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Dogs and cats undergoing surgery for penetrating thoracic trauma have high survival despite frequent complications, and imaging may underestimate injury severity

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Objective
To describe clinical and radiographic findings in dogs and cats with surgically confirmed penetrating thoracic trauma and evaluate associations with outcomes.

Methods
This retrospective, multicenter observational study reviewed records from 5 referral hospitals to identify dogs and cats with surgically confirmed penetrating thoracic trauma between July 1, 2010, and July 31, 2025. Inclusion required thoracic radiographs, surgical reports, and perioperative records.

Results
A total of 86 dogs and 5 cats were identified. Mean animal trauma triage score was higher in nonsurvivors (7.6 ± 2.4; n = 20) than survivors (5.2 ± 2.5; 71). Radiographic findings included pneumothorax (73.6%), pulmonary contusions (65.9%), and rib fractures (62.6%). Computed tomography findings often identified more injuries. Time from presentation to surgery did not differ in survivors versus nonsurvivors. Lung lobectomy was performed in 24.2% of patients and was more common in nonsurvivors (45.0% vs 18.3%). Intra- and postoperative complications occurred in 56% and 51.7% of patients, respectively. Survival to discharge was 78.0% (71 of 91 patients), with a median hospitalization of 3.3 days (range, 1 to 12 days). Among 55 patients with follow up, 11 (20%) had complications related to thoracic trauma.

Conclusions
Surgical management of penetrating thoracic trauma was associated with a high survival rate despite frequent complications. Animal trauma triage is a useful prognostic indicator. Computed tomography may alter treatment plans.

Clinical Relevance
Clinicians should anticipate higher injury severity than anticipated based on routine imaging and examination. Higher animal trauma triage scores were associated with nonsurvival and may provide useful prognostic information. Close monitoring is needed following surgery for penetrating thoracic trauma.

Keywords: penetrating thoracic trauma, emergency, canine, feline, soft tissue surgery

Trauma is estimated to represent 12% of all admissions to small animal veterinary emergency rooms.[1,2] Canine and feline patients with traumatic injuries are frequently affected in the thoracic region,[1,3] but it is often difficult to adequately assess the extent of their injuries. Thoracic trauma can occur secondary to blunt or penetrating injury, with bite wounds or other animal interactions being the leading cause of penetrating trauma.[1] One study[1] reported that 17% to 60% of canine and feline patients with penetrating injuries have damage to deeper structures, which is not always reflected by the extent of external injuries. It is suspected that due to the high skin mobility and elasticity of dogs and cats, external wounds may not

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provide an accurate representation of the full extent of underlying injury.[4] It is also often difficult to determine on initial presentation if thoracic injuries sustained will require surgical intervention.[3]

Treatment recommendations are typically based on the presenting history, initial physical examination, and diagnostics, such as bloodwork and radiographic imaging of the thorax. In dogs and cats with thoracic trauma, common physical examination findings include evidence of puncture wounds, swelling, edema, subcutaneous emphysema, flail chest, pseudo–flail chest, abnormal respiratory patterns, muffled lung sounds on auscultation, tachycardia, hypothermia, tachypnea, and hypoxia.[1,3] Common radiographic findings included rib fractures, pulmonary contusions, pneumothorax, and pleural effusion.[1,3] Cats also may have radiographic evidence of diaphragmatic hernias, sternal fractures, atelectasis, or pneumomediastinum.[1] One study[4] identified that the presence of > 3 radiographic lesions was associated with the existence of a penetrating wound and need for thoracic exploration. Radiographs are less sensitive than CT at detecting pulmonary lacerations, with radiographic evidence in only 59% of 22 dogs with CT evidence of pulmonary lacerations secondary to trauma in 1 study.[5] No specific radiologic finding has been significantly associated with lung parenchyma damage, emphasizing that internal trauma can be missed without surgical exploration.[2]

The ideal timing of surgical treatment for veterinary patients following thoracic trauma remains unclear. In clinical practice, the decision to proceed with surgery is multifactorial and depends on considerations such as patient stability, extent of injury, response to initial stabilization, and clinician preference.[1] A recent study[6] of 464 dogs that had emergency soft tissue surgery found that American Society of Anesthesiologists status was associated with morbidity and mortality in dogs, but timing of the emergency surgery was not. To the authors' knowledge, no current studies have investigated timing of surgical treatment for penetrating thoracic trauma in veterinary patients in relation to outcome.

The objectives of this retrospective study were to describe the clinical presentation, imaging findings, surgical findings, and outcomes of dogs and cats with surgically confirmed penetrating thoracic trauma; evaluate associations between clinical variables and outcome; and determine whether physical examination and thoracic radiographic findings accurately reflected the extent of intraoperative injury.

Methods

Case selection and medical records review

A call for penetrating thoracic trauma cases was sent out through the Society of Veterinary Soft Tissue Surgery email list. Institutions contributing case data included the Schwarzman Animal Medical Center, University of Florida, University of Tennessee, Ontario Veterinary College, and Texas A&M University. A search was performed through the medical record system at each institution for the terms *penetrating thoracic trauma*, *penetrating thoracic wound*, *thoracic wound*, *thoracic trauma*, and *intrathoracic trauma* appearing between July 1, 2010, and July 31, 2025. One investigator from each institution recorded data.

