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Feasibility of thoracoscopic attenuation of the azygos vein as a model for portoazygos shunts: A canine cadaveric study

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Abstract

Objective: To evaluate the feasibility of thoracoscopic placement of three vascular attenuation devices by using the azygos vein as a model for portoazygos (PA) shunts and to describe the approach for thoracoscopic placement of these attenuation devices in small breed dogs.

Study design: Randomized, prospective, cadaveric study.

Animals: Cadavers of 10 adult small breed dogs.

Methods: Cadavers were placed in sternal recumbency with left dorsolateral obliquity, and three thoracoscopic ports were established in the right hemithorax at the mid-10th intercostal space and dorsal third of the ninth and 11th intercostal spaces. The caudal azygos vein was thoracoscopically isolated along three adjacent segments bordered by four intercostal arteries, beginning just cranial to the first intercostal artery visualized cranial to the diaphragm. Three attenuation devices including coated cellophane, uncoated cellophane, and a 5-mm ameroid constrictor were thoracoscopically placed around one segment in each dog. Minor port access modifications were required to improve working space and triangulation in three dogs. Ability to successfully place the device, time required for placement, endoscopic clip configuration, and complications associated with placement were recorded.

Results: Median dog weight was 7.7 kg (range, 1.8-11). All attenuation devices were successfully placed thoracoscopically in all cadavers. No difference was detected in time required for placement between the ameroid constrictor and coated and uncoated cellophane (range, 2.3-33.8 minutes, $P = .8$).

Conclusion: Ameroid constrictors and thin film bands were consistently placed via thoracoscopy around the caudal azygos vein of small breed dogs.

Clinical significance: These results justify further investigation of thoracoscopic PA shunt attenuation in affected dogs.

1 | INTRODUCTION

Congenital extrahepatic portosystemic shunts (CEPSS) are common in small breed dogs and allow blood from the gastrointestinal viscera to bypass the liver and directly enter systemic circulation.[1-3] Standard of care consists of gradual attenuation of the shunting vessel, most commonly with ameroid constrictors or thin film

banding (eg, cellophane).[4,5] While both devices are associated with similar rates of postoperative complications (approximately 25%) and mortality (approximately 2%), thin film banding techniques may allow slower attenuation over ameroid constrictors, thereby minimizing the risks of portal hypertension and acquired shunting.[2,4,5] Revision surgery for persistent shunting, however, is more common after thin film banding techniques than after placement of ameroid constrictors.[6,7] The lack of consensus in the literature prompts surgeons to select the device for CEPSS attenuation based on their preference.

The majority of CEPSS (eg, portocaval) terminate within the peritoneal cavity, and, as a result, attenuation devices have been investigated primarily for their use in the abdomen.[8] However, approximately 25% of CEPSS terminate on the azygos vein within the thoracic cavity.[2,3,7,9] While attenuation of CEPSS is recommended as close to the termination as possible to prevent persistent shunting through distal tributaries, portoazygos (PA) shunts are traditionally attenuated intra-abdominally.[7] Continued postoperative shunting is a concern if the attenuating device is placed distant from the shunt's termination because PA shunts may also have tributaries from gastric veins prior to crossing the diaphragm.[9] In addition, dissection of the PA shunt from the muscle fibers and fascia of the dorsal diaphragm can be technically challenging and risks inadvertent tearing of the shunt and iatrogenic pneumothorax.[7] Intrathoracic attenuation of this subset of CEPSS ensures that attenuation occurs downstream of all contributing tributaries and provides improved visualization of the distal shunt compared with an intra-abdominal approach.[7] To the best of the authors' knowledge, only two reports have described the use of ameroid constrictors or thin film banding for intrathoracic PA shunt attenuation, either through an open intercostal or a transdiaphragmatic approach.[7,10]

Although laparoscopic CEPSS attenuation is described in a report of two cases, thoracoscopic shunt attenuation has not been reported.[11] Thoracoscopic attenuation of PA shunts may provide the advantages of a minimally invasive approach while simultaneously harnessing the previously discussed advantages of an intrathoracic approach to PA shunt attenuation.[12-14] The objective of this study, therefore, was to evaluate the feasibility of thoracoscopic placement of three attenuation devices by using the azygos vein as a model for PA shunts and describe the approach for thoracoscopic placement of attenuation devices in small breed dogs. We hypothesized that thoracoscopic placement of both ameroid constrictors and cellophane bands on the caudal azygos vein via a novel thoracoscopic approach would be feasible.

