Early Experience in the Management of Postoperative Lymphatic Leakage Using Lipiodol Lymphangiography and Adjunctive Glue Embolization

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ABSTRACT

Purpose: To evaluate the safety and efficacy of Lipiodol lymphangiography and 3 adjunctive N-butyl cyanoacrylate (NBCA) glue embolization techniques for the management of postoperative lymphatic leakage.

Materials and Methods: This retrospective study included 27 patients with postoperative lymphatic leakage (17 with ascites, 3 with chylothorax, 6 with lymphoceles, and 1 with a skin fistula) who underwent Lipiodol lymphangiography for diagnostic and therapeutic purposes in 3 tertiary referral centers between August 2010 and January 2016. Adjunctive glue embolization was performed as needed by using 3 different techniques: “lymphopseudoaneurysm” embolization, closest upstream lymph node embolization, or direct upstream lymphatic vessel embolization.

Results: Sixteen patients were observed to determine the therapeutic effect of lymphangiography, and 8 patients (50%) recovered without further embolization. In 16 patients, including 11 who underwent immediate embolization after lymphangiography and 5 who underwent delayed embolization, a total of 28 embolizations (12 lymphopseudoaneurysms, 14 lymph nodes, and 2 lymphatic vessels) were performed. The technical and clinical success rates of the adjunctive embolizations were 89% (25 of 28) and 94% (15 of 16), respectively. The overall clinical success rate was 85% (23 of 27). The median time from initial lymphangiography to recovery was 5 days. No procedure-related major complications were reported.

Conclusions: Lipiodol lymphangiography and adjunctive glue embolization techniques appear safe and provide promising efficacy for the management of postoperative lymphatic leakage.

ABBREVIATIONS

D5W = dextrose 5% in water, NBCA = N-butyl cyanoacrylate

Postoperative lymphatic leakage can manifest in various forms, from clear lymphoceles to chylous ascites or chylothorax (1). The common initial event is the inadvertent transection of lymphatic vessels during the original surgery, even though the reason is unclear why it persists with clinical symptoms in some patients but spontaneously resolves without the development of symptoms in the majority of patients (2).

The standard treatment of choice is conservative treatment, which consists of percutaneous catheter drainage and parenteral nutrition to decrease the production of lymphatic fluid until the damaged lymphatic channel spontaneously heals. However, there are some refractory cases that require more aggressive methods, including surgery.
Lipiodol (Guerbet, Villepinte, France) lymphangiography, which was originally used to visualize leakage points or cisterna chyli during thoracic duct embolization, is currently in the spotlight for its potential therapeutic effects on refractory lymphatic leakage (3–8). However, it takes a few days to weeks to be effective, and a significant proportion of patients do not show a response. Unlike chylothorax, for which thoracic duct embolization has been established as a minimally invasive treatment option (9), there have been only a few case reports of embolization for chylous ascites or lymphocele because of the difficulty of catheterizing the fine lymphatic vessels below the cisterna chyli (10–12).

In the present study, we evaluated the safety and efficacy of Lipiodol lymphangiography and adjunctive embolization techniques using N-butyl cyanoacrylate (NBCA) glue for the management of postoperative lymphatic leakage.

MATERIALS AND METHODS

The obligation to obtain informed consent was waived by the institutional review boards of the three tertiary referral centers (Seoul National University Hospital, Asan Medical Center, and National Cancer Center) in view of the retrospective nature of the study. All patients who underwent Lipiodol lymphangiography for postoperative lymphatic leakage at the three study centers between August 16, 2010, and January 26, 2016, were included in the study. Figure 1 describes the enrollment of the patients and timing of the introduction of new techniques during the study period. The electronic medical records and picture archiving and communication systems were retrospectively reviewed to determine the type of original surgery, duration of lymphatic leakage, daily drainage amount, triglyceride content of the leakage, and conservative management methods before lymphangiography. The imaging findings on lymphangiography, interventional radiologic procedures, and computed tomography (CT), and the daily drainage amount after the interventional procedure were also carefully reviewed.