Inclusion criteria included dogs and cats of any age and breed presented for evaluation of trauma that were ultimately confirmed to have penetrating thoracic injuries. For the purposes of this study, a penetrating thoracic injury was defined as a wound with documented communication between the external thorax and the pleural cavity, confirmed during surgical exploration. Patients were required to have thoracic radiographs, surgical exploration of the trauma, and complete medical records containing thoracic radiograph reports, surgical reports, perioperative and postoperative medical therapies, and outcome data. No animals were excluded based on species, signalment, health status, previous treatments, or diagnostic testing. Medical records identified through the search strategy were reviewed to confirm eligibility, and cases were excluded if they lacked thoracic radiographs, surgical confirmation of penetrating thoracic trauma, or complete medical records.

Case information collected included signalment, date of presentation, estimated time elapsed from injury to time of presentation, cause of trauma, physical examination findings at time of presentation, preoperative bloodwork findings, initial diagnostic findings if performed (pulse oximetry, electrocardiography, blood pressure, thoracic point-of-care ultrasound), findings on thoracic radiograph, CT findings if performed, preoperative treatments if performed (wound care, bandage placement, thoracocentesis, chest tube placement and production, fluid therapy, administration of analgesics and antibiotics), surgical findings, postoperative treatments if performed (chest tube placement and production, fluid therapy, administration of analgesics and antibiotics), outcome, complications, and follow-up. Tachypnea was defined as a respiratory rate > 30 breaths/min, based on published reference data indicating that healthy dogs and cats rarely exceed this rate at rest or while sleeping.[7,8] Tachycardia was defined as > 200 beats/min for feline patients and > 140 beats/min for canine patients.[9] Hypothermia was defined as a rectal temperature < 100 °F (37.8 °C).[7] Animal trauma triage (ATT) scores were calculated for each case retrospectively with available information by 1 investigator (NP).[9]

Intraoperative complications were graded as follows: grade 1 (self-resolving), grade 2 (single intervention such as a fluid bolus, single anticholinergic or vasopressor dose, temporary oxygen supplementation, or active warming), grade 3 (sustained intervention such as a vasopressor constant-rate infusion or blood-product administration), or grade 4 (life-threatening and resulting in intraoperative cardiac arrest). This grading scheme is an adaptation of a previously published Veterinary Cooperative Oncology Group–Common Terminology Criteria for Adverse Events (ie, VCOG-CTCAE) system.[10] Postoperative complications were graded as follows: level 1 (mild, requiring only minor bedside interventions), 2 (moderate, requiring pharmacologic intervention other than analgesics or antiemetics), 3 (severe, requiring reoperation or development of organ

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failure), or 4 (death) using Accordion Severity Classification of Postoperative Complications: Contracted Classification criteria.[11]

Statistical analysis

Data were recorded in Excel, version 16.106 (Microsoft Corp). Descriptive and comparative statistics were calculated in Prism for macOS, version 11.0.0 (GraphPad Software Inc). Continuous data were assessed for normality using the Shapiro-Wilk test and described with mean ± SD (for normally distributed data) or median and IQR (for nonnormally distributed data), as appropriate. Continuous data were compared between groups using a Mann-Whitney *U* test or unpaired *t* test, as appropriate based on normality. Categorical data were compared between groups using a Fisher exact test. Because comparisons between survivors and nonsurvivors were performed across multiple variables, a Holm-Šídák correction for multiple comparisons was applied to these *P* values. Comparisons with a Holm-Šídák–adjusted *P* value < .05 were considered significant after correction for multiple testing.

Results

Animals

A total of 105 dogs and 5 cats were identified across 5 institutions during the study period. Of the 105 dogs identified, 19 dogs were excluded due to lacking 1 or more of the following: thoracic radiographs, confirmation of penetrating thoracic trauma, or complete medical records. Data are reported on the remaining 86 dogs and 5 cats that met inclusion criteria. One case is reported twice for 2 separate penetrating thoracic traumas. Dogs were classified as mixed breed (n = 25), Chihuahua (9), Yorkshire Terrier (7), Dachshund (5), Maltese (5), Labrador Retriever (4), Jack Russell Terrier (3), pit bull type (3), Miniature Pinscher (2), Miniature Schnauzer (2), Shih Tzu (2), Treeing Walker Coonhound (2), or 1 each of 17 additional breeds. All 5 cats were domestic shorthair. Median age was 60 months (range, 9 to 182 months). Median body weight was 6.9 kg for dogs (range, 1.8 to 46.5 kg), with 36.0% of dogs weighing < 5 kg, 34.9% from 5 to 10 kg, 14.0% from 10 to 25 kg, and 24.4% > 25 kg. The median body weight was 4.8 kg for cats (range, 4.2 to 5 kg). Of the 86 dogs, there were 39 males (39 of 86 [45.3%]), of which 27 were castrated and 12 were sexually intact; there were also 47 females (47 of 86 [54.7%]), of which 34 were spayed and 13 were sexually intact. Of the 5 cats, 2 (40%) were castrated males and 3 (60%) were spayed females.

