Lymphatic imaging and intervention for chylothorax following thoracic aortic surgery

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Abstract
Reports on lymphatic intervention for chylothorax complicating thoracic aortic surgery are limited. We aimed to evaluate technical and clinical outcomes of lymphangiography and thoracic duct embolization (TDE) for chylothorax complicating thoracic aortic surgery.

Nine patients (mean age, 38.9 years) who underwent chylothorax interventions after thoracic aortic surgery (aorta replacement [n = 7] with [n = 2] or without [n = 5] lung resection, and vascular ring repair [n = 2]) were reviewed retrospectively. Magnetic resonance (MR) lymphangiograms were obtained in 5 patients. The median interval between surgery and conventional lymphangiography was 9 days (range, 4–28 days). TDE clinical success was defined as lymphatic leakage resolution with chest tube removal within 2 weeks.

MR lymphangiograms revealed contrast leakage from the thoracic duct (n = 4) or no definite leakage (n = 1), which correlated well with conventional lymphangiogram findings. The technical success rate of conventional lymphangiography was 88.9% (8/9); 8 patients showed contrast leakage, while the patient without definite leakage on MR lymphangiography had small inguinal lymph nodes, and thoracic duct visualization by conventional lymphangiography failed. The technical success rates of antegrade and retrograde TDE via pleural access were 75% (6/8) and 100% (3/3), respectively. Clinical outcomes after embolization, as judged by the tube-removal day, were similar between low- (<500 mL/day) and high-output (≥500 mL/day) chylothorax patients. The drainage amount decreased significantly after lymphangiography/TDE, from 710.0 mL/day to 109.7 mL/day (p < .05). The clinical success rate of TDE was 87.8% (7/8).

Conventional lymphangiography and TDE yielded high technical success rates and demonstrated encouraging clinical outcomes for chylothorax complicating thoracic aortic surgery.

Abbreviations: MR = magnetic resonance, TDE = thoracic duct embolization, THRIVE = T1-weighted high-resolution imaging with volumetric excitation.

Keywords: embolization, thoracic aorta, thoracic duct

1. Introduction
Chylothorax arises when chyle accumulates in the pleural cavity due to leakage from lymphatic vessels. Chylothorax caused by damage to the thoracic duct or its tributaries during thoracic surgery can compromise the immune system and cause nutritional depletion, because the thoracic duct transports large amounts of lymphatic fluid from the gastrointestinal, hepatic, and iliac regions.[1,2] Traditionally, low-output chylothorax is treated conservatively with total parenteral nutrition or a medium-chain fatty acid diet.[3] High-output chylothorax usually requires early surgical ligation.[4] Mortality rates after conservative treatment of chylothorax can reach 50%; those following surgical repair are reported to reach 10%.[5,6]

Common causes of postoperative chylothorax are esophagectomy, pneumonectomy, pleurectomy, lobectomy, or coronary bypass, and uncommonly occurs after thoracic aortic surgery.[7,8] Injuries to the thoracic duct or tributaries after thoracic aortic surgery are close to aortic surgical fields at the mid-thoracic vertebral level. Therefore, surgical intervention for thoracic duct injury complicated with thoracic aortic surgery should be carefully considered due to the increased risk of surgery.

Recently, thoracic duct lymphangiography with thoracic duct embolization (TDE) has become a minimally invasive alternative to surgical thoracic duct ligation, due to the former’s efficacy and feasibility.[7–11] However, reports on lymphatic intervention for
chylothorax complicating thoracic aortic surgery are limited. Therefore, the purpose of this study was to evaluate the technical and clinical outcomes of lymphangiography and TDE for patients with chylothorax complicating thoracic aortic surgery.

2. Methods

2.1. Patients

The Asan Medical Center review board approved the use of clinical data for this study, and the requirement for informed consent was waived because of the retrospective design of the study. The inclusion criteria were (1) patients with chylothorax after thoracic aortic surgery and (2) those who underwent conventional lymphangiography and TDE.

The exclusion criterion was chylothorax after heart valve surgery. Nine patients who met the inclusion and exclusion criteria from 2 tertiary referral hospitals, from November 2017 to December 2019, were reviewed retrospectively.

