Efficacy of En Bloc Ligation of the Thoracic Duct: Descriptive Study in 14 Dogs

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Objective—To assess whether en bloc ligation of all caudal mediastinal tissue between the aorta and thoracic vertebrae will occlude all branches of the thoracic duct.

Study Design—Descriptive study.

Animals—Canine cadavers (n = 15).

Methods—The cisterna chyli was approached through a right paralumbar abdominal incision and cannulated. A right 10th intercostal thoracotomy was performed and the tissue of the caudal mediastinum dorsal to the aorta and ventral to the thoracic vertebrae was ligated. Radio-opaque contrast material was injected into the cisterna chyli during fluoroscopic imaging of the thorax and cranial abdomen. Still images were obtained before and after contrast injection and a subtraction image produced. Gray values were measured from these images, cranial and caudal to the ligature site.

Results—Cannulation of the cisterna chyli in 1 cadaver was impossible and it was, therefore, excluded. In 13 (93%) cadavers contrast material did not pass cranial to the ligature site. In 1 cadaver, an intact thoracic duct was identified on lymphangiography outside the en bloc ligation.

Conclusion—En bloc ligation of the caudal mediastinal tissue dorsal to the aorta was successful in preventing opacification with contrast material of all branches of the thoracic duct in 93% of cadavers.

Clinical Relevance—En bloc ligation is successful in 93% of cadavers and reduces the operative time compared with techniques requiring some type of mesenteric lymphangiography to aid identification of the thoracic duct.

INTRODUCTION

THORACIC DUCT ligation is currently the most common surgical technique for treatment of idiopathic chylothorax. The surgical objective is to completely occlude the duct at a caudal thoracic location, preventing leakage from it, and encouraging formation of alternative pathways for lymph return to the systemic circulation. The procedure can be technically challenging because of difficulty identifying the duct and the likelihood of multiple branches requiring ligation. The thoracic duct is often collapsed if no lymph is present and because of its thin walls, it may be impossible to identify against the mediastinum. In dogs with chylothorax the mediastinum can be thickened and more opaque than normal, further precluding accurate identification of the thoracic duct.

Techniques for identifying the thoracic duct involve increasing its visibility or use of imaging to define its location and branches.

The most widely accepted imaging method is lymphangiography, originally described as injecting aqueous contrast material into a cannulated mesenteric lymph vessel.¹ Because of difficulty identifying these vessels in small dogs and cats, recent technique simplifications involve direct injection of contrast material (radiographic
Feeding cream or corn oil in the hours immediately before induction of anesthesia has been recommended to distend the lymphatics and facilitate identification and cannulation of the thoracic duct.\textsuperscript{1,4} One treatment technique for idiopathic chylothorax that does not require visual identification of the branches of the thoracic duct involves en bloc ligation of all caudal mediastinal tissue between the aorta and thoracic vertebrae.\textsuperscript{5–7} Reportedly, success with this technique is 50%,\textsuperscript{5} which is comparable with all but the most recent published results.\textsuperscript{4,8–10} En bloc ligation of the thoracic duct has been reported in humans\textsuperscript{11,12} and has become more widely used with video-assisted thoracoscopic surgery and endoscopic stapling equipment.\textsuperscript{13}

Our purpose was to determine whether en bloc ligation of all caudal mediastinal tissue dorsal to the aorta would effectively occlude all branches of the thoracic duct at the surgical site. Our hypothesis was that an en bloc ligation technique would completely occlude all branches of the thoracic duct in normal canine cadavers. We tested this by performing en bloc ligation followed by a lymphangiogram after cannulation of the cisterna chyli.

