Received: 15 January 2023 | Revised: 4 September 2024 | Accepted: 12 September 2024

DOI: 10.1111/vsu.14174

CLINICAL RESEARCH

WILEY

Comparison of three approaches for accessory lung lobectomy in the canine cadaveric model: Intercostal thoracotomy, median sternotomy, and a transdiaphragmatic approach combined with caudal median sternotomy

Camille B. Duvieusart BVMS[1] | **Laura A. Barbur DVM, DACVS (Small Animal)**[1] | **Marie F. Burneko VMD, DACVS (Small Animal)**[2] | **Rebecka S. Hess DVM, MSCE, DACVIM**[2]

[1]Friendship Hospital for Animals, Washington, District of Columbia, USA

[2]Ryan Animal Hospital, University of Pennsylvania, Philadelphia, Pennsylvania, USA

Correspondence
Laura A. Barbur, Friendship Hospital for Animals, 2650 15th St NW Apt 4, Washington D.C, 20009, USA.
Email: laura.a.barbur@gmail.com

Abstract

Objective: To describe a combined transdiaphragmatic and caudal median sternotomy (TDCM) approach to the accessory lung lobe and to compare its accessibility with intercostal thoracotomy (ICT) and median sternotomy (MS).

Study design: Cadaveric study.

Animals: Twelve canine cadavers.

Methods: Cadavers underwent an accessory lung lobectomy using an articulating EndoGIA stapler via randomly assigned approach: ICT ($n = 4$), MS ($n = 4$) or TDCM ($n = 4$). The percentage of accessory lung tissue removed was measured in surface area and weight. Exposure was measured as area of cavitary or bicavitary exposure at maximal retraction, by tracing a line around the circumference of the exposed cavity using an imaging software. Staple line leak pressures were evaluated to 40 cmH_2O.

Results: The average area of exposure was larger in the TDCM approach (TDCM = 193.5 cm^2, MS = 106.5 cm^2, ICT = 73.5 cm^2); ($p = .01$). Two of four ICT staple lines leaked at 40 cmH_2O or lower, and 1/4 MS resulted in iatrogenic damage to an adjacent lobe. There was no difference in the percentage of the lobe excised by weight or surface area between groups.

Conclusion: The transdiaphragmatic and caudal median sternotomy approach provided greater exposure, although the percentage of the lobe excised and the surgical time did not differ between approaches.

Clinical significance: All three approaches allowed for adequate excision of the accessory lung lobe (ALL) with similar surgical times; however, the TDCM approach provided a greater area of exposure, which could increase accessibility to the ALL.

1 | INTRODUCTION

Three open thoracic approaches were previously described for surgical management of thoracic diseases:[1–5] intercostal thoracotomy (ICT), median sternotomy (MS), and a transdiaphragmatic approach.[3] Minimally invasive thoracoscopic and thoracoscopic-assisted approaches have also been reported.[6] Traditionally, an ICT is performed when exposure to only one hemithorax is needed.[1] A MS allows thorough exploration of the entire thoracic cavity and better access to ventral mediastinal structures. The transdiaphragmatic approach for the purpose of a lung lobectomy has not been described, although this approach is employed routinely for other thoracic procedures.[2] In contrast with all other lung lobes, there is a lack of consensus regarding the optimum open approach to the accessory lung lobe (ALL) for lung lobectomy in veterinary literature.[7]

The ALL lies toward the right side of the caudal thorax, between the right and left caudal lung lobes, and is in contact with the diaphragm. The ALL has three distinct processes: dorsal, right lateral, and ventral. The ventral process fills the recess demarcated by the plica vena cava and mediastinal pleura. The caudal vena cava (CVC) and right phrenic nerve pass through a notch separating the right lateral and dorsal processes.[8]

In a recent study on at anatomical considerations for the surgical approach to the canine ALL, Mather et al. noted a preference for a right sixth ICT over a MS due to challenges with visualization of vital structures via MS.[7] However, the ICT approach limits evaluation to the right hemithorax. To date, transdiaphragmatic approach to the ALL has not been described. Due to the close association of the ALL with the right caudal lobe and CVC, the multiple processes of the ALL, and the proximity of the barrel-shaped diaphragm, the ALL has historically been difficult to approach using the conventional ICT and MS. The lack of a standardized approach warrants comparison of current approaches and exploration of alternative surgical options.

The objectives of this study were threefold. First, to introduce a novel application of the transdiaphragmatic approach combined with caudal median sternotomy (TDCM) for the accessory lung lobectomy. Second, to describe thoroughly and compare exposure of the ALL via three different approaches: ICT, MS, and TDCM. Third, to compare the area of cavity exposure and the percentage of ALL excised using each of the three approaches. The null hypothesis was that there will be no difference in percentage of ALL excised or area of exposure achieved.