2 | MATERIALS AND METHODS

Prior to the study, medical records of dogs with PA shunts were retrospectively reviewed. Preliminary computed tomography (CT) measurements were performed by the authors to evaluate the diameters of the caudal thoracic azygos vein and PA shunts in five clinical dogs. In addition, three adult canine cadavers were obtained after humane euthanasia from a local animal shelter; these pilot dogs were used to confirm initial port configuration and feasibility of azygos vein dissection and attenuation device placement. Ten adult canine cadavers (<11 kg each) were then obtained after humane euthanasia from a local animal shelter (n = 7) and another terminal study at our institution (n = 3; institutional animal care and use committee approval No. 19-066-O). Approval from the shelter was obtained for all cadaver inclusion in the study. Dogs were free of clinically apparent thoracic disease. All procedures were performed by a single board-certified surgeon (V.F.S.) experienced in thoracoscopic surgery assisted by a surgical resident or intern.

Cadavers were placed in sternal recumbency with left dorsolateral obliquity, and the right thorax and paracostal region was clipped. Three ports were established on the right thorax. Specifically, a 5.5-mm cannula (Thoracoport; Medtronic, Minneapolis, Minnesota) was inserted at the middle of the 10th intercostal space. A 5-mm, 30° rigid endoscope (HopkinsII 5-mm laparoscope; Karl Storz Veterinary Endoscopy, Goleta, California) was introduced through this portal. Two additional cannulas (Thoracoport; Medtronic) were inserted in the dorsal third of the 11th intercostal space (5.5-mm cannula) and the dorsal third of the ninth intercostal space (11.5-mm cannula; Figure 1). Thoracoscopic Metzenbaum scissors, right-angle forceps, and Kelly dissecting forceps (Karl Storz Veterinary Endoscopy) were used to thoracoscopically isolate the azygos vein along three adjacent segments bordered by four intercostal arteries, beginning immediately cranial to the caudal-most intercostal artery visualized cranial to the diaphragm.

Three different attenuation devices were assessed during this study including coated cellophane (polymer coated cellophane; CelloVet, Fremantle, Western Australia, Australia), uncoated cellophane (original uncoated cellophane; CelloVet), and a 5-mm ameroid ring constrictor (Jorgensen Laboratories, Loveland, Colorado). For each cadaver, one device was placed around the azygos vein at the midpoint of the cranial, middle, or caudal segment. A randomized block design was used to determine the device placed on each segment in a given

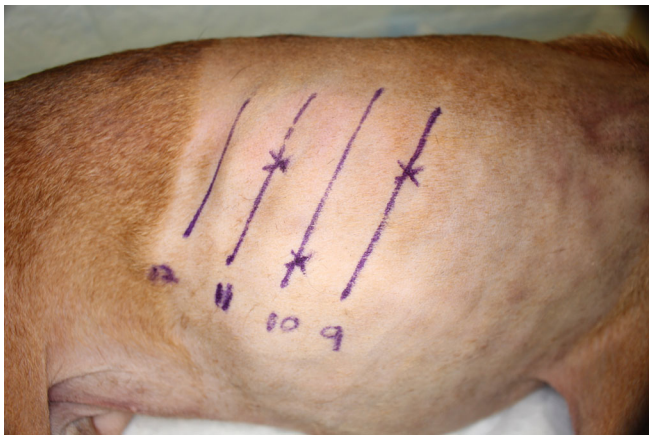

FIGURE 1 Location of three right-sided ports for thoracoscopic placement of attenuation devices on the caudal azygos vein. Lines illustrate the ninth through 12th intercostal spaces, with an "X" marking the location of each port

