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Parasternal thoracotomy via sternocostal disarticulation: a novel surgical approach to the canine thorax

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OBJECTIVE
To describe the technique and outcomes of a modified paramedian thoracic approach in dogs involving a parasternal thoracotomy via rib disarticulation at the sternocostal joint.

ANIMALS
93 client-owned dogs.

METHODS
Medical records of dogs that underwent parasternal thoracotomy at a private practice between the years 2015 and 2021 were reviewed. Signalment, weight, clinical presentation, surgical details, complications, and short-term outcomes were recorded. Cox proportional hazards regression models were utilized to analyze the impact of covariates on hazard events. Kaplan-Meier curves were employed to evaluate survival functions for select variables.

RESULTS
Parasternal thoracotomy via sternocostal disarticulation was performed in 93 dogs. Eighty-eight dogs (94.6%) survived the procedure. Eighty-three dogs (89.2%) survived to discharge from the hospital. Age, weight, postoperative time to eating, postoperative ambulation, and surgical or anesthetic duration were not significantly associated with survival to discharge. Thoracostomy tube duration significantly decreased the likelihood for survival to discharge; for each additional hour of thoracostomy tube placement, the odds of survival to discharge diminished by 5.7% (hazard ratio, 0.94; 95% CI, 0.912 to 0.976).

CLINICAL RELEVANCE
Parasternal thoracotomy via rib disarticulation at the sternocostal joints may be a viable alternative to median sternotomy that does not require specialized equipment for bilateral hemithoracic visualization. Postoperative complications and short-term outcomes are comparable to those reported for the traditional median sternotomy approach. Prolonged thoracostomy tube duration may impact survival to discharge.

Keywords: sternocostal, disarticulations, parasternal thoracotomy, median sternotomy, thoracostomy tube

Thoracotomy is a common surgery in the dog to access intrathoracic structures.[1–7] Previously described approaches include lateral or intercostal thoracotomy (ICT), median sternotomy (MS), transdiaphragmatic thoracotomy, rib resection thoracotomy, or thoracoscopy.[1–9] The choice of thoracic approach is dependent on the diseased organ location, the intended procedure, and clinician preference.[1–7]

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Median sternotomy is currently the only open thoracic approach that allows bilateral thoracic access through a single incision.[2,10–13] Median sternotomy is performed utilizing an oscillating bone saw to section the sternum.[2,13,14] Indications for MS may include thoracic exploration, pyothorax, cranial mediastinal malignancy, subtotal pericardiectomy, or cranial intrathoracic trachea or esophageal access, among others.[15,16] Thoracic surgery utilizing the MS approach can be expensive and limit owner access to care, as specialized orthopedic equipment is typically needed.[17] Different thoracotomy techniques utilizing common surgical tools could save cost and aid in greater access to care in emergency thoracic cases.

There may be reluctance among veterinary surgeons to use the MS approach due to the previously reported high postoperative complication rate, ranging from 14% to 78%.[7,11–13,15,18] The reported postoperative complications include pain, lameness, infection, dehiscence, draining tracts, internal thoracic artery compromise, and osteomyelitis, among others.[11,13,18,19] In a retrospective study[7] that compared short-term outcomes in dogs undergoing MS versus ICT, MS was associated with higher morbidity when used for specific indications (specifically, the resection of primary and metastatic lung tumors). In another retrospective study[6] evaluating the factors influencing short-term outcomes after thoracic surgery, a significant association was identified among complication rates, with 71% of MS patients developing wound complications compared to only 23% of ICT patients. Given the shape of the canine sternebrae and its smaller size compared to humans, it is not uncommon for the oscillating bone saw to wander from median to parasternal, separating the costal cartilage from the sternum.[14] Contrary to MS in humans, deviation in this approach does not result in any reported difficulties.[14] Alternative approaches could be devised deviating from midline to potentially improve complication rates compared to MS.

In humans, sternal instability is associated with pain, incisional dehiscence, and implant failure.[20,21] Rigid fixation with plates provides reduction and stabilization of a human sternum, a method of repair not currently available in canines due to their anatomical differences.[22,23] To avoid complications associated with sternal instability, veterinary literature[3,24] recommends leaving 1 end of the sternum intact (ie, the manubrium or xiphoid sternebrae). In support of sternal stability, orthopedic stainless steel wire in a figure-eight pattern is the MS closure of choice in veterinary medicine for dogs > 10 kg.[2,3,11] However, orthopedic wire closure is associated with reported complications of MS, such as postoperative pain, infection, dehiscence, and osteomyelitis.[11–13,15] Sutures have been suggested in humans as an alternative to wire closure in an attempt to reduce postoperative pain and decrease surgical time.[25–27] A veterinary study[28] examined outcomes following different MS closure methods in large dogs. The likelihood of MS-closure–related complications was equivalent between sutures and wires and independent of dog size.[28] Regardless of the closure method for MS, the significant postoperative complications remain.[28] Consideration for an alternative anatomical approach allowing similar exposure could potentially be beneficial.

The objective of this study was to describe an alternative approach to the traditional median sternotomy, a parasternal thoracotomy (PT) via rib disarticulation at the sternocostal joint, that may provide a more simplistic and cost-effective method of thoracic entry and closure without the need for orthopedic equipment. We aimed to report postoperative complications and short-term outcomes of this approach. To the best of our knowledge, this approach has not been previously described in humans or canines. The secondary objective was to report survival outcomes, complications, and factors associated with mortality for this novel technique.