2 | MATERIALS AND METHODS

2.1 | Study design

Twelve canine cadavers were obtained, three of which were donated for research from clients at a private practice, and nine of which were purchased from a third party. Written consent for donation of cadavers for research was obtained for all client-owned animals. Inclusion criteria included cadaver weight of 10–35 kg, frozen within 2 h of euthanasia, and thawed for use within 3 weeks of freezing. All cadavers were euthanized for reasons unrelated to this study. Each cadaver was randomly assigned to one of three thoracic approach groups: sixth ICT, MS, or TDCM. The length of the skin incision was measured in centimeters. Photographs to assess exposure were obtained at maximal retraction with either a Finochietto retractor (ICT, MS) or Balfour retractor in combination with a Gelpi retractor (TDCM), at a standardized height that allowed visualization of the entire incision for all cases (21 cm), using a camera on a mounting stand. All images were calibrated with a ruler placed at the level of the incision and perpendicular to the mounting stand. Exposure was defined as an area of cavitary or bicavitary exposure at maximal retraction, as measured by tracing a line around the circumference of the exposed cavity in the imaging processing software (Figure 1) (ImageJ 1.49, 182 US National Institutes of Health, Bethesda, Maryland).

Each approach was performed by the same board-certified surgeon in a randomized order. Each cadaver was intubated and mechanically ventilated at a pressure of 12 cmH_2O with a rate of 12 breaths per minute. Once the assigned approach was completed, visual inspection along with saline leak test were used to confirmed that no preexisting ALL pathology was present. The ALL was identified and freed from its ligamentous and mediastinal attachments (described below). A lung lobectomy was performed as close to the hilus as possible, using a vascular/medium EndoGIA Tri-Staple device of either 45 or 60 mm length, depending on patient size and lung lobe size at the level that the stapler was able to be placed. Time from skin incision to lobectomy completion was recorded. After each lobectomy, airway leak testing was performed as described in previous studies.[9–11] Briefly, this method involved submerging the lobectomy site in saline, and increasing the inflation pressure slowly from 12 cmH_2O to 40 cmH_2O in increments of 5 cmH_2O. The pressure at which leakage occurred was defined as the pressure at which air bubbles were seen at the staple line. If no leaks occurred, pressure was maintained at 40 cmH_2O for 10 s and maximum pressure was recorded as 40 cmH_2O.

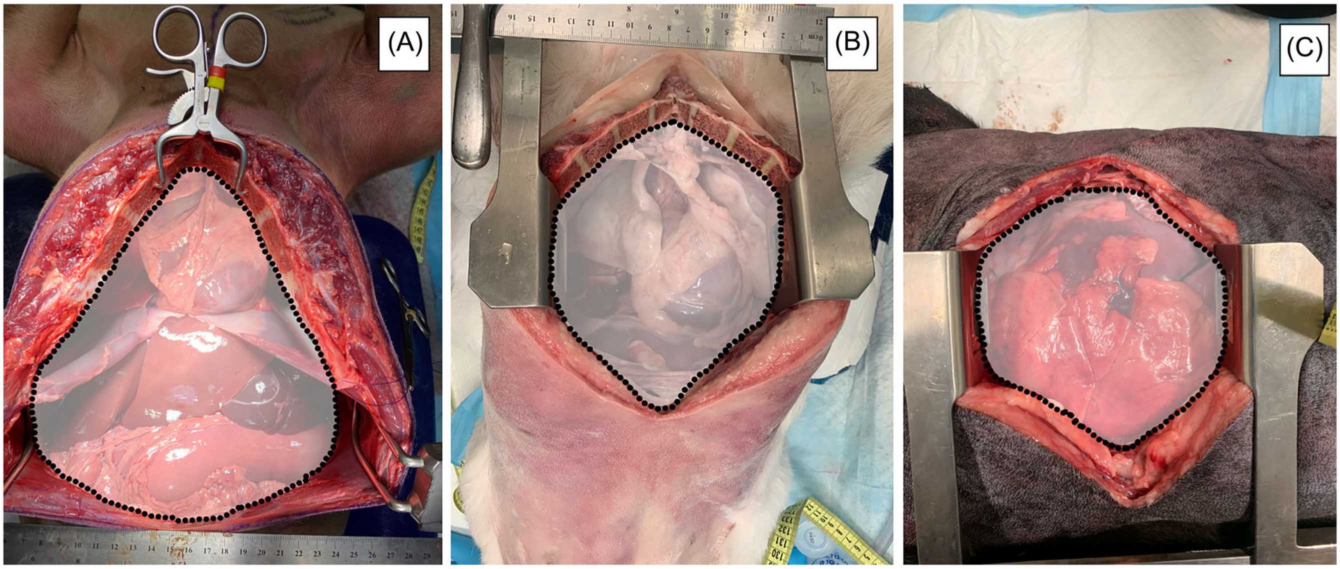

FIGURE 1 Areas of exposure for the transdiaphragmatic and caudal median sternotomy (A), median sternotomy (B), and intercostal thoracotomy (C) approaches. The exposed cavity is outlined (dotted line), and the area of exposure (faded region) was measured in cm^2.

When leak testing was complete, residual accessory lung tissue left in situ was excised at the level of the hilus. The artery, vein, and bronchus within the parenchyma were left in situ, as to not disrupt the surrounding parenchyma. The percentage of tissue removed during lobectomy was calculated based on total mass of ALL (mass of excised tissue + mass of residual tissue). The percentage of lung tissue excised was also calculated by area using digital imaging software. Images were calibrated using a ruler in each picture. Each ALL was placed on a dry surface and the tissue was gently fully spread out, with the stapled edge facing down, and all the processes extended outwards.

