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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Feasibility study of percutaneous thoracic duct embolization with lower-limb intermittent pneumatic compression devices

Ravivarma Balasubramaniam
Mona Mossad

PURPOSE

To demonstrate intranodal thoracic duct embolization (TDE) for treating chyle leaks following thoracic surgery and the feasibility of applying lower-limb intermittent pneumatic compression devices during TDE.

METHODS

Between December 2017 and October 2020, 12 consecutive TDEs for post-operative chyle leaks were performed in 11 patients using intranodal lymphangiogram (IL) with an intermittent pneumatic compressive device applied to the lower limb. The procedure's duration, technical/clinical success, and complications were retrospectively evaluated.

RESULTS

IL was successful at imaging the thoracic duct in all procedures (100%), and TDE had an intention-to-treat success rate of 92% (11/12). No related complications were observed during follow-up, which took place at a mean of 27 days. The time from the commencement of lymphangiogram until visualization of the thoracic duct was a mean of 21.6 min, and the mean overall procedure time was 87.3 min.

CONCLUSION

This study supports IL-guided TDE as a safe and effective option to treat post-thoracic surgery chyle leaks. We revealed shorter lymphangiogram times compared with previously published studies, and we postulate that the application of intermittent lower-limb pneumatic compressive devices contributed toward this study's results by expediting the return of lymph from the lower limb. This study is the first to illustrate this approach in TDE and advocates for randomized controlled studies to further evaluate the influence of intermittent pneumatic compressive devices on the procedure.

KEYWORDS

Thoracic duct, embolization, chyle leak, intermittent pneumatic venous compression devices, lymphangiogram

Injury to the thoracic duct can occur as a post-operative complication and is encountered in 1% to 9% of transthoracic esophagectomies and in 1.4% to 4% of pulmonary resections.[1-4] This results in a chyle leak, which can lead to respiratory failure, hypovolemia, malnutrition, or septicemia, with a mortality ranging from 3.7% to 46%.[3,5,6] Conservative management with nutritional support, sometimes combined with octreotide, can be trialed; however, for higher-volume chyle leaks, early surgical intervention and ligation of the thoracic duct has been shown to be critical to improving outcomes.[2,3,7,8] Surgical repair of a chyle leak has a success rate of 68% to 90% but carries a mortality rate of 10% to 16%.[3,7-9] In recent times, thoracic duct embolization (TDE) has emerged as a less invasive alternative, with an intention-to-treat success rate of 53% to 100% combined with a significantly lower complication rate.[10-17] It has the advantage of providing comprehensive delineation of the thoracic duct and can better identify the site of the chyle leak; this is of particular relevance given the recognized variance

From the Department of Radiology (R.B. ✉ Ravivarma.Balasubramaniam@uhnm.nhs.uk, M.M.), Royal Stoke University Hospital, Staffordshire, England.

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in thoracic duct anatomy.[12,18] TDE entails a lymphangiogram, which is conventionally done via exposure of the pedal lymphatics, followed by cannulation of the cisterna chyli/thoracic duct and subsequent embolization. Recently, ultrasound-guided intranodal access has been demonstrated as an alternative method to support the lymphangiogram to guide TDE, with fewer complications; however, published data on this technique remains limited.[19-24] The transport of lymph is similar to venous return and is primarily regulated by the contraction of the smooth muscles in the lymphatic channels and surrounding skeletal muscles. We theorize that intermittent pneumatic compressive devices, which expedite venous return when used as a prophylaxis in the prevention of deep vein thrombosis, may have a similar influence on the return of lymph and could shorten TDE procedure times.

We detail a study of consecutive intranodal lymphangiogram (IL)-guided TDEs to treat post-thoracic surgery chyle leaks and illustrate the application of intermittent pneumatic compression devices.

Methods

Permission from the Institutional Review Board of the University Hospital of North Midlands Ethics Committee's Research and Design Department was obtained for this study (protocol number: 210421). A retrospective analysis of 12 procedures in 11 consecutive patients who underwent TDE at our institute between December 2017 and October 2020 was performed. All chyle leaks occurred as a post-operative complication: eight after esophagectomy, two following thoracotomies, and one after video-assisted thoracoscopic surgery. All the operations were performed to treat malignancy, except for one thoracotomy that was undertaken to resect a first rib to treat thoracic outlet syndrome. The thoracic duct was not ligated during any of the operations. There were seven male and four female patients, ranging in age from 25 to 81 years, with a mean age of 57.5 years. All patients presented with the classic milky white appearance of post-operative pleural fluid. A pleural fluid analysis with a triglyceride content of >1.2 mmol and cholesterol of <5.1 mmol were used to differentiate between a chylothorax and pseudochylothorax. A chylomicrons analysis of the pleural fluid was not available at our institute. Prior to the IL TDE, all patients had a trial of conservative treatment for a minimum of 5 days (fat-free diet and octreotide therapy). The inclusion criteria were that patients had a drain output of >500 mL/day, despite conservative management, and a full blood count with a lymphocytopenia ranging from 0.1 to 1 (normal value is 1.5).

