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Efficacy of en bloc thoracic duct ligation in combination with pericardiectomy by video-assisted thoracoscopic surgery for canine idiopathic chylothorax

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Abstract

Objective: To compare the outcomes of pericardiectomy performed with conventional clipping thoracic duct ligation (C-TDL) to those with en bloc thoracic duct ligation (EB-TDL) using video-assisted thoracoscopic surgery (VATS) for canine idiopathic chylothorax.

Study design: Retrospective consecutive case series.

Animals: Thirteen client-owned dogs with idiopathic chylothorax.

Methods: Medical records of dogs treated with pericardiectomy in combination with TDL by VATS without intraoperative contrast were reviewed. Five and seven dogs underwent C-TDL and EB-TDL, respectively, and 11 dogs were evaluated by preoperative and 7- to 10-days-postoperative computed tomography-lymphography (CTLG). No clinical symptoms with absent or minimal pleural effusion was defined as clinical improvement. Long-term remission (LTR) was defined as rapid resolution of pleural effusion and no recurrence for more than 1 year. Anesthesia time, operation time, the duration of hospitalization, and time until pleural effusion resolution were compared.

Results: Clinical improvement was achieved in 91.7% of the cases (C-TDL, 4/5; EB-TDL, 7/7), excluding one case of intraoperative death. The LTR rate was significantly higher with EB-TDL (6/7 [85.7%]) than with C-TDL (1/5 [20%]). Anesthesia time, operation time, and time until pleural effusion resolution were significantly better with EB-TDL than with C-TDL. The rates of thoracic ducts visualization by postoperative CTLG were 100% (5/5) with C-TDL and 42.9% (3/7) with EB-TDL.

Conclusion: En bloc TDL was an effective treatment for canine idiopathic chylothorax in this patient population. It compared favorably to C-TDL, although missed branches at the time of surgery may explain the difference between C-TDL and EB-TDL in this small population of cases.

Clinical significance: En bloc TDL by VATS was an effective minimally invasive treatment for canine idiopathic chylothorax. Computed tomography-lymphography can be used for surgical planning and postoperative evaluation.

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1 | INTRODUCTION

Canine idiopathic chylothorax is a devastating disease that requires surgical intervention using techniques including thoracic duct embolization, active or passive shunting, omentalization of the thorax, and thoracic duct ligation (TDL).[1-5] Thoracic duct ligation is a widely used surgical approach for treating idiopathic chylothorax, although none of the techniques have effectively resolved pleural effusion in every dog. Thoracic duct ligation in combination with partial pericardiectomy has been shown to lead to successful outcomes in canine idiopathic chylothorax.[6] Another surgical procedure, cisterna chyli ablation, was also demonstrated as an effective option that was often performed in combination with TDL and/or pericardiectomy.[7-9] Although all identified thoracic duct branches should be completely ligated to minimize the risk of recurrence, recurrent pleural effusion or chylothorax is experienced in certain cases regardless of a successful operative approach.[6,10-12]

Conventional TDL is performed at the most caudal level of the thoracic duct as it enters the thoracic cavity.[6,9,10] Two approaches used for TDL are clipping TDL (C-TDL) and en bloc TDL (EB-TDL).[13-15] In C-TDL, all thoracic duct branches are ligated by using endoscopic hemoclips, whereas EB-TDL uses collective ligation of the surrounding tissues including the thoracic duct by sutures. En bloc TDL is considered unlikely to lead to the recanalization of lymph flow or the formation of collateral bypasses after ligation because the method enables the ligation of fine and invisible branches.[14] Video-assisted thoracoscopic surgery (VATS) has been developed as a less invasive surgical method and is used for C-TDL to chylothorax.[16-18] The reported rates of successful prognosis with C-TDL and pericardiectomy are 83.3% and 85.7%, respectively,[15,19] which are comparable to that with thoracotomy, although none of the current approaches achieve complete cure. Minimally invasive thoracoscopic EB-TDL is a curative method that is potentially equivalent to open surgery in efficacy. However, to the best of our knowledge, no cohort studies in veterinary medicine have examined its efficacy.

Some dogs exhibit persistent pleural effusion or recurrent chylothorax after TDL.[10,12,19,20] Despite the possibility of invisible thoracic ducts and formation of lymphatic duct colaterals around the thoracic ligation site, no study has elucidated the underlying mechanisms by using postoperative imaging. Recent reports have described computed tomography (CT)-lymphography (CTLG) as a useful method to visualize thoracic ducts without thoracotomy.[21-23]

We compared the outcomes of pericardiectomy in combination with C-TDL or EB-TDL performed by using VATS for canine idiopathic chylothorax and examined changes in lymph duct flow by preoperative and postoperative CTLG in a retrospective case series.