2.2 | Description of approaches

2.2.1 | ICT approach

Cadavers were positioned in left lateral recumbency and a standard 6th intercostal approach was made to the right thoracic cavity. A Finochietto retractor was placed and the hand-cranked lever was rotated to the point of resistance, which allowed for malleable deformation of ribs without iatrogenic fracture. The right caudal lobe was retracted cranially to expose the ALL (Figure 2A). Sharp dissection of the plica vena cava overlying the right lateral process of the ALL was performed (Figure 2B) to expose the ALL present in the mediastinal recess. The right lateral and ventral processes of the ALL were displaced medially and dorsally in relation to the CVC. Upward traction of all processes of the ALL allowed visualization of the right pulmonary ligament (Figure 2C). Two leaves of the ligament were visualized initially: the right caudal pulmonary ligament, which tethers the ALL to the right caudal lobe, and the lateral pulmonary ligament of the ALL, which merges into the esophageal mediastinal pleura (Figure 3A). The medial pulmonary ligament of the ALL was then transected from its insertion on the lateral pulmonary ligament toward the cranial hilus. Once the ALL was isolated (Figure 3B) the EndoGIA Tri-Staple device was placed near the pulmonary hilus.

2.2.2 | The TDCM approach

Cadavers were positioned in dorsal recumbency, and a skin incision of predetermined length was made from the 6th sternebra to the umbilicus, followed by incision of the underlying linea alba. A caudal median sternotomy of the xiphoid, 6th, 7th and 8th sternebrae was performed with an oscillating saw, and a Balfour retractor placed. A Gelpi was placed between the transected 6th sternebrae. A vertical diaphragmatic incision was made from the xiphoid, through the central tendon, ending 1 cm ventral to the caval foramen. Stay sutures were placed in both right and left sections of the transected diaphragm for caudal retraction (Figure 4A,B). Dissection of the phrenicopericardial ligament and ventral and caudal mediastinum was performed, taking care to visualize and avoid transection of the phrenic nerves. When the caudal mediastinum was transected, the plica vena cava was dissected to the level of the CVC. It should be noted that ventrally, the plica vena cava was continuous with the caudal mediastinum. The dorsal process of the ALL was temporarily displaced dorsomedial in relation to the CVC

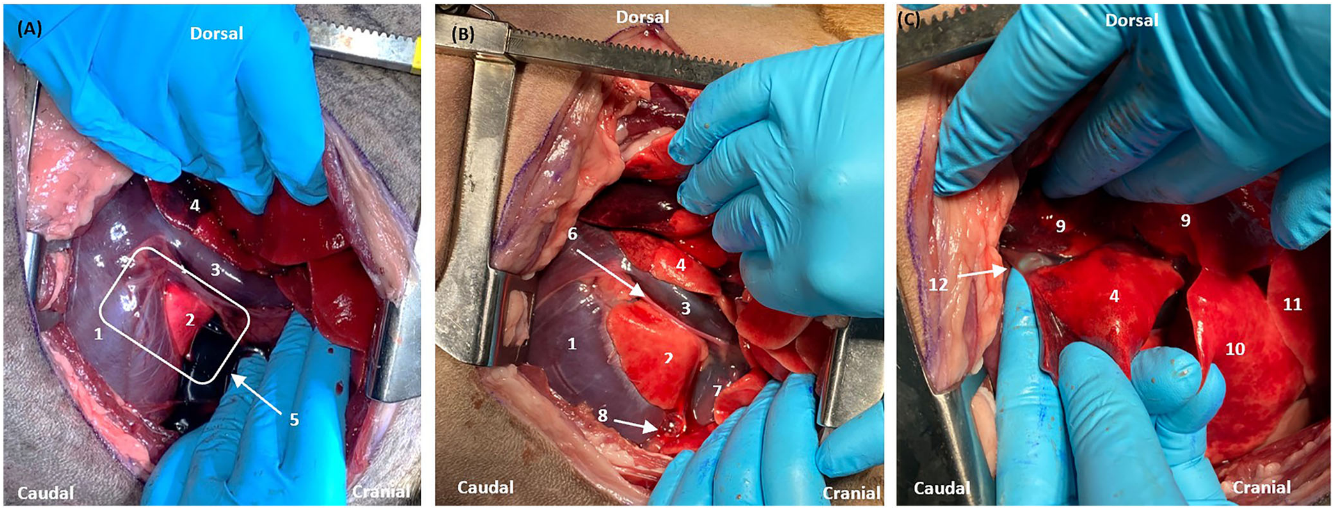

FIGURE 2 Intercostal thoracotomy. (A) Exposure with retraction: 1. diaphragm; 2. accessory lung lobe (ALL), right lateral process; 3. caudal vena cava (CVC); 4. ALL, dorsal process; 5. plica vena cava overlying ALL. (B) After dissection of the plica vena cava: 6. right phrenic nerve; 7. heart; 8. ALL, ventral process. (C) Dorsal and ventral process of ALL displaced dorsal and lateral to the CVC: 9. right caudal lobe; 10. right middle lobe; 11. right cranial lobe; 12. right pulmonary ligament.