Of the 29 patients with postoperative lymphatic leakage who were referred to the interventional radiology department for Lipiodol lymphangiography, 27 patients were finally enrolled after the exclusion of two patients whose ascites were at least partly caused by underlying portal hypertension, with a serum/ascites albumin level gradient > 1.1 mg/dL.

Among the patients included in the study, 63% (n = 17) had ascites, 11% (n = 3) had pleural effusion, 22% (n = 6) had lymphoceles, and 4% (n = 1) had a cutaneous fistula. The mean duration of leakage at the time of the initial lymphangiography was 31 days (range, 3–128 d). The mean drainage amount was 1,171 mL/d (range, 100–2,700 mL/d) in 24 patients who had drainage catheters. Fluid analysis revealed that 11 patients (41%) had chyle leakage with triglyceride levels >250 mg/dL; three patients underwent sclerotherapy and four patients underwent surgical ligation before lymphangiography, all of which were unsuccessful (Table 1).

Lipiodol Lymphangiography

Lipiodol lymphangiography was performed by using two different methods: intranodal or pedal lymphangiography. Intranodal lymphangiography has been the basic technique used for lymphangiography since reviewed to determine the type of original surgery, duration of lymphatic leakage, daily drainage amount, triglyceride content of the leakage, and conservative management methods before lymphangiography. The imaging findings on lymphangiography, interventional radiologic procedures, and computed tomography (CT), and the daily drainage amount after the interventional procedure were also carefully reviewed.

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<table>
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<th>Pt. No./ Age (y)/Sex</th>
<th>Original Surgery</th>
<th>Previous Treatment for Leakage</th>
<th>Duration (d)</th>
<th>Type Chyle</th>
<th>Daily Drain (mL)</th>
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<th>Complication</th>
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</table>

LG = lymphangiography; LN = lymph node; NA = not applicable.

*Including two direct upstream lymphatic vessel embolizations.
2012. All cases were performed by three experienced interventional radiologists (S.H., J.H.S., I.J.L.). Pedal lymphangiography was performed before the introduction of intranodal lymphangiography (n = 2) or for an inguinal cutaneous lymphatic fistula (n = 1) by one interventional radiologist (J.H.S.). Detailed techniques for both methods are described in Appendix A (available online at www.jvir.org) (1).

### Observation after Lymphangiography

Before the embolization technique was introduced, all patients were observed to determine the therapeutic effect of lymphangiography. If a response was not evident, patients underwent surgical intervention if possible. After the introduction of embolization, the interventional radiologist decided whether to allow a trial observation for a few days or immediately perform embolization based on the imaging findings and clinical symptoms (Fig 2).

### Embolization Techniques

Embolization was performed immediately after lymphangiography (immediate embolization) or as a “bailout” procedure in refractory cases after a few days of observation (delayed embolization). All embolization procedures were performed under fluoroscopic and/or C-arm CT guidance (Dyna CT; Siemens, Erlangen, Germany).

### Lymphopseudoaneurysm Embolization

A “lymphopseudoaneurysm” was defined as a small extravasated lymphatic fluid collections contained by the surrounding tissue before draining into larger spaces, such as the peritoneum or lymphocele (Fig 3).

![Flowchart of patient management](image-url)
Lymphopseudoaneurysms were punctured by using a 21-gauge Chiba needle, which was preconnected to a short connector (Cook, Bloomington, Indiana) and a small syringe filled with Lipiodol. Accurate puncture of the lymphopseudoaneurysm was confirmed by the regurgitation of the lymphatic fluid and through a test injection of Lipiodol. Then, the needle and connector system were flushed with dextrose 5% in water (D5W) to distinguish the glue mixture (NBCA and Lipiodol) and the test-injected Lipiodol, as well as to prevent premature polymerization of the glue within the lumen of the needle or connector. The ratio of NBCA to Lipiodol ranged between 1:1 and 1:2, and this glue mixture was injected to completely fill the lymphopseudoaneurysm. The needle was removed after 10–30 seconds to allow the injected glue to stabilize.

