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EXPERIMENTAL LAB RESEARCH

WILEY

Traumatic pulmonary pseudocysts in nine dogs and two cats

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Abstract

Objective: To describe the clinical presentation, imaging findings, treatment, and outcome in dogs and cats with traumatic pulmonary pseudocysts (TPP).

Study design: Retrospective observational study.

Animals: Nine client-owned dogs and two cats.

Methods: The hospital database of Anderson Moores Veterinary Specialists was reviewed for cases with a diagnosis of TPP based on computed tomography (CT). Clinical presentation, additional injuries, treatment, and outcome were recorded.

Results: Eleven patients with TPP were identified. The ratio of TPP detected by radiographs when compared to CT was 7:11 (64%). Seven cases were managed conservatively, and three underwent lung lobectomy. One cat was euthanized due to the severity of concomitant injuries. The decision to perform thoracic surgery was due to refractory pneumothorax (2) or very large TPP (1). Ten patients survived to discharge. No patients died as a result of the TPP.

Conclusion: Radiographic lesions were identified in about two-thirds of cases diagnosed by CT. TPPs were not fatal in our population but were commonly associated with severe concomitant injuries. Conservative treatment led to the resolution of smaller TPPs.

Clinical significance: Conservative management of TPP is appropriate in most cases, although selected cases may benefit from surgical treatment.

1 | INTRODUCTION

Traumatic pulmonary pseudocysts (TPP) are cavitary lesions, without an epithelial lining, resulting from blunt or penetrating chest trauma.[1,2] These lesions have been assigned various names in the literature, including traumatic pulmonary pseudocysts, traumatic pneumatocele, trauma-associated pulmonary lacerations, and traumatic lung cyst.[3,4] The exact mechanism leading to the development of TPP is unknown, but several theories have been proposed. Williams and Bonte suggested that concussive waves produced by the trauma create shearing forces that tear the lung parenchyma.[5] Fagan and Swischuk proposed an alternative theory and speculated that severe and sudden compression of the bronchi and bronchioles could obstruct the bronchial tree while leading to distal transmission of explosive pressures, which cause a "bursting lesion".[6] These theories led to a two-step inclusive mechanism, which is now widely accepted.[7] First, the pulmonary parenchyma suffers a laceration as a consequence of sudden intrapulmonary pressure increment. This is followed by decompression of the chest with sudden negative intrathoracic pressure and subsequent elastic recoil of the surrounding lung, leading to the formation of small cavities filled with air or fluid.[8,9] Each pseudocyst tends to increase in size until the intraluminal pressure equals the pressure of the surrounding parenchyma.[8,10] Unlike pulmonary contusions and hematomas, TPPs are rare. The prevalence of TPP in patients with blunt chest trauma has been reported in several human studies but is affected by the imaging modality used (radiography versus CT). Cho et al reported that 81 of 978 (8.3%) human patients with blunt chest trauma were found to have TPP on CT.[8] Another study found that 13% of children with pulmonary contusion had TPP.[11] The only available veterinary case series (using the terminology "trauma-associated pulmonary lacerations") reported a prevalence of 12.5% in dogs following thoracic trauma using CT examination.[3] Given this relatively high prevalence, the lack of veterinary publications reporting TPP is surprising, suggesting TPPs remain a relatively poorly recognized injury and may go unnoticed or under-reported in imaging studies. TPPs have not been reported in cats.

Timing significantly affects the ability to identify TPP on radiographs. Human studies suggest that TPPs become apparent within the first 24–48 hours after trauma.[12,13] Radiographs obtained on the day of injury are diagnostic in only 33%–50% of cases due to the initial small size and concurrent presence of pulmonary contusions, which can mask the lesions,[1,14] and in one study, TPP less than 2 cm in diameter were not visible on radiographs.[15]

Diagnosis of TPP is based on a history of blunt chest trauma and specific imaging findings. Accurate and early diagnosis is the key to a successful outcome and high clinical suspicion is crucial to avoid misdiagnosis which may lead to inappropriate treatment. The main significance of TPP is that they must be distinguished from other cavitary pulmonary lesions, such as bullae, subpleural blebs, bronchial cysts, bronchiectasis, abscesses, fungal infections, granulomas, paragonimus cysts, and cavitating neoplastic lesions.[16,17]

The size and shape of TPP change in the days following trauma.[1] Therefore, serial imaging studies may help to differentiate TPP from other lesions.[13,18] Once intraluminal pressure and pressure within the surrounding parenchyma equalize, TPP decrease in size until resolution. However, in people, some TPP may enlarge for up to 2 weeks following trauma.[19] In veterinary patients, this observation may raise clinical concerns about the origin of the lesions, leading to further investigations, many of which require invasive testing and treatment, thus increasing the risk of complications.

Complications in conservatively managed TPP are uncommon but have been reported and include hemorrhage, infection, TPP enlargement or rupture with secondary pneumothorax, and compression of local pulmonary parenchyma.[13] Phillips et al. suggested that pseudocysts larger than 6 cm, or those that have failed to improve following conservative management, are potential candidates for surgical resection and surgery is likely to be indicated for a large infected TPP; however, it is not clear if the size of the lesion alone should influence the clinical decision for management of uncomplicated TPP.[8,13] Prophylactic antibiotic therapy is generally not indicated as infections tend to occur late in the course of the TPP.[13]

The veterinary literature on this topic is scant and consists of four clinical case reports and a single case series reporting the imaging findings.[3,20–23] The aim of this study was to describe the clinical presentation, imaging findings, treatment, and long-term outcome in a cohort of dogs and cats with TPP referred to a single multidisciplinary referral hospital.