There were 8 males and 1 female with a mean age of 38.9 ± 21.5 years (standard deviation) (range: 1–62 years). Patient characteristics are shown in Table 1. Underlying diseases included aortic dissection (n = 2), mycotic or traumatic aneurysm (n = 2), vascular ring (n = 2), lung or pleural malignancy with aortic invasion (n = 2), and aortic anuloeectasia (n = 1). Surgeries were aorta replacement (n = 3) with (n = 2) or without (n = 5) lung resection and vascular ring repair (n = 2). Magnetic resonance (MR) lymphangiograms were obtained in 5 patients. The median interval between surgery and conventional lymphangiogram was 9 days (range, 4–28 days). The diagnosis of chylothorax was confirmed with the finding of elevated triglyceride levels (>110 mg/dL) on cellular analysis of pleural fluid. The mean drainage amount during the 3 days before TDE was 710.0 mL/d (range, 150–2200 mL/d).

The decision to perform conventional lymphangiography was made based on multidisciplinary consensus that conservative treatment by total parenteral nutrition or medium-chain fatty acid diet would be ineffective. Data on clinical characteristics, MR and conventional lymphangiography findings, TDE details, and clinical outcomes were obtained.

2.2. MR and conventional intranodal lymphangiograms and TDE

MR lymphangiography was started with an ultrasound-guided puncture of bilateral inguinal lymph nodes using 25-gauge spinal needles (Tae-Chang Industrial, Gongju, Korea) with the patient in the supine position on an MR-compatible table. The needle (with connector) was coupled to a mixture of contrast material (Gadovist, gadobutrol; 1 cc per 10 kg; Bayer, Leverkusen, Germany) and saline (contrast material:saline = 1:1). The patient and table were carefully moved into the MR imaging room and placed within the gantry. Using 3-T MR imaging (Ingenia; Philips Healthcare, Best, the Netherlands), a T2-weighted turbo spin-echo fat saturation sequence (repetition time (ms)/echo time (ms), 1744.8/650.0; flip angle, 90°; Cartesian k-space acquisition; field-of-view, 340.0 mm) was performed. After obtaining T2-weighted images and unenhanced T1-weighted high-resolution imaging with volumetric contrast (THRIVE) sequence images, the mixture of contrast material and saline was gently injected into the bilateral inguinal lymph nodes (approximately 1 cc per 30 s). Free-breath axial and coronal dynamic THRIVE enhancement (repetition time (ms)/echo time (ms), 3.0/1.5; flip angle, 15°; field-of-view, 340.0 mm) was performed for both the chest and abdomen. The acquisition duration for the THRIVE sequence was less than 1 minute. The enhanced THRIVE sequence was acquired every 1 to 2 minute to evaluate the location of the cisterna chyli and thoracic duct leakage site.

Conventional lymphangiography was performed with an ultrasound-guided puncture of inguinal lymph nodes with an injection of lipiodol through a 25-gauge spinal needle. Lipiodol injection was observed under fluoroscopic guidance to identify upward lymphatic opacification into the retroperitoneal lumbar lymphatics. Once the cisterna chyli was opacified with lipiodol, percutaneous cannulation of the cisterna chyli was performed using a 21- or 22-gauge, 15- to 20-cm Chiba needle (Cook, Bloomington, IL) via a transabdominal approach. Efforts were made to avoid access through the large intestine or aorta. A 0.018-inch microwire (Meister; Asahi Intecc, Nagoya, Japan) was advanced through the needle into the cisterna chyli and further into the thoracic duct. A microcatheter (Progreat Lambda 1.9 Fr; Terumo, Tokyo, Japan) was advanced into the thoracic duct over the microwire. Iodinated water-soluble contrast was injected to confirm appropriate entry into the thoracic duct and to verify the leak.

When the thoracic duct was continuous beyond the leakage site, the distal part was embolized with microcoils and the proximal part with an N-butyl-cyanoacrylate and lipiodol mixture, or both the proximal and distal parts were embolized with the NBCA mixture. When leakage occurred from the discontinued thoracic duct or thoracic duct branch, embolization of the thoracic duct below the leak or thoracic duct branch was performed using only the NBCA mixture. When the thoracic duct was cannulated via retrograde pleural access through the chest tube, the thoracic duct was embolized with coils and/or the NBCA mixture.