2 | MATERIALS AND METHODS

2.1 | Case selection

Consecutive dogs diagnosed with canine idiopathic chylothorax between November 2012 and June 2019 at Kanai Veterinary Surgery were retrospectively reviewed. All dogs were treated with thoracentesis and/or medications, such as glucocorticoids, diuretic agents, and rutin, to resolve pleural effusion but experienced recurrence, which was difficult to control. Initial CTLG was performed 1 to 3 days before VATS for pericardiectomy and TDL. Postoperative CTLG was performed 7 to 10 days after VATS.

2.2 | Anesthesia

General anesthesia was induced with butorphanol (0.2 mg/kg IV; Vetorphale; Meiji Seika Pharma, Tokyo, Japan), midazolam (0.2 mg/kg IV; Dormicum; Astellas Pharma, Tokyo, Japan), and propofol (dose to effect IV; Rapinovet; MSD Animal Health, Ibaraki, Japan) and maintained with 3.0% to 3.7% sevoflurane (Maruishi Medical, Osaka, Japan) in O_2. Fentanyl (0.5 μg/kg/h constant rate infusion; Daiichi Sankyo Propharma, Tokyo, Japan) and Meloxicam (0.2 mg/kg subcutaneous; Metacam; Boehringer Ingelheim Animal Health Japan, Tokyo, Japan) were used as analgesic agents during operation and postoperative period according to the animal's condition. Cefazolin (20 mg/kg subcutaneous; Rasenazolin; Nichi-Iko Pharmaceutical, Toyama, Japan) was used for prevention of wound infection.

2.3 | Computed tomography-lymphography

Computed tomography-lymphography was performed as previously reported.[23] Briefly, 0.6 mL/kg of the nonionic contrast agent iopamidol (Oypalomin 370; Fuji Pharma, Tokyo, Japan) was injected into the rectal submucosa or anus with the dog in supine position. A 16-slice CT scanner (Brivo CT 385; GE Healthcare, Fairfield, New Jersey) was used with the following parameters: tube voltage levels, 100 and 120 kV; slice thickness, 1.25 to 2.50 mm; and pitch, 1.375:1. The scans were examined 5 and 10 minutes after the administration of the contrast agent. Additional injections (0.6-1.2 mL/kg) were administered when the initial dose was not sufficient for the visualization of the thoracic duct. OsiriX (Newton Graphics, Sapporo, Japan) imaging software was used to reconstruct three-dimensional lymphography and visualize the localization of the thoracic duct before and after the operation. Thoracic duct ligation was considered successful when the contrast agent did not reach sites cranial to the ligated thoracic duct.

2.4 | Pericardiectomy by VATS

In this study, VATS was performed by using an endoscopic surgical system (VISERA 4 K UHD; Olympus, Tokyo, Japan). A three-port technique was used for thoracoscopic pericardiectomy. First, the dog was situated in the dorsal recumbency position, and the first trocar was inserted from the right side of the xiphoid process by using the optical view.[15,19] Next, two 5-mm trocars were inserted bilaterally at the eighth intercostal level (Figure 1A). Subtotal pericardiectomy was performed as follows. The mediastinum was cut with an ultrasonically activated device (Sonosurge; Olympus), the pericardium was gripped with forceps, and a small incision was made with scissors. Pericardium ventral to the phrenic nerve was removed piece by piece, starting from the initial small incision (Figure 1B,C).[24,25]

2.5 | Thoracic duct ligation by VATS

After pericardiectomy, the position of the dog was changed to the left lateral position in all dogs except dog No. 2, in which the thoracic duct was identified on the left side by preoperative CTLG, and TDL was performed in the right lateral position. A stereoscopic camera port was inserted at the tenth intercostal space, a right-hand operation port was set at the eight or the ninth intercostal space, and a left-hand operation port was set at the eleventh intercostal space. We used a 4 K ultra–high-definition system (Visera 4 K UHD, Olympus) to identify thoracic ducts during VATS (Figure 2A). In the current case series, two TDL approaches were used: C-TDL and EB-TDL. In C-TDL, pleura between the aorta and the azygous vein were bluntly dissected, and hemoclips (LIGA-CLIP; Johnson & Johnson, Tokyo, Japan) were used for ligation with visual inspection of a patent thoracic duct (Figure 2B). In EB-TDL, the dorsal side of the aorta and the ventral side of the sympathetic nerve chain were bluntly dissected, and all tissues were ligated with 3-0 vicryl (Johnson & Johnson) sutures (Figure 2C). A hemoclip was placed at the suture site as a marker for postoperative CTLG. The EB-TDL technique was performed as described in a previous report.[26] In addition, in bilateral EB-TDL (bEB-TDL), the entire tissue surrounding the aorta was peeled after EB-TDL (Figure 2D). Gauze and vascular tape were wrapped around the aorta and pulled upward by assistant forceps; next, the tissues on opposing sides of the aorta were collectively ligated to achieve bilateral EB-TDL (Figure 2E).