\textbf{MATERIALS AND METHODS}

\textit{Pilot Study}

Using 3 mixed breed canine cadavers (weight, 17–20 kg) we assessed the feasibility of cannulating the cisterna chyli and to perform thoracic duct lymphangiography. After a right 10th intercostal thoracotomy, Finochietto retractors were positioned to achieve and maintain exposure of the caudal aspect of the thorax, and the right caudal lung lobe was retracted cranially to expose the caudal mediastinum. A right paralumbar abdominal incision was made from the costal arch to the cranial aspect of the ilium. The caudal vena cava was bluntly elevated from the hypaxial muscles and retracted ventrally to allow identification of the aorta and the cisterna chyli. The dorsal part of the cisterna chyli was cannulated with a 22-g intravenous (IV) cannula (Jelco IV catheter; Medex Medical Ltd., Rossendale, UK). Extension tubing, prefilled with iodinated contrast material (ioxaglic acid; Hexabrix, Guerbet Laboratories, Milton Keynes, UK) mixed with methylene blue (a pinch of methylene blue powder/100 mL contrast material), was connected to the cannula and the extension tubing was then secured to the abdominal wall to prevent dislodgement of the cannula. A bolus (10–20 mL) of iodinated contrast material mixed with methylene blue was injected over several seconds into the cisterna chyli during fluoroscopic imaging (Siemens Siremobil 2000; Siemens Medical Solutions, Camberley, UK) of the thorax and cranial abdomen. The caudal mediastinum was observed for coloration of the thoracic duct after fluoroscopy. Opacification and coloration of the duct was observed in all 3 cadavers.

\textit{En Bloc Ligation Study}

Canine cadavers (n = 15) of various breeds (weight range, 8–33 kg) euthanatized for reasons unrelated to this study were obtained. After right caudal thoracotomy (as described above), the mediastinum was incised with Metzenbaum scissors adjacent and parallel to the dorsolateral wall of the caudal thoracic aorta for a length of 1–2 cm and, using these instruments and a pair of right angled forceps, a path was dissected across the mediastinum immediately dorsal to the aorta, and similarly immediately below the ventral aspect of the thoracic vertebrae and hypaxial muscles. The tissue dorsal to the aorta and ventral to the thoracic vertebrae was ligated by passing a 3 metric silk ligature through the mediastinum immediately dorsal to the aorta and passing it back through the mediastinum immediately ventral to the thoracic vertebrae.

A 22-g hypodermic needle was placed in the thoracic spinal musculature at the level of the ligature to allow identification of this site during fluoroscopy. The cisterna chyli was cannulated (as described above) and a maximum of 20 mL contrast material/methylene blue mixture was injected during fluoroscopic imaging. Video was captured digitally (Matrox Meteor-II PCI Frame Grabber card and Matrox Inspector software; Matrox Imaging, Harefield, UK). This produced a video file of 640 × 612, 8 bit pixels (256 shades of gray) at 32 frames/s. Photographs of the mediastinum were obtained both before ligation and after lymphangiography.

Still images were obtained from each video sample, 1 before and 1 after contrast injection. A subtraction image (Fig 1) was obtained from these images using image processing software (ImageJ; NIH, Bethesda, MD). Using the same software, gray values were obtained from a linear region cranial to the thoracic vertebrae.

\textbf{Fig 1.} Pilot study. Lateral lymphangiogram (cranial to the left) demonstrating a normal thoracic duct. (A) Before injection of contrast; (B) after contrast administration; (C) subtraction view using image A as a subtraction mask.
ligature and a similar region caudal to the ligature. Maximum values were recorded in each of these regions and compared. Any value above 0 was considered to demonstrate presence of contrast material.

RESULTS

Cisterna chyli cannulation and lymphangiography was successful in 14 of 15 cadavers. In 1 dog it was not possible to successfully cannulate the cisterna chyli; hence, this dog was excluded from the study. Mean ± SD cadaver weight was 19.8 ± 6.0 kg (range, 8–33 kg). Fifty percent of the cadavers were Staffordshire bull terrier or its crossbreeds; other breeds were crossbreeds, a German Shepherd cross, a Collie cross, and a Dobermann Pinscher.

Gray values caudal to the ligature ranged from 14 to 124. Thirteen of 14 studies (93%) had gray values of 0 cranial to the ligature site confirming contrast material did not pass beyond the ligature (Fig 2; Videoclip S1).

The single failure had a gray value of 18 (Table 1). In 1 cadaver, en bloc ligation failed to obstruct the thoracic duct or 1 of its branches as evident on postligation lymphangiography and photography (Fig 3; Videoclip S2).

DISCUSSION

We demonstrated that en bloc ligation of the caudal mediastinal tissue dorsal to the aorta successfully prevented opacification with contrast material of all branches of the thoracic duct cranial to the ligature in 93% of the cadavers studied.