Closest Upstream Lymph Node Embolization
The closest upstream lymph node was identified as the lymph node from which efferent lymphatic vessels extravasated on lymphangiography (Figs 4, 5). The direct puncture of the Lipiodol-stained lymph node could be easily performed under fluoroscopy and/or C-arm CT. For intranodal lymphangiography, a 26-gauge or smaller needle is preferred to prevent disruption of the lymph node parenchyma. After successful intranodal puncture, the test Lipiodol was injected to confirm the feeding of the damaged vessel by the lymph node and the extent of the vessels to be embolized. If the interventional radiologist judged that there was a high risk of premature polymerization of the glue mixture before reaching the leakage point based on the flow rate of the test Lipiodol and its traveling distance, the lymph node embolization was withheld and another target lymph node was sought. Otherwise, the glue mixture with Lipiodol (ratio range, 1:3–1:9) was injected to fill the draining lymphatic vessels as well as the lymph node itself after flushing the needle/connector system and the draining vessels with D5W. The needle was removed 10–30 seconds after the injection of the mixture.

Direct Upstream Lymphatic Vessel Embolization
The direct upstream lymphatic vessel was identified as the lymphatic vessel that directly extravasated into the lymphopseudoaneurysm, lymphocele, or other body cavities on lymphangiography. Direct puncture of the Lipiodol-filled lymphatic vessel could be performed under fluoroscopic guidance by using a 21-gauge needle (13). After successful lymphatic vessel puncture, an 0.018-inch short guide wire and the inner sheath of the 5-F dilator of the micropuncture set (Cook) were inserted through the lymphatic vessel via Seldinger technique. Accurate cannulation of the lymphatic vessel was confirmed by the aspiration of lymphatic fluid and the test injection of Lipiodol. Then, the sheath was flushed with D5W to distinguish the glue mixture (NBCA and Lipiodol) from the test-injected Lipiodol, as well as to prevent premature polymerization of the glue within the lumen of the sheath. The ratio of NBCA to Lipiodol was 1:1.5, and this glue mixture was injected to completely fill the cannulated lymphatic vessel. The sheath was slowly retrieved while the glue mixture was gently injected to completely fill the puncture tract as well as the lymphatic vessel (Fig 6).

Complications
Major complications were defined as those that resulted in admission to a hospital for therapy (for outpatient
Figure 5. Images from a 49-year-old female patient (patient 15) who underwent lymphangiography as a result of persistent drainage from a Jackson–Pratt catheter placed in the peritoneum after hysterosalpingo-oophorectomy and pelvic lymphadenectomy for advanced ovarian cancer. (a) Intranodal lymphangiography through a right inguinal lymph node shows extravasated Lipiodol (arrowheads) draining from multiple hypertrophied efferent vessels of two iliac lymph nodes (white arrows). Left intranodal lymphangiography revealed a lymphopseudoaneurysm (black arrow), which is not related to the peritoneal lymphatic leakage and was therefore only observed. (b) Embolizations of both iliac lymph nodes were performed immediately after lymphangiography because the rate of extravasation was fast and the drainage amount was 1.8 L/d. The needle was inserted into the upstream lymph node under fluoroscopic guidance, and the glue mixture (NBCA:Lipiodol ratio, 1:3) filled the lymph node (arrow) and extravasating efferent lymphatic vessels while the test-injected Lipiodol dispersed (arrowheads) along the ridge formed by the small bowel loop. Daily drainage began to reduce immediately after embolization, and the peritoneal catheter was removed 3 days later.