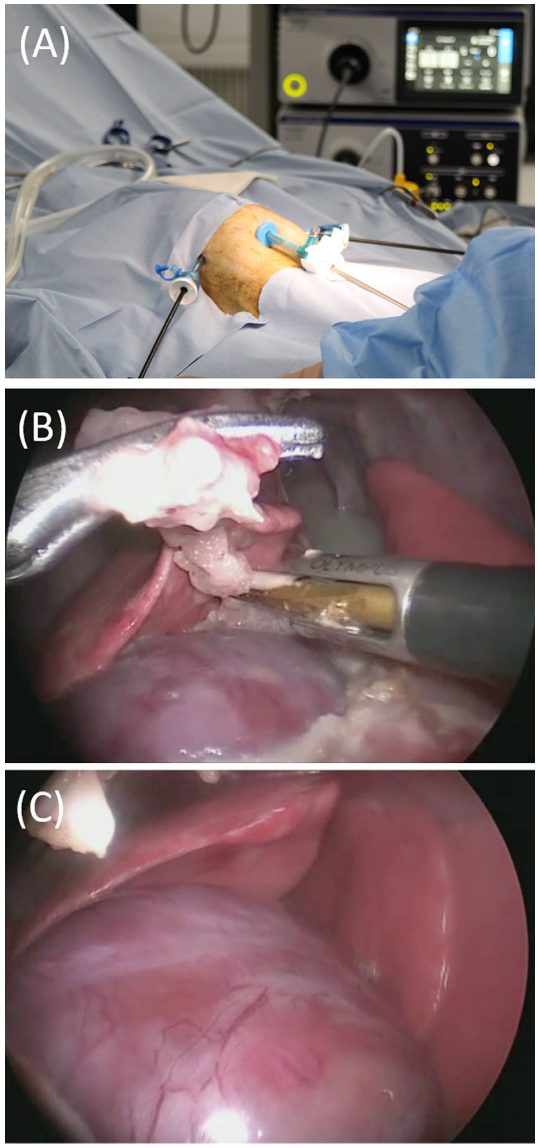

FIGURE 1 A, Pericardiectomy was performed with all dogs positioned in dorsal recumbency. The transxiphoid process approach is used with the optical view method. B, The mediastinum is dissected with ultrasonically activated devices, the pericardium is gripped with forceps, and a small incision is made with scissors. Pericardium is cut piece by piece starting from the initial small incision. C, Image of the pericardium at the end of the procedure. Pericardium should be completely removed until all restraints on the heart are released

2.6 | Assessment of TDL

Age, body weight, anesthesia time, operation time, duration of hospitalization, time until the resolution of pleural effusion, and prognosis were compared between the C-TDL and EB-TDL groups. Because idiopathic chylothorax is a refractory disease, clinical improvement has been defined as cure in most reports.[10,12,20] However, in real-world practice, some dogs require reoperation or