2 | MATERIALS AND METHODS

This was a retrospective observational study. A medical record search was performed for all dogs and cats that underwent thoracic CT examination at Anderson Moores Veterinary Specialists between January 2016 and February 2020. All studies were originally reported by board-certified radiologists and the reports were searched for the keywords "bulla", "bleb", "cyst", or "pseudocyst". The CT reports were then read to confirm the presence of these lesions. The CT images of cases deemed eligible on the basis of the original report were then reviewed by a single board-certified radiologist (PA) to identify TPP. TPPs were defined as round, oval, or irregular parenchymal defects surrounded by a thin pseudomembrane with air or fluid content or air-fluid levels and accompanied by perilesional pulmonary contusions[12] in a patient that sustained thoracic trauma. Dogs and cats were included in the study if there was a history of recent trauma as well as cavitary pulmonary lesions with CT features compatible with TPP based on the previous descriptions in the human and veterinary literature.[3,8,22–24] Dogs and cats with bullae and blebs associated with spontaneous pneumothorax or with incidentally identified bullae and blebs and no history of trauma were excluded. Cases were included if follow-up was available for a minimum of 4 months (if alive) or until death. Cases included in the study were reviewed for signalment, clinical history, mechanism of trauma, examination findings, diagnostic procedures performed, days between trauma and imaging studies, treatment, additional injuries, duration of the hospitalization, complications, long-term outcome, and

TABLE 1 Computed tomography (CT) findings

Animal	CT scan (days after trauma)	Pneumothorax and/or effusion	Volume pneumothorax and/or effusion	Type	Location (lung lobe)	Shape	Content (gas and/or fluid)	Size (mm)		
								DV	ML	Crcd
1	4	Both	Mild, right-sided	I	CrS LCr	R	Gas	3.9	3.8	3.7
				IV	LCd	O	Both	67.1	47.4	67.4
				IV	LCd	FO	Both	20.5	7.6	19.7
				II	LCd	SU	Both	35.7	2.1	51.2
				I	RCd	O	Gas	5.1	5.5	8.8
2	1	Both	Moderate on right side, mild on left side	I	CrS LCr	SU	Gas	13.7	9.3	10
				IV	CrS LCr	C	Both	24.1	12.9	14.1
				IV	CrS LCr	O	Both	8.2	6.6	8.2
				I	CrS LCr	O	Both	15.1	7.5	8.4
				I	LCd	O	Both	12.1	9.7	12.9
				IV	LCd	O	Gas +/− soft tissue/ fluid	13.3	6.6	7.4
				I	RM	O	Both	14	10	9.6
				I	RCr	O	Gas	9.9	10.4	13.5
				IV	RCr	O	Both	16.8	18	31.7
3	Unknown	Both	Mild on left side, moderate on right side	IV	RCr	FO	Both	11.5	22.4	6.8
				I	Ac	R	Both	7.7	6.8	5.7
4	Same day	Both	Marked on left side, moderate on right side	IV	RM	O	Gas	18.1	14.4	25.2
5	1	Pneumothorax	Moderate to marked bilaterally	IV	RCd	R	Gas	2.5	2.5	2.5
				I	RCd	R	Gas	13.4	11.2	15
				I	RCd	R	Gas	7.5	8.4	9.3
				I	RCd	R	Gas	11.2	12.6	8.1
				IV	RCd	R	Gas	5	4.5	3.3
				I	RCd	C	Gas	11.6	16	13.2
6	Same day	Both	Marked bilaterally	I	RCd	FO	Gas	9	7	4.6
7	2	Pneumothorax	Moderate on left side, mild on right side	II	RCd	FO	Gas	5.4	3.4	8.6
				II	RCr	FO	Gas	10.4	2.2	2.1
8	2	Pneumothorax	Mild on left side, marked on right side	IV	LCd	R	Gas	10.2	8.7	9.1
				IV	LCd	O	Both	10.8	8	7.9
				IV	LCd	O	Gas	8.6	7	9.3
				I	LCd	R	Gas	3.4	3.6	3.9
				I	LCd	SU	Gas	5.1	3.8	4.6
				III	LCd	O	Both	17.1	20.7	32
				III	RCd	O	Both	12.8	18.9	20.8
				IV	RCd	R	Gas	2.1	2	2.2
				I	Ac	R	Gas	3.3	3.3	4.4
				IV	RM	R	Both	14	14.8	14.6

(Continues)

TABLE 1 (Continued)

Animal	CT scan (days after trauma)	Pneumothorax and/or effusion	Volume pneumothorax and/or effusion	Type	Location (lung lobe)	Shape	Content (gas and/or fluid)	Size (mm)		
								DV	ML	Crcd
				I	RCr	R	Gas	4.7	5.4	5
				I	RCr	O	Both	10.8	5.4	5
9	7	Pneumothorax	Minimal on right side	IV	RCr	FO	Gas	7.1	3.7	7
10	1	Pneumothorax	Initially marked bilaterally (left > right), after drainage moderate on right side and mild on left side	IV	LCr	O	Both	13.2	8	14.4
				IV	RCd	FO	Gas +/− soft tissue/ fluid	5.4	12.3	6.7
				IV	RCd	FO	Both	6.6	12.2	8.1
				IV	RCd	O	Both	18.5	23.2	35
				I	RCd	C	Gas	13.9	21.1	22.8
				I	RCd	O	Gas	7.2	10	9.4
				IV	RCd	O	Gas +/− soft tissue/ fluid	6	10	8.9
				I	RCd	O	Gas +/− soft tissue/ fluid	5.6	8.6	13.1
				IV	RM	O	Gas	12.1	7.8	11.8
11	1	Pneumothorax	Mild bilaterally	I	LCr	O	Both	15.2	11.1	16.9