2.3. Definitions and analysis

Technical success of conventional lymphangiography was defined as successful visualization of the cisterna chyli and leakage site. Technical success of antegrade TDE was defined as successful cisterna chyli cannulation and successful embolization of the leakage site, and technical success of retrograde TDE via pleural access was defined as successful embolization at the thoracic duct or leakage site. Clinical success of TDE was defined as the resolution of lymphatic leakage and removal of the chest tube within 2 weeks.

Treatment outcomes were compared according to high- (> 500 mL/d) or low- (< 500 mL/d) output chylothorax. The Wilcoxon signed-rank test was used to compare the mean drainage amounts during the 3 days before and after embolization. A P-value <.05 was considered statistically significant. PASW Statistics for Windows/Macintosh version 18.0 (IBM; Armonk, NY) was used for data analysis.

3. Results

Treatment details and outcomes are summarized in Table 1. A flowchart of patient management is shown in Figure 1. MR lymphangiography findings in the 5 evaluated patients included contrast leakage (n=4) with (Patient Nos. 3, 4) (Fig. 2) or...
### Table 1

**Patient characteristics, treatment details, and outcomes.**

| No./Age/ Sex | Underlying disease | Surgery | MR LG findings | Interval (d) | Lipiodol LG findings | TDE | Embolic materials | Drainage (pre–post, mL) | Tube removal day | Remark |
|--------------|--------------------|---------|----------------|--------------|----------------------|-----|------------------|----------------------|----------------|--------|
| 1/62/M       | Chronic AD type III | TAAA replacement, TD ligation | NA | 12 | Leakage (T9) from TD branch | AG TDE | NBCA (1:3) | 150–70 | 10 |                  |
| 2/40/F       | Aortic aneurysm with aortic regurgitation | Bental op., total arch replacement | No leakage | 28 | R0 TD cath. failed, No TD visualization | No | NA | 550–60 | NA | Retrograde TD cath. failed, drainage amount was 300mL/day. TD ligation 21 days after LG |
| 3/57/M       | Lung ca. with aorta invasion | DTA replacement, left pneumonectomy | TD DC & leakage | 8 | TD DC & leakage (T6–9) | AG TDE | NBCA (1:3) | 800–490 | 3 | |
| 4/53/M       | Chronic AD type I | Distal aortic arch and TAAA replacement | TD DC & leakage | 13 | TD DC & leakage (T6–7) | AG TDE | NBCA (1:3) | 150–27 | 4 | |
| 5/47/M       | Mycotic aneurysm, pyogenic aortitis at DTA | DTA replacement | TD leakage | 4 | TD leakage (T9) | Lipiodol injection at CC after CC cath. failure | No | 150–93 | 7 | |
| 6/30/M       | Traumatic aneurysm at aortic isthmus | DTA replacement | NA | 4 | TD leakage (T7) | AG TDE | Coils (x 2), NBCA (1:1) | 2200–74 | 6 | |
| 7/1/M        | Double aortic arch | Left arch division | TD leakage | 9 | TD leakage (T5) | AG TDE | NBCA (1:4) | 300–10 at 1 day later | 2 | |
| 8/4/M        | Right aortic arch, aberrant LSCA, Kommerell's diverticulum | Diverticular resection, LSCA reimplantation | NA | 6 | TD leakage (T5) | TD leakage exit emb. via pleural access after CC cath. failure | NBCA (1:2) | 900–73 | 4 | |
| 9/56/M       | Epithelioid malignant mesothelioma with aorta invasion | Total arch replacement, left upper lobectomy | NA | 12, 17, 21 | TD leakage (T4–5) | #1 AG TDE, #2 & #3 TDE via pleural access | #1 NBCA (1:4), #2 Coils (x 5), #3 Coil (x 1), NBCA (1:2) | 1100 before #3–90 | 10 | Died d/t multi-organ failure 2 mo later |

AD = aortic dissection, AG = antegrade, ca. = cancer, cath. = catheterization, CC = cisterna chyli, DC = discontinuation, DTA = descending thoracic aorta, emb. = embolization, LG = lymphangiography, LSCA = left subclavian artery, NA = not available, NBCA = N-butyl-cyanoacrylate, RG = retrograde, TAAA = thoracoabdominal aortic aneurysm, TD = thoracic duct, TDE = thoracic duct embolization.