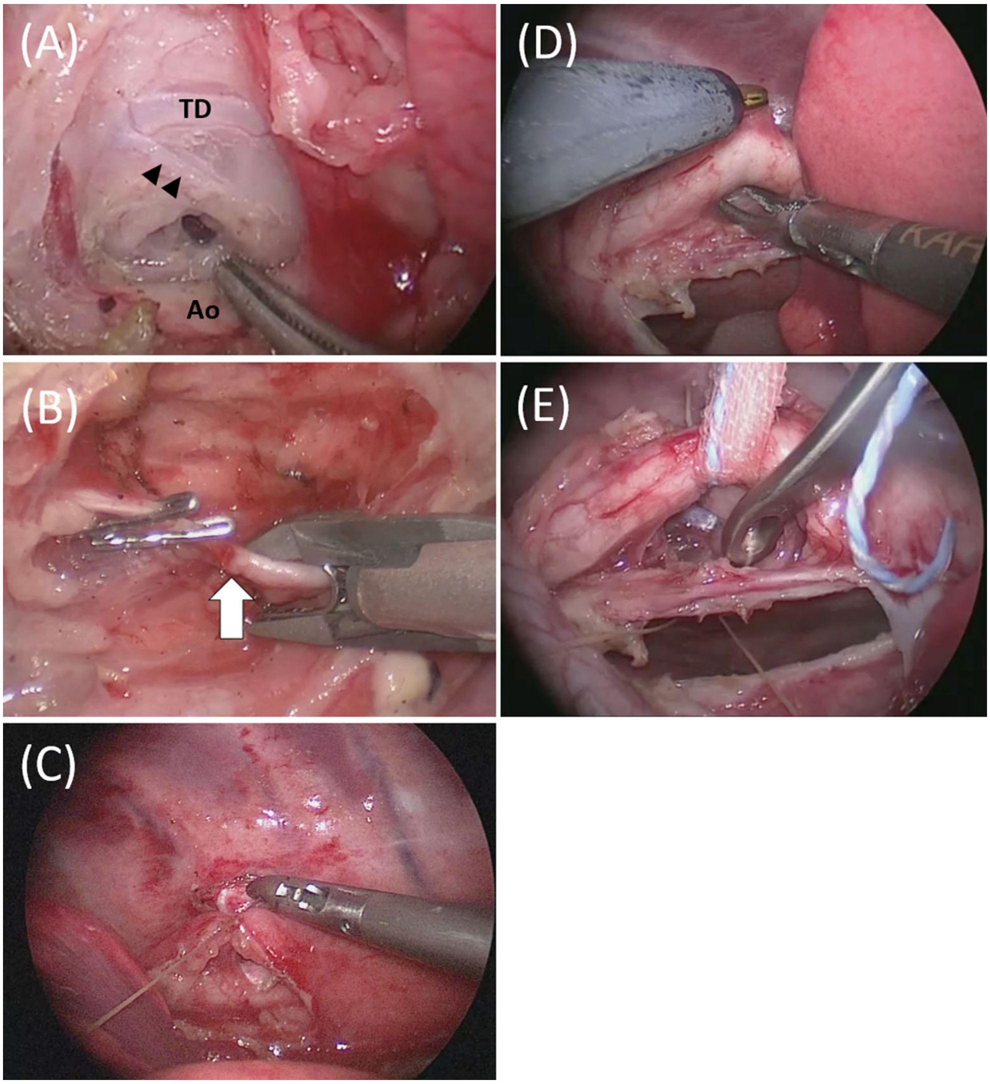

FIGURE 2 A, Thoracoscopic view with a 4 K ultra–high-definition system. Thoracic duct (TD), thoracic duct branch (arrowheads) and aorta (Ao) are identified. B, Conventional clipping TDL technique. Thoracic duct (arrow) is identified by preoperative computed tomography-lymphography. The duct is occluded by using metal clips. C, En block TDL technique. The thickened pleura is dissected on the ventral side of the sympathetic nerve chain, a tunnel is cut from that site to the dorsal side of the aorta, and all tissues including the azygous vein are ligated. D, Bilateral EB-TDL technique. The other side of the aorta is dissected after EB-TDL. The aorta is lifted very gently with careful monitoring of blood pressure and heart rate. E, The gauze is passed around the back of the aorta and pulled upward with assistant forceps. The wide region on the opposite side of the mediastinum is peeled, and all tissues on the opposite side of aorta are ligated to complete the bilateral EB-TDL. EB-TDL, en bloc TDL; TDL, thoracic duct ligation

have slight, albeit persistent, pleural effusion with no clinical signs. We used the following definitions of prognosis for canine idiopathic chylothorax in this study: absent or minimal pleural effusion by radiography or no clinical symptoms due to pleural effusion as "clinical improvement" and the disappearance of pleural effusion by radiography within at least 1 week after surgery and no recurrence for at least 1 year after surgery as "long-term remission" (LTR). Long-term follow-up was performed by reevaluation based on clinical signs, radiography every few months, and/or by telephone contact with the referring veterinarians or owners.

2.7 | Statistical analysis

Data with nonnormal distribution are presented as median (range). The Mann–Whitney U test was used to compare C-TDL and EB-TDL for age, body weight, anesthesia time, operation time, duration of hospitalization, and time until pleural effusion resolution. Long-term remission rate was compared with Fisher's exact test. All analyses were performed in Ekuseru-Toukei (Social Survey Research Information, Tokyo, Japan) statistical software. $P < .05$ was considered statistically significant.

TABLE 1 Summary data on CTLG and thoracoscopic surgery of 13 dogs in the current case series

Dog	Age (mo), sex, breed, bodyweight (kg)	Preoperative CTLG	Surgical procedure	Anesthesia time, min	Operating time, min	Period until pleural effusion resolution, d	Hospitalization, d	Postoperative CTLG	Postsurgical outcome
1	36, M, SS, 11.7	N/A	PC + C-TDL	225	145	5	8	N/A	Relapse after 1 mo
2	49, F, SI, 6.5	L	PC + C-TDL	171	115	8	11	R	LTR
3	32, NF, TP, 5	R	PC + C-TDL	192	122	10	15	R	Improvement
4	77, NM, LR, 27	L, R	PC + C-TDL	209	133	23	27	L	Relapse after 6 mo
5	52, M, SI, 11.2	R	PC + C-TDL	231	116	10	13	R	Improvement
6	49, M, SI, 4.8	R	N/A	N/A	N/A	N/A	N/A	N/A	Intraoperative death
7	84, M, MD, 8.2	R	PC + EB-TDL(R)	170	111	1	3	L	LTR
8	74, NF, LR, 21.7	R	PC + EB-TDL(R)	158	94	4	10	R	LTR
9	99, M, SI, 8.2	N/A	PC + bEB-TDL	179	113	3	11	N/D	LTR
10	27, F, SI, 10.9	R	PC + bEB-TDL	191	121	2	9	N/D	LTR
11	53, M, SI, 10.8	R	PC + bEB-TDL	162	106	1	3	N/D	LTR
12	48, M, MD, 6.6	R	PC + bEB-TDL	170	113	5	13	R	Improvement
13	51, NF, SI, 7.7	R	PC + bEB-TDL	159	96	2	9	N/D	LTR