Findings on admission through the emergency department

The time elapsed from injury to time of presentation to the specialty hospital was reported in 87 cases, and the median was 180 minutes (range, 10 to 50,400 minutes), with presentation in ≤ 120 minutes in 35 cases (40.2%), 121 to 300 minutes in 26 cases (29.9%), 301 to 720 minutes in 10 cases (11.5%), 720 to 1,440 minutes in 7 cases (8.0%), and > 1,441 minutes in 9 cases (10.3%). Prior to presentation at the referral hospital, 23 patients were documented to have been evaluated by another veterinarian. The cause of trauma was reported for 88 patients and was classified as secondary to attack by a dog (50 of 91 [54.9%]), nondomestic animal attack (14 of 91 [15%]; from animals including coyotes, hogs, porcupine, and owls), foreign-body penetration (9 of 91 [9.9%]), undefined bite wounds (5 of 91 [5.5%]), gunshot wounds (4 of 91 [4.4%]), stab wounds (4 of 91 [4.4%]), fall from high rise (1 of 91 [1.1%]), hit by car (1 of 91 [1.1%]), or unknown (3 of 91 [3.3%]).

Physical examination findings included 62 patients (62 of 91 [68%]) presenting with increased respiratory rate (defined as a rate of > 30 breaths/min),[7,8] 14 (15.3%) with panting, and 47 (51.6%) with increased respiratory effort on presentation. Eighty-nine patients (97.8%) had thoracic wounds present, which were characterized based on physical examination to be superficial wounds of skin only (3 of 89 [3.4%]); deep, involving the subcutaneous space (38 of 89 [42.7%]); or penetrating, in which the wound was described to be connecting the external thorax and pleural space (40 of 89 [44.9%]). Wound depth was unclear in 8 patients (8 of 89 [9.0%]). Subcutaneous emphysema was present in 51 patients (51 of 91 [56%]), and 29 patients (29 of 91 [31.9%]) were described to have a presence of flail chest. Thoracic auscultation revealed abnormal lung sounds in 42 (46.2%) patients, characterized as absent lung sounds (n = 4 [9.5%]), decreased or muffled lung sounds (24 [57.1%]), increased lung sounds (8 [19.0%]), crackles (5 [11.9%]), and muffled heart sounds (1 [2.4%]).

Animal trauma triage[7] score was calculated in 91 (100%) patients. The mean ATT score for all patients was 5.7 ± 2.7 (n = 91), 5.2 ± 2.5 for survivors (71), and 7.6 ± 2.4 for nonsurvivors (20). Animal trauma triage score was significantly higher in nonsurvivors (*P* = .0004; adjusted *P* = .01). Mentation was noted on presentation in 88 patients, and of those, 1 (1.1%) was stuporous; 1 (1.1%) was comatose; 1 (1.1%) was depressed; 4 (4.5%) were sedated; 5 (5.7%) were laterally recumbent; 11 (12.5%) were dull; 24 (27.3%) were bright, alert, and responsive; and 41 (46.6%) were quiet, alert, and responsive. Tachycardia was present in 35 (38.5%) patients at initial evaluation, while 3 (3.3%) had bradycardia (defined as ≤ 120 beats/min for feline patients and ≤ 60 beats/min for canine patients).[9] Of the 87 patients with rectal temperatures recorded, 37 (42.5%) patients were hypothermic. Oxygen saturation was reported in 63 patients, 11 (17.5%) of which were considered hypoxic (defined as an oxygen saturation measured by pulse oximetry < 94%).[1] Arterial blood pressure was measured indirectly via Doppler ultrasonic flow detector in 27 patients or oscillometry in 53 patients, of which 4 (5.0%) were considered hypotensive (defined as systolic blood pressure < 90 mm Hg)[3] and 24 (30.0%) were considered hypertensive (defined as systolic blood pressure > 150 mm Hg).[3] Electrocardiography was performed on 56 patients, of which 10 (17.9%) had abnormalities characterized as sinus tachycardia (n = 4 [7.1%]), intermittent ventricular premature contractions (3 [5.4%]), paroxysmal ventricular

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tachycardia (1 [1.8%]), grade II atrioventricular block (1 [1.8%]), or right bundle branch block (1 [1.8%]).

Results of select clinicopathologic tests are reported in **Supplementary Table S1**. Common abnormalities included acidemia (21 of 74 [28.4%]), hypercapnia (31 of 73 [42.5%]), findings supportive of metabolic acidosis (47 of 68 [69.1%]), hypernatremia (15 of 84 [17.9%]), hypochloremia (24 of 84 [28.6%]), hypokalemia (45 of 84 [53.6%]), hyperlactatemia (36 of 78 [46.2%]), hypoglycemia (2 of 86 [2.3%]), anemia (16 of 67 [23.9%]), and elevated alanine aminotransferase (28 of 46 [60.9%]).

Imaging findings

Thoracic point-of-care ultrasound was performed in 52 (57.1%) patients. Findings included pneumothorax (n = 12 [23.1%]), B-lines (13 [25.0%]), > 3 B-lines/field (8 [15.4%]), absent glide sign (13 [25.0%]), pleural effusion (10 [19.2%]), shred sign (2 [3.8%]), and abdominal effusion (2 [3.8%]). No reports documented findings of a step sign or pericardial effusion.