Note: Round = fully circular; ovoid = regular oval shape; flat-ovoid = regular slit-like shape; slightly uneven = not fully conforming to regular round, ovoid or flat-ovoid due to focal bulge; complex = multicavitated lesions containing internal septations.
Abbreviations: Ac, accessory; C, complex; CrCd, craniocaudal; CrS, cranial segment; DV, dorsoventral; FO, flat ovoid; LCd, left caudal; LCr, left cranial; ML, mediolateral; O, ovoid; R, round; RCd, right caudal; RM, right medial; SU, slightly uneven.

follow-up imaging. All CT examinations were performed with a dual slice (HiSpeed Dual, GE Medical Systems, Chicago, Illinois) or 64-slice CT scanner (Somaton Perspective, Siemens Healthcare, Germany). All post-referral radiographic images were obtained with a computed radiography system (Regius model 190, Konica Minolta, Japan) or direct digital radiography (FDR Nano, Fujifilm, Japan). All imaging studies were reviewed by one of the authors (PA) and the number of TPP, location, shape, size, type of content, and wall thickness were recorded. Additionally, each lesion was categorized according to an adapted classification scheme previously reported:[3] Type 1—large TPP located deep in pulmonary parenchyma or around an interlobar fissure; type 2—TPP in paraspinal lung parenchyma not associated with vertebral fracture; type 3—subpleural TPP closely associated with fractured rib or vertebra; type 4—subpleural lesion not associated with rib fractures. Radiographs performed prior to referral, if available, were reviewed. The patient ratio with TPP identified on radiographs compared with CT was calculated. At the end of the study, owners and referring veterinarians were contacted to obtain long-term follow-up, including the clinical progress of the patient, any residual or recurrent respiratory problem, and whether any additional follow-up imaging had been performed. Prior owner consent was obtained for participating in the study.

3 | RESULTS

A total of 2595 cases undergoing thoracic CT were identified (2221 dogs and 374 cats). A total of 30 dogs and one cat were diagnosed with incidentally identified pulmonary bullae and blebs and excluded from the study. A total of 11 patients with TPP were identified and met the inclusion criteria for the present study (nine dogs, two cats) (Table 1). The breed of dogs affected was whippet

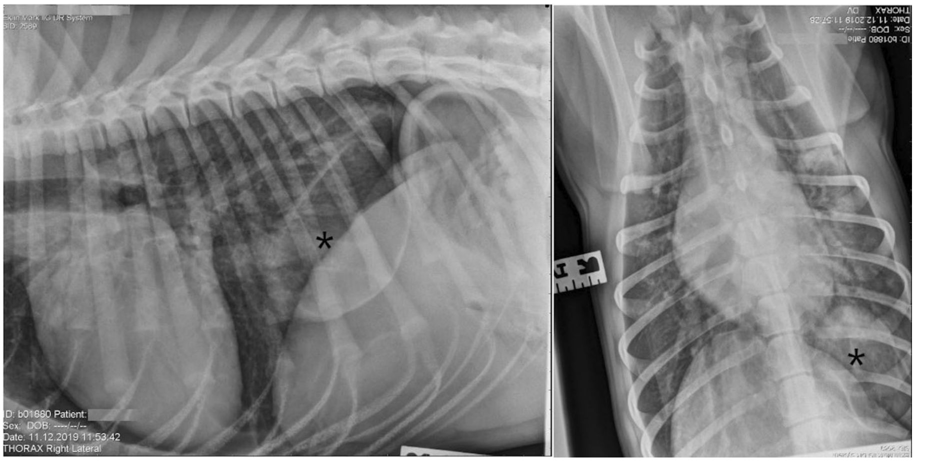

FIGURE 1 Lateral and ventrodorsal thoracic X-rays from case 1. *, traumatic pulmonary pseudocysts (TPP)

(3), German shorthair pointer (1), crossbreed (2), Munsterlander, English setter, and Border terrier. Both cats were domestic short-haired. Four dogs were neutered males, four were intact males, and one was a spayed female. Both cats were neutered males. The median age was 2 years and 5 months (range 7 months to 12 years). Trauma was caused by road traffic accidents (6 cases), falling from a height, being kicked by a horse, or being attacked and shaken by a dog (1 case each). In two cases the nature of the traumatic event was unknown but a road traffic accident was suspected.

3.1 | Imaging findings

Imaging findings including CT features and classification of identified TTP are summarized in Table 1. A total of 49 TPP were identified with an average of 4.5 TPP per patient (range 1–12). Thoracic radiographs were performed in all patients, 10 at the referring veterinary practice and one case post referral. Radiographs were obtained on the day of the traumatic event in nine cases, with TPP identifiable in 6/9 (67%) cases. In one case (case 1), radiographs were performed one day after trauma and showed an identifiable TPP. The radiographs were repeated on day 3 due to increased respiratory effort and confirmed the presence of a large TPP (Figure 1). In case 9, radiographs were obtained 6 days after trauma, no TPPs were reported but the radiographic study was not available for review. Overall, 7/11 (64%) of patients had TPP identifiable on radiographs.

