>0.4</td>
<td>83</td>
<td>Distal</td>
<td>14</td>
</tr>
<tr>
<td>11</td>
<td>58</td>
<td>27.0</td>
<td>12</td>
<td>4</td>
<td>VSLN</td>
<td>Pre-op 30.5, Post-op 13.6</td>
<td>50.0</td>
<td>0.5</td>
<td>120</td>
<td>Distal</td>
<td>16</td>
</tr>
<tr>
<td>12</td>
<td>55</td>
<td>24.0</td>
<td>60</td>
<td>4</td>
<td>VSLN</td>
<td>Pre-op 44.0, Post-op 40.5</td>
<td>5.0</td>
<td>0.3</td>
<td>350</td>
<td>Distal</td>
<td>14</td>
</tr>
<tr>
<td>13</td>
<td>56</td>
<td>25.2</td>
<td>36</td>
<td>4</td>
<td>VSLN</td>
<td>Pre-op 29.9, Post-op 23.1</td>
<td>14.4</td>
<td>0.3</td>
<td>420</td>
<td>Distal</td>
<td>14</td>
</tr>
<tr>
<td>14</td>
<td>47</td>
<td>22.0</td>
<td>84</td>
<td>4</td>
<td>VSLN</td>
<td>Pre-op 28.2, Post-op 13.0</td>
<td>73.9</td>
<td>0.6</td>
<td>156</td>
<td>Distal</td>
<td>34</td>
</tr>
<tr>
<td>15</td>
<td>72</td>
<td>30.0</td>
<td>120</td>
<td>1</td>
<td>VSLN</td>
<td>Pre-op 7.7, Post-op 3.4</td>
<td>70.0</td>
<td>0.3</td>
<td>38</td>
<td>Distal</td>
<td>19</td>
</tr>
<tr>
<td>16</td>
<td>50</td>
<td>27.0</td>
<td>48</td>
<td>4</td>
<td>VSLN</td>
<td>Pre-op 55.7, Post-op 33.5</td>
<td>37.9</td>
<td>0.5</td>
<td>221</td>
<td>Distal</td>
<td>19</td>
</tr>
<tr>
<td>17</td>
<td>60</td>
<td>35.0</td>
<td>60</td>
<td>1</td>
<td>VSLN</td>
<td>Pre-op 9.5, Post-op 7.3</td>
<td>29.0</td>
<td>0.5</td>
<td>240</td>
<td>Distal</td>
<td>22</td>
</tr>
<tr>
<td>18</td>
<td>61</td>
<td>26.0</td>
<td>24</td>
<td>3</td>
<td>VSLN</td>
<td>Pre-op 22.3, Post-op 7.5</td>
<td>60.7</td>
<td>0.5</td>
<td>78</td>
<td>Distal</td>
<td>22</td>
</tr>
<tr>
<td>19</td>
<td>61</td>
<td>26.0</td>
<td>36</td>
<td>4</td>
<td>VSLN</td>
<td>Pre-op 25.2, Post-op 24.9</td>
<td>8.2</td>
<td>0.5</td>
<td>420</td>
<td>Distal</td>
<td>15</td>
</tr>
<tr>
<td>20</td>
<td>43</td>
<td>31.1</td>
<td>12</td>
<td>4</td>
<td>VSLN</td>
<td>Pre-op 40.3, Post-op 11.4</td>
<td>59.3</td>
<td>0.5</td>
<td>96</td>
<td>Distal</td>
<td>12</td>
</tr>
</tbody>
</table>

| Average | 54.9 ± 7.9 | 27.1 ± 3.9 | 51.2 ± 32.8 | 31.9 ± 19.9 | 18.3 ± 9.4 | 40.5 ± 22.2 | 0.4 ± 0.1 | 178.3 ± 114.4 | 27.3 ± 26.7 |

Abbreviations: BMI, body mass index; ICG, indocyanine green; VGLN, vascularized groin lymph node; VSLN, vascularized submental lymph node.
she had limb circumference reduction of 47.3% over the course of 14 months (Fig. 3). She underwent ICG lymphodynamic evaluation at 13 months, which exhibited a latency period of 83 seconds. Distal flow of proximally placed ICG was found when the patient was lying in the supine position.

**Discussion**

In an early animal study by Shesol et al, VLN transfer to a lymph node–depleted area resulted in restoration of lymphatic flow, whereas transferred nodes to a normal, unoperated area did not induce additional lymphangiogenesis. Conclusions from this landmark animal study and others have supported the use of VLN flaps in anatomic (proximal) locations to replace lymph nodes and induce lymphangiogenesis for obstructive lymphedema with restoration of normal lymphatic flow.

Unfortunately, the “stop-cock” theory may oversimplify this complex disease process and may not account for the progressive changes seen in a lymphedematous extremity. In the same landmark study by Shesol et al, the results suggest a significant decrease in efficacy of anatomic lymphatic restoration when VLN flap techniques are delayed from surgical lymphadenectomy. These findings highlight the temporal changes occurring to the severed ends of the lymphatic ducts, which likely result in significant scarring. A recent histologic evaluation found progressive and characteristic changes to the distal lymphatic collecting ducts, which correlated with decreased lymphatic function and worsening clinical lymphedema following proximal injury. Intrinsic changes to the lymphatic vasculature occur with loss of contractility and alterations to the secondary valve system. Altogether, the progressive changes that occur following proximal injury result in distal lymphatic pump failure.

Lymphatic pump failure results in backflow into lymphatic capillaries, lymphatic precollectors, and the interstitium. In addition, intrinsic changes to lymphatic collectors result in secondary valve regurgitation and bidirectional lymphatic flow. Clinically, these changes manifest as pitting edema and are consistently more pronounced in the gravity-dependent (distal) portion of the extremity. With these concepts in mind, distal nonanatomic placement of VLN flaps may represent the ideal recipient location when contemplating...
action for advanced lymphedema. With the results of this study, flap integration into the surrounding tissue results in ICG appearance within the flap, which confirms neo-lymphatic development. Distal flow of lymph fluid is clearly seen despite patients being in a gravity-neutral position (supine). Flow in the gravity-dependent position is amplified when patients are in the upright or standing position. Also, the latency period appears to have an inverse relationship to the degree of limb circumference reduction, which may provide clinical validation of the importance of ICG clearance via the VLN transfer. Future studies are needed to investigate why decreased latency periods are witnessed in certain patients, and why some patient cohorts have greater clinical responses as compared with matched cohorts. In addition, our findings demonstrate the continued patency of intrinsic lymphovenous connections within the VLN flap and continued venous clearance of interstitial fluid in a long-term follow-up evaluation.

There are limitations to this study that must be considered when evaluating the demonstrated outcomes. Correlations made related to the latency period may likely be influenced by factors related to the area and location of injection. Although each patient presented with similar conditions, the differences in etiology and previous treatments likely impact the results of VLN transfer techniques. Also, postoperative exercise and activity levels greatly differ between patients and likely influence perceived outcomes during long-term evaluation. Altogether, patient variables represent confounding factors during long-term evaluation of circumferential changes in lymphedema patients.

Conclusions

Distal VLN transfers provide continued venous shunting of lymphatic fluid following long-term evaluation. Recipient site integration occurs with development of new lymphatic connections. Lymphodynamic assessment with ICG demonstrates distal migration of dye toward the flap and drainage via intrinsic lymphovenous connections occurring in all patients. Decreases in the latency period may result in improvements in clinical limb circumference.

Disclosures

No funding was utilized for the preparation of this article.

References