Thoracic radiographs were performed in 91 (100%) patients; results in survivors versus nonsurvivors are reported in **Table 1**. Time from presentation to thoracic radiographs was recorded in 85 patients, of which the median time from presentation to imaging was 60 minutes (range, 7 to 600 minutes). Findings included pneumothorax **(Figure 1)** (n = 64 [73.6%]), pulmonary contusions (60 [65.9%]), rib fractures (57 [62.6%]), pleural effusion (43 [47.3%]), flail segment (15 [16.5%]), pneumomediastinum (12 [13.2%]), mediastinal shift (11 [12.1%]), widening of an intercostal space (10 [11.0%]), thoracic body wall defect (9 [9.9%]), foreign material in the thorax (5 [5.5%]), lung hypoinflation (4 [4.4%]), sternal fracture or luxation (4 [4.4%]), and diaphragmatic hernia (4 [4.4%]). Lung patterns were identified in 61 patients, of which findings included interstitial pulmonary pattern only (n = 28 [45.9%]), interstitial to alveolar pattern (17 [27.9%]), alveolar pulmonary pattern only (10 [16.4%]), and interstitial and alveolar pulmonary patterns in different lung lobes (4 [6.6%]).

Computed tomography was performed in 10 (11.0%) patients, of which 1 lacked a CT report. Overall, findings in those with reports included subcutaneous emphysema (n = 8 [88.9%]), pneumothorax (7 [77.8%]), pleural effusion (6 [66.7%]), pulmonary contusions (5 [55.6%]), pneumomediastinum (3 [33.3%]), rib fractures (2 [22.2%]), flail chest (1 [11.1%]), and lung lobe retraction (1 [11.1%]). Comparisons of CT and radiographic findings, as well as potential clinical implications, are presented in **Table 2**. Three of the 9 patients with CT reports had pulmonary lacerations identified during surgical exploration. One of these patients had no evidence of pneumothorax on CT despite the presence of pulmonary laceration identified intraoperatively.

Preoperative treatments

Preoperative treatments included wound care (n = 59 [64.8%]) and bandaging (58 [63.7%]). Wound care was defined as clipping and cleaning of the area. Thoracocentesis was performed in 25 (27.5%) patients, and a chest tube was placed in 8 (8.8%) patients. Fluid therapy was initiated in 83 (91.2%) patients, analgesics were administered to 90 (98.9%) patients, and antibiotics were started in 84 (92.3%) patients. Oxygen therapy was initiated in 13 (14.3%) patients.

Surgical findings

Time from presentation to surgery was recorded for 87 (95.6%) patients. The remaining 4 patients had an estimated time based on admission time and the start of the anesthetic record. Median time from presentation to surgery was 401 minutes (range, 50 to 11,520 minutes) across all patients, 452 minutes (range, 50 to 11,520 minutes; n = 71) in survivors, and 351 minutes (range, 135 to 1,440 minutes; 20) in nonsurvivors. There was no significant difference in time from presentation to surgery between survivors and nonsurvivors (adjusted *P* = .99). Surgical time was reported in 81 patients, of which median surgical time was 96 minutes (range, 15 to 240 minutes) across all patients, 95 minutes (range, 15 to 240 minutes; n = 61) in survivors, and 98 minutes (range, 30 to 220 minutes; 20) in nonsurvivors. Anesthetic time was reported in 77 patients, of which median anesthetic time was 180 minutes (range, 50 to 890 minutes) across all patients, 175 minutes (range, 50

Table 1—Thoracic radiograph findings in 86 dogs and 5 cats presenting to 5 referral institutions between 2010 and 2025 that underwent surgery for penetrating thoracic trauma.

Thoracic radiograph finding	Survivors (n = 71)	Nonsurvivors (n = 20)	Adjusted *P* value
Pneumothorax	52 (73.2)	12 (60.0)	.99
Lung contusions	49 (69.0)	16 (80.0)	.99
Rib fractures	41 (57.8)	16 (80.0)	.92
Pleural effusion	34 (47.9)	9 (45.0)	1.0
Flail segment	9 (12.7)	6 (30.0)	.89
Pneumomediastinum	9 (12.7)	3 (15.0)	1.0
Mediastinal shift	10 (14.1)	1 (5.0)	.99
Widening of an intercostal space	6 (8.5)	4 (20.0)	.99
Thoracic body wall defect	4 (5.6)	5 (25.0)	.40
Foreign material in the thorax	4 (5.6)	1 (5.0)	1.0
Lung hypoinflation	4 (5.6)	0	1.0
Sternal fracture or luxation	4 (5.6)	0	1.0
Diaphragmatic hernia	4 (5.6)	0	1.0

Values are reported as n (%). Adjusted *P* values reflect Holm-Šídák adjusted significance for the family of comparisons reported throughout the manuscript.