3.2 | Clinical findings and treatment options

Clinical signs, summarized in Table 2, were consistent with lower airway disease in 6/11 (55%) at the time of presentation at the referral institution. Four out of 11 (36%) cases presented with tachypnoea and 5/11 (45%) had decreased lung sounds on auscultation. Additional injuries were reported in nine cases and included: full-thickness skin wounds or abrasions in 4/11 (36%) cases, maxillo-facial or mandibular fractures in 1/11 (9%), limb fractures/joint luxations in 3/11 (27%) and spinal fractures/luxations in 2/11 (18%) patients. Orthopedic surgery was performed in three dogs: pancarpal arthrodesis for carpal hyperextension injury (case 2), multiple mandibular surgeries to address extensive mandibular fractures (case 4), open reduction and internal fixation of a left ilial body fracture and right sacroiliac luxation, right hock transarticular external fixator placement to address lateral malleolar fracture and concurrent shear injury (case 10). Hip luxation in case 6 was managed via closed reduction.

Pneumothorax was reported in all animals (bilateral in 9, unilateral in 2). A low-profile chest drain was placed in 8/11 (73%) patients and maintained in place for a median of 2 days (range 1–5). The remaining three patients were managed conservatively due to the small volume of pneumothorax and absence of respiratory signs. Pulmonary contusions were reported in 8/11 (73%) patients. One cat (case 7), was euthanized at the request of the owner due to the severity of the maxillo-facial and mandibular injuries. The remaining 10 patients were discharged from the hospital. The median duration of hospitalization was 5 days (range 3–11).

3.3 | Clinical outcome

Among the 10 patients that survived beyond 24 hours, TPPs were managed conservatively in seven. Thoracic surgery was performed in three dogs (cases 1, 5, and 6). The decision to perform surgery was based on persistent pneumothorax unresponsive to conservative management in

TABLE 2 Clinical findings

Case number	Signalment	Type of trauma	Clinical findings	Additional injuries
1	Munsterlander. 7 months. Male	RTA	Cough. Reduced left lung sounds	Skin abrasions. Left-sided pneumothorax
2	English setter. 10 years. Male neutered	Fall from height	Right carpal hyperextension	Sternal fracture, rib fractures, right carpal hyperextension injury
3	Whippet. 8 years 9 months. Male neutered	RTA	Tachypnoea. Muffled right thoracic sounds. Abdominal pain	Skin wounds right antebrachium, left elbow, right pelvic limb. Bilateral pneumothorax, hemothorax
4	Border terrier. 2 years 6 months. Male neutered	RTA	Unstable mandible, oral hemorrhage, swollen tongue	Rib fractures, multiple mandibular fracture, bilateral pneumothorax
5	Whippet. 7 years 1 months. Male neutered	Kicked by a horse	Tachypneic. Muffled lungs sound	Bilateral pneumothorax
6	Crossbreed. 1 year 5 months. Female	RTA	Tachypneic. Muffled thoracic sounds. Subcutaneous emphysema. Right pelvic lameness	Right hip luxation, bilateral pneumothorax
7	Domestic short haired cat. 1 year 6 months. Male neutered	RTA	Facial swelling. Hemorrhagic and swollen conjunctiva	Multiple maxillofacial and mandibular fractures. Bilateral corneal ulcers. Skin wounds. Mild to moderate bilateral pneumothorax
8	Whippet. 7 months. Male	RTA	Muffled right lung sounds. Kyphosis. Bilateral pelvic proprioceptive delay	Fracture/subluxation T11–T12. Incomplete left scapular fracture. Bilateral pneumothorax
9	Domestic short haired cat. 4 years 3 months. Male neutered	Dog bite/ shake	Perilaryngeal swelling and emphysema. Retching on neck palpation	Segmental fracture of the left stylohyoid bone. Perilaryngeal abscess. Mild right-sided pneumothorax
10	German shorthaired pointer. 10 months. Male	RTA	Severe pain. Nonambulatory	Nondisplaced end-plate T10 fracture. Left iliac body fracture. Right sacroiliac fracture. Fracture of the right tibial lateral malleolus and shear injury. Bilateral pneumothorax.
11	Crossbreed. 5 years 2 months. Male	Unknown trauma	Tachypnoea. Bilateral subcutaneous emphysema	Bilateral pneumothorax

Abbreviation: RTA, road traffic accident.

two out of three cases (case 5 and 6). Case 5 underwent a preliminary thoracic decompression by the placement of a low-profile drain (MILA International, Kentucky). Increased air production 24 hours later led to the decision to perform a CT examination that showed bilateral pneumothorax, multiple TPP, and a single large laceration in the right caudal lung lobe. The thoracic cavity was explored via a median sternotomy, and the right caudal lung lobe was removed via stapled hilar lung lobectomy (Ethicon TA, Ohio). The pneumothorax in case six was initially treated with bilateral low-profile drains (MILA international, Kentucky) and intermittent drainage for 24 hours, but it was not possible to achieve negative pressure. A continuous suction device (Thora-Seal Chest Drainage Unit, Cardinal Health, Ohio) was then used, achieving a seal after 36 hours in the left but not the right hemithorax. The thoracic cavity was explored through a right fifth intercostal thoracotomy; an area of severe bruising, hemorrhage, and air leakage consistent with the CT location of the TPP in the right caudal lung lobe was confirmed and a stapled lung lobectomy was performed (MILA International, Kentucky). In one dog (case 1), the decision to progress to surgery was based on the large size (67 × 47 × 67 mm) of the lesion (Figure 2), concerns that it might not spontaneously regress, and potential future complications such as infection, spontaneous rupture, and pneumothorax. The lesion was approached via a left fifth intercostal thoracotomy and removed via stapled lung lobectomy (Ethicon TA, Ohio) (Figure 3).