Main points

- Thoracic duct embolization (TDE) is a viable option to surgical ligation in the management of post-operative chyle leaks.
- Ultrasound guided intranodal lymphangiogram is a safe and effective alternative to pedal lymphangiogram to guide TDE.
- Intermittent pneumatic compressive devices may have a role in expediting lower-limb lymphangiography and TDE procedures.

All patients underwent TDE with ultrasound-guided IL, performed by a single interventional radiologist with 3 years of procedural experience. The duration from the initial thoracic surgery to TDE had a range of 2 to 25 days, with a mean of 12.2 days. Chylothorax resolution and removal of the chest drain were considered the endpoint for clinical success. Informed written consent and a surgical safety checklist were completed before commencing the intervention. Prophylactic intravenous antibiotics consisting of 1.2 g of intravenous co-amoxiclav was administered at the initiation of the procedure. Prior to cleaning and draping the patient, bilateral pneumatic compression boots were applied around both of the patient's lower limbs but remained switched off. An ultrasound examination of both groins was performed using a Philips Purewave CX 50 ultrasound machine, and the largest and most superficial inguinal lymph node was targeted. Under ultrasound guidance using an aseptic technique, an inguinal node was punctured using a 22 G 3.5-inch BD spinal needle and a maximum of 20 mL of lipiodol injected. If extravasation was demonstrated, another unilateral inguinal node was targeted, with a maximum of three inguinal nodes punctured in one procedure. After successfully accessing an inguinal node, the ipsilateral intermittent pneumatic compressive sleeve was turned on, and the progression of Lipiodol through the lymphatic system was monitored under intermittent fluoroscopy until visualization of the cisterna chyli or thoracic duct (see Table 1 column for the visualization of cisterna chyle for the duration of intermittent compression device application). At this point, the pneumatic compression device was turned off for the remainder of the procedure to avoid the rapid transit/washout of the contrast and maximize the visualization of the thoracic duct. A maximum sedation of 250 µg of fentanyl and 7.5 mg of midazolam was then administered before 10–20 mL of 1% lignocaine was infiltrated locally and the cisterna chyli or thoracic duct directly punctured at L1/L2 level using an AccuStick II kit (Boston Scientific; introducer needle with stylet 21 G 15 cm). Once the cisterna chyli/thoracic duct was cannulated, a V18 short taper 0.018 inch × 200 cm control wire (Boston Scientific) was introduced, and the 21 G needle was subsequently exchanged for a Progreat micro-catheter system (2.7 F, 130 cm; Terumo). Visipaque contrast was then injected into the micro-catheter to confirm the position and delineate the site of the chyle leak. A detachable coil was next inserted upstream of the leak (Concerto; detachable coil system with nylon fibers, 4 mm × 8 cm × 0.0125 inch, ev3), followed by a mixture of tissue adhesive glue (Histoacryl, B. Braun) and lipiodol (Ultra fluid, Guerbet) with a mixing ratio of 1:2. The glue was injected along the course of the thoracic duct as the micro-catheter was pulled out under fluoroscopic guidance. Completion X-rays were subsequently obtained of the chest, abdomen, and pelvis for a reference of embolic position (Figure 1).

Results

Technique

The site of the chyle leak was identified using IL in each of the 12 cases. In all 11 patients, the chyle leak was treated successfully with TDE using two micro-coils combined with a mixture of cyanoacrylic glue and lipiodol. The overall intention-to-treat success rate was 11/12 (92%), as there was one patient with an abdominal chyle injury that required a repeat procedure 17 days later to achieve successful treatment (Figure 2). In cases where local extravasation of lipiodol from the inguinal node puncture site occurred, clinical follow-up over the ensuing 24 to 48 h was conducted with no local symptoms of pain or swelling reported. There were no long-term post-procedure complications on follow-up, which ranged from 9 to 91 days, with a mean of 27 days.