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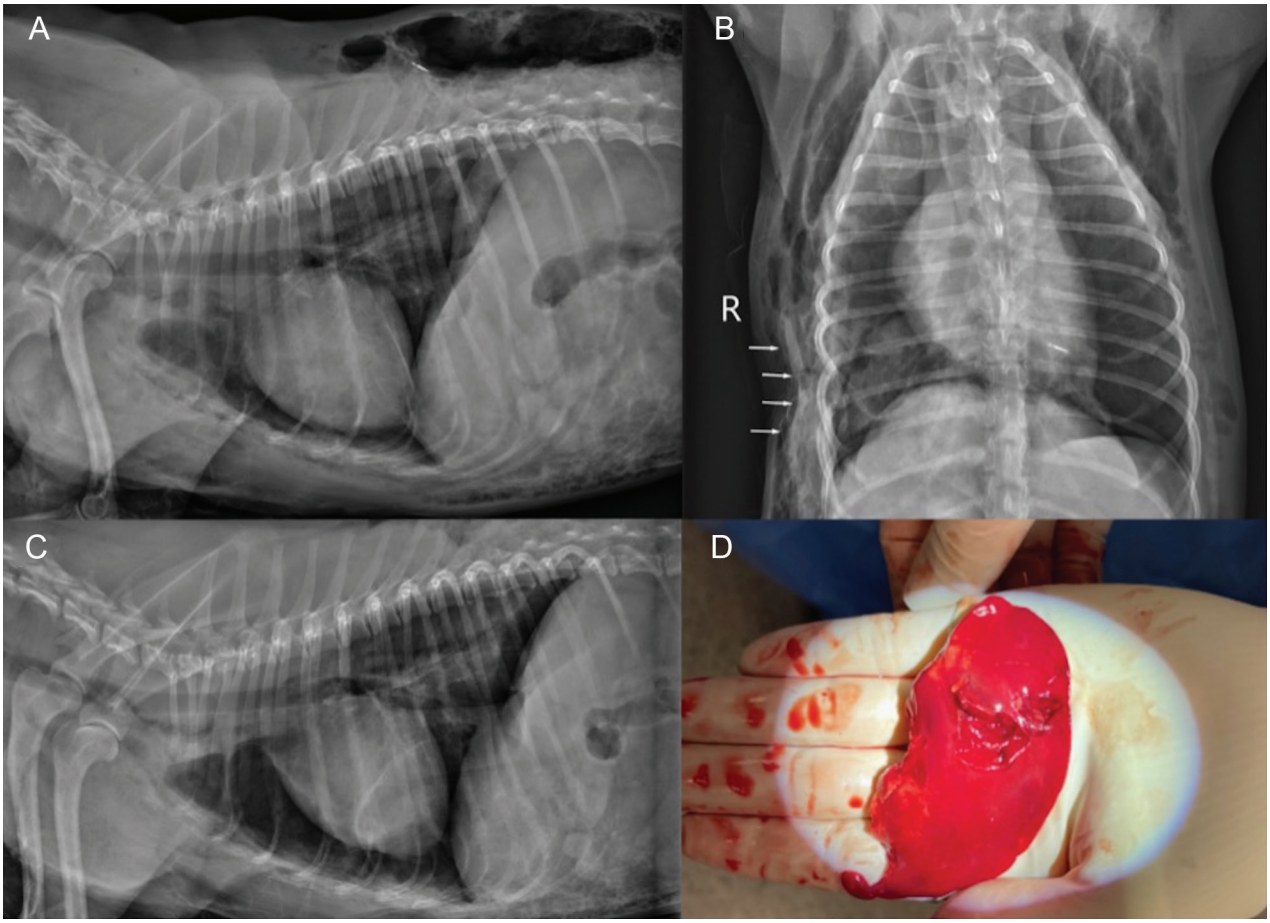


Figure 1—Left lateral (A), ventrodorsal (B), and right lateral (C) thoracic radiographs from a dog that was not described to have evidence of a penetrating thoracic trauma on presentation but radiographically had a moderate-volume pneumothorax, severe multifocal subcutaneous emphysema, and focal alveolar change within the right caudal lung lobe. The pneumothorax is best highlighted in panel C, where there is clear retraction of the caudal lung lobes away from the thoracic wall and increased space between the cardiac silhouette and stern. The white arrows in panel B highlight a broad-based soft tissue defect in the right lateral thoracic subcutaneous tissues and thoracic wall musculature centered over the right ninth rib. Immediately adjacent to this region, there is well-demarcated alveolar change noted within the right caudal lung lobe. Intraoperative image (D) demonstrates bite marks in the pulmonary parenchyma of the right caudal lung lobe, which prompted lung lobectomy.

Table 2—Comparison of thoracic CT and radiographic findings in 9 dogs with surgically confirmed penetrating thoracic trauma.