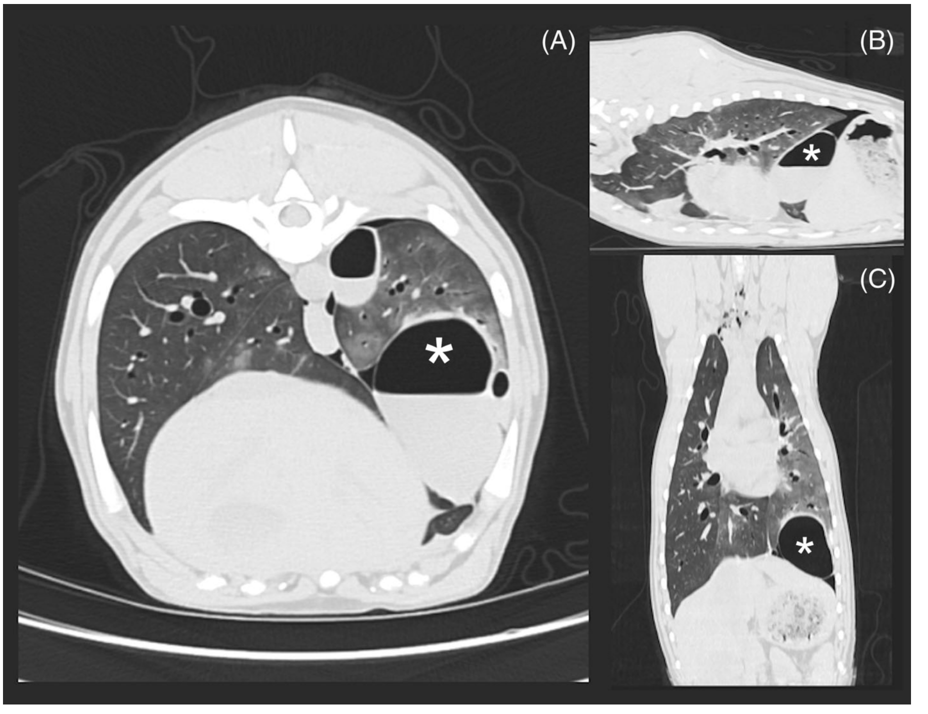

FIGURE 2 Computed tomography (CT) scan from case 1. *, traumatic pulmonary pseudocysts (TPP)

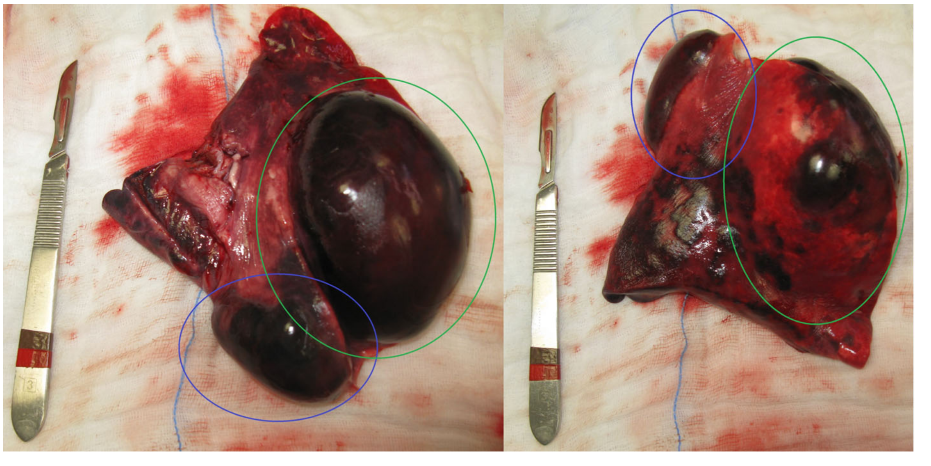

FIGURE 3 Left caudal lung lobe removed with two traumatic pulmonary pseudocysts (TPP) (green and blue circle)

3.4 | Follow-up

Long-term follow-up was available for all patients discharged from the hospital, with a median follow-up time of 768 days (range 171–1508 days). Nine of 10 patients did not show any respiratory complications. One patient (case 2) developed two consecutive episodes of pneumonia 18 months after diagnosis of TPP. This patient had a total of nine TPP in the original CT examination, affecting the left cranial and left caudal lung lobes, and the right cranial and right middle lung lobes. Radiographs at presentation and after completion of antibiotic treatment for the first episode of pneumonia showed two faint structures consistent with TPP originally detected in the left caudal lung lobe. These lesions could not be clearly identified in the radiographs obtained during the second episode. In both follow-up radiographic studies, a mixed, patchy interstitial to alveolar lung pattern consistent with pneumonia was present in the mid-ventral lung fields, in the first episode predominantly affecting the left cranial lung lobe and in the second episode the right middle lung lobe. However, the previously identified TPPs in these lung lobes on CT examination were not detected in either of the follow-up radiographic studies.