Methods

Case selection

Electronic medical records of a small animal specialty hospital were retrospectively reviewed to identify canines that underwent PT between January 1, 2015, and December 31, 2021. As this was a novel approach, the procedure was discussed and informed consent was obtained from each owner. Cases with multiple thoracic surgeries were included if PT was performed; however, only the initial PT procedure was included for data analysis. Procedures were performed at the same institution by board-certified surgeons or residents with direct supervision from a board-certified surgeon. Exclusion criteria included the following: procedure performed by a non–board-certified surgeon, severe thoracic trauma preventing or complicating closure, or combined thoracic approaches (ie, ICT and PT). Cases with concurrent procedures were not excluded, such as abdominal exploration or mass removal.

Medical records review

Demographic data were retrieved from electronic medical records. Dogs were stratified based on body weight into 4 categories: small breeds (< 10 kg), medium breeds (10 to 25 kg), large breeds (26 to 45 kg), and giant breeds (> 45 kg).[29] Data collection encompassed variables including body condition score, duration of surgery, anesthesia duration, eating behavior, ambulation ability, thoracostomy tube management, discharge status, duration of hospitalization, incidence of postoperative recheck examinations, and time to recheck after or equal to 10 days after surgery.

Complications classification

Complications were classified according to previously reported guidelines.[30] A complication was defined as an adverse event that occurred from admission to hospital until reported recheck examination, death, or humane euthanasia. Complications were further classified as preoperative (after initiation of anesthesia but prior to skin incision), intraoperative (from skin incision to skin closure), and postoperative complications (after skin closure).[30] Postoperative complications were associated or attributed to surgical intervention in the time after skin closure until recheck examination. Postoperative complications were also graded in terms of severity based on the Accordion Severity Grading System.[30] Minor or mild complications were treatable with minimally invasive procedures, such as a bandage change or the administration of additional analgesics. Moderate complications required pharmacologic treatment with other drugs, such as additional antibiotics. Major or severe complications were defined as necessitating surgical intervention. A surgical site infection was classified as an infection within 30 days of the PT procedure involving the skin, subcutaneous tissue, and/or the deep soft tissues of the incision.[31] Infections were presumed based on previously described surgical site infection criteria[31] and subsequent prescription of antibiotic therapy; confirmation with positive bacterial culture was not required. Patients without evidence of a recheck examination or with recheck examinations conducted < 10 days after surgery (prior to staple/suture removal) with no subsequent documentation of status were considered lost to follow-up. Cases with recheck data available at least 10 days after surgery were included in recheck survival analysis.

Description of surgical technique

The anesthetic protocols varied at the attending clinician's discretion. General anesthesia was induced with propofol and titrated to effect to facilitate endotracheal intubation. A surgical plane of anesthesia was maintained with isoflurane in a mixture of oxygen delivered through a standard circle anesthetic system with intermittent positive pressure ventilation initiated just prior to entering the pleural space. Additional analgesia was often provided via an opioid administered at a constant rate infusion. Cefazolin was administered prior to starting the surgical procedure, repeated every 90 minutes during surgery, and continued approximately 12 to 24 hours after surgery.

The patients were clipped from the mid cervical region to the umbilicus, laterally extending dorsally one-half the distance to the dorsal midline. All dogs were positioned in dorsal recumbency; the front limbs were either tied caudally or extended cranially at the discretion of the surgeon. Sandbags were placed on either side of the body to maintain the desired position of the patient. Patients were then prepared for aseptic surgery. A ventral midline skin incision was performed from just cranial to the manubrium to the caudal extent of the xiphoid cartilage **(Figure 1)**. The subcutaneous tissue and pectoral muscles were incised along the midline via sharp or electrocautery dissection and elevated from either the right or left side of the sternum, exposing the sternum and sternocostal articulations. A groove was made with either a blade or monopolar electrocautery along each rib insertion site to the sternum at the sternocostal joint to be transected. The manubrium and/or xiphoid ribs were left intact, transecting the articular cartilage of ribs 1 to 7, 2 to 7, or 2 to 9, depending on the needed exposure. Mayo scissors were then used to complete the disarticulation of the sternocostal joint. No orthopedic saw or other special equipment was necessary for thoracic entry. The side and extent of sternocostal joint disarticulation was dependent on the preference of the surgeon and/or the location of the expected disease process in the thorax. Gelpi retractors were utilized for exposure during cartilage transection. Care was taken to avoid the internal thoracic artery and branching vasculature on entry. If hemorrhage occurred, it was controlled with electrocautery, a bipolar vessel sealing device (LigaSure; Medtronic Inc), and/or hemoclips. The mediastinum, if intact, was broken down either bluntly, with electrocautery, or with a bipolar vessel sealing device (LigaSure; Medtronic Inc). Moistened laparotomy sponges were then placed along the edges of the incision to help prevent tissue desiccation. Finochietto or Gelpi retractors can be used to maintain exposure of the thoracic cavity. Varying procedures were performed per patient indication; samples for culture and susceptibility testing, cytology, and/or histopathology were obtained. If not already present, unilateral or bilateral indwelling thoracostomy tubes were placed and secured with a purse-string and finger-trap suture pattern by use of a nonabsorbable monofilament polyamide suture. The thoracostomy tube was left open for the duration of the thoracic wall closure.[2]