Case	Outcome	Key radiographic findings	Additional/discordant CT findings	Potential clinical impact?
1	Survived	Pneumothorax, pleural effusion, pulmonary contusions, pneumomediastinum	More precisely located site of pleural penetration, otherwise concordant	No new pathology or change in management
2	Nonsurvivor	Left-sided rib fractures and pneumothorax	Right-sided thoracic wall penetration and pneumothorax; thoracic vertebral fractures	Revealed bilateral injury and axial skeletal trauma (outside field on radiographs)
3	Survived	Right scapular fracture, pneumothorax, pleural effusion	Additional left scapular fracture, 2 cervical vertebral fractures	Revealed additional fractures (treated conservatively)
4	Survived	Sternal fracture, bilateral pneumothorax, pleural effusion	Concordant with radiographs	No new pathology or change in management
5	Survived	Bilateral pneumothorax	Porcupine quill identified in lung parenchyma	Intrapulmonary material localized (known porcupine attack)
6	Survived	Metallic pleural foreign body, pleural effusion	Full bullet trajectory identified (transdiaphragmatic), pneumoperitoneum	Identified bicavitary trajectory of bullet prompting exploratory laparotomy
7	Survived	Pneumothorax, pleural effusion, penetrating trauma inferred from subcutaneous emphysema	Site of penetration localized to right side	Precise localization of thoracic wall defect
8	Nonsurvivor	Rib fractures, lung lobe herniation through thoracic wall	Mild pleural and peritoneal effusion, cervical vertebral fractures, abdominal wall hernia	Revealed additional injuries
9	Nonsurvivor	Single rib fracture, pulmonary contusions	Pneumothorax identified, traumatic herniation of right lung lobes with torsion, 3 fractured ribs	Identified pneumothorax and lung lobe herniation

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to 890 minutes; n = 57) in survivors, and 221 minutes (range, 60 to 390 minutes; 20) in nonsurvivors. There was no significant difference in surgical time (adjusted *P* = .99) or anesthetic time (adjusted *P* = .99) between survivors and nonsurvivors.

A total of 128 wounds were described in 91 patients. Wounds were characterized as superficial with only skin involved (n = 4 [3.1%]); deep, involving the subcutaneous space (51 [39.8]); or penetrating, in which the wound was described to be connecting the external thorax and pleural space (65 [50.8%]). Wound depth was not clear in 12 (13.2%) patients. There were 15 (11.7%) patients in which no external wound was described, but trauma to deeper layers of the thoracic cavity was described following skin incision during surgical exploration. There were 5 (5.5%) patients in which the trauma penetrated from the abdomen into the thorax.

The surgical approach used to address the penetrating thoracic injury included full thoracotomy with thoracic exploration (n = 54 [59.3%]), wound exploration confirming thoracic penetration but without a full thoracic exploration (17 [18.7%]), thoracotomy combined with exploratory laparotomy (7 [7.7%]), median sternotomy (6 [6.6%]), exploratory laparotomy with thoracic wound exploration through the diaphragm (4 [4.4%]), exploratory laparotomy extended to median sternotomy (2 [2.2%]), and median sternotomy combined with thoracotomy (1 [1.1%]). Common additional procedures included lung lobectomy (n = 22 [24.2%]) and herniorrhaphy (10 [11.0%]). Indications for lung lobectomy were described in 20 of 22 cases and included pulmonary laceration (n = 16 [80.0%]), pulmonary contusions (6 [30.0%]), pulmonary bulla (2 [10.0%]), and severity of inflammation (1 [5.0%]).

Table 3—Description of intraoperative and postoperative complications encountered in 86 dogs and 5 cats with surgically confirmed penetrating thoracic trauma.

	Survivors (n = 71)	**Nonsurvivors (n = 20)**
Intraoperative complications		
None	33 (46.5%)	7 (35.0%)
Grade 1	2 (2.8%) Hypothermia (2)	1 (5.0%) Hypothermia (1)
Grade 2	22 (31.0%) Hypotension (9) Thoracocentesis after induction (3) Dysphoric recovery (3) Moderate hypothermia (2) Need for oxygen on recovery, tachycardia, hypertension, hypoglycemia (1 each)	2 (10.0%) Thoracocentesis after induction (1) Hypotension (1)
Grade 3	13 (18.3%) Severe hypotension (6) Ventricular arrhythmias (4) Blood product administration (3)	8 (40.0%) Severe hypotension (3) Blood product administration (3) Ventricular arrhythmias, hyperkalemia (1 each)
Grade 4	1 (1.4%) CPA with ROSC (1)	2 (10.0%) CPA (2)
Postoperative complications		
None	41 (57.7%)	—
Level 1	13 (18.3%) Gastrointestinal signs (9) Hypercoagulability, hypothermia, lung consolidation, seroma (1 each)	—
Level 2	14 (19.7%) Anemia (6) Pneumothorax managed with chest tube (2) Partial incision dehiscence (2) Arrhythmias, hypotension, need for albumin, hyperbilirubinemia (1 each)	—
Level 3	3 (4.2%) Surgical site dehiscence requiring anesthetized reexploration (3)	
Level 4	— — — —	18 (90.0%) CPA: unspecified reason (10) Euthanasia: neurologic signs (3) Euthanasia: ARDS/hypotension, oxygen dependence, MODS, AKI (1 each)

— = Not applicable. AKI = Acute kidney injury. ARDS = Acute respiratory distress syndrome. CPA = Cardiopulmonary arrest. MODS = Multiorgan dysfunction syndrome. ROSC = Return of spontaneous circulation.