Figure 4. Images from a 65-year-old male patient (patient 14) who underwent Lipiodol lymphangiography for a lymphocele and leakage from a surgical wound that developed after radical prostatectomy, which was refractory to sclerotherapy. (a) A complicated lymphocele communicating with the midline surgical wound is seen on noncontrast CT performed before lymphangiography. Note a lymph node (arrow) medial to the common femoral vein. (b) Lymphangiography shows that extravasated Lipiodol (arrowhead) collected around the tip of the drainage catheter. Note the closest upstream lymph node (white arrow) just inferior to the leakage point. A lymphopseudoaneurysm (black arrow), which is not related to the lymphocele, is seen around the sciatic notch. (c) As a result of persistent chylous leakage after 4 days of observation, the closest upstream lymph node (white arrows) was directly punctured and embolized by using a glue mixture (NBCA:Lipiodol ratio, 1:3). Note that the lymph node and the damaged efferent lymphatic vessel were filled with the glue mixture and that the test-injected Lipiodol drained through the drainage catheter (arrowheads). The drainage amount decreased immediately, and leakage from the wound stopped 2 days after the embolization. The silent lymphopseudoaneurysm (black arrow) around the sciatic notch is still visible.
procedures), an unplanned increase in the level of care, prolonged hospitalization, permanent adverse sequelae, or death. All other complications were considered minor (14).

**Technical and Clinical Success**

Lipiodol lymphangiography was considered technically successful if a sufficient amount of Lipiodol could be injected into the lymphatic system to obtain an adequate lymphangiogram of the area of interest, which is usually 3–5 mL per side. Lymphopseudoaneurysm embolization was considered technically successful if the targeted lymphopseudoaneurysm was filled with the glue mixture and not washed out before the polymerization process was completed. Closest upstream lymph node embolization was considered technically successful if the glue mixture could reach the extravasating point through the efferent vessels of the punctured lymph node and was not washed out before the polymerization process was completed. Direct upstream lymphatic vessel embolization was considered technically successful if the glue mixture could fill the cannulated lymphatic vessel and was not washed out before the polymerization process was completed. Clinical success of lymphangiography or embolization was defined as the resolution of the lymphatic leakage, which was judged by monitoring daily drainage amount \((n = 26)\) or by serial follow-up chest radiographs for pleural effusion \((n = 1)\).

**RESULTS**

Lipiodol lymphangiography was technically successful in all 27 patients. Lymphangiograms showed extravasation in 24 patients (89%). Among the 16 patients who were observed after lymphangiography while expecting a therapeutic effect from Lipiodol treatment, eight recovered from leakage without further intervention such as embolization or surgery; therefore, the clinical success rate of lymphangiography was 50%. Whereas six patients recovered within 5 days of observation (mean, 3.3 d) after a single session of lymphangiography, two had to undergo a second lymphangiography session on the 10th or 11th day after lymphangiography and recovered after additional observation periods of 17 and 21 days, respectively. Adjunctive embolization was not possible for a patient who was treated before the introduction of the technique and was not necessary for another patient who had no signs of extravasation. Three cases were regarded as clinical failures without adjunctive embolization. Two patients underwent surgical treatment after 4 and 7 days of observation, respectively, because embolization had not been introduced at that time. The third patient underwent surgical treatment after 3 days of observation because the lymphangiogram showed no extravasation to be embolized.

Five patients underwent delayed embolization after confirmation of a poor response to Lipiodol lymphangiography during the 3–5-day observation period. The
other 11 patients underwent embolization immediately after lymphangiography. A total of 28 embolizations were attempted on 16 patients in 26 sessions. The technical success rate for embolization was 89% (25 of 28 embolization attempts). Three technical failures occurred during attempts at lymph node embolization in two patients, in whom glue could not be placed into the lymph node or the leakage point.

Among the eight patients who underwent lymphopseudoaneurysm embolization, four recovered without further treatment within 3–43 days (mean, 14.0 d; median, 4.5 d) after embolization (Fig 2, group A), whereas three patients recovered only after additional closest upstream lymph node or direct upstream lymphatic vessel embolization (Fig 2, groups C and D). The other patient (patient 18) who underwent additional lymph node embolization and surgical exploration finally recovered after the second session of lymphopseudoaneurysm embolization (Fig 2, group E). Seven of eight patients in whom only closest upstream lymph node embolization was attempted recovered within 2–6 days (mean, 3.0 d; median, 2 d), whereas the other patient was lost to follow-up after unsuccessful lymph node embolization (patient 22; Fig 2, group B). Therefore, the clinical success rate for adjunctive embolization was 94% (15 of 16 patients).