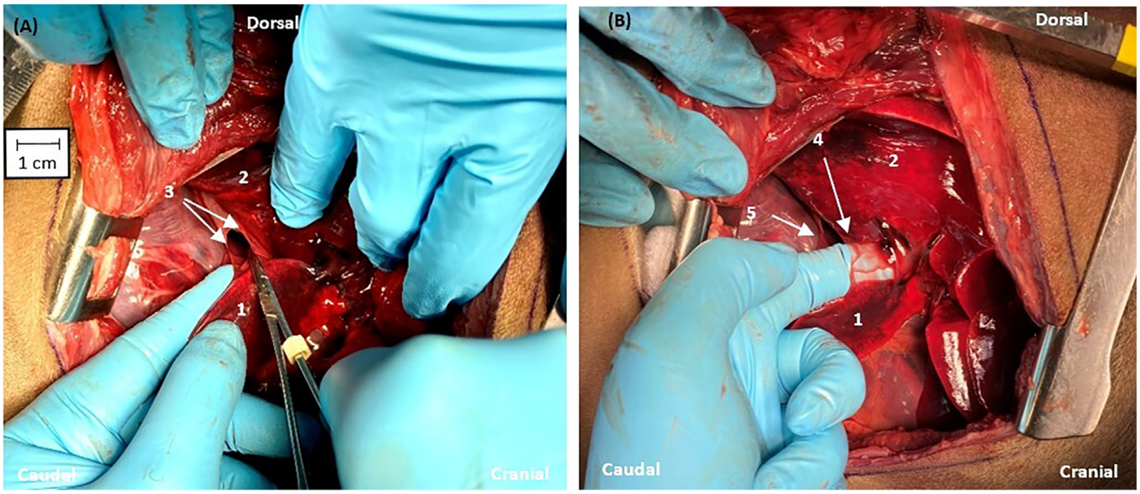

FIGURE 3 Intercostal thoracotomy. (A) Incision into pulmonary ligament: 1. accessory lung lobe (ALL), dorsal process; 2. right caudal lobe; 3. incised pulmonary ligament. (B) Continuation of dissection of pulmonary ligament: 4. leaf attaching right caudal and ALL; 5. leaf joining the right mediastinal pleura.

(Figure 5A,B), allowing visualization and transection of all three leaves of the right pulmonary ligament. All three processes of the ALL were then displaced dorsolateral in relation to the CVC prior to stapler placement (Figure 5C).

2.2.3 | The MS approach

Cadavers were positioned in dorsal recumbency. Skin and subcutaneous tissue were incised along the entire length of the sternum. An oscillating saw was used to perform a sternotomy from the xiphoid to the manubrium, leaving the manubrium intact. A Finochietto retractor was placed and the hand-cranked lever was rotated to the point of resistance, which allowed for malleable deformation of sternebrae without iatrogenic fracture (Figure 6A,B). From the point of dissection of the phrenicopericardial ligament, the remainder of the procedure was performed as described for the TDCM approach.

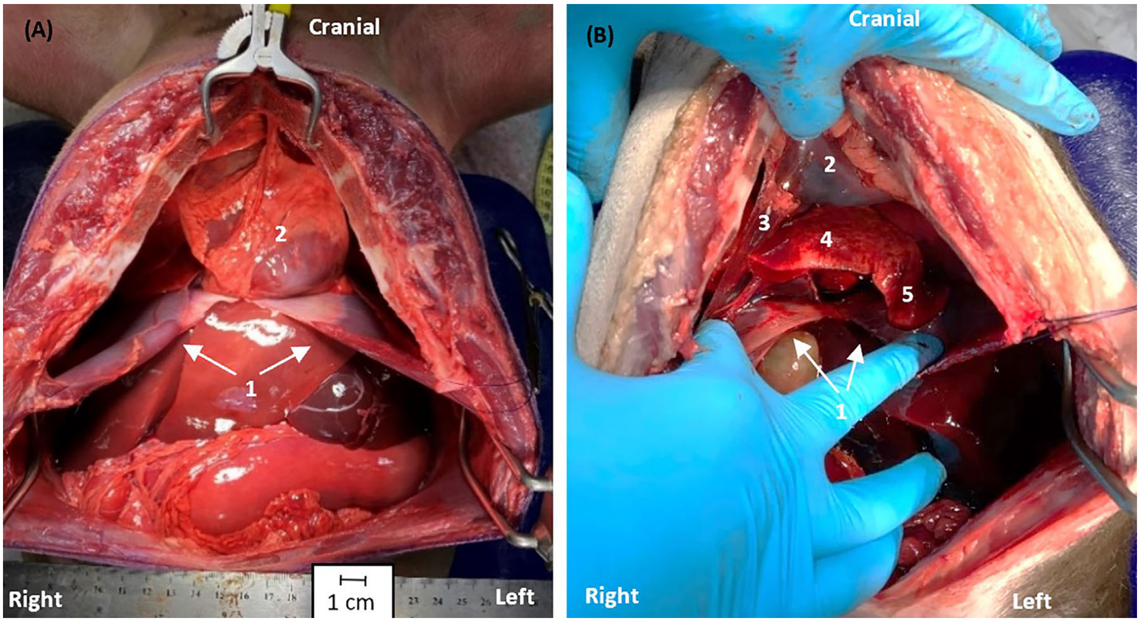

FIGURE 4 Transdiaphragmatic and caudal median sternotomy. (A) Initial exposure: 1. diaphragm; 2. heart. (B) Exposure with retraction: 3. plica vena cava; 4. accessory lung lobe (ALL), right lateral process; 5. ALL, ventral process.