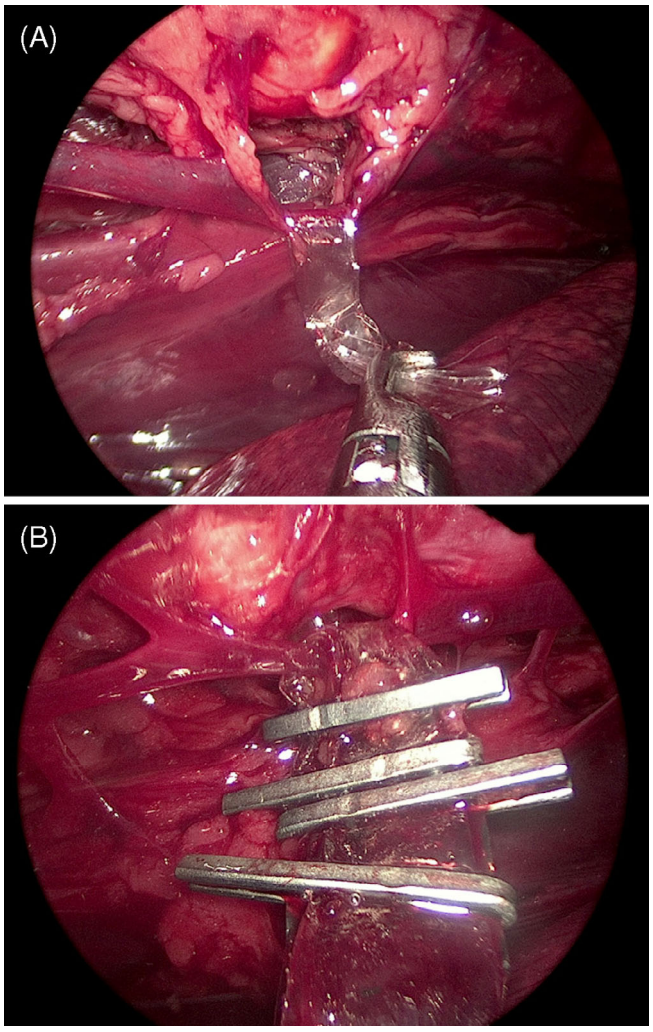

FIGURE 2 Thoracoscopic placement of cellophane around the caudal azygos vein. Right-angle forceps were used to appose the ends of the cellophane band prior to endoscopic clip placement (A). Final configuration of four 11.5-mm clips placed in alternating fashion to secure the cellophane band around the azygos vein (B)

cadaver to minimize the effect of segment location and order of device placement on variables assessed. Variables evaluated for each device were duration of placement, number of attempts to pass the device around the azygos vein, number and configuration of endoscopic clips on cellophane, cellophane band alignment, cellophane tearing, and any complications encountered in placing the device. Duration of placement was defined as the time from device insertion into the thorax to either last endoscopic clip application for cellophane or successful (flush) insertion of key for ameroid placement. Cellophane alignment was defined as the completeness of overlap of the distal ends of the cellophane band, with >70% overlap classified as "good," 50% to 70% overlap classified as "fair," and < 50% overlap classified as "poor."

For cellophane placement, cellophane bands (both coated and uncoated) were cut into 60- × 12-mm strips which were then folded longitudinally twice to create a 4-mm-wide triple-layer band.[15] For smaller cadavers, the 60-mm length was shortened to 45 mm to improve maneuverability within the thorax. After they had been introduced through the cranial port by using Kelly dissecting forceps, 5-mm right-angle forceps were inserted through the caudal port and passed along the medial aspect of the azygos vein segment from ventral to dorsal. The right-angle forceps were used to apply slight lateral traction to the azygos vein and then grasp the cellophane band from the Kelly forceps, pulling the band around the medial aspect of the vein from dorsal to ventral. The right-angle and Kelly forceps were then used to appose the ends of the cellophane band. While they were held in apposition with the right-angle forceps, the Kelly forceps were removed and a 12-mm endoscopic hemostatic clip applicator (LIGACLIP endoscopic rotating multiple clip applier, medium/large; Ethicon, Somerville, New Jersey) was introduced through the cranial port. Each cellophane band was then secured via endoscopic clip placement as previously described.[15,16] Briefly, the surgeon attempted to place four 11.5-mm clips in alternating fashion from both sides of the cellophane construct such that the inner diameter of the resulting cellophane band approximated the predissection diameter of the azygos vein segment around which it was placed. In addition, the surgeon attempted to place all clips at a 90° angle to the long edge of the band while maintaining apposition and alignment of both ends of the cellophane band (Figure 2).[15,16]