The overall clinical success rate of Lipiodol lymphangiography and adjunctive embolization was 85% (23 of 27 patients). No major complications related to lymphangiography or adjunctive embolization were reported. Three patients reportedly had mild transient leg edema, which could be managed conservatively.

**DISCUSSION**

The reported therapeutic efficacy of Lipiodol lymphangiography for postoperative lymphatic leakage is 46%–89% according to six recent reports in the literature (3–8) (Table 2), which corresponds well to our 50% clinical success rate of observation following lymphangiography. In addition to the fact that nearly half of the leakages required further intervention, its slow effect significantly limits the value of lymphangiography as a definitive treatment modality for postoperative lymphatic leakage. To overcome these limitations, we performed adjunctive embolization techniques with glue in addition to Lipiodol lymphangiography.

The first technique was lymphopseudoaneurysm embolization with NBCA and a Lipiodol mixture, which has been reported in three independent case reports (10–12). The lymphatic fluid that leaks from the retroperitoneal lymphatic vessel sometimes forms a sac-like space as a result of the resistance of the surrounding tissue, which, in previous studies in the literature (10–12), has been described with terms such as “lymphocele-like extravasation,” “extravasated Lipiodol pool,” or

<table>
<thead>
<tr>
<th>Study, Year</th>
<th>No. of Pts.</th>
<th>Ascites</th>
<th>Thorax Fatula</th>
<th>Lymphocele/Fistula</th>
<th>Daily Drainage (mL)</th>
<th>Positive Findings of Leaks</th>
<th>Clinical Success</th>
<th>Immediate Adjunctive Procedures</th>
<th>Delayed Adjunctive Procedures</th>
<th>Overall Adjunctive Procedures</th>
<th>Clinical Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study, 2016</td>
<td>27</td>
<td>17 (63)</td>
<td>0</td>
<td>3 (11)</td>
<td>1,471 (200–1,200)</td>
<td>123 (69)</td>
<td>10/11 (91)</td>
<td>Glue embolization</td>
<td>5/5 (100)</td>
<td>10/11 (91)</td>
<td>23/27 (85)</td>
</tr>
<tr>
<td>Kortes et al (3), 2014</td>
<td>18</td>
<td>2 (11)</td>
<td>0</td>
<td>6 (33)</td>
<td>542 (150–1,000)</td>
<td>9 (5)</td>
<td>15/16 (94)</td>
<td>No</td>
<td>CT-guided sclerotherapy</td>
<td>16 (89)</td>
<td>15/16 (94)</td>
</tr>
<tr>
<td>Gruber-Rouh et al (6), 2014</td>
<td>64</td>
<td>10 (16)</td>
<td>13 (20)</td>
<td>48 (75)</td>
<td>300 (10–1,000)</td>
<td>0</td>
<td>45/46 (98)</td>
<td>No</td>
<td>No</td>
<td>45/46 (98)</td>
<td></td>
</tr>
<tr>
<td>Kawasaki et al (8), 2013</td>
<td>14</td>
<td>3 (21)</td>
<td>13 (79)</td>
<td>0</td>
<td>950 (300–3,000)</td>
<td>11/14 (79)</td>
<td>14 (100)</td>
<td>No</td>
<td>No</td>
<td>11/14 (79)</td>
<td></td>
</tr>
<tr>
<td>Matsumoto et al (7), 2009</td>
<td>9</td>
<td>2 (22)</td>
<td>1 (11)</td>
<td>0</td>
<td>533 (150–1,500)</td>
<td>2 (22)</td>
<td>8/9 (89)</td>
<td>No</td>
<td>No</td>
<td>8/9 (89)</td>
<td></td>
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<tr>
<td>Alejandre-Lafont et al (7), 2011</td>
<td>43</td>
<td>11 (26)</td>
<td>30 (70)</td>
<td>12 (28)</td>
<td>950 (300–3,000)</td>
<td>11/14 (79)</td>
<td>14 (100)</td>
<td>No</td>
<td>No</td>
<td>11/14 (79)</td>
<td></td>
</tr>
<tr>
<td>Kos et al (5), 2007</td>
<td>20</td>
<td>2 (10)</td>
<td>8 (40)</td>
<td>12 (60)</td>
<td>533 (150–1,000)</td>
<td>0</td>
<td>12/16 (75)</td>
<td>No</td>
<td>No</td>
<td>12/16 (75)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Recent Studies in the Literature of Lipiodol Lymphangiography to Manage Postoperative Lymphatic Leakage**

Note: Values in parentheses are percentages or ranges as appropriate.