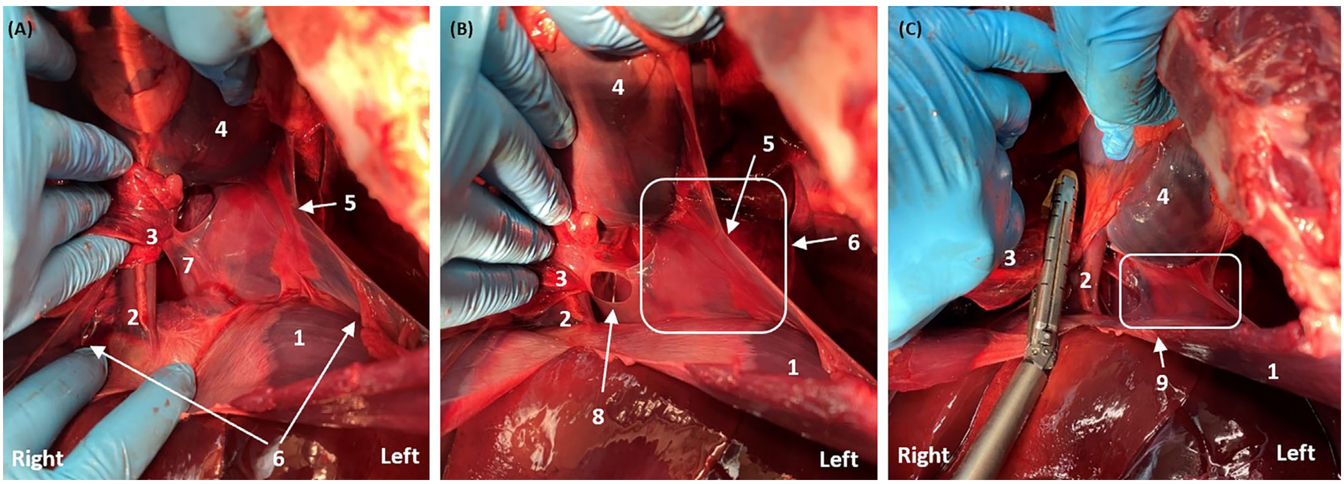

FIGURE 5 Transdiaphragmatic and caudal median sternotomy. (A) 1. Diaphragm; 2. caudal vena cava (CVC); 3. accessory lung lobe (ALL) (all processes retracted medial to the CVC); 4. heart; 5. left phrenic nerve; 6. mediastinal pleura (transected); 7. pulmonary ligament. (B) Incision of pulmonary ligament: 8. pulmonary ligament (incised). (C) EndoGIA stapler placement after displacement of ALL lateral to the CVC; 9. remainder of transected mediastinal pleura.

2.3 | Statistical analysis

Continuous variables were assumed to be not normally distributed and are reported as median and range. The Kruskal–Wallis test was employed to determine the association between a categorical variable with more than two levels, and if the association was significant, it was followed up by pairwise comparisons. The Fisher's exact test was used for pairwise comparisons to determine if there was a relationship between two categorical variables because cells had fewer than five observations. Because of the small sample sizes, p values were not corrected. p values $<.05$ were considered significant for all comparisons. All statistical analyses were performed using a statistical software package (Stata, version 14.0 for Mac; Stata Corp, College Station, Texas).

3 | RESULTS

The median and range weights of the cadavers were 22.3 kg (19.9–25.3 kg) for the ICT group, 22.2 kg (19.5–