1 Interval means operation and thoracic duct embolization.
2 Drainage amount is the average of the 3 days before or after the embolization.
3 Tube removal day after index procedure.
4 Lymphangiography was incomplete due to very small inguinal lymph nodes.
without (Patient Nos. 5, 7) thoracic duct discontinuation, as well as no definite leakage (n = 1, Patient No. 2), and their findings and locations of leakage, and the location of cisterna chyli were well-correlated with conventional lymphangiography findings.

Conventional lymphangiography was technically successful in 8 patients (88.9%, 8/9). Conventional lymphangiography findings in these 8 patients were thoracic duct leakage (Figs. 2 and 3), with (n = 2) or without (n = 5) thoracic duct discontinuation, or thoracic duct branch leakage (n = 1, Patient No. 1). The leakage level was at T6–7 or below for 5 of the patients (Figs. 2 and 3) who underwent descending thoracic aorta or thoracoabdominal aortic aneurysm replacement, at T5 for 2 patients (Patient Nos. 7, 8) who underwent vascular ring surgery (Fig. 4), and T4–5 for 1 patient (Patient No. 9) who underwent total aortic arch replacement. In 1 patient (Patient No. 2) in whom no definite leakage was seen on the MR lymphangiogram, retrograde transvenous thoracic duct cannulation was attempted first, because the inguinal lymph nodes were too small (<5 mm in diameter). However, retrograde transvenous thoracic duct cannulation failed. Intranodal lipiodol lymphangiography was attempted; however, thoracic duct visualization failed, probably due to insufficient lipiodol injection.

TDE was attempted in all 8 patients in whom conventional lymphangiography was successful. Antegrade TDE (Figs. 2 and 3) was successfully performed with NBCA (mixed 1:1 to 1:4 with
lipiodol), with (n = 1) or without (n = 5) microcoils, in 6 patients, resulting in a 75% (6/8) technical success rate of antegrade TDE. In 2 patients (Patient Nos. 5, 8), antegrade TDE failed due to cisterna chyli catheterization failure. However, lipiodol injection was performed at the cisterna chyli level (No. 5) or embolization of the leakage site as seen on conventional lymphangiogram with NBCA (mixed 1:2 with lipiodol) via pleural access through the chest tube by means of a microcatheter (Patient No. 8) (Fig. 4). In the remaining 1 patient (No. 9), antegrade TDE was performed with NBCA (mixed 1:4 with lipiodol); however, the drainage amount did not decrease. The 2nd TDE was performed 5 days later, using 5 microcoils via retrograde thoracic duct catheterization with a microcatheter with pleural access through the chest tube; however, the drainage amount did not decrease. The 3rd TDE was performed 4 days later with 1 microcoil and NBCA (mixed 1:2 with lipiodol), via retrograde thoracic duct catheterization with a microcatheter with pleural access through the chest tube, with resolution of the drainage and removal of the chest tube 10 days later. The technical success rate of retrograde TDE via pleural access was, therefore, 100% (3 procedures in 2 patients, Patient Nos. 8 and 9).

Patients (n = 4, No. 1, 4, 5, 7) with low-output chylothorax underwent successful antegrade TDE (n = 3) or lipiodol injection at the cisterna chyli level (n = 1), and all had chylothorax resolution. Patients (n = 5, Patient Nos. 2, 3, 6, 8, 9) with high-output chylothorax underwent successful antegrade TDE (n = 2) or retrograde TDE via pleural access (n = 2), with chylothorax resolution. In 1 patient (Patient No. 2), TDE was not attempted due to failed visualization of the cisterna chyli. The mean tube removal day after the last embolization procedure was the same, 5.75 days, for both low- and high-output chylothorax patients (P > .05).