Duration

There were no records of the time taken to access the inguinal node for the lymphangiogram under ultrasound guidance. The procedure time from the initiation of the lymphangiogram to visualization of the target lymphatic (thoracic duct or a major tributary) ranged from 9 to 29 min, with a mean of 21.6 min and a standard deviation of ± 6.0 min. The duration from the commencement

of the lymphangiogram to catheterization of the thoracic duct ranged from 28 to 106 min, with a mean of 55.5 min and a standard deviation of ±24.2 min. The time from the beginning of the lymphangiogram to embolization of the thoracic duct ranged from 47 to 124 min, with a mean of 83.1 min and a standard deviation of ± 24.3 min. Intermittent pneumatic compression devices were activated from the commencement of the lymphangiogram until visualization of the cisterna chyli, with a duration ranging from 9 to 29 min and mean application time of 21.6 min. The overall procedure time from the start of the lymphangiogram to completion of the TDE procedure had a mean of 87.3 min with a standard deviation of ± 23.9 min (see Table 1 for the individual times).

Figure 1. Fluoroscopic images of a thoracic duct chyle leak post esophagectomy. **(a)** Fluoroscopic intranodal lymphangiogram (IL) image delineating the site of the thoracic duct chyle leak (white arrow), **(b)** fluoroscopic IL image after successful thoracic duct embolization with detachable coil, adhesive glue. and lipiodol (white arrow heads).

Discussion

Technique

TDE was first illustrated by Cope et al.[10] in 1998 through the transabdominal catheterization of the cisterna chyli guided by a pedal lymphangiogram. In a subsequent study of 42 patients by Cope and Kaiser[11] in 2002, TDE delivered favorable outcomes, with a treatment response of 78%. However, the emergence of computed tomography and magnetic resonance imaging lymphan-

Figure 2. Abdominal chyle leak post esophagectomy; fluoroscopic intranodal lymphangiogram image showing the site of the abdominal chyle leak (white arrows).

Table 1. Procedure times for intranodal lymphangiography and thoracic duct embolization

Patient	Age in years (sex)	Surgery	Site of chyle leak	Visualization of CC	Time to cannulation of TD	Time to embolization of TD	Total procedure time
1	25 (F)	VATS	T11	18	37	67	68
2	69 (M)	Esophagectomy	T12/L1	21	39	76	78
3	-			22	54	80	95
4	58 (M)	Esophagectomy	T10	28	81	105	108
5	63 (M)	Esophagectomy	T11	14	33	56	59
6	54 (M)	Esophagectomy	T10	18	34	57	67
7	81 (F)	Thoracotomy	TD- LSV	20	37	70	72
8	60 (F)	Esophagectomy	T8	23	61	95	102
9	66 (M)	Esophagectomy	T11	28	71	102	104
10	56 (M)	Esophagectomy	T8	29	106	124	126
11	56 (M)	Esophagectomy	T10	9	28	47	49
12	44 (F)	Thoracotomy	T12	29	85	118	119
Mean (SD)	**57.5**			**21.6 (± 6.3)**	**55.5 (± 25.27)**	**83.1 (± 25.4)**	**87.25 (± 25.0)**

The light line shaded area denotes a repeat procedure on the same patient. CC, cisterna chyli; TD, thoracic duct; VATS, video-assisted thoracoscopic surgery; TD-LSV, junction of the thoracic duct with the left subclavian vein; SD, standard deviation; F, female; M, male.