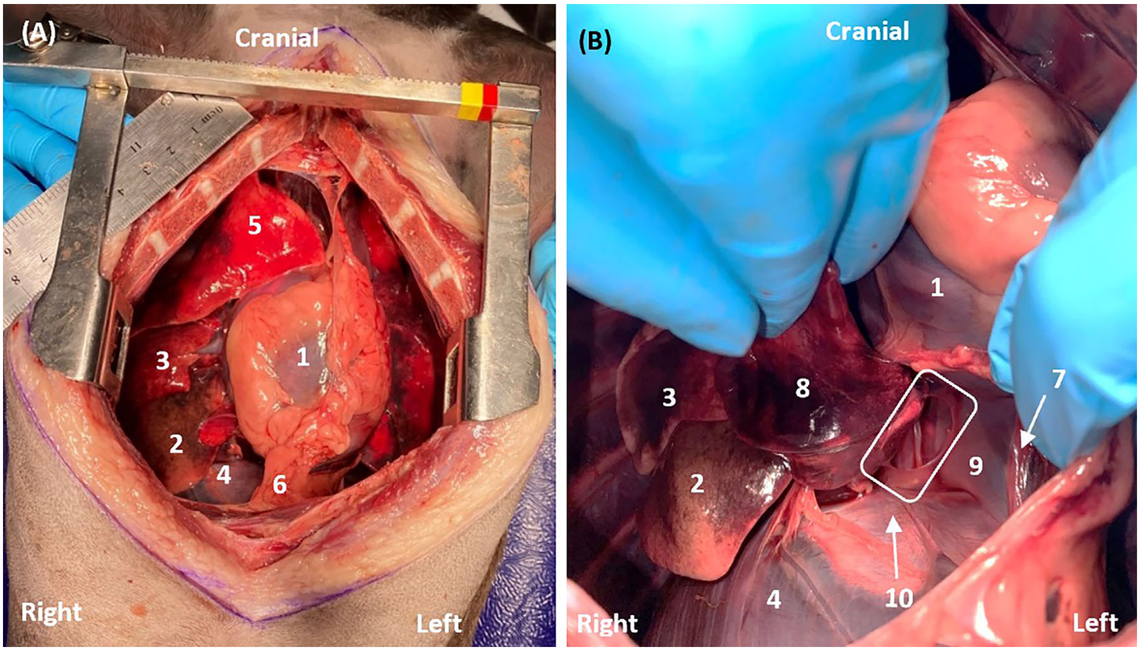

FIGURE 6 Median sternotomy. (A) Exposure: 1. heart; 2. right caudal lobe; 3. right middle lobectomy; 4. diaphragm; 5. right cranial lobe; 6. phrenicopericardial ligament and caudal mediastinum. (B) Exposure with retraction: 7. left phrenic nerve; 8. accessory lung lobe (ALL) (right lateral and ventral process); 9. caudal mediastinum, left side; 10. transected pulmonary ligament.

25.0 kg) for the MS group, and 20.8 kg (17.6–24.0 kg) for the TDCM group, with no differences ($p = 1.0$). There was no difference in skin incision length ($p = .08$), percent of total surface area ($p = .4$) or percent of total weight ($p = .4$) of ALL parenchyma excised between the groups (Table 1). Time from skin incision to completion of lung lobectomy did not differ among groups ($p = .06$) (Table 1). A Kruskal–Wallis test showed no difference among groups for leakage of the staple line at pressures lower than the maximum leak pressure of 40 cmH_2O ($p = .09$). The area of exposure at maximal retraction differed among the approaches, with TDCM having the largest ($p = .01$) (Table 1). When analyzed as paired variables, TDCM was larger than ICT and MS ($p = .02$, .02 respectively) and MS was larger than ICT ($p = .04$).

4 | DISCUSSION

The TDCM approach resulted in a greater area of exposure in comparison with the other two approaches, despite incision lengths in the 3 approaches not being different. This was likely due to the greater pliability of the abdominal wall in comparison with the thoracic wall, allowing a greater degree of retraction during the TDCM approach, as well as a decrease in resistance caused by incising the diaphragm. In our study, it was decided that bicavitary exposure via the TDCM approach warranted investigation. This approach better centered the ALL and took advantage of the more pliable abdominal wall. Given the proximity of the ALL to the diaphragm, the phrenotomy performed allowed for caudal retraction of abdominal organs and additional space in the caudal thorax for movement of hands, instrumentation, and maneuvering the stapling device. Including the cranial abdomen as part of the working space was therefore an integral part of this approach. Instead of performing a full sternotomy incision and retracting surrounding structures predominantly in a cranial direction, a caudal sternotomy, a phrenotomy, and a laparotomy were performed and surrounding structures were predominantly retracted in a caudal direction. As such, only measuring the exposure of the thorax would not be representative of the space used during this approach. Subjectively, visualization of the ALL and surrounding vital structures with the TDCM approach was improved in comparison with MS and ICT. However, the approach did not result in any difference in surgical time, weight/surface area of ALL removed, or maximum leak pressure sustained.

None of the procedures required en bloc removal of the ALL with the right caudal lobe, as has previously been the recommendation in a surgical textbook.[7,12] Identification and careful dissection of all parts of the right pulmonary ligament was crucial to isolate the ALL for lobectomy adequately. In a recent publication, Mather et al.[7] further described the right pulmonary ligamentous attachments as consisting of three parts: the lateral and medial ligaments of the ALL, and the ligament of the

TABLE 1 Baseline characteristics and outcomes of interest.