The mean drainage amount during the 3 days after embolization was 109.7 mL/d (range, 10–490 mL/d). The decrease in drainage amount was significant after lymphangiography/TDE (P < .05). The drainage tubes were removed a mean 5.7 days (range, 2–10 days) after embolization in 8 patients. Clinically successful TDE was achieved in 87.8% (7/8). One patient (Patient No. 5) who underwent lipiodol injection at the cisterna chyli after cisterna chyli catheterization failure did not meet the definition of clinical successful TDE; however, chylothorax resolved with tube removal 7 days later. One patient (Patient No. 2) with failure of conventional lymphangiography underwent thoracic duct ligation 21 days later with chylothorax resolution.

There were no procedure-related complications. One patient (No. 9) died due to multi-organ failure 2 months later, although chylothorax was resolved after 3 TDE procedures.

### 4. Discussion

The incidence of chylothorax following thoracic aortic surgery (excluding valve surgery) has not been well-described; however, the proportion of chylothorax after thoracic aortic surgeries among chylothorax after all thoracic surgeries was 8.1% (range, 1.5–12.4%).
Figure 3. A 30-year-old male (Patient No. 6) who underwent descending thoracic aorta replacement for mycotic aneurysm, presenting with chylothorax. (A) Oblique view intranodal lymphangiograms shows a prominent cisterna chyli, which was punctured with a 21-gauge Chiba needle (arrow). A microwire (arrowhead) was advanced through the thoracic duct. (B) Lipiodol extravasation (arrow) is noted during lipiodol injection through the microcatheter, apparently from a small branch (arrowhead) of the thoracic duct. (C) The proximal part was embolized with microcoils, and the distal part was embolized with N-butyl-cyanoacrylate (mixed 1:1 with lipiodol). The chest tube was removed 6 days later.

Figure 4. A 4-year old male (Patient No. 8) who underwent Kommerell’s diverticulum resection and aberrant left subclavian artery reimplantation for vascular ring, presenting with chylothorax. (A) Thoracic duct cannulation failed due to thin lymphatic channels from lumbar lymphatics to the thoracic duct on intranodal lymphangiogram (not shown). Lipiodol leakage (arrow) is seen at the T5 level and lipiodol pooling (asterisk) is notable at the left pleural cavity. (B) The microcatheter (arrows) was negotiated through the chest tube (long arrow) to the contrast leakage site (arrowhead); however, catheterization of the thoracic duct failed. (C) Radiograph imaging 4 hours after N-butyl-cyanoacrylate (NBCA; mixed 1:2 with lipiodol) embolization (arrows) at the leakage site by pleural access reveals NBCA packing the probable lymphatic leakage site (arrows). The chest tube was removed 4 days later.
The incidence of chylothorax after thoracoabdominal aortic aneurysm was reported to be 0.4% to 0.9%.[17,18] In one recent report, chylothorax occurred in 0.86% of 4896 cardiovascular surgeries, of which chylothorax after thoracic aortic surgeries accounted for 0.27% of the total cases.[19] Therefore, the incidence of chylothorax after aortic surgery seems uncommon. However, among patients who underwent thoracic surgery, chylothorax after thoracic aortic surgery is not uncommon.

As a treatment for chylothorax after cardiovascular surgery, including thoracic aortic surgery, surgical operations such as thoracic duct ligation or pleurodesis have been performed until recently.[10] However, the risk of reoperation is high due to postoperative adhesion, the proximity of the aortic surgical field, and possible anatomical anomalies of the thoracic duct and tributaries.[20] Therefore, if interventional TDE is safe and effective in these clinical settings, it will provide an excellent guide to the management of chylothorax after thoracic aortic surgery.

The mechanism of injury in chylothorax is closely related to the anatomy of the thoracic duct. The thoracic duct is a continuation of the cisterna chyli, which is located at the L2 level, and ascends between the aorta and the azygos vein. Opposite T5, it inclines toward the left side, ascends posteriorly to the aortic arch, and then passes behind the origin of the left subclavian artery. These anatomical characteristics explain why the leakage sites are well-matched to the surgery. For example, the leakage site was below the T5 level for patients who underwent descending thoracic aorta or thoracoabdominal aortic aneurysm replacement. Therefore, the leakage site can be anticipated according to surgical history, before lymphangiography.