giogram meant pedal lymphangiography (PL) became less frequently utilized, resulting in diminished clinical experience in the technique.[25-27] This has limited the development of conventional TDE as an alternative to surgical ligation in the management of thoracic duct injuries, and literature on the topic is limited, with research primarily originating from a small number of institutes. Ultrasound-guided intranodal access as an alternative to PL was first demonstrated by Hall and Krementz[28] in 1967 and replicated by Rajebi et al.[19] in 2011 in a pediatric group. Intranodal lymphangiography complements ultrasound intervention practice, thereby offering scope to broaden access to TDE as a treatment option for chyle leaks. The technique was first utilized as a viable substitute for PL to guide TDE by Nadolski and Itkin[20] in 2012 and has since been replicated in other studies.[10] This is substantiated by our findings, with the thoracic duct visualized and the site of the chyle leak identified in all 12 procedures. Our technical success rate of 100% for IL is consistent with figures from previous studies by Nadolski and Itkin[21], which attained rates of 98% to 100% employing both PL and IL for TDE. The chyle leak was successfully treated with IL-guided TDE in all 11 patients in our study, with one case requiring a repeat procedure. Our 92% technical success rate was similar to the 86% reported by Ushinsky et al.[22] in treating chyle leaks after head/neck cancer surgery and superior to other smaller IL TDE studies by Kariya et al.[23] and Kim et al.[24], which accomplished rates of 75% and 67%, respectively. Our study is the largest series of consecutive IL TDEs to treat chyle leaks following thoracic surgery, with results comparable to the largest similar study by Nadolski and Itkin[21], which reported a technical success rate of 98% in 50 patients, 22 of whom underwent TDE using an IL method. Our overall intention-to-treat success rate of 92% (11/12) supports IL as an alternative to PL for TDE in the treatment of post-operative chyle leaks, being equivalent to the 75–97% stated in previous PL TDE studies, including the two largest studies by Pamarthi et al.[15] (involving 105 patients) and Itkin et al.[16] (involving 106 patients).[17,20-24] Our intention-to-treat rate of 92% is also equivalent to the clinical success rate of surgical ligation, which ranges from 68% to 90%, with the additional benefits of being minimally invasive.[5,7-9] Complications related to TDE include intra-alveolar hemorrhage or pulmonary embolism from the injected lipiodol and infection, which occurs in 0.9–2.9% of cases; this is primarily related to lymphatic exposure in the PL group.[25,29,30] No complications were reported in our study during a mean follow-up of 27 days.

Duration

Comparison with other studies on procedure times are limited by a lack of relevant published data. The most applicable study was by Nadolski and Itkin[20] in 2012, which compared the durations of six IL and six PL-guided TDEs. The time taken to visualize the thoracic duct with IL was significantly shorter in our study, with a range of 9 to 29 min and a mean of 21.6 min compared with a range of 23 to 64 min and mean of 40 min reported in the IL-guided TDE group in the study by Nadolski and Itkin.[20] The overall procedure time in our study was also noticeably shorter, with a mean of 87.3 min compared with a mean of 105.3 min in their study.[20] We postulate that utilizing lower-limb intermittent pneumatic compressive devices may have contributed toward our shorter IL and TDE procedure times. The active transport of lymph from nodes follows a similar process to lower-limb venous return and is primarily governed by the contraction of skeletal muscle and smooth muscle in the walls of lymphatic vessels.[31-33] Intermittent pneumatic compressive devices applied to the lower limbs can improve venous return by increasing blood velocity in the deep veins, and they have been utilized as prophylaxis in the prevention of deep vein thrombosis. For our study, we postulate that the use of pneumatic venous compression devices may have had a similar influence on the return of lymph from the lower limbs to the cisterna chyli and may also have contributed toward the reduced mean time for IL and overall TDE procedure time.[34] This rationale is corroborated by a retrospective study by Meisinger et al.[35], which demonstrated a significantly shorter IL mean time of 29 min with lower-limb pneumatic compression devices compared with 56 min without. Their results are comparable to the 21.6-min IL duration achieved in our study, but their study predominantly involved patients with non-traumatic chyle leaks (7/19) or research cases with no leak (5/19).[35]

The primary limitations of the present study are its retrospective nature and the absence of a randomized control. However, it remains the largest case series demonstrating consecutive IL-guided TDE to treat post-operative chyle leaks with the application of intermittent pneumatic venous compression devices. Large prospective randomized controlled studies evaluating the effect of pneumatic venous compression boots in TDE, using both an IL and PL technique, are required to further validate the hypothesis proposed. All TDEs were also performed by a single radiologist, which makes assumptions of wide reproducibility less certain. The radiologist also had relatively limited experience, with only 3 years using this technique. As such, it is assumed that operative duration would be reduced for a radiologist of greater experience.[16] Finally, our study has a relatively small sample size; however, this remains the largest study to date on consecutive TDE using IL to treat post-thoracic surgery chyle leaks.

In conclusion, with an intention-to-treat success rate of 92%, our findings endorse IL-guided TDE as a safe alternative to surgical ligation in the management of post-operative chyle leaks. This is the largest study of consecutive IL-guided TDE to treat post-operative chyle leaks after thoracic surgery, illustrating technical and clinical success rates that compare favorably with larger studies performed using a PL method. This study demonstrates significantly shorter lymphangiogram procedure times compared with previous TDE studies and postulates that utilizing lower-limb intermittent pneumatic compressive devices contributed to these outcomes by expediting lymph return toward the cisterna chyli/thoracic duct. This study is the first to illustrate this approach in TDE and recommends that further prospective randomized studies be performed to evaluate the influence of intermittent pneumatic compressive devices on procedure times in TDE.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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