		ICT ($N = 4$)	MS ($N = 4$)	TDCM ($N = 4$)	p
Patient weight (kg)[a]		22.3 (19.9–25.3)	22.2 (19.5–25.0)	20.8 (17.6–24.0)	1.0
Skin incision length (cm)[a]		23 (21.2–25.0)	28.8 (27.1–29.5)	25.1 (23.7–26.0)	.08
Total weight of lung (g)[a]		38 (31.9–41.3)	30.3 (25.9–35.4)	25.5 (24.9–26.1)	.3
Total surface area of lung (cm^2)[a]		54 (39.8–69.3)	52 (46.2–56.0)	41.5 (40.9–42.3)	.5
OUTCOMES					
Excised lung weight (g)[a]		34.5 (31.0–36.3)	29 (24.5–34.0)	24.5 (24.0–25.3)	.4
Residual lung weight (g)[a]		1.0 (0.9–2.5)	1.3 (1.0–1.7)	0.8 (0.6–0.9)	.06
Percentage of total lung weight excised[a]		96.9 (93.3–97.1)	95.7 (94.1–96.3)	97.0 (96.5–97.5)	.4
Leakage before 40 cmH_2O[b]		2/4	0/4	0/4	.09
maximum keak pressure (cmH_2O)[a]		39 (38–40)	40 (40–40)	40 (40–40)	.1
Surface area excised lung (cm^2)[a]		51.2 (37.5–63.6)	48.8 (43.0–52.2)	39.6 (38.9–40.1)	.7
Surface area residual lung (cm^2)[a]		2.6 (2.3–4.5)	3.7 (3.5–4.0)	2.4 (2.0–2.6)	.1
Percentage of total lung surface area excised[a]		94.4 (92.0–95.0)	93.2 (91.4–93.7)	94.4 (93.6–95.2)	.4
Surface area exposure (cm^2)[a]		73.5 (65.8–83.4)	106.5 (99.7–111.8)	193.5 (177.3–207.0)	.01*
Time incision to lobectomy (total s)[a]		650 (547–752)	927 (855–1064)	1016 (908–1137)	.06
Stapler size used (mm)[b]	45	3	2	4	.3
	60	1	2	0	

Abbreviations: ICT: Intercostal thoracotomy; MS: Median sternotomy; TDCM: Transdiaphragmatic with caudal median sternotomy.
[a]Kruskal–Wallis test.
[b]χ^2 test.
*Significant difference.

right caudal lung lobe. In this study, during the ICT approach, the medial pulmonary ligament was visualized only after transection of the other two parts of the ligament. During the MS and the TDCM approaches, all three parts of the ligament could be visualized readily. Although this study was performed on normal lungs and further studies on lungs with pathology are needed, it is the authors' opinion that dissecting the ligament from the TDCM approach was subjectively easier due to centering of the target lobe and immediate visualization of all three parts of the ligament. As a consequence, the TDCM approach might provide a means to resect the ALL without removal of the right caudal lung lobe even in cases of pulmonary neoplasia, depending on the location and extent of disease.

The MS created a smaller surgical field than TDCM and it was not well centered over the ALL, which might have limited the ability to grasp or retract from multiple sides. The barrel shape of the diaphragm might obstruct visualization of the ALL and limit space for retraction and stapler placement. Finally, an intact diaphragm placed resistance on the incision and therefore limited lateral retraction of the body wall. The authors speculate that these three factors all contributed to the limited exposure of the caudal thorax in the MS and ultimately limited access to the ALL for stapler placement. This assessment aligns with that of Mather et al., which states that an ALL lobectomy performed through a MS was not optimal, due to challenging visualization of the essential hilar structures given their depth within the thorax, and the presence of other structures obscuring the ALL. The decision to use the 6th intercostal space for the ICT group was based on previous recommendations.[6,7] However, the absence of comparison of more than one intercostal approach was a limitation of this study. In a cadaveric study, Singh et al.[6] described that thoracoscopic-assisted lung lobectomy of the ALL performed at the fifth or sixth intercostal space resulted in the shortest distance from the stapler anvil to the pulmonary hilus. A previous case study describing an accessory lung lobectomy via ICT suggested displacing the ALL medial and dorsal to the CVC prior to stapler placement, to facilitate placement closer to the hilus.[13] This same maneuver was replicated in our ICT approach.

Although dissection of the pulmonary ligament, stapler placement, and subsequent excision of the lobe was subjectively easier in the TDCM approach, the percentage of the ALL removed by weight and surface area did not differ between approaches, so the null hypothesis could not be rejected. Two previous caprine and feline cadaveric studies comparing maximum pressure sustained by airways sealed with either a resorbable self-locking ligation device (LigaTie) or a thoracoabdominal (TA) stapler have been published.[9,14] In the later study, all leaks occurred when the staple line was more than 5 mm from the hilus, suggesting that correct stapler placement may play a role in the success of the lobectomy. In our study, all approaches resulted in the removal of a similar amount of lung tissue, suggesting similar proximity of the stapler anvil to the hilus in all approaches.

In this study, we elected to use an EndoGIA stapler in lieu of a TA stapler. Successful use of EndoGIA stapler for complete or partial lung lobectomy has been described for thoracoscopic surgery[13,15] and for ex vivo lung biopsy studies.[10,11] An MIS approach was not within the scope of this study, which was a limitation. Preference was given to the use of the EndoGIA stapler for this study given that it provides three rows of staggered staples regardless of staple size, the anvil articulates for ergonomic adaption, and it provides a simultaneous staple/cut function while sealing both the excised and in situ parenchyma.