When planning TDE for the management of lymphatic leakage, accurate identification of the leakage site and structural assessment of the thoracic duct is important. Recent advances in MR imaging systems have made it possible to indicate locations of lymphatic leakage and the cisterna chyli, as well as to obtain information related to obstruction or reflux of the lymphatics.[10,21] MR lymphangiography may be helpful in patients predicted to have high-flow or large amounts of lymphatic leakage, which can lead to contrast material dilution and venous contamination.[10] In this study, MR lymphangiography findings in 5 patients who underwent MR lymphangiography before TDE were well-correlated with those of conventional lymphangiography. MR lymphangiography is minimally invasive and will help in planning TDE and access routes as well as information regarding the lymphatic leakage site.

Since the successful puncture of the cisterna chyli is a prerequisite for TDE, it is very important to visualize the cisterna chyli on conventional lymphangiography. The cisterna chyli is generally well-opacified on conventional intranodal lymphangiograms, but it can be difficult to opacify the cisterna chyli when inguinal lymph nodes are absent or very small, as experienced in 1 patient in our study, or when patients are uncooperative.[22] In that case, transvenous retrograde thoracic duct cannulation can be attempted, but the technical success rate of transvenous retrograde thoracic duct cannulation was 69.2% (9/13) in a previous report.[23] In a recent report by Bundy et al., percutaneous transcervical retrograde access into the thoracic duct facilitated successful TDE after failed antegrade transabdominal access.[24] However, to date, reports on pleural access for thoracic duct cannulation are very limited. Notably, in our study, a retrograde thoracic duct approach via pleural access was attempted in 3 procedures in 2 patients, and it was technically feasible. Thus, percutaneous transpleural retrograde access into the thoracic duct can be an alternative approach after unsuccessful transabdominal cisterna chyli cannulation, to perform TDE in treating chylothorax.

The rate of technical success of antegrade TDE, defined as total occlusion of the target lymphatic duct, was 62.9% (range, 48.0%–81.0%) in a recent meta-analysis of TDE.[11] Therefore, the technical success rate of 75% (68/91) in this study seems quite acceptable. The cause of technical failure is most commonly an unsuccessful cannulation of the cisterna chyli, as seen in 2 patients in our study.[11] Thoracic duct disruption or embolization at the level of the cisterna chyli can be performed as a salvage intervention when technical failure of TDE occurs as clinical improvement can be expected.[11]

The overall clinical success rate of TDE (87.8% in this study) was quite promising and was higher than the 60.9% reported in a meta-analysis based on 407 patients.[11] This higher clinical success rate results from the utilization of an alternative technique, such as TDE or leakage site embolization via pleural access. However, even when TDE is technically successful, clinical results are not always satisfactory. In our study, 1 patient (Patient No. 9) had 2 unsuccessful clinical outcomes: after antegrade TDE with NBCA (mixed 1:4 with lipiodol) and after retrograde TDE with microcoils via pleural access. At the third attempt via pleural access, TDE could be reinforced with proximal coil packing and denser NBCA (mixed 1:2 with lipiodol), and clinical success was achieved. Therefore, denser NBCA and appropriate use of coils seem to be very important to ensure embolization. Coils are also very useful in avoiding spillage of NBCA into the systemic veins.

There was no difference in clinical outcome according to tube-removal day after embolization between the low- and high-output chylothorax patients. Once secure embolization is achieved, resolution of chylothorax is achieved rapidly, regardless of the daily drainage amount.

This study had a few limitations. First, it was a retrospective study. Second, the number of patients was small, and since the operations that caused chylothorax were heterogeneous, analysis according to the type of surgery could not be performed. Third, only patients referred for interventional treatment were included; therefore, actual incidence rates or comprehensive treatment strategies have not been addressed in this study.

In conclusion, conventional lymphangiography and TDE showed a high technical success rate and yielded encouraging clinical outcomes for treatment of chylothorax complicating thoracic aortic surgery.

Author contributions

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