NA = not applicable.
“leakage pouch.” We suggest a new term—lymphopseudoaneurysm—for this entity because its nature is similar to that of a pseudoaneurysm in the arterial system. We think a lymphocele is formed by the rupture or expansion of this space into the adjacent retroperitoneal tissue, whereas chyloous ascites or chylothorax are caused by direct communication between the lymphopseudoaneurysm or the connected lymphocele and peritoneum or pleural space. If the flow rate of the injected Lipiodol from the lymphopseudoaneurysm to a larger space is slow, the direct injection of a dense glue can fill it and cause significant flow resistance to the lymphatic leakage. Unlike the high-pressure arterial system, in which the selective embolization of a pseudoaneurysm should be avoided (15), low-pressure lymphatic leakage can be slowed down or occluded by increased outflow resistance (12). However, half of the patients in the present series (four of eight patients) needed additional embolizations via an upstream lymph node or lymphatic vessel.

Closest upstream lymph node and direct upstream lymphatic vessel embolizations are newer techniques. Injecting a diluted NBCA mixture via the inguinal lymph node may have not been attempted even though intranodal lymphangiography revealed the extravasation of Lipiodol, in view of concerns of premature polymerization of the glue before it reached the leakage point and possible lymphedema secondary to the occlusion of the lymphatic channel to a wide extent. We hypothesize that the injected glue can reach the damaged point if an upstream lymph node close to the extravasating point can be selectively punctured and embolized. In this manner, the extent of occlusion can also be minimized. Based on our experiences, embolization of one or two lymph nodes does not seem to cause clinically significant lymphedema. Such selective puncture can be easily performed under fluoroscopic and/or C-arm CT guidance because the leakage point and its closest upstream lymph node are easily visible as a result of the accumulation of Lipiodol following initial lymphangiography (Figs 4, 5). Direct upstream lymphatic vessel embolization may not always be feasible because of the small size and fragility of the lymphatic vessels, but we have proven that it can be performed in some selected cases (Fig 6) (13). These techniques are somewhat similar to the superselective embolization of arterial bleeding with the use of NBCA in that it directly occludes lymphatic inflow to the extravasating point.

Injury to the lymphatic vessels can be extensive depending on the invasiveness of the original surgery. A realistic goal in the treatment of lymphatic leakage is not to completely occlude all leakage sites, but to reduce the leakage rate to below the maximal absorption capacity of the body cavity so that the drainage catheter can be removed until the damaged lymphatic channels can spontaneously heal. This can be achieved by increasing the outflow resistance with lymphopseudoaneurysm embolization or by decreasing the inflow of the lymphatic fluid into the damaged channels with upstream lymph node embolization. A combination of these techniques can be helpful because their mechanisms of action are complementary.

Which is the better strategy for managing postoperative lymphatic leakage: (i) to perform additional intervention as soon as lymphatic leakage is detected on lymphangiography or (ii) to allow observation for a short predetermined period and expect therapeutic lymphangiography to take effect? Even though insufficient data are available to answer this question, we suggest a more aggressive approach if the extravasating point can be identified on lymphangiography because almost half of cases are refractory to lymphangiography and adjunctive embolization is safe. Even for cases in which it is decided that observation is the better strategy, the response should be evaluated within 5–7 days and further intervention should be considered to shorten the hospital stay and morbidity period caused by lymphatic leakage.