This study has several limitations. Due to ethical concerns of sourcing cadavers, the sample size for each group was small. All approaches were performed on thawed lungs from frozen cadavers. A previous study did not find a difference in leak pressures sustained between lungs that were frozen and then thawed versus fresh lungs,[14] but this may have impacted the integrity of lung tissue. Degree of inflation of ALL tissue excised was not assessed, which might have marginally impacted the surface area measurements; however, it would not have affected our weight measurements. Using "area of incision when maximally retracted" as a measure of exposure is subjective; however, all retractors were placed by the same surgeon, providing some consistency in the interpretation of maximal retraction. Incision area of exposure does not directly measure access to the desired lung lobe, although one can surmise that greater exposure allows for greater working space when placing the stapler. In future studies, other measures of exposure should be explored, such as the area of ALL visible in each approach with standardized retraction. All procedures were performed in cadavers without pulmonary pathology because this study's objective was to describe a novel application of the TDCM approach. Additional studies are warranted to compare accessibility of the ALL and hilar lymph nodes via each of the three approaches when pulmonary pathology is present. Finally, the variation in the stapler size (45 vs. 60 mm) and the lack of comparison of stapler types was a limitation of this study.

In conclusion, all approaches allowed for adequate stapler placement and adequate seal on leak testing. TDCM resulted in a greater area of exposure. There were no differences in the percentage of the ALL excised by weight or area, and no differences in surgical time. This study introduces a novel application of the transdiaphragmatic approach to the thorax, allowing for a larger surgical field, and improved centralization of the ALL. Additional larger scale studies would be welcomed to further assess the feasibility of the TDCM for accessory lung lobectomy in the presence of pathological changes.

ACKNOWLEDGMENTS

Author Contributions: Duvieusart CB, BVMS: Contributed to study design, assisted with procedures, drafted the manuscript. Barbur LA, DVM, DACVS (Small Animal): Contributed to study design, performed procedures, revised the manuscript. Burneko MF, VMD, DACVS (Small Animal): Contributed to the revision of the manuscript. Hess RS, DVM, MSCE, DACVIM: Contributed to the statistical analysis of the data.

FUNDING INFORMATION

Friendship Hospital for Animals provided financial support.

CONFLICT OF INTEREST

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

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

1. Monnet E. Lungs. In: Tobias KM, Johnston SA, eds. *Veterinary Surgery: Small Animal*. Vol 1983-1999. Elsevier; 2018.
2. Hunt GB. Thoracic wall. In: Tobias KM, Johnston SA, eds. *Veterinary Surgery: Small Animal*. Elsevier; 2018:2001-2019.
3. Tillson DM. Thoracic surgery; important considerations and practical steps. *Vet Clin North Am Small Anim Pract*. 2015; 45(3):489-506.
4. Moores AL, Halfacree ZJ, Baines SJ, Lipscomb VJ. Indications, outcomes and complications following lateral thoracotomy in dogs and cats. *J Small Anim Pract*. 2007;48(12):695-698.
5. Bleakley S, Phipps K, Petrov-sky B, Monnet E. Median sternotomy versus intercostal thoracotomy for lung lobectomy: a comparison of short-term outcome in 134 dogs. *Vet Surg*. 2018; 47(1):104-113.
6. Singh A, Scott J, Case JB, Mayhew PD, Runge JJ. Optimization of surgical approach for thoracoscopic-assisted pulmonary surgery in dogs. *Vet Surg*. 2019;48(S1):O99-O104.
7. Mather AJ, Chanoit G, Meakin L, Friend E. Anatomical considerations for the surgical approach to the canine accessory lung lobe. *Vet Surg*. 2023;52(7):1064-1073.

8. Lora-Michiels M, Biller DS, Olsen D, Hoskinson JJ, Kraft SL, Jones JC. The accessory lung lobe in thoracic disease: a case series and anatomical review. *J Am Anim Hosp Assoc*. 2003;39(5):452-458.
9. Nylund AM, Chen C-Y, Höglund OV, Campbell BG, Fransson BA. Evaluation of a resorbable self-locking ligation device for performing peripheral lung biopsies in a caprine cadaveric model. *Vet Surg*. 2019;48(5):845-849.
10. Imhoff DJ, Monnet E. Inflation pressures for ex vivo lung biopsies after application of graduated compression staples. *Vet Surg*. 2016;45(1):79-82.
11. Marvel S, Monnet E. Ex vivo evaluation of canine lung biopsy techniques. *Vet Surg*. 2013;42(4):473-477.
12. Orton EC, Monet E. Lung. *Small Animal Thoracic Surgery*. Wiley; 2017:129-138.
13. Shamir S, Mayhew PD, Zwingenberger A, Johnson LR. Treatment of intrathoracic grass awn migration with video-assisted thoracic surgery in two dogs. *J Am Vet Med Assoc*. 2016;249(2):214-220.
14. Nylund AM, Höglund OV, Fransson BA. Thoracoscopic-assisted lung lobectomy in cat cadavers using a resorbable self-locking ligation device. *Vet Surg*. 2019;48(4):563-569.
15. Case JB, Mayhew PD, Singh A. Evaluation of video-assisted thoracic surgery for treatment of spontaneous pneumothorax and pulmonary bullae in dogs. *Vet Surg*. 2015;44(Suppl 1):31-38.

How to cite this article: Duvieusart CB, Barbur LA, Burneko MF, Hess RS. Comparison of three approaches for accessory lung lobectomy in the canine cadaveric model: Intercostal thoracotomy, median sternotomy, and a transdiaphragmatic approach combined with caudal median sternotomy. *Veterinary Surgery*. 2025;54(1):89-97. doi:10.1111/vsu.14174