All sternal closures were completed with the sequential placement or preplacement of sutures in a simple interrupted or cruciate mattress pattern, apposing the costal cartilage to the respective insertion site of intersternebral cartilages (Figure 1). The thickened periosteum overlying the sternum provided additional anchorage for the apposition.[3] Thoracotomy incisions were reapposed by use of heavy monofilament sutures (ranging from 2-0 to 2 polypropylene or polydioxanone), dependent on clinician preference and patient size. The pectoral muscles and fascia were reapposed over the sternotomy site by use of absorbable monofilament sutures (polydioxanone), ranging from 3-0 to 0 polydioxanone, in a simple continuous pattern. Subcutaneous tissues and skin were closed routinely in separate layers. After thoracic closure, negative pressure was reestablished through the thoracostomy tube.

Postoperative considerations

Depending on surgeon preference, either a chest bandage or local nonadherent wound dressings were applied to the incision and thoracostomy tube site. Postoperative analgesia varied at the discretion of the surgeon. All dogs received 1 or a combination of the following: SC injection of an NSAID; IV constant rate infusion of an opioid or a combination of an opioid, lidocaine, and ketamine; IM, SC, and/or skin injection of local anesthetics, such as bupivacaine or liposome-encapsulated bupivacaine; or intermittent intrapleural bupivacaine administration via the thoracostomy tube.

All dogs were examined and monitored routinely for the extent of hospitalization. Aspiration of the thoracostomy tube was performed every 1 to 6 hours depending on the time from surgery, fluid production, and clinician preference. Removal of the thoracostomy tube was performed when thoracic aspirates were minimally productive or approximately equivalent to 2 mL/kg/d.[16] Upon transition to oral medications, postoperative analgesia was further managed with either NSAIDs (meloxicam or carprofen), parenteral opioids (codeine or tramadol), a neuropathic pain analgesic (gabapentin), a transdermal fentanyl patch, or a combination of these; protocols and dose ranges varied per surgeon. An Elizabethan collar, soft-padded chest bandage, or fabric shirt was recommended upon discharge for 10 to 14 days after surgery or until the incision was reevaluated. Exercise restrictions were recommended until recheck for suture/staple removal in 10 to 14 days by a veterinarian, followed by a gradual return to normal activity over the subsequent 14-day period.