Ameroid constrictors were similarly introduced through the cranial port by using 10-mm right-angle forceps (Karl Storz Veterinary Endoscopy). The ameroid

constrictor was introduced such that the opening in the ring faced caudally, and 5-mm right-angle forceps introduced through the caudal port were used to gently manipulate the azygos vein to facilitate ameroid constrictor placement. The ameroid constrictor was placed by laying the flat side either dorsal or ventral to the azygos with the opening facing caudally and rotating the constrictor 90° to place the azygos vein within the ameroid constrictor. Alternatively, the ameroid constrictor was positioned vertically with the opening facing laterally or ventrally, and the 5-mm right-angle forceps were used to gently retract the azygos vein ventrolaterally to allow placement of the constrictor from dorsally or medially. After the ameroid constrictor had been placed around the azygos vein, the constrictor was gently rotated by using the right-angle forceps until the opening faced laterally in preparation for key placement. The caudal port was then removed, and the ameroid key was placed with approximately one-third of the key within the tips of Rochester-Carmalt forceps. The forceps and key were then introduced through the 11th intercostal port site, and the key was inserted approximately 10% to 20% into the opening on the ameroid constrictor. The key was then released by the Rochester-Carmalt forceps, and a 10-mm or 5-mm right-angle forceps was used to grip the ameroid constrictor along both sides to advance the key such that it was flush with the edge of the constrictor (Figure 3).

Each cellophane construct was removed thoracoscopically after placement to avoid interference with placement of subsequent devices. Ameroid constrictors were removed via a ninth intercostal thoracotomy after all devices were placed.

Cadaveric and procedural variables were evaluated for normality via assessment of histogram conformation. Nonnormally distributed data are expressed as medians and the associated range. Duration of placement for each device was compared by using a nonparametric (Friedman) test. All analyses were performed in GraphPad Prism 8 (GraphPad Software, San Diego, California), and $P < .05$ was considered statistically significant.

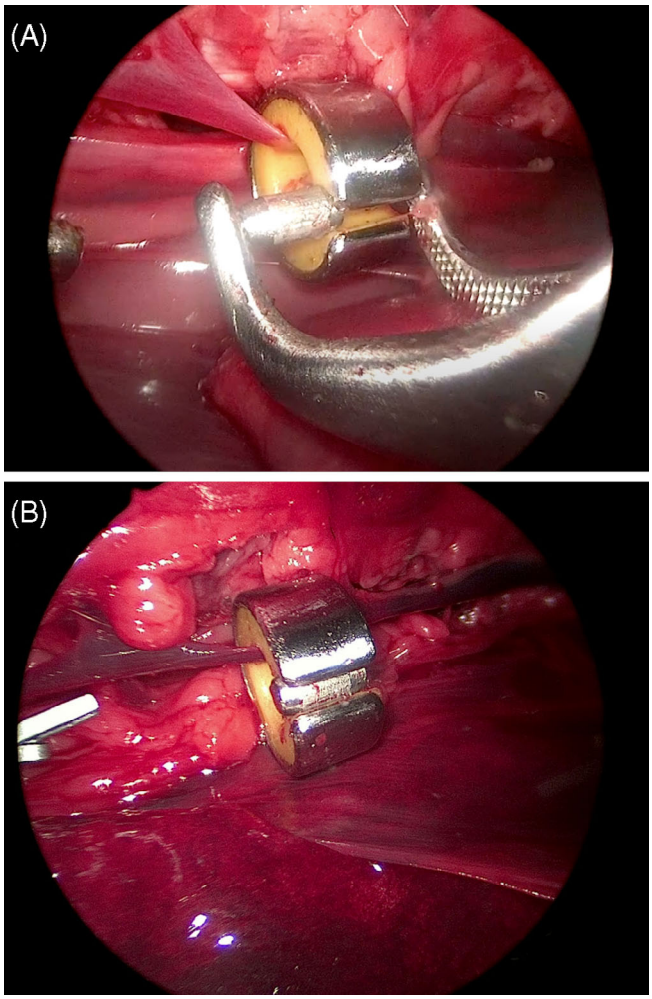

FIGURE 3 Thoracoscopic images of an ameroid constrictor placed around the caudal azygos vein. After initial placement, the ameroid constrictor was rotated around the azygos vein such that the constrictor faced laterally in preparation for key placement with right-angle forceps (A). The key has been successfully placed flush with the edge of the ameroid constrictor (B)

3 | RESULTS

Prior to study initiation, five clinical cases of dogs that presented to our institution with PA shunts were reviewed; median body weight was 4.7 kg (range, 3.6-19.6). Review of CT images from these cases provided evidence that the diameter of PA shunts at the termination on the azygos vein was similar to the diameter of the caudal thoracic azygos vein. Port configuration for access to the caudal thoracic azygos vein was then confirmed through thoracoscopic dissection of the azygos vein and placement of attenuation devices in three pilot cadavers.