Intraoperative complications are graded with an adaptation of a previously published Veterinary Cooperative Oncology Group–Common Terminology Criteria for Adverse Events (ie, VCOG-CTCAE) system.[10] Postoperative complications are graded using Accordion Severity Classification of Postoperative Complications: Contracted Classification criteria.[11]

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Five lung lobectomies were described to have multiple indications. Treatment of rib fractures was described in the operative reports of 35 of 57 patients with rib fractures on imaging. Treatments included reapposition with circumcostal interrupted and/or cruciate sutures (n = 18), intercostal muscle apposition only (6), debridement of sharp rib fragments only (5), and primary apposition of rib ends with suture placed through predrilled holes in the rib fragments (1). In 5 animals, rib fractures were noted in the operative report, but no specific treatment was described. Additional surgical findings included muscle lacerations (n = 83 [91.2%]), pulmonary contusions (36 [39.6%]), pulmonary lacerations (Figure 1) (19 [20.9%]), and diaphragmatic hernia (9 [9.9%]). Of the 19 patients with pulmonary lacerations, 13 (68.4%) had evidence of pneumothorax on thoracic radiographs.

A thoracostomy tube was placed in 68 patients (74.7%) for a median time of 1.5 days (n = 68; range, 0.08 to 4.5 days) overall, 1.5 days (53; range, 0.08 to 4.5 days) in survivors, and 1.25 days (15; range, 0.6 to 3 days) in nonsurvivors. Jackson-Pratt drains (within the subcutaneous space only) were placed in 13 patients (19.1%).

Intraoperative cultures were taken in 50 (54.9%) patients, and 18 of those (36.0%) yielded bacterial growth. The most common species cultures were *Klebsiella pneumoniae* in 11.1% (2 of 18) of patients, *Microbacterium* species in 11.1% (2 of 18), and *Bacillus cereus* in 11.1% (2 of 18).

Intraoperative complications were recorded in 51 (56.0%) patients overall. Intraoperative complications were scored as grade 1 (n = 3 [3.3%]), grade 2 (24 [26.4%]), grade 3 (21 [23.1%]), and grade 4 (3 [3.3%]) **(Table 3)**. All grade 4 complications were cardiopulmonary arrest events; successful return of spontaneous circulation was achieved after open chest CPR in 1 dog, 1 dog was not resuscitated per owners' wishes, and 1 dog was euthanized following CPR. Thus, 89 animals (97.8%) survived the surgical procedure. Median intraoperative complication grade in survivors was 2 (IQR, 0 to 2) and 2.5 (IQR, 0 to 3) in nonsurvivors, with no significant difference between groups (adjusted *P* = .84).

Postoperative findings

Fluid therapy was initiated in 82 (92.1%) patients that survived surgery; analgesics were recorded for 88 (98.9%) patients, and antibiotics were administered in 86 (96.6%) patients. Oxygen therapy was initiated in 19 (21.3%) patients. Overall, postoperative complications occurred in 46 of 89 (51.7%) patients that survived surgery. Postoperative complications were scored as level 1 (n = 13 [14.6%]), level 2 (14 [15.7%]), level 3 (3 [3.4%]), and level 4 (18 [20.2%]) (Table 3). Median postoperative complication level was 2 (IQR, 1 to 2) in survivors; by definition, all nonsurvivors had level 4 complications. Postoperative death occurred in a median of 2.5 days (range, 0 to 5 days).

Outcomes

The number of patients that survived to discharge was 71 (78.0%; 67 dogs, 4 cats). Comparison of variables between survivors and nonsurvivors is noted in Tables 1 and **4**. Of the patients that did not survive, 7 (35.0%) patients were euthanized and 13 (65.0%) patients suffered cardiopulmonary arrest. Including intra- and postoperative deaths, the median time from initial presentation to euthanasia was 3 days (range, 0 to 5 days; n = 7) and median time from initial presentation to cardiopulmonary arrest was 2 days (range, 0 to 4 days; 13). Those that survived to discharge were hospitalized for a median of 3.3 days (range, 1 to 12 days). Of the 55 (62.4%) patients that had follow-up, the median time to follow-up from time of presentation was 15 days (range, 3 to 3,235 days). Of those, 11 (20%) patients were reported to have issues related to prior thoracic trauma. These included incisional complications in 7 (63.6%), pain in 2 (18.2%), pneumothorax in 1 (9.1%), and flail chest in 1 (9.1%).

Table 4—Comparison of variables between survivors and nonsurvivors in 86 dogs and 5 cats that underwent surgery for penetrating thoracic trauma.

Variable	Survivors (n = 71)	Nonsurvivors (n = 20)	Adjusted *P* value
Median ATT	5 (range, 0–11)	8 (range, 2–12)	.01
Median time from presentation to surgery in min	452 (range, 50–11,540 min)	351 (range, 135–1,440 min)	.99
Presence of flail chest	20 (28.2%)	9 (45.0%)	.98
No external wound described but visualized thoracic cavity following incision of skin and subcutaneous layer	13 (18.3%)	2 (10.0%)	.99
Intraoperative presence of muscle laceration	64 (90.1.3%)	19 (95.0%)	1.0
Lung contusion	27 (38.0%)	9 (45.0%)	1.0
Lung lobectomy	13 (18.3%)	9 (45.0%)	.40
Positive cultures	12 (16.9%)	3 (15.0%)	1.0
Chest tube placement	51 (71.8%)	17 (85.0%)	.99

ATT = Animal trauma triage.

Values are reported as median (range) or n (%). Adjusted *P* values reflect Holm-Šídák adjusted significance for the family of comparisons reported throughout the manuscript.