On examination of the photographs obtained from the single unsuccessful procedure, the thoracic duct was found to be lying in very close association with the aorta along the right lateral wall. The thoracic duct was not recognized until review of the pre- and postlymphangiography photographic images and even with the benefit of magnification it was still not immediately obvious. It is possible that if we had intended to specifically identify the duct before en bloc ligation and had optimal surgical

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Fig 2. Lateral lymphangiogram after successful en bloc ligation of the thoracic duct. Hypodermic needle indicates level of the ligature (cadaver 15).

Fig 3. Photographs of the thoracic duct (black and white arrowheads) overlying the aorta in cadaver 6 in which the thoracic duct was unsuccessfully ligated. (A) Before tightening the ligature and injection of contrast. (B) After ligation and contrast injection.
lighting and intraoperative magnification, the thoracic duct would have been identified and included in the ligature; however, the study was performed in a radiographic suite without directable overhead lighting.

No attempt was made to identify the duct; hence, we would not artificially increase the procedure’s success rate and also to replicate the likely difficulty in observing the duct in a patient with mediastinal thickening and pleural fibrosis associated with chylothorax.

En bloc ligation of the thoracic duct is likely to reduce the operative time compared with previously reported techniques that involve a 2nd surgical approach to aid thoracic duct identification. By eliminating the need for an additional surgical procedure to isolate a mesenteric lymph node or vessel and the requirement for intraoperative radiographic techniques, the anesthetic and surgical time and also the cost of the procedure will be reduced. Also, by eliminating a 2nd surgical site, postoperative pain may be reduced and recovery time from the procedure shortened. The less invasive technique of percutaneous injection of the popliteal lymph node has been reported but has been less effective than injection into a mesenteric lymph node.

Dissection and ligation of the caudal mediastinum took <5 minutes in each cadaver. Thus, in a patient the anesthetic and surgical time to perform this procedure would include the time necessary to prepare for and perform a right intercostal thoracotomy plus a few additional minutes for en bloc ligation of the caudal mediastinum dorsal to the aorta.

We acknowledge that the time to perform this ligation in a cadaver may not reflect that in a patient where there may be thickening of the mediastinum secondary to the chylothorax, and respiratory movements hindering and slowing dissection.

Feeding of fatty agents immediately before induction would be unnecessary because identification of the thoracic duct is not essential with en bloc ligation, thus reducing the risk of regurgitation of gastric contents under anesthesia. Methylene blue administration has been associated with Heinz body anemia, pseudocyanosis (which may interfere with anesthetic monitoring), elevated serum alkaline phosphatase concentrations and renal failure. Injection of hyperosmotic radiographic contrast agents may cause tissue injury if extravasation occurs or can cause volume overload if excessive amounts pass into the systemic circulation. This en bloc ligation technique also eliminates these small risks.

Methylene blue was mixed with the contrast material in our study only to aid direct identification of the thoracic duct in any cadavers where this ligation technique had failed to interrupt flow of contrast material as seen fluoroscopically. In the single cadaver where ligation failed, methylene blue did aid identification of the thoracic duct by coloration of the vessel.

We made no attempt to identify the thoracic duct. Clinically, it may be possible to identify the duct intraoperatively but it would seem prudent to perform en bloc ligation to ensure any unidentified branches are occluded, rather than assuming the observed duct is the only patent channel.

Viehoff reported that complete resolution of clinical signs occurred in 6 of 12 (50%) dogs treated by en bloc ligation of the thoracic duct, although only 2 of the 12 dogs had persistent chylothorax after surgery. Delayed recurrence of chylothorax and persistent nonchylous effusion were the main causes of failure. If, as our study demonstrates, successful occlusion of the thoracic duct was achieved, then 50% of the dogs required more than thoracic duct ligation alone to successfully treat their chylothorax, i.e. pericardectomy or omentalization. Unfortunately, lymphangiography was not performed during the initial procedure in these 12 dogs; hence, complete ligation of the thoracic duct could not be demonstrated, leaving the possibility that en bloc ligation did not completely interrupt flow. Omentalization alone or combined with passive pleuroperitoneal drainage was attempted in 3 dogs treated unsuccessfully with en bloc ligation of the thoracic duct but did not resolve the clinical signs. A success rate of 90% in dogs and cats was reported after treatment with a combination of thoracic duct ligation and subtotal pericardectomy, or subtotal pericardectomy alone. Combining pericardectomy with en bloc ligation may yield similar results without the requirement for lymphangiography. It may be possible to perform both procedures through a single intercostal thoracotomy, depending on the thoracic conformation of the patient.