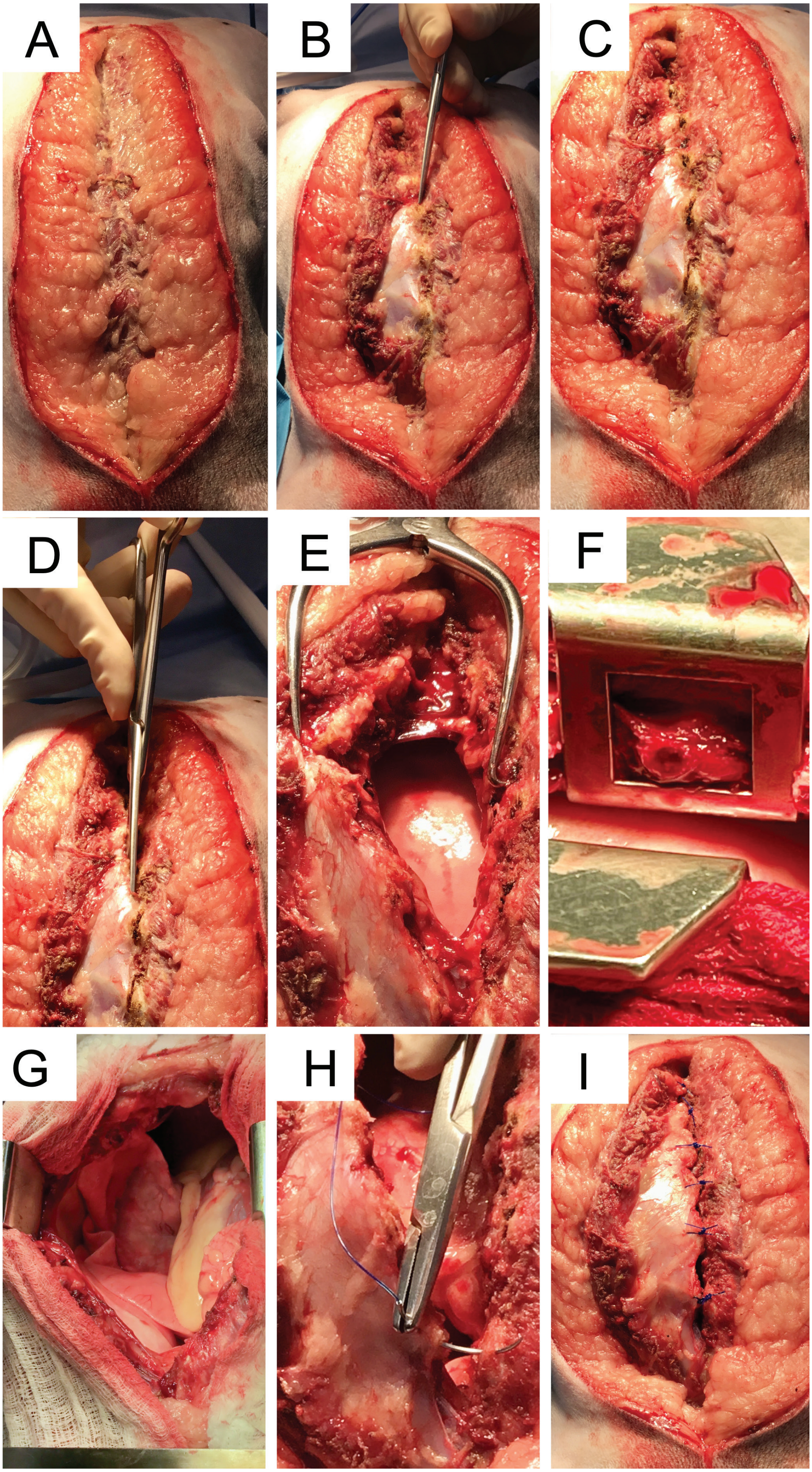

Figure 1—Depiction of surgical approach/technique. A—Skin, subcutaneous, and pectoral muscles are incised on sternal midline from manubrium to xiphoid. B—Electrocautery or sharp dissection is used to expose sternocostal joints. C—Electrocautery or sharp transection of sternocostal joint. D—Mayo scissors or bone cutters aid in disarticulation of the sternocostal joint proximal to the sternum to avoid laceration of the internal thoracic and intercostal vessels. E—Gelpi retractors aid in exposure as the parasternal thoracotomy progresses. F—Lateral perspective of sternocostal disarticulation. G—Finochietto retractors aid in thoracic exploration and demonstrate visualization provided by this approach to expose a left caudal lung lobe mass. H—Closure was performed with a nonabsorbable monofilament suture in a simple interrupted pattern engaging the periosteum of the rib to the sternocostal cartilage. I—Sternal closure demonstrated with simple interrupted apposition of the costal cartilage of ribs 2 to 7 to the corresponding intersternebral cartilage with 1 polypropylene suture.

Statistical analysis

All statistical analyses were executed with R statistical software, version 4.3.0 (The R Foundation for Statistical Computing). Descriptive statistics were performed where appropriate. Kaplan-Meier survival curves were employed to estimate survival functions based on the duration of hospitalization and discharge status. Cumulative event estimates and their 95% CIs were derived from these survival curves. Cox proportional hazards regression models were utilized to analyze the impact of various covariates on the hazard of the event of interest; results were presented as hazard ratios (HRs) with 95% CIs. Interactions between variables were evaluated by use of likelihood ratio tests to evaluate potential effect modifications on the HRs. Significance was set at $P < .05$.

Results

Of the 177 thoracic procedures that occurred, a total of 93 canines underwent PT and were included in analysis. The mean age and body weight at the time of PT was 7.4 years old (range, 1 to 16 years) and 19.6 kg (range, 2 to 50 kg). Castrated male dogs (n = 55) were most prevalent, followed by spayed females (36), sexually intact males (9), and sexually intact females (2). Individual patient data and signalment data per diagnosis are summarized in **Supplementary Table S1**. Thirty different canine breeds were represented **(Table 1)**.

Table 1–Breeds of dogs that underwent parasternal thoracotomy (PT) via sternocostal disarticulation over a 6-year period.

Dog breeds	No. of dogs per breed
Mixed breed	33
German Shepherd Dog	7
Labrador Retriever	6
Husky	5
Boxer, Golden Retriever	4
Shih Tzu, Rottweiler	3
Corgi, English Bulldog, Lhasa Apso, Vizsla, WHWT, Yorkshire Terrier	2
ACD, AH, AS, BH, Beagle, BC, BT, CD, CKCS, DH, ESS, GD, GSP, MS, Pom, SP	1

ACD = Australian Cattle Dog. AH = Afghan Hound. AS = Australian Shepherd. BC = Border Collie. BH = Basset Hound. BT = Boston Terrier. CD = Carolina Dog. CKCS = Cavalier King Charles Spaniel. DH = Dachshund. ESS = English Springer Spaniel. GD = Great Dane. GSP = German Shorthaired Pointer. MS = Miniature Schnauzer. Pom = Pomeranian. SP = Standard Poodle. WHWT = West Highland White Terrier.

Mixed-breed dogs were the most represented breed to undergo the PT procedure (n = 33). Both weight and breed were available for 92 of 93 dogs; there were 31 large-breed dogs, 31 medium-breed dogs, and 30 small-breed dogs. The overall mean duration of surgery was 64.4 minutes (range, 25 to 138 minutes), mean anesthesia duration was 156.6 minutes (range, 74 to 276 minutes), and mean thoracostomy tube duration after surgery was 65.0 hours (range, 15 to 451 hours). The median number of postoperative days of hospitalization was 3.0 (range, 1 to 20 days). The most common diagnosis among the 93 cases was neoplasia (45.2% total; 37.6% with histopathologic confirmation), followed by pulmonary bullae (17.2% total; 14.0% with histopathologic confirmation). Data regarding diagnosis, surgical procedure, hospitalization, and complications are summarized in **Table 2**. Diseased organ location was identified in 91% (85 of 93) of cases. Six patients were diagnosed with spontaneous pneumothorax and underwent preoperative CT scans, and findings from subsequent surgical exploration via a PT approach were negative. The remaining 2 patients had additional lesions not identified in the primary surgery via a PT approach, and a subsequent PT thoracic exploration was necessary due to persistent pneumothorax.