Median time from presentation to surgery was 401 minutes (range, 50 to 11,520 minutes) across all patients, 452 minutes (range, 50 to 11,520 minutes; n = 71) in survivors, and 351 minutes (range, 135 to 1,440 minutes; 20) in nonsurvivors.

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Discussion

This retrospective multi-institutional study evaluated the clinical presentation, imaging findings, surgical findings, and outcomes of dogs and cats with surgically confirmed penetrating thoracic trauma. The key finding was that physical examination and thoracic radiograph findings did not always reflect the severity of injury to the thoracic cavity. Common thoracic radiographic findings in patients with confirmed penetrating thoracic traumas included pneumothorax, pulmonary contusions, and rib fractures; concurrent CT found additional injuries that may have changed the surgical plan in 6 of 9 patients with both imaging modalities. The only finding associated with nonsurvival was a higher ATT score; supporting that incorporation of ATT score into initial triage may help identify patients at greatest risk of nonsurvival. Overall, surgical management was associated with a survival to discharge rate of 78%. These findings may help clinicians identify which patients may have a worse outcome and develop a more complete diagnostic plan.

Severity of trauma during surgical intervention did not always correlate with initial physical examination or radiographic imaging findings. There were 15 (11.7%) patients that lacked findings of external puncture wounds, but during surgical exploration, extensive trauma to deeper layers of the thoracic cavity was described following skin incision. Of the 19 patients with surgical findings of pulmonary laceration, only 13 (68.4%) had evidence of pneumothorax on thoracic radiographs. Only 9 dogs had thoracic CT performed; however, information that may have altered the surgical plan was found in 6 of the 9 dogs with CT. Thoracic radiography has previously been reported[12,13] to be less sensitive than thoracic CT at detection of injuries to the thoracic cavity; findings of the present study provide further evidence that CT should be considered in patients that have sustained thoracic trauma. Interestingly, 1 patient with a surgically confirmed pulmonary laceration had no evidence of pneumothorax on thoracic radiographs or CT. Overall, these findings suggest that reliance solely on physical examination or imaging may underestimate injury severity of thoracic wall wounds and intrathoracic trauma.

While not statistically significant, lung lobectomy was performed in more nonsurvivors than survivors. Indication for lung lobectomy was described in 20 surgical reports and was typically performed due to pulmonary lacerations (80%). Though all patients had confirmed penetration of the thoracic cavity, not all patients had a complete thoracic exploration, and thus the percentage of pulmonary injuries may be higher than reported in the current study. Human literature describes success with placement of a chest tube for medical management of pulmonary lacerations as well as to guide decision-making for the need for thoracotomy and/or lung lobectomy.[5] There is a paucity of veterinary literature evaluating outcomes in small animals with pulmonary lacerations managed conservatively; therefore, it is possible that lung lobectomy may not have been necessary in these cases, particularly those that did not have a clinically significant pneumothorax.

The overall mortality rate of 22.0% identified in this study is consistent with, or slightly higher than, previously reported[1,3] mortality rates in animals undergoing surgery for thoracic trauma. Perioperative complications were common, occurring in over half of patients; however, the severity of intraoperative complications did not differ significantly between survivors and nonsurvivors, suggesting that complication occurrence alone is a less reliable prognostic indicator than variables such as ATT score. Most deaths occurred postoperatively rather than intraoperatively, and the underlying cause of spontaneous cardiopulmonary arrest was frequently not documented, limiting our ability to identify a common, modifiable etiology. These findings support the importance of vigilant postoperative monitoring and proactive owner communication regarding the potential for prolonged hospitalization, additional intervention, or a guarded prognosis. Notably, nearly half of euthanasia decisions in this cohort were driven by declining neurologic status rather than progression of thoracic disease, highlighting that concurrent injuries outside the thorax may meaningfully influence outcome and should be incorporated into prognostic discussions.

This study has several limitations. A major limitation of the present study is its retrospective nature, which may contribute to incomplete data and case information. Several limitations were considered regarding point-of-care ultrasounds, such as variability in performer experience and incomplete reports. Auscultation findings were recorded as documented by the original clinician without standardized terminology. Additionally, not all cases provided detailed reports of wound exploration on initial presentation, making it challenging to fully compare all cases to intraoperative findings. The presence and severity of traumatic injuries outside the thorax were not systematically recorded and therefore could not be evaluated for associations with intrathoracic injury severity or outcome. Additionally, antimicrobial susceptibility data were not consistently available and therefore were not evaluated. Future studies investigating bacterial isolates and antimicrobial susceptibility patterns may help guide empiric antimicrobial selection in patients with penetrating thoracic trauma. Finally, ATT scores were calculated retrospectively, which may have resulted in inaccurate scoring.

In conclusion, the findings from the present study may be used to aid veterinarians in making clinical decisions or leading discussions with clients for patients with penetrating thoracic trauma, prioritizing patient stabilization and emphasizing the benefit of thorough surgical explorations of thoracic wounds, regardless of severity of thoracic imaging findings. Additionally, information from the current study may guide future studies regarding surgical intervention for patients with penetrating thoracic trauma. Further investigation into the indication of lung lobectomies for patients with pulmonary lacerations and outcomes is indicated.

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Supplementary Materials

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