The decrease in operative time gained by not performing lymphangiography would undoubtedly benefit debilitated animals. However, without lymphangiographic confirmation, the question of whether en bloc ligation was successful or an abnormal thoracic duct was present would remain in animals in which the procedure did not resolve the chylothorax. The absence of lymphangiographic data that may show the extent and location of lymphatic leakage or lymphangiectasia may also hinder our further understanding of this disease and assessment of treatment methods.

Study Limitations

None of the cadavers in this study had any evidence of chylothorax. Dogs with chylothorax may have alterations in the branching and anatomy of the thoracic duct compared with a normal animal. This may be secondary to as yet unidentified primary factors and thus may alter the success of en bloc ligation.

Preligation lymphangiograms were not performed because an earlier pilot study we performed demonstrated that dissipation of contrast material in the cadavers was
slow and obscured the findings of the postligation lymphangiograms. Interruption of contrast flow by the ligature does not confirm complete ligation of all branches of the thoracic duct because it is possible that there are other branches of the thoracic duct that have not filled with contrast material and thus remain unidentified on lymphangiography. However, considering that the contrast material was injected under pressure in this study, it seems unlikely that such patent vessels would not be filled.

It is possible that in patients, nonpatent lymphatic vessels may open up after thoracic duct ligation and these would not be demonstrated by lymphangiography at initial ligation. This may explain why, despite lymphangiographic occlusion of the thoracic duct and its branches at surgery, chylothorax recurs in some patients.

Few small dogs were included in our study, but it would seem likely that direct thoracic duct identification, and techniques involving cannulation of the lymphatics for lymphangiography would be more difficult in small dogs. For this reason the en bloc ligation technique might be even more desirable in small dogs.

Despite reported variations in thoracic duct anatomy, there was little variation in apparent anatomy of the thoracic duct in the caudal thorax. All cadavers, including the dog that had unsuccessful ligation, had only 1 branch evident between the cranial aspect of the diaphragm and the location of the ligature. There were, however, a limited number of cadavers in our study and only a lateral lymphangiographic study was performed. It is possible that superimposition of branches of the thoracic duct occurred, obscuring anatomic variations that might have been identified with a ventrodorsal angiographic study, but this was considered unlikely.

We considered the video files to be of adequate resolution, frame rate, and gray scale depth to accurately assess the effect of the ligation. It is possible that the resolution might be insufficient to detect very small branches of the thoracic duct, but the increase in opacity should be detected because of the sensitivity of the software. These image characteristics are the same as those used in clinical fluoroscopy in our hospital.

Half of the cadavers in this study were Staffordshire bull terrier or crosses of this breed, which reflects its local popularity and the available cadavers. It is not possible to exclude the possibility of anatomic variations in different breeds that might have an effect on our findings, although this is unlikely.

Inclusion of theazygos vein decreases the chance of missing branches of the thoracic duct within the dorsal mediastinum. It is possible that ligation of the azygos vein might alter venous pressure at the site of entry of the thoracic duct, which may also have a beneficial effect on thoracic chyle flow. Further studies investigating the hemodynamic effects of the inclusion of the azygos vein in the ligature should be performed to ensure there are no deleterious effects. In humans, ligation of the azygos vein at a superior site causes reversal of flow and decreased velocity within the vein. Ligation of the azygos vein at its entry to the vena cava did not have any obvious effects in normal dogs but the effect of more caudal ligation should be investigated.

Using en bloc ligation, we successfully occluded the thoracic duct in 13 of 14 (93%) canine cadavers. Use of en bloc ligation of the thoracic duct as a means of eliminating the need for lymphangiography may result in substantial reduction in operative time that may prove beneficial for severely debilitated animals. It may also reduce postoperative pain and the risks of administration of oral fatty agents, methylene blue, and hyperosmotic radiographic contrast materials.

REFERENCES


Supporting Information

Additional supporting information may be found in the online version of this article:

Videoclip S1. Video file of a lateral view lymphangiogram after successful en bloc ligation of the thoracic duct. Hypodermic needle indicates level of the ligature (Cadaver 15).

Videoclip S2. Video file of a lateral view lymphangiogram after unsuccessful en bloc ligation of the thoracic duct. Hypodermic needle indicates level of the ligature (Cadaver 6).

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