Patient age (P = .716), sex (P = .489), weight (P = .463), body condition score (P = .089), duration of surgery (P = .221), duration of anesthesia (P = .446), postsurgical time to ambulation (P = .271), and time to voluntary food intake (P = .911) were not significantly associated with survival to discharge or recheck examination. The specific breed (P = .460) and weight (P = .463) per dog were not significantly associated with survival, but there were significant associations with breed size. Only 92 dogs could be evaluated based on weight or size, as 1 dog did not have a weight recorded in the record. When compared to small-breed dogs, medium-breed dogs were more likely to experience a 2.2-fold increase in risk of not surviving to discharge (95% CI, 1.15 to 4.11; P = .017). When large- (P = .210) and giant-breed dogs (P = .898) were compared to the smaller-breed dogs, there was no significant difference in the risk of survival. Kaplan-Meier curves depicted survival to discharge in dogs that underwent PT, differentiated by breed size **(Figure 2)**.

The overall survival rate of dogs undergoing the PT procedure was 94.6% (88 of 93). Survival to discharge was 89.2% (83 of 93). Fifty-eight dogs (62.4%) were known to have survived to recheck at least 10 days after surgery. Twenty-one dogs (22.6%) were lost to follow-up after discharge from the hospital.

Five of 93 patients (5.4%) died or were euthanized during surgery. Intraoperative deaths were due to hemorrhage (dogs 80 and 84), cardiopulmonary arrest (dog 14), or inoperable underlying disease and owner-elected humane euthanasia (dogs 58 and 60). There were no reported complications of hemorrhage associated with the PT approach.

Thirty dogs (32.3%) experienced postoperative complications. Three dogs (dogs 9, 70, and 73) experienced 2 postoperative complications among the various classifications (minor, moderate, major, or death). Seventeen dogs (18.3%) experienced minor complications that were either self-limiting or resolved with minimally invasive interventions. The minor complications included the following: mild incisional inflammation without evidence of infection (dog 68), mild incisional serosanguinous discharge (dogs 68 and 73), patient interference with the incision that did not result in further dehiscence or

Table 2 – Summary of 93 dogs that underwent PT procedure(s), including the duration of the surgery, anesthesia, and thoracostomy tube placement over a 6-year period.

Diagnosis	Neoplasia	Bulla	Pyo-thorax	Pneu-monia	Negative explora-tion`	Peri-cardia	Thymus inflammation	Pulmonary fibrosis	Trauma	Lung lobe torsion	Total
Total	42	16	12	6	5	4	2	3	2	1	93
Age (y)[a]	9.8 ± 2.8	7.8 ± 2.5	3.5 ± 4.0	4.8 ± 3.5	4.6 ± 3.4	4.7	1.5 ± 3.4	8.7 ± 0.7	6.5 ± 4.6	4.0 ± 0.7	7.4 ± 3.9
Weight (kg)[a]	16.7 ± 11.9	25.6 ± 12.4	18.3 ± 15.7	23.0 ± 17.6	19.4 ± 18.7	18.8 ± 16.4	26.0 ± 4.2	32.3 ± 10.7	16.0 ± 17.0	9.0	19.6 ± 13.5
Males											
Intact	1	1	4	2	0	1	0	0	0	0	9
Neutered	21	6	4	4	3	2	2	3	1	0	46
Females											
Intact	0	1	1	0	0	0	0	0	0	0	2
Spayed	20	8	3	0	2	1	0	0	1	1	36
Procedure											
PT	39	16	11	6	4	4	2	3	2	1	88
PT + AE	3	0	1	0	1	0	0	0	0	0	5
Surgery duration (min)[a]	63.4 ± 30.6	79.0 ± 29.3	65.6 ± 23.0	43.5 ± 19.3	64.6 ± 19.2	70.8 ± 33.0	43.0 ± 4.2	62.0 ± 31.1	69.0	35.0	64.4 ± 27.8
Intraoperative death	3	0	2	0	0	0	0	0	0	0	5
Anesthesia duration (min)[a]	158.2 ± 33.8	151.5 ± 33.0	160.2 ± 45.6	140.5 ± 79.2	175.0 ± 39.6	172.0 ± 69.9	116.0 ± 33.2	156.0 ± 84.9	171.0	105.0	156.6 ± 42.0
Thoracostomy tube duration (h)[a]	60.3 ± 80.6	88.9 ± 4.3	59.6 ± 1.8	61.3 ± 6.0	67.8 ± 36.1	52.5 ± 13.7	54.0 ± 11.3	66.0 ± 31.1	90.0	20.0	65.0 ± 60.7
Postoperative hospitalization (d)[b]	2.5 (1–20)	4.0 (2–10)	3.0 (1–4)	3.0 (2–5)	2.0 (2–5)	2.5 (2–4)	2.5 (2–3)	4.0 (3–8)	3.5 (3–4)	2.0	3.0 (1–20)
Postoperative complications											
Minor	8	3	1	3	0	0	0	0	1	1	17
Moderate	2	0	1	0	1	0	0	0	0	0	4
Major	1	2	0	0	0	0	0	0	0	0	3
Death	3	2	2	1	0	0	0	1	0	0	9
Total	13	6	3	4	1	0	0	1	1	1	30
Confirmed diagnosis via histopathology and/or culture	35	13	10	6	0	4	2	3	2	1	76
Presumed diagnosis via surgical findings	7	3	2	0	5	0	0	0	0	0	17
Lost to follow-up	8	5	1	1	2	1	1	1	0	1	21
Survived to recheck	28	9	7	4	3	3	1	1	2	0	58

Data are reported as number of affected dogs unless otherwise indicated.
AE = Abdominal exploration.
[a]Values are reported as mean ± SD. [b]Values are reported as median (range).