After collection of pilot data, cadavers were obtained from three beagles and one each of shih tzu, Chihuahua, Jack Russel terrier, Maltese, toy poodle, French bulldog, and mixed breed dogs. Seven dogs were female (six intact and one spayed) and three were male (one intact and two neutered). Median body weight was 7.7 kg (range, 1.8-11).

Minor port access modifications were required to improve working space and triangulation in three dogs. In the 1.8-kg dog, the cranial and caudal instrument cannulas were removed to facilitate placement of the attenuation devices without interference from the cannulas because of decreased working room within the thorax. Thoracoscopic instruments were reinserted through the

port sites without the cannulas, and attenuation device placement proceeded without complication. In the 11-kg dog, the 11.5-mm cranial cannula was removed to facilitate manipulation of the 12-mm endoscopic clip applicator because of interference from the rigidity of the surrounding ribs. In the third dog (4.8 kg), an additional 11.5-mm port was placed in the dorsal fourth intercostal space to introduce the 10-mm right-angle forceps to improve triangulation for placement of the ameroid key. After these modifications, placement of the attenuation devices proceeded as previously described.

Median device placement times were 5.5 minutes (range, 5-5.3) for uncoated cellophane, 5.9 minutes (range, 2.3-8) for coated cellophane, and 8 minutes (range, 2.8-33.8) for ameroid constrictors. No difference was detected between placement times for the different attenuation devices ($P = .830$). Each cellophane band (both coated and uncoated) was passed around the azygos vein with only one attempt. In contrast, the median number of attempts required for passing the ameroid constrictor was 1.5 (range, 1-6). The ameroid constrictor was dropped once in one dog, and the key was dropped once, twice, and six times in three additional dogs. Both the ameroid constrictor and the key were successfully retrieved thoracoscopically without conversion. In the 1.8-kg dog, the 5-mm right-angle forceps rather than the 10-mm right-angle forceps was used to place the ameroid key.

No observable tearing of the cellophane was noted in any of the constructs during placement. Four (median; range, 4-6) hemostatic clips were placed to secure both the coated and uncoated cellophane bands. Median estimated hemoclip angulation was 90° (range, 45°-90°), and appropriate clip alternation was achieved in 60% of placements for both coated and uncoated cellophane. Appropriate clip alternation was achieved in 100% of cranial segments, 63% of middle segments, and 29% of caudal segments. Coated cellophane alignment was described as good in eight of the 10 dogs, fair in one dog, and poor in one dog. Alignment for the uncoated cellophane was described as good in six of 10 dogs, fair in three dogs, and poor in one dog. No cellophane bands were dropped during placement.

4 | DISCUSSION

Cellophane bands and ameroid constrictors were consistently placed via thoracoscopy around the canine azygos vein in 10 small dog cadavers. The caudal azygos vein was chosen as a model for PA shunts because of similarity in the right-sided caudodorsal thoracic location of this vessel compared with the most frequently described termination of PA shunts on the azygos vein.[3,17] In addition, the diameter of PA shunts in clinical dogs that underwent CT was similar to the diameter of the caudal thoracic azygos vein in dogs of equivalent body weight. Although the size and location of the azygos vein support its use as a model for PA shunts in dogs, the characteristic "L" shape of terminal PA shunts differs from the straight, sagitally oriented azygos vein.[3,18] While the unique shape of terminal PA shunts could affect the ability to thoracoscopically dissect and place a vascular attenuation device compared with placement on the azygos vein, the authors believe that this "L" shape may actually facilitate the placement of vascular attenuation devices on PA shunts. With segments of the terminal shunt oriented both dorsoventrally and craniocaudally as part of the "L," the surgeon has two orthogonal options for orienting the attenuation device during placement, which may improve access and reduce placement time.[3,18]

Ports were established in the right caudal thorax to facilitate triangulation around the caudal thoracic azygos vein. Port location was derived from previous descriptions of thoracoscopic thoracic duct ligation because of the similarity in location.[19,20] Because of the right-handed dominance of the surgeon, the ninth rather than the 11th intercostal space was selected for placement of the 11.5-mm cannula to facilitate insertion of the ameroid constrictor and endoscopic clips by using 10-mm and 12-mm instruments, respectively, with the dominant hand.

