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PAPER

Computed tomographic findings in canine pyothorax and correlation with findings at exploratory thoracotomy

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Objectives: To describe computed tomographic (CT) findings in canine spontaneous pyothorax and compare them to surgical findings and to assess the utility of CT in guiding case management.

Methods: Records from 2003 to 2010 were reviewed to identify dogs, with spontaneous pyothorax, which had undergone CT. Cases were managed medically or surgically. CT images and surgery reports were reviewed and compared for surgical cases.

Results: Twelve dogs were included. Eight were managed surgically, three were managed medically and one died before management. Pleural fluid was present in all dogs on CT (n=12) and at surgery (n=8). Pleural gas was identified in five dogs on CT. Pleural thickening was detected in eight dogs on CT (seven visceral, one parietal and six mediastinal) and eight dogs at surgery (seven visceral, eight parietal and six mediastinal), six of which were identified by CT. Abnormal pulmonary parenchyma was detected in 10 dogs on CT and 5 dogs at surgery, all of which were identified by CT. Mediastinal involvement was detected in 10 dogs on CT and 6 dogs at surgery, 5 of which were identified by CT.

Conclusions: CT and surgical findings are similar in most cases of canine spontaneous pyothorax. CT may be a useful diagnostic tool for guiding case management.

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INTRODUCTION

Pyothorax is a septic inflammation of the pleural space. Canine spontaneous pyothorax, defined as