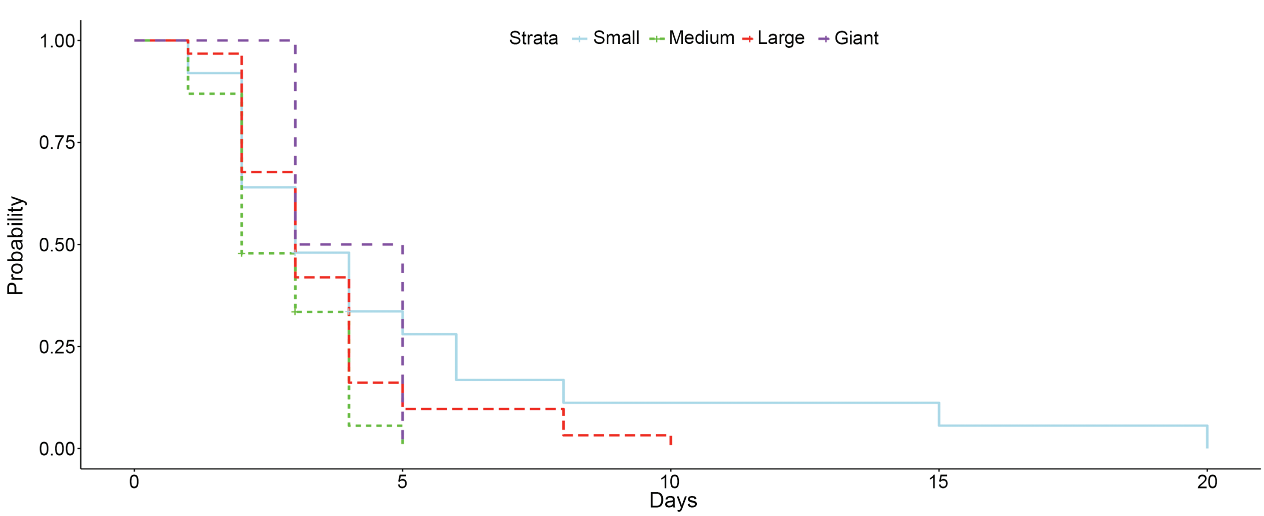

Figure 2—Kaplan-Meier survival curve depicts survival to discharge in dogs that underwent parasternal thoracotomy, differentiated by breed size. Groups were classified as small (< 10 kg), medium (10 to 24 kg), large (25 to 45 kg), and giant (> 45 kg). Medium-breed dogs demonstrated a significantly higher risk of not surviving to discharge (hazard ratio, 2.18; 95% CI, 1.15 to 4.11; *P* = .0167) compared to small-breed dogs, while large- and giant-breed dogs showed no significant difference compared to small-breed dogs.

infection (dog 81), seroma associated with the thoracostomy tube site (dogs 65 and 85), serosanguinous discharge from the thoracostomy tube site (dogs 66, 67, and 68), thoracic limb edema (dogs 33 and 73,), thoracic limb lameness not initially documented on presentation (dogs 5 and 30), premature malfunction or dislodging of the thoracostomy tube without necessary replacement (dogs 2, 40, 42, and 81), strikethrough in the chest bandage requiring premature bandage change (dogs 2, 79, and 89), and rehospitalization due to owner concern for dyspnea but without additional therapies necessary (dog 13).

Four dogs (4.3%) experienced moderate postoperative complications and were prescribed antibiotic treatment; these included thoracostomy tube site infection (dog 66) and incisional infection (dogs 33, 51, and 93). Dog 51 was the only patient with negative exploration findings to experience a postoperative complication. Of the 4 dogs prescribed antibiotics for presumed infection, a culture was obtained only for dog 93, but the results were not available in the record.

Three dogs (3.2%) experienced major complications that required an additional surgical procedure within the recheck period of 10 to 14 days (dogs 9, 55, and 62). Dog 70 had PT performed without additional surgical procedures, as the mass was deemed inoperable. This patient experienced incisional drainage (minor complication) after the initial procedure and underwent an additional PT procedure 21 days later. This patient died intraoperatively due to hemorrhage and cardiopulmonary arrest. This case was not included in the reported major or fatal complications, as the hemorrhage and cardiopulmonary arrest were deemed secondary to disease progression. Dog 9, diagnosed with pulmonary bulla, underwent an additional PT procedure immediately upon thoracic closure due to inability to obtain negative pressure. Ultimately, this dog was humanely euthanized 2 days after surgery due to persistent pneumothorax and respiratory distress. Dog 55, diagnosed with a pulmonary bulla on preoperative CT imaging, had a PT with negative thoracic exploration findings. During hospitalization, an additional PT procedure was performed 3 days postoperatively due to persistent pneumothorax. Repeat exploration identified a leak in the accessory lung lobe that was not appreciated earlier. Dog 62, diagnosed with squamous cell carcinoma, experienced persistent pneumothorax after surgery and required an additional PT procedure during the same hospitalization for omental graft (7 days postoperatively).