Abbreviations: bEB-TDL, bilateral en bloc TDL; CTLG, computed tomography-lymphography; C-TDL, clipping TDL; EB-TDL(R), en bloc TDL on right side; F, intact female; L, left side; LTR, long-term remission; LR, Labrador retriever; M, intact male; MD, miniature dachshund; N/A, not available; N/D, not detected; NF, neutered female; NM, neutered male; PC, pericardiectomy; R, right side; SI, shiba inu; SS, Shetland sheepdog; TDL, thoracic duct ligation; TP, toy poodle.

3 | RESULTS

3.1 | Animals

Thirteen dogs met the inclusion criteria and were included in the study: seven shiba inus, two Labrador retrievers, two miniature dachshunds, one Shetland sheepdog, and one toy poodle (Table 1). Median age was 51 months (range, 27-99), and median weight was 8.2 kg (range, 4.8-27). The cohort study included eight males (one castrated) and five females (three spayed).

Although pericardiectomy and TDL by VATS were planned in all 13 dogs, dog No. 6 was excluded due to intraoperative death. The dog had received several thoracenteses previously and had been in serious condition (American Society of Anesthesiologists class 4) at the time of surgery. The VATS was performed, but unrecoverable cardiopulmonary arrest occurred before TDL could be completed. Therefore, 12 dogs were included for subsequent analyses in this study.

3.2 | Computed tomography-lymphography

Preoperative and postoperative CTLG were performed in 11 of 13 (dog Nos. 2-7, 9-13) and 11 of 13 (dog Nos. 2-5, 7-13) dogs, respectively. Dog No. 1 was not evaluated with either preoperative or postoperative CTLG, and dog No. 6 did not undergo postoperative CTLG due to the intraoperative death. Dog No. 8 was evaluated by preoperative CTLG, which was unsuccessful, at another institution and was evaluated by postoperative CTLG only.

By preoperative CTLG, the thoracic ducts were determined to run on the right side in nine dogs (Nos. 3, 5-13), on the left side in one dog (No. 2; Figure 3A), and