All cadavers in this study weighed less than 11 kg. However, the median body weight of cadavers in this study (7.7 kg; range, 1.8-11) remained higher than that of dogs that have presented to our institution with PA shunts over the past 4 years (4.7 kg; range, 3.6-19.6). Thus, surgeons may experience more challenges related to the small body size of dogs with PA shunts compared with those encountered in this cadaveric study. Nonetheless, the median body weight of cadavers in this study (7.7 kg) was similar to the median body weights reported in other studies of dogs with CEPSS (range, 4.5-6.5 kg).[7,21-23] In our study, the only modifications required to faclititate device placement in smaller cadavers consisted of removing the cannulas and using the 5-mm right-angle forceps to place the ameroid key. With the exception of the 10-mm right-angle forceps and the 12-mm endoscopic clip applicator, 5-mm instruments were used to isolate the azygos vein and place the attenuation devices. For smaller dogs, the use of pediatric instruments with smaller diameters (thereby requiring smaller cannulas) may facilitate dissection and placement of the device.

Cellophane bands were secured with medium-large (11.5-mm) endoscopic clips in this study because, in a

previous study, these clips resisted higher yield loads compared with smaller 9-mm endoscopic clips.[15] In the same study, four 11.5-mm clips placed in alternating fashion achieved maximum security in securing cellophane bands.[15] The clinical importance of the clip size and orientation for securing thin film bands around CEPSS, however, has not been established.[16] Thus, the use of smaller clips in a nonalternating fashion may better facilitate thoracoscopic thin film band placement without jeopardizing the security of the band. While 11.5-mm endoscopic clips are available only in a 12-mm diameter applicator, 9-mm clips are available in both 5-mm and 10-mm diameter applicators, which would decrease the port size required for their introduction in very small dogs. Appropriate clip alternation was achieved for 100% of the cranial azygos segments but for only 63% and 29% of the middle and caudal segments, respectively, providing evidence that clip alternation was more feasible with increasing distance from the diaphragm. From CT observations and clinical experience with an intercostal approach to PA shunts, the authors believe that the termination of PA shunts are commonly located at the equivalent of the cranial or middle azygos vein segments used in this study. Thus, surgeons should be aware that a more caudal termination of PA shunt closer to the diaphragm in a clinical dog may make clip alternation more challenging.

The two most commonly used vascular attenuation devices were evaluated for feasibility of thoracoscopic placement in this study. Although no difference between the placement times for the attenuation devices was observed in this study, a trend toward longer placement times of the ameroid constrictor may have reached significance were it tested in a larger sample. In addition, while all cellophane bands were successfully passed around the azygos vein on the first attempt, passing of the ameroid constrictor around the azygos vein required more than one attempt in five dogs. These attempts may have important clinical implications because handling of PA shunts may increase the risk of shunt tearing during dissection. Conversely, the authors felt that more traction and torsion were applied to the azygos vein when we attempted to rotate the cellophane band to place endoscopic clips in alternating fashion, which could also predispose the PA shunt to tearing during cellophane placement. While no tears of the azygos vein were observed during dissection and placement of the attenuation devices during this study, we cannot rule out a small tear which would have important clinical implications in a live dog. Because of the risk of portal hypertension from ligating a torn shunt acutely, rapid conversion to an intercostal thoracotomy would likely be required to repair a tear of the PA shunt in a clinical dog. Another potential risk of this approach is damage to the thoracic duct during dissection of the shunt. In the authors' experience with an intercostal approach to PA shunts, the shunting vessel is usually relatively lateral compared with the thoracic duct and minimally associated with the surrounding connective tissue through which the thoracic duct courses, minimizing risk of iatrogenic damage to the thoracic duct. Iatrogenic thoracic duct damage has been reported in two dogs that underwent surgical correction of persistent right aortic arch; these cases resolved without further intervention, providing evidence that chylothorax resulting from damage to the thoracic duct via the approach described here may also be transient and self-limiting.[24]