Complications resulting in death occurred in 9 dogs (9.7%). Six dogs experienced cardiopulmonary arrest. Three dogs died within 24 hours of surgery, and 3 dogs died at home after discharge. Three dogs were humanely euthanized: 2 dogs within 48 hours of surgery due to postoperative respiratory distress and persistent pneumothorax and 1 dog 3 days after discharge from the hospital due to quality-of-life concerns.

Variables that were assessed for dogs that survived to discharge and dogs that survived to recheck are summarized in **Table 3**. Thoracostomy tube duration was significantly associated with decreased likelihood of survival to discharge (HR, 0.94; 95% CI, 0.912 to 0.976; $P < .001$). For each additional hour of thoracostomy tube placement, survival to discharge was reduced by approximately 5.7%. Surgery duration was not significantly associated with survival to discharge. For each additional hour of thoracostomy tube placement, survival to discharge was altered by approximately 0.05% (HR, 1.00; 95% CI, 1.000 to 1.001).

Discussion

This newly described technique was implemented in 93 cases over a 6-year period. The PT approach provided adequate exposure for diagnosis and/or treatment in all but 8 cases. The inability to identify the pathology in these cases could have yielded a similar result if the MS procedure had been performed instead of PT. Alternatively, the PT approach may have provided inadequate exposure in these dogs. Nonetheless, 5 of the dogs that were diagnosed with pneumothorax preoperatively but had negative exploration findings did not experience postoperative recurrence of the pneumothorax and did not require an additional surgical procedure.

This novel PT technique was devised considering the potential disadvantages of the traditional MS approach: high complication rate, difficulty in maintaining a midline transection of the canine sternebrae due to the anatomical shape, possible perceived difficulty, and the need for specialized orthopedic equipment, such as an oscillating saw and/or bone cutters.[7,11–13,19,28,32–34] Rationale for the utilization of the novel technique included the lack of reported complications associated with an inadvertent parasternal approach and accessibility of equipment, though no prior approaches have been described in either dogs or humans.[14]

This newly described approach may be an alternative to previously reported[1-9] approaches. As

Table 3—Final multivariate logistic regression model for dogs that underwent PT. Variables were assessed for dogs that survived to discharge from the hospital and for those that survived to recheck (at least 10 days after surgery).

	Survival to discharge			Survival to recheck		
Variable	**HR**	**95% CI**	***P* value**	**HR**	**95% CI**	***P* value**
Age	0.93	0.85–1.00	.062	1.04	0.95–1.13	.413
Time to eating	0.98	0.65–1.46	.911	1.88	1.19–2.97	.007
TT duration	0.94	0.91–0.98	< .001	0.98	0.96–1.00	.017
Sx duration	0.98	0.96–1.01	.221	—	—	—
TT + Sx duration	1.00	1.00–1.00	.055	—	—	—

For cells containing a single dash without a value, the result was not calculated.
HR = Hazard ratio. Sx = Surgery. TT = Thoracostomy tube.

this technique (specifically, disarticulation at the sternocostal joint) was achieved with Mayo scissors, equipment such as an oscillating bone saw was not needed to achieve exposure, in contrast to the MS technique. As the approach can be performed without specialized equipment, the PT approach could be implemented at multiple levels of practice and may be more cost-effective for clients. In addition, it could be utilized in an emergency setting if no orthopedic equipment is available. Thoracic trauma can occur as a result of blunt or penetrating injury, and in dogs with vehicular trauma, the thorax is the most common area of injury.[35,36] Dogs with pseudo-flail-chest, rib fracture, or pneumothorax are more likely to undergo exploratory thoracotomy.[37] This approach could expand access to care and provide more opportunity for effective treatment, potentially decreasing the higher mortality rates associated with these injuries. No direct comparisons of cost of PT compared to MS were evaluated but could be investigated in further studies. We feel that this approach is practical with the use of simple surgery equipment and easily performed among surgeons of various training levels (ie, residents and interns with supervision), but this is subjective, and further comparison to the standard MS technique is needed to obtain a more quantitative assessment.

Reports of mortality directly attributed to median sternotomy complications in dogs are lacking.[34,38] Previously reported mortality rates in dogs following thoracic surgery (not specifically median sternotomy) are dated and range from 5.9% to 45%; there is also variation in the inclusion of euthanized patients.[4–6,13,38] Our study yielded rates of procedural survival (94.6%), survival to discharge (89.2%), and postoperative complications (32.2%) comparable to previously described[7,11-13,15,18,19,28,39] thoracotomy approaches. Our mortality results included cases of humane euthanasia, as these cases ultimately could not be distinguished from postoperative surgical complications. Despite inclusion, however, mortality rates in this study remained in the lower range.

Previous studies[6,11,12,19] have reported wound healing complications for sternotomy closure ranging from 31% to 55%. The total postoperative complication rate in our study was 32.3%. The majority of postoperative complications were minor (17 of 30), and only 7 dogs (7.5%) had incisional complications: 4 minor and 3 major postoperative complications. Parasternal thoracotomy may provide fewer closure-related complications than the traditional MS approach. Our lower incisional complication rate could be directly related to the difference of approach, but further biomechanical and prospective comparative studies would be necessary to draw conclusions.

Increased mortality has been previously associated with increased age and the presence of neoplastic disease.[5,6] In our study, age was not significantly associated with survival to discharge or recheck. The most common indication/diagnosis for PT was neoplasia (n = 42). The greatest incidence of complications was associated with a neoplastic diagnosis (13 of 30). This may be due to the underlying diagnosis or may be attributed to dogs with neoplasia being overrepresented in our population.