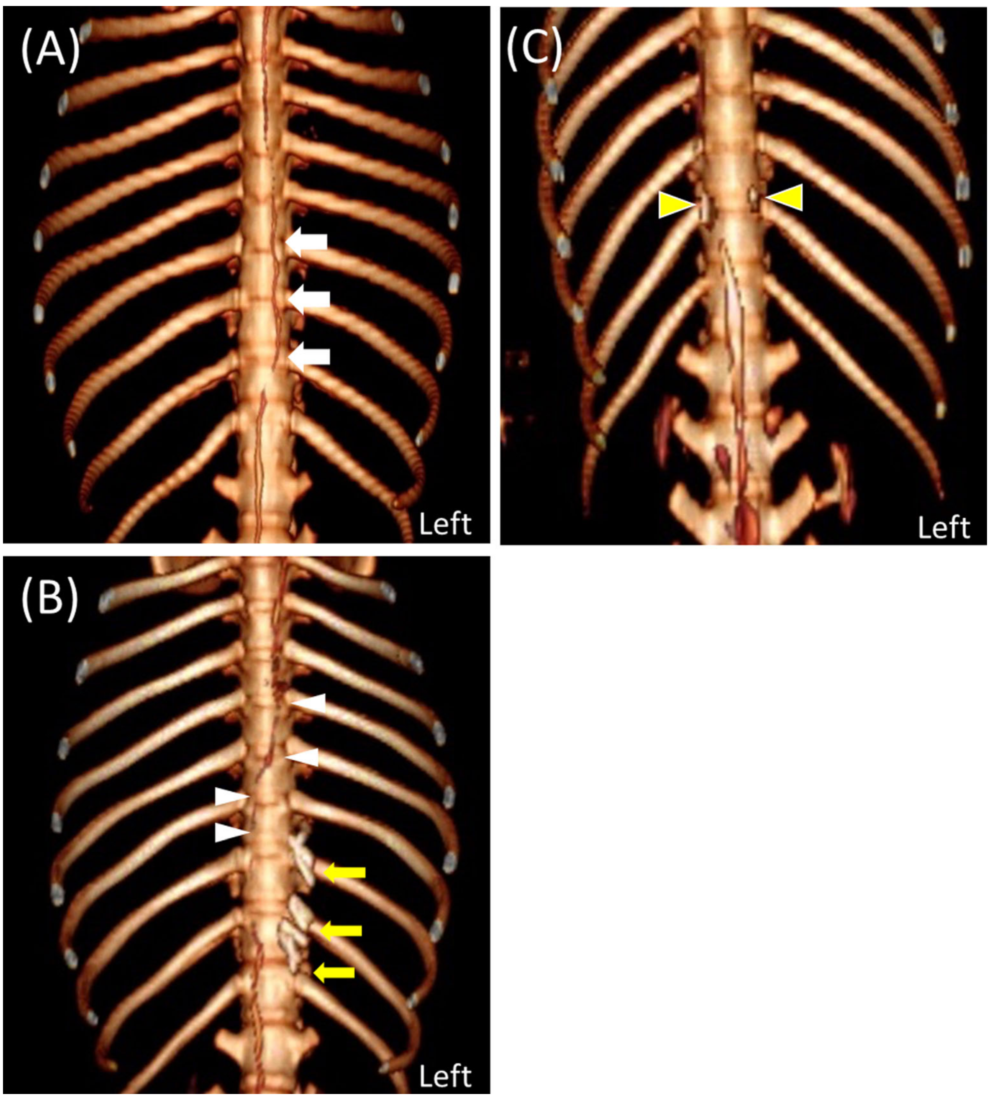

FIGURE 3 Volume rendering images of CTLG. Preoperative CTLG (A) and postoperative CTLG (B) of dog No. 2 with C-TDL. The thoracic duct was located in the left side before surgery (white arrows) and was visualized tortuously on the right to left side after C-TDL (arrowheads), which was cranial to hemoclips (yellow arrows). C, Postoperative CTLG of dog No. 10 with bEB-TDL. Thoracic duct wasn't developed at the cranial area to the ligation. Yellow arrowheads indicate ligation site. CTLG, computed tomography-lymphography; C-TDL, clipping TDL; bEB-TDL, bilateral en bloc TDL; TDL, thoracic duct ligation

bilaterally in one dog (dog No. 4). Also, in seven of the 11 (63.6%) dogs, thoracic ducts were identified at the cranial area to the ligation site by postoperative CTLG (Table 1, Figure 3B). In the C-TDL group, those thoracic ducts were observed in all dogs (4/4 [100%]) by postoperative CTLG. In the EB-TDL group, postoperative CTLG was performed in all seven dogs (Nos. 7-13), and thoracic ducts after surgery were detected in three dogs (Nos. 7, 8, and 12; 3/7 [42.9%]) and not detected in the other four dogs (Table 1, Figure 3C).

3.3 | Surgical procedures

Pericardiectomy was performed in all cases in the current case series. Clipping TDL was performed in the first five cases treated between November 2012 and October 2014, and EB-TDL was performed in the latter seven cases treated between November 2015 and July 2017. There were no differences in the data distribution for age or body weight between the C-TDL and the EB-TDL groups. In the EB-TDL group, five dogs were treated with the novel bEB-TDL method, in which bilateral thoracic ducts were ligated by using a one-sided approach with no changes in posture during surgery.

3.4 | Complications and outcome

3.4.1 | Complications

Intraoperative complications occurred in two dogs (Nos. 4 and 8; 2/13 [15.6%]). Both dogs had mild chyle leaks but immediately improved after the removal of the chest tube. Conversion to an open thoracic approach was not required in any of the dogs in this case series. Late postoperative recurrence of pleural effusion was observed in two of the 12 (16.7%) dogs, including dog Nos. 1 and 4, at 5 and 6 months postoperatively, respectively. The azygous vein was ligated in 10 of the 12 dogs (Nos. 2, 4, 5, 7-13), which was confirmed with postoperative CTLG.

3.4.2 | Clipping TDL

The details of the five dogs that underwent C-TDL are presented in Table 1. Median anesthesia and operation times were 209 minutes (range, 171-231) and 122 minutes (range, 115-145), respectively, in the C-TDL group. Median duration of hospitalization was 13 days (range, 8-27), and median time until the resolution of pleural effusion was 10 days (range, 5-23; Table 2).

Postoperative outcomes of the five dogs in the C-TDL group were as follows. Dog No. 1 underwent pericardiectomy and C-TDL, but pleural effusion relapsed at five months after the operation. The dog underwent thoracentesis to remove pleural effusion but died due to respiratory disorder 9 months after the surgery. Pleural effusion resolved quickly after the surgery in dog No. 2 that achieved LTR. In dog No. 3, mild pleural effusion persisted and resolved by medication 10 months after surgery. In dog No. 4, pleural effusion did not resolve, and the dog underwent C-TDL again; however, pleural effusion relapsed 6 months after the second surgery. Dog No. 5 had persistent mild pleural effusion that did not require removal, and the dog was maintained with medication and appeared well clinically without any pleural tap for more than 4 years.