A potential disadvantage of using ameroid constrictors for thoracoscopic PA shunt attenuation is the propensity for the ameroid ring or key to be dropped during placement. While both the key and the ring were successfully retrieved thoracoscopically, retrieving the ameroid constrictor or key may prove more challenging in clinical dogs, in which lung excursion may displace a dropped device and impair visualization during retrieval. To overcome this potential issue and to maintain control of the device, a long piece of absorbable suture could be tied to the ameroid constrictor or the key prior to introduction into the thorax; this would facilitate retrieval of the device and key, and the suture anchor could be trimmed short after successful placement. Conversely, the cellophane was comparatively easy to grasp and was not dropped in any cadavers. Ameroid constrictors may also cause kinking of the azygos vein due to the weight of the device, especially when an animal is in sternal recumbency. While this could theoretically cause acute occlusion of the shunt leading to portal hypertension, a previous article in which intrathoracic shunt attenuation with ameroid constrictors was described did not report any findings suggestive of premature occlusion due to the weight of the ameroid constrictors.[7]

Two variations of cellophane bands were evaluated in this study to represent the variety of thin film bands used clinically and to evaluate whether differences in handling characteristics affected the ability to place them thoracoscopically. Subjectively, the uncoated cellophane had a “stickier” feel, which made it easier to hold together during placement but also made it more difficult to keep the ends of the strand smoothly aligned while forming the band. As a result, the ends of coated cellophane bands tended to be more aligned compared with those of uncoated cellophane; we therefore recommend coated cellophane for thoracoscopic attenuation of CEPSS.

Complete but gradual attenuation of the shunt is indicated to improve the outcome of dogs with CEPSS.[4,5] Thin film banding has been suggested to be less effective

at attenuating shunts in the thorax compared with in the abdomen, which may be attributed to a reduced inflammatory and fibroblastic reaction compared with that in the abdomen.[7,25] However, the duration of follow-up was limited to 3 months in a study in which incomplete attenuation of PA shunts with thin film banding in the thorax was reported.[7] Longer follow-up may have allowed complete attenuation, which was suggested in a case report of intrathoracic attenuation of a PA shunt with a thin film band through an intercostal approach.[10] The ability of thin film banding to achieve complete vascular attenuation within the thorax and the time required for attenuation require additional investigation.

The thoracoscopic approach described here provides a direct approach to the terminal PA shunt with minimal soft tissue dissection while potentially harnessing the benefits of minimally invasive surgery.[12,26] Nonetheless, there are potential limitations of this approach. Thoracoscopic PA shunt attenuation does not allow the surgeon to retrieve a liver biopsy without a separate approach to the abdomen. Hepatic biopsy during surgical CEPSS attenuation has historically been recommended to assess hepatic morphology and diagnose concurrent portal vein hypoplasia.[27,28] However, no association was detected between histopathology and prognosis in a recent study; intraoperative biopsy sample results were, threrefore, not predictive of long-term outcome in dogs with CEPSS.[29] An intra-abdominal approach also allows for intraoperative assessment of potential portal hypertension, both through direct measurement of portal pressures and through observation of changes in the viscera during shunt dissection and attenuation.[28] Direct portal pressure measurements, however, are rarely indicated with the use of gradual attenuation devices such as thin film bands and ameroid constrictors compared with older suture ligation techniques.[5,28] Rather, sustained portal hypertension during shunt manipulation is uncommon and may be assessed noninvasively via evaluation of cardiovascular variables including heart rate and systemic blood pressure.[30]

The main limitation of the study was the use of a cadaveric model to simulate clinical dogs with PA shunts. In addition to anatomical variations between PA shunts and the azygos vein, lung ventilation to simulate the respiration of the anesthetized dog was not performed. Because one-lung ventilation is not used during thoracoscopic thoracic duct ligation, we believe that that pulmonary excursion from ventilation is unlikely to interfere with the caudodorsal thoracoscopic approach for PA shunt attenuation.[19,20] Nonetheless, if the right caudal lung lobe interferes with shunt visualization, selective ventilation of the left lung may be considered for thoracoscopic PA shunt attenuation.

In conclusion, this study provides evidence to support the feasibility of thoracoscopic placement of attenuation devices by using the azygos vein as a model for PA shunts. To the best of the authors' knowledge, this report is the first to describe an approach for thoracoscopic attenuation of PA shunts in dogs. Additional prospective study is warranted to evaluate the feasibility and safety of thoracoscopic PA shunt attenuation in affected dogs and to evaluate the efficacy of thin film bands for intrathoracic vascular attenuation.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose related to this report.

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