Specific breed and weight did not influence discharge time or survival; however, when the dogs were organized into small-breed (< 10 kg; n = 30), medium-breed (10 to 25 kg; 29), large-breed (26 to 45 kg; 31), and giant-breed dogs (> 45 kg; 2), the medium-breed dogs were more likely to have decreased odds of survival compared to small-breed dogs. This may correlate with previous reports[13] that heavier dogs (> 20 kg) undergoing MS are more likely to experience short-term complications. Interestingly, when large- and giant-breed dogs were compared to small-breed dogs, the survival rates were not different. This may be a type 2 error. Variables such as age, diagnosis, and postoperative complications among these weight/breed divisions were not evaluated. Further studies evaluating these factors could elucidate this finding.

Our study suggested that the duration of thoracostomy tube management was significantly associated with increased risk for survival. While this could reflect the severity of disease, these results emphasize the importance of efficient thoracostomy tube management. A retrospective evaluation[39] of fluid production at the time of thoracostomy tube removal after elective and emergency surgery in dogs found that patients with preoperative pleural effusion (compared to those without preoperative pleural effusion) as well as patients undergoing an MS procedure (compared to a lateral thoracotomy) had significantly higher median fluid production at the time of tube removal. Thoracostomy tubes were removed at pleural fluid production rates exceeding the current veterinary guidelines: removed at a median fluid production rate of 0.09 mL/kg/h rather than the recommended 0.04 to 0.08 mL/kg/h (1 to 2 mL/kg/d).[39] Dogs with preoperative pleural effusion, lung lobe torsion (44.4%), or idiopathic chylothorax (28.5%) had pleural effusion diagnosed within 2 weeks of thoracostomy tube removal.[39] However, fluid production rates at the time of tube removal were not associated with the detection of pleural effusion upon 2-week recheck (7.1%) and the reintervention rates were low (4.7%). These results suggest that, despite variable fluid production rates upon tube removal, compensatory mechanisms often restore homeostasis, and fluid production does not need to return to the prior recommended values for safe thoracostomy tube removal.[39] The results of this study suggest that it may be safe to consider earlier thoracostomy tube removal protocols in dogs. Veterinary surgeons should be aware that prolonged thoracostomy tube placement could increase the risk of tube complications, patient discomfort, cost to the client, use of hospital resources, and survival.

There were several limitations in this study. Given the retrospective nature, patient factors, surgical technique, and postoperative care were not standardized. Additionally, retrospective data regarding some aspects of the novel approach were not recorded. The specific duration of entry into the thorax, hemorrhagic events sustained on entry (eg, internal thoracic artery and intercostal branches are more exposed with this approach), and quantification of adequate visualization of bilateral hemithoraces were lacking. In our experience, the timing of entry into the thorax with the PT approach is comparable to the MS technique. However, there were no obtainable data for this variable; thus, this assessment is subjective. The feasibility of the procedure can only seemingly be surmised in the outcomes and obtaining a diagnosis.

It is unknown whether a partial sternotomy with preservation of the manubrium and/or xiphoid process is mechanically stronger than complete median sternotomies upon closure.[28] Depending on the necessary exposure, it has been recommended that either the manubrium or xiphoid cartilage, with the adjacent 1 to 2 sternebrae, remain intact to increase the sternotomy closure stability and subsequent healing and reduce postoperative pain.[14] Similarly, it is unknown and not the purpose of this study to determine whether partial versus complete PT has an effect on postoperative outcome. Furthermore, there is recent literature[28] to support the use of sutures for MS closure in dogs of all sizes. While sutures were used for thoracic closure in this study (rather than wire), the variance in technique involves apposition of the sternocostal cartilage, which requires further evaluation. Although no instances were documented, we cannot rule out the possibility that suture failure or closure instability were direct causes of any patient complications.

Other limitations included the short follow-up time and variations in assessment. It is possible that some complications may not have been included or were missed due to the short follow-up time. The short-term outcomes of the dogs in our study were based on subjective evaluations by the surgeon, resident, technician, referring veterinarian, and/or owner. Surgical site infections were not routinely confirmed with culture and sensitivity and were often presumptive. This assessment is less reliable to determine true infection. Lastly, this novel technique is not previously described in dogs or humans and no standardized cadaveric exploration occurred prior to its implementation. We recognize the ethical limitations of this without approved protocol from IACUC due to the retrospective nature of the study. However, all owners were advised of the novelty of this approach and informed consent was obtained.

Future biomechanical and clinical studies are necessary to objectively compare PT to other thoracic approaches in technical execution and specific patient outcomes. Postoperative pain score evaluations and client assessment surveys may also be beneficial in the future to further document pain assessment, complications, and mortality in the short- and long-term period after surgery.

In conclusion, this study of client-owned dogs described a novel thoracic approach (accessing the thorax via rib disarticulation at the sternocostal joint) in a substantial number of canines as an alternative to the traditional median sternotomy. This technique requires no specialized orthopedic equipment and results in low rates of mortality and postoperative complications comparable to those prior reported for MS.[12,13,15,19,40] Prolonged thoracostomy tube duration was significantly associated with decreased survival to discharge, highlighting the importance of responsible thoracostomy tube management.

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Supplementary Materials

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