In total, the clinical improvement rate in the C-TDL group was 80% (4/5), and LTR rate was 20% (1/5; Table 2). The median long-term follow-up period was 58 months (range, 9-71).

3.4.3 | En bloc TDL

Details of the seven dogs that underwent EB-TDL are presented in Table 1. The median anesthesia and operation times were 170 minutes (range, 158-191) and

TABLE 2 Comparison of surgical parameters and outcomes between C-TDL and EB-TDL

Procedure	Anesthesia time, min (range)	Operation time, min (range)	Period until pleural effusion resolution, d (range)	Hospitalization, d (range)	LTR, n	Outcome improvement, n	Relapse, n
C-TDL, n = 5	209 (171-231)	122 (115-145)	10 (5-23)	13 (8-27)	1/5	4/5	2/5
EB-TDL, n = 7	170 (158-191)	111 (94-121)	2 (1-5)	9.5 (3-13)	6/7	7/7	0/7
P value	.010*	.010*	.003**	.106	.045*	.364	.152

Abbreviations: C-TDL, clipping TDL; EB-TDL, en bloc TDL; LTR, long-term remission; TDL, thoracic duct ligation.
*$P < .05$, **$P < .01$.

111 minutes (range, 94-121), respectively, which were shorter than those in the C-TDL group (P = .010 and .010, respectively). The median duration hospitalization was 9 days (range, 3-13), which was not different than that in the C-TDL group (P = .106; Table 2). In six of the seven (85.7%; dog Nos. 7-11 and 13) cases, pleural effusion resolved promptly after surgery. In dog No. 12, pleural effusion was persistent for 8 months after the surgery. The dog was maintained without any treatment, and pleural effusion disappeared 11 months after surgery. In the EB-TDL group, the median time until pleural effusion resolution was 2 days (range, 1-5), which was shorter than that in the C-TDL group (P = .003; Table 2). The clinical improvement rate in the EB-TDL group was 100% (7/7), and the LTR rate was 85.7% (6/7), which was higher than that of the C-TDL group (P = .045; Table 2). In the EB-TDL group, postoperative late recurrence of pleural effusion was not identified in any of the dogs during the long-term follow-up (median, 32 months; range, 24-44).

4 | DISCUSSION

In the current case series of dogs with canine idiopathic chylothorax that underwent pericardiectomy in combination with TDL by VATS, the anesthesia time, operation time, duration of hospitalization, period until pleural effusion resolution, and LTR rate were significantly improved in the EB-TDL group compared with the CL-TDL group. In addition, the thoracic ducts were developed at the cranial area to the ligation site by postoperative CTLG in some dogs even though they did not show any clinical signs.

Video-assisted thoracoscopic surgery was developed as a less invasive surgical technique in 2010.[15,17] Clipping TDL has been a common method to treat chylothorax. The prognosis of thoracoscopic pericardiectomy and TDL has been reported as about the same as those of thoracotomy, although some dogs do not achieve lasting and complete chylothorax resolution.[19]

We performed pericardiectomy and TDL by VATS as a less invasive approach for canine idiopathic chylothorax. In addition, we examined the patency of the anatomical thoracic duct by preoperative and postoperative CTLG to determine the relationship of the approach with recurrence and/or resolution of chylothorax. Computed tomography-lymphography used in the current case series was a simple and reproducible method in which the contrast agent was injected into the rectal submucosa or anus with the dog in supine position. The method did not require surgical invasion and was useful in visualizing the thoracic duct preoperatively as well as postoperatively, as reported.[23] It has been reported that CTLG has high efficiency to highlight thoracic ducts (12/13 vs 13/13 with near-infrared fluorescence lymphography using indocyanine green).[27] Also, in this study, we applied a 4 K ultra–high-definition system to improve the identification of thoracic ducts during VATS. We speculate that those combination methods could provide a benefit to identify thoracic ducts. Postoperative CTLG to confirm successful TDL is conventionally performed immediately after the ligation.[15,19,25] However, studies have provided evidence that the thoracic duct lymph flow might be obstructed only by the blunt dissection of the surrounding tissues.[28] Therefore, the dogs in the current case series were evaluated by postoperative CTLG 7 to 10 days after surgery. To the best of our knowledge, this is the first report evaluating postoperative thoracic duct anatomy within a certain period.