4 | DISCUSSION

According to our literature search, this is the first case series reporting the clinical presentation, treatment, and outcome in dogs with TPP and the first to report TPP in cats. Traumatic pulmonary pseudocysts are relatively rare and they remain poorly described in veterinary medicine.[3,20–23] The literature reporting TPP in humans is more extensive, although a significant proportion of publications consists of case reports[4,25–29] with a few case series[1,5–7,9,15,19,30,31] and no prospective studies. Most authors agree that the term traumatic pulmonary pseudocyst, proposed by Santos and Mahendra, is the most accurate[4,8,32] and for this reason, we elected to use the term TPP in this study. To our knowledge, there is only a single case series on TPP available in veterinary medicine which reports only the CT features of the lesions.[3] Bertolini et al. chose to use the term pulmonary laceration rather than TPP, using a classification system previously proposed by Wagner et al.[3,33]

Development of TPP following thoracic trauma is reportedly more common in young human patients, because they have a more pliable chest wall, allowing the force to be more easily transferred to the lungs.[4,9] The median age in our study was 2 years and 3 months supporting similar conclusions in veterinary patients, and Bertolini et al. reported that dogs undergoing CT for blunt chest trauma with TPP were significantly younger than patients without TPP lesions.[3] In humans, TPPs are more common in males, which is believed to be due to their higher propensity to involvement in traumatic accidents in general.[11] A total of 91% of our patients (10/11) and 60.4% of dogs in the study by Bertolini et al. were males, suggesting that this may also be true in veterinary patients.

Computed tomography is known to be more sensitive than radiography to identify TPP in humans, due to the ability to detect smaller lesions in the face of concurrent pulmonary contusions.[8] Our study made similar conclusions, with TPP confirmed in only six of nine animals (67%) that had radiographs on the day of injury, and 7/11 (64%) of all cases in the study. This was similar to the Bertolini et al. study which reported TPP visible on radiographs in 13/22 (59%) of dogs with CT-confirmed TPP.[3] These data compare favorably with the human data of 33%–50% TPP detected with radiography on the day of injury but could reflect our low numbers of cases and lack of independent veterinary studies.[1,14]

Failure to accurately diagnose TPP may lead to unnecessary and potentially harmful diagnostic and therapeutic procedures. Peripheral TPPs in contact with the visceral pleura were common in this study (43/49 TPP, Table 1), and misdiagnosis of a peripheral TPP as a pneumothorax or pneumomediastinum may prompt additional testing or placement of a thoracostomy tube, which could be unnecessary. Confusing an uncomplicated TPP with a pulmonary abscess or neoplasia could channel the patient into the wrong treatment algorithm, increasing the risk of complications and a simple TPP may become a complicated problem.[13]

The TPP in our study commonly showed a round or oval shape with variable content (gas, fluid, or both), which is consistent with CT features from previous publications.[3,8,15,22,24] They were commonly surrounded by pulmonary contusions and/or, in cases of significant pneumothorax, pulmonary atelectasis; however, our findings also revealed variations to the only previous veterinary study in terms of frequency and CT features of different types of TPP.[3] Whereas previously type 1 TPP was the most common, type 1 and type 4 TPP were observed with equal frequency in our patients. In our study, most patients had a mixed pattern with TPP of different types. A single type of TPP was observed in only 4/11 patients, whereas the previous study reported a significantly higher total number of patients with a single type of TPP (32/46). There were also some differences in the observed shape and size concerning TPP type: Type 1 TPP were previously reported to be ovoid and larger than other types, but the shape of type 1 TPP was more variable in our patients with 12/22 type 1 TPP showing a different shape (8/12 round, 2/12 slightly uneven, 2/12 complex) (Table 1). Furthermore, type 1 and type 4 were similar in size. Finally, in the Bertolini et al. study pneumothorax was only consistently identified in association with type 3 TPP, whereas pneumothorax or pneumohydrothorax was present in all our patients regardless of the number or type of TPP recorded. The cause for the observed differences between the two study populations is uncertain but may represent variations in the type of trauma/velocity of impact, the timing between trauma and CT examination, or other patient factors. It is also possible that the classification of the TPP as defined in a canine population is not appropriate for a feline population due to variations in the thoracic pliability, body weight, and pulmonary mesenchymal tissue.

The most common traumatic event in the patients in this report was a motor vehicle collision, which is similar to previous studies in both human and veterinary patients.[3,8] The high prevalence of additional injuries is not surprising given the high energy trauma involved, with 5/11 patients presenting with concurrent significant orthopedic, spinal or maxillofacial injuries, and 1/11 being euthanized. Pneumothorax was noted in all patients in this case series and placement of a thoracostomy tube was necessary for 67% of patients. This is similar to the findings in humans with 58% of patients requiring closed thoracostomy due to concurrent pneumothorax and/or hemothorax in one study.[8] Prevalence of concurrent pneumothorax and the need for thoracotomy tube placement was not reported in the study by Bertolini et al.[3]

In the majority of animals in this study, specific treatment of the TPP was not necessary, which is consistent with reports in the human literature. In 2003, Melloni et al. proposed a treatment algorithm for TPP that is still widely accepted.[8] In the vast majority of cases, management of TPP focuses on supportive measures and treatment of associated injuries. In adults, TPPs have been reported to regress spontaneously[14] and in two recent case series, all TPP identified in human patients were self-limiting and did not require intervention.[8,11] Radiological resolution averaged 3 months but ranged from 4 weeks to 6 months in people[27] although large TPP required significantly longer for resolution. A study by Chon et al. found that lesions filled with blood or greater than 2 cm in diameter had an average resolution time of approximately 5 months.[15] It is unknown how long spontaneous resolution of TPP can take in dogs and cats because studies with follow-up imaging are lacking.