The present study has innate limitations as a result of its retrospective design and small, heterogeneous population. First, there was no advanced protocol regarding how to conduct observation following lymphangiography, when to perform immediate embolization, or how long the observation period should be. Second, the available treatment options changed during the study period, as seen in Figure 1, so that the clinical outcomes could not be consistently analyzed. Two cases of clinical failure were indeed good candidates for lymphopseudoaneurysm embolization treatment, but it was not available at that time. Third, lymphopseudoaneurysm itself was a common finding on lymphangiography in postoperative patients, and not all of them contributed to leakage. Identifying the culprit lymphopseudoaneurysm is not always straightforward. Therefore, occasionally, it might be difficult to differentiate the effect of lymphopseudoaneurysm from that of Lipiodol lymphangiography itself, especially if lymphangiography is performed without a subsequent observation period. Fourth, there should be a time threshold in the determination of clinical success to differentiate the effect of conservative treatment from that of Lipiodol lymphangiography and adjunctive embolization. A well-designed prospective study with protocols determined in advance and adequate standards for the evaluation of treatment response is warranted in the future.

In conclusion, Lipiodol lymphangiography and the three glue embolization techniques described here appear safe and provide promising efficacy for the management of postoperative lymphatic leakage. We believe these techniques can be used as bailout procedures for lymphatic leakage that is refractory to conservative treatment, sclerotherapy, or even surgery. These techniques also have the potential to become the initial treatment modality for postoperative lymphatic leakage.
ACKNOWLEDGEMENT

This work was supported by grant No. 0420160950 (2016-1191) from the SNUH Research Fund.

REFERENCES

APPENDIX A.
LIPIODOL LYMPHANGIOGRAPHY
TECHNIQUES

All procedures were performed under the guidance of angiographic machines (AXIOM Artis Zee, Siemens) that were installed in the angiographic suites of the three participating centers.

Intranodal Lymphangiography
The largest and most distal inguinal lymph node (away from the inguinal area) was directly accessed under ultrasound guidance by using a 26-gauge needle (Dong Yang Industrial, Seoul, Korea). To minimize needle movement, the injection system was assembled before nodal access. The needle was attached to a connecting tube (Cook) and flushed with Lipiodol. The needle tip was positioned in the transitional zone between the cortex and the hilum of the lymph node under sonographic guidance. Lipiodol injection was fluoroscopically observed to identify the efferent lymphatic fluid or lymph node and confirm the proper positioning of the needle. A total volume of 2–10 mL Lipiodol was injected manually at an injection rate of 0.2–0.4 mL/min on one side. Upward serial fluoroscopic spot images were obtained during the course of the Lipiodol injection.

Intranodal lymphangiography is considered technically successful if the target lymph node is successfully selected and the lymphatic channels of interest are adequately visualized by using Lipiodol.

Pedal Lymphangiography
For patients with inguinal lymphatic leakage, the ipsilateral foot to the site of the leakage was used. Five to 10 mL indigo carmine (Korea United Pharm, Seoul, Korea) was injected into the cutaneous and subcutaneous web spaces of the first to third toes after administering lidocaine as a local anesthetic agent. After waiting 20–30 minutes, the course of the lymphatic vessels were identified at the dorsum of the foot. After dissection of the surrounding tissue, a longitudinal or transverse cutaneous incision was made at the base of the first metatarsal bone to expose a lymphatic vessel with blue staining. The isolated lymphatic vessel was then cannulated by using a 30-gauge lymphangiography needle (Cook). Often, a surgical loop or magnifying loop was used to better visualize the lymphatic vessels. The needle and lymphatic vessel were firmly tied together by using 3–0 silk thread and then secured with adhesive strips.

After accessing the lymphatic vessel, 6–12 mL Lipiodol was injected at a rate of 0.2–0.4 mL/min by using a dedicated lymphangiogram pump (Cordis, Miami Lakes, Florida) or, more commonly, an advanced anesthesia injection pump. Serial fluoroscopic spot images were obtained in an upward direction every 5–10 minutes over the course of the Lipiodol injection. If Lipiodol does not reach the area of interest, normal saline solution can be injected at the same rate to push the Lipiodol further into the area of interest. After the injection was completed, the needles were removed and the wounds were closed by suture.

Pedal lymphangiography is considered technically successful if the lymphatic vessel is successfully selected and the lymphatic channels of interest are adequately visualized by using Lipiodol.
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