In the current study, C-TDL was performed in the first five dogs during the study period. The clinical improvement rate of 80% is comparable to that reported in previous studies, although most (4/5) cases showed persistent pleural effusion or required additional surgery before the clinical improvement was achieved. The thoracic ducts were identified at the cranial area to the ligation site by postoperative CTLG in all dogs that underwent C-TDL, providing evidence that clinical improvement by C-TDL may not always indicate complete thoracic duct ligation. Therefore, the next seven dogs in the current case series underwent EB-TDL; EB-TDL with VATS has not been reported in veterinary medicine. We compared the preoperative and postoperative CTLG findings between the dogs that underwent EB-TDL and those that underwent C-TDL and found that the detection rate of thoracic duct was lower in the EB-TDL group (3/7) by postoperative CTLG.

The canine thoracic duct is reported to be generally located on the right side of the thoracic cavity, but the evidence is primarily from experimental examination. Recent articles have reported that CTLG might facilitate the visualization of more thoracic duct branches than those observed with radiographic lymphangiography.[25,29,30] However, information is limited on the anatomical changes created by TDL in dogs.[31] In the current study, the thoracic duct was located on the left side in only one dog (No. 2) and was observed bilaterally in another dog (No. 4) among a total of 11 dogs that were evaluated by preoperative CTLG. The determination of the location and the trajectory of the thoracic duct before surgery is essential for successful TDL. Therefore, in dog No. 2, we performed TDL using the left-side approach because the thoracic duct was visualized on the left side by preoperative CTLG. Variations in the thoracic duct location have been reported in man,[32] an unexpected finding because the thoracic duct, which develops bilaterally in the early embryonic period, involutes subsequently and closes with the progression of development.[33] A similar process could occur in dogs, although the anatomical variation of thoracic ducts has been unclear. In the present study, the thoracic duct, which did not uptake contrast in preoperative CTLG, appeared to be newly visualized in dogs (Nos. 2, 3 and 7) by postoperative CTLG after TDL. The reasons why the thoracic ducts were identified in postoperative CTLG might be the communication by bypass formation, the existence of fine ducts which couldn't be identified by CTLG, or missed thoracic duct ligation. These speculations also support the utility of EB-TDL that allows for the complete ligation of the thoracic duct even when the collateral branches and invisible ducts are existent. An additional advantage is that EB-TDL is less likely to damage the thoracic duct because of the ligation of the thoracic duct together with the surrounding tissues, although it has been previously reported that thoracic duct trauma might occur during the peeling process of the soft tissues.[25] In addition, EB-TDL may shorten the operation time compared with C-TDL, as suggested in previous reports,[15,19,34] because EB-TDL does not require intraoperative thoracic duct imaging or unnecessary blunt dissection of the surround tissues for TDL. Therefore, we suggest that EB-TDL is a potentially safe approach, although the azygous vein was ligated in most cases in the current study. In one study in which Mayhew and colleagues[34] examined long-term outcomes of surgery for canine idiopathic chylothorax in 36 cases, late recurrence of chylothorax after VATS occurred in three cases at 12 to 19 months. In the present study, the recurrence rate after C-TDL was 16.7% at 5 months (dog No. 1) and 6 months (dog No. 4) after C-TDL, whereas complications were not observed not only in the perioperative period but were not observed during the long-term follow-up period after EB-TDL as well. The recurrence rate was reported as 9% in the recent study with C-TDL[34]. The important finding in the present study is that there was no recurrence with EB-TDL, although the case number is so small.

We also examined bEB-TDL as an approach for the ligation of bilateral thoracic ducts using a one-sided approach because the thoracic ducts were recognized at cranial area to ligation site by postoperative CTLG in two dogs (Nos. 7 and 8) that underwent EB-TDL. The bEB-TDL approach was performed in five dogs (Nos. 9-13) to ensure a more reliable TDL. As a result, in four of the five dogs that underwent bEB-TDL, pleural effusion disappeared quickly, and the dogs achieved LTR. Although we could not evaluate its efficacy because of the small number of cases, bEB-TDL appears to be a reasonable treatment approach. In the current case series, one dog (No. 12) showed clinical improvement but did not achieve LTR, highlighting that there is still room for improvement in bEB-TDL.

The current study has several limitations. First, this was a single-center study with a nonrandomized design and a small sample. Second, all cases were treated by the same surgeon, and the learning curve for VATS can improve surgical performance during the course of a consecutive case series. Third, we did not compare the efficacy of CTLG with intraoperative contrast to visualize thoracic ducts during VATS. Finally, the follow-up period to determine long-term prognosis was not longer than that reported in previous studies. Therefore, future studies should include larger samples with long follow-up periods to determine lifelong prognosis.

In conclusion, the therapeutic benefit of combination treatment with pericardiectomy and TDL with VATS was comparable to previous reports of thoracotomy in canine idiopathic chylothorax. En bloc TDL, including bEB-TDL, is an effective method that does not require dissection of the thoracic duct. In this small retrospective, nonrandomized study, we found better long-term outcome compared with C-TDL because EB-TDL may inhibit collateral lymphatic circulation and/or the ligation of invisible small branches. We found CTLG could be used for surgical planning and postoperative evaluation.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

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