The decision to proceed with surgery in our patients was based on a treatment algorithm similar to the one used for humans.[8] In the study by Bertolini et al. only 1/46 (2.1%) dogs required lung lobectomy due to abscess formation and 1/46 (2.1%) dogs developed subpleural TPP rupture and subsequent persistent pneumothorax but was successfully managed with a continuous drainage system. The prevalence of animals undergoing thoracic surgery was much higher in our cohort of patients, where three out of 10 (30%) animals surviving beyond 24 hours underwent surgery, all of which survived. The decision to progress to surgery was based on the presence of severe refractory pneumothorax in two cases; however, in both cases, the pneumothorax was treated with intermittent or continuous drainage for less than 36 hours. It is possible that drainage via the thoracostomy tubes for longer might have been successful. In case 1, the decision to proceed to surgery was elective and based on the large size of the lesion (6.7 cm diameter) and the perceived risk of life-threatening complications in case of rupture. Early surgery is a consideration for large TPP in people, but spontaneous regression of large TPP has also been reported. One veterinary case study reported successful conservative management of a 6.6 cm diameter TPP, although follow-up imaging was not performed and spontaneous regression was not confirmed.[21] For this reason an alternative approach in case 1 could have consisted of follow-up imaging every one to 3 months, committing to surgery only if the TPP was enlarging or persisting beyond 6 months or in case of complications.

Data on the natural progression of conservatively managed TPP in veterinary medicine is scant as follow-up imaging was either not performed or did not extend beyond 1 month and complete TPP resolution has never been documented.[3,20,21] Regular imaging follow-up is generally recommended in human patients with conservatively managed TPP, to document resolution and ensure no complications. The recommended follow-up includes scheduled radiographs and, less commonly, CT, which is reserved for monitoring complicated TPP or those not clinically detectable with radiography.[1,4] The follow-up imaging schedule varies, with many centers considering radiographs every two to 3 months until 6 months or documented resolution.[8,13] However the protocol is controversial with the authors of a recent study reporting that, in their institution, repeat imaging is obtained only if patients are symptomatic, and they do not report delayed complications with this approach.[11] Only one dog in our case series underwent repeat radiographs for possibly unrelated pneumonia. Two TPP were still evident in the left caudal lung lobe at the time of the pneumonia diagnosis 18 months after the original trauma, although the surrounding parenchyma showed no significant focal changes. These lesions were no longer identified in the final radiographic study; however, the full resolution of all TPP in this patient cannot be confirmed without a follow-up CT examination.

4.1 | Study limitations

The main limitations of this case series are its retrospective nature as well as the small study population. Diagnostic investigations and treatment protocols were not standardized and were at the discretion of the attending clinician. Follow-up was based on a telephone conversation and clinical assessment of the referring veterinarian, and imaging follow-up was lacking for the majority of animals.

In conclusion, traumatic pulmonary pseudocysts are uncommon and underreported lesions secondary to blunt chest trauma. The results of this study are similar to findings derived from the human literature. Radiographs identified TPP lesions in about two-thirds of cases diagnosed by CT. Severe concomitant maxillo-facial, neurological and orthopedic injuries as well as pneumothorax were common. None of the patients in this study died as a result of the TPP. Conservative management of TPP was appropriate in most cases, but surgery may be required in selected cases or in case of complications. Follow-up imaging of conservatively managed cases may be prudent but remains controversial in asymptomatic patients. Further studies are necessary to clarify if the treatment algorithm designed for people can be adopted and successfully applied to veterinary patients and if very large but uncomplicated lesions can be managed conservatively.

AUTHOR CONTRIBUTIONS

Montaño HG, MRCVS: Data acquisition, analysis, organization, and interpretation, primarily drafted and revised the manuscript, figures and tables preparation, accountable for all aspects of integrity and accuracy, and approval of the published manuscript. Agthe P, MRCVS, DipECVDI: Study design, data analysis and interpretation, CT classification and revision of radiographic and CT studies, draft revision, approval of the published manuscript. Cantatore M, MRCVS, DipECVS: Study design and concept, data analysis, and interpretation, primarily drafted and revised the manuscript, accountable for all aspects of integrity and accuracy, approval of the published manuscript.

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CONFLICT OF INTEREST

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

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REFERENCES

1. Ulutas H, Celik MR, Ozgel M, Soysal O, Kuzucu A. Pulmonary pseudocyst secondary to blunt or penetrating chest trauma: clinical course and diagnostic issues. *Eur J Trauma Emerg Surg*. 2015;41(2):181-188.
2. Beattie G, Cohan CM, Tang A, Yasumoto E, Victorino GP. Differences in clinical characteristics and outcomes for blunt versus penetrating traumatic pulmonary pseudocysts. *Am J Emerg Med*. 2021;45:433-438.
3. Bertolini G, Briola C, Angeloni L, Costa A, Rocchi P, Caldin M. Trauma-associated pulmonary laceration in dogs-a cross sectional study of 364 dogs. *Vet Sci*. 2020;7(2):41.
4. Yang TC, Huang CH, Yu JW, Hsieh FC, Huang YF. Traumatic pneumatocele. *Pediatr Neonatol*. 2010;51(2):135-138.
5. Williams JR, Bonte FJ. Pulmonary damage in nonpenetrating chest injuries. *Radiol Clin North Am*. 1963;1:439-448.
6. Fagan CJ, Swischuk LE. Traumatic lung and paramediastinal pneumatoceles. *Radiology*. 1976;120(1):11-18.
7. Zheng Z, Pan Y, Guo F, Pan T, Li J. Traumatic pulmonary pseudocyst: a rare but noteworthy entity. *Am Surg*. 2011;77(8):1098-1100.
8. Cho HJ, Jeon YB, Ma DS, Lee JN, Chung M. Traumatic pulmonary pseudocysts after blunt chest trauma: prevalence, mechanisms of injury, and computed tomography findings. *J Trauma Acute Care Surg*. 2015;79(3):425-430.
9. Athanassiadi K, Gerazounis M, Kalantzi N, Kazakidis P, Fakou A, Kourousis D. Primary traumatic pulmonary pseudocysts: a rare entity. *Eur J Cardiothorac Surg*. 2003;23(1):43-45.
10. Hazer S, Orhan Söylemez UP. Clinical features, diagnosis, and treatment of traumatic pulmonary pseudocysts. *Ulus Travma Acil Cerrahi Derg*. 2018;24(1):49-55.
11. Armstrong LB, Mooney DP. Pneumatoceles in pediatric blunt trauma: common and benign. *J Pediatr Surg*. 2018;53(7):1310-1312.
12. Houtman S, Janssen R. Traumatic pneumatoceles. *Neth J Crit Care*. 2012;16:224-225.
13. Phillips B, Shaw J, Turco L, et al. Traumatic pulmonary pseudocyst: an underreported entity. *Injury*. 2017;48(2):214-220.
14. Kato R, Horinouchi H, Maenaka Y. Traumatic pulmonary pseudocyst. Report of twelve cases. *J Thorac Cardiovasc Surg*. 1989;97(2):309-312.
15. Chon SH, Lee CB, Kim H, Chung WS, Kim YH. Diagnosis and prognosis of traumatic pulmonary pseudocysts: a review of 12 cases. *Eur J Cardiothorac Surg*. 2006;29(5):819-823.
16. Lamb CR, Neiger R. Radiology corner: differential diagnosis of pulmonary cavitary lesions. *Vet Radiol Ultrasound*. 2000;41(4):340-341.
17. Kamiyoshihara M, Yoshikawa R, Igai H, Ohsawa F, Yazawa T. The risk of misdiagnosing pulmonary adenocarcinoma as traumatic Pseudocyst in a young adult. *Ann Thorac Surg*. 2019;107(4):e279-e280.
18. Yazkan R, Ozpolat B, Sahinalp S. Diagnosis and management of post-traumatic pulmonary pseudocyst. *Respir Care*. 2009;54(4):538-541.
19. Moore FA, Moore EE, Haenel JB, Waring BJ, Parsons PE. Post-traumatic pulmonary pseudocyst in the adult: pathophysiology, recognition, and selective management. *J Trauma*. 1989;29(10):1380-1385.
20. Barge P, Fernández-Del Palacio MJ, Santarelli G, Soler M, Agut A. Traumatic pulmonary pseudocysts associated with pneumothorax and rib fractures in a dog. *Vet Rec Case Rep*. 2018;6:e000593.
21. Mulholland N, Keir I. Traumatic pulmonary Pseudocysts in a young dog following non-penetrating blunt thoracic trauma. *Front Vet Sci*. 2019;6:237.
22. Mella S, White C, Mapletoft EK, Llabres-Diaz F, Cook SD. Multimodality diagnostic imaging findings in a dog with a traumatic pulmonary pseudocyst. *J Small Anim Pract*. 2021;62(6):501.
23. Oura TJ, Rozanski EA, King RG, Sato AF. What is your diagnosis? Traumatic pulmonary pseudocysts. *J Am Vet Med Assoc*. 2008;232(3):357-358.
24. Kaewlai R, Avery LL, Asrani AV, Novelline RA. Multidetector CT of blunt thoracic trauma. *Radiographics*. 2008;28(6):1555-1570.
25. van Hoorebeke E, Jorens PG, Wojciechowski M, et al. An unusual case of traumatic pneumatocele in a nine-year-old girl: a bronchial tear with clear bronchial laceration. *Pediatr Pulmonol*. 2009;44(8):826-828.
26. Gupta N, George J, Gupta RC, Dixit R. Traumatic pulmonary pseudocyst. *Int J Crit Illn Inj Sci*. 2013;3(2):155-158.
27. Kocer B, Gulbahar G, Gunal N, Dural K, Sakinci U. Traumatic pulmonary pseuodocysts: two case reports. *J Med Case Reports*. 2007;1:112.
28. Voutsas V, Giakamozis A, Lazaridis T, Bitzani M. Post-traumatic lung pseudocysts: two case reports in ICU patients. *J Thorac Dis*. 2012;4:74-78.
29. Yang PJ, Tsai IT, Liu TH. Traumatic pulmonary Pseudocyst. *J Pediatr*. 2015;167(3):777.e1.
30. Luo L, Yin L, Liu Z, Xiang Z. Posttraumatic pulmonary pseudocyst: computed tomography findings and management in 33 patients. *J Trauma Acute Care Surg*. 2012;73(5):1225-1228.

31. El-Hag-Aly MA, Allam HK. Fate of traumatic pulmonary pseudocyst: factors of resolution. *Asian Cardiovasc Thorac Ann*. 2015;23(2):176-179.
32. Santos GH, Mahendra T. Traumatic pulmonary pseudocysts. *Ann Thorac Surg*. 1978;27:359-362.
33. Wagner RB, Crawford WO Jr, Schimpf PP. Classification of parenchymal injuries of the lung. *Radiology*. 1988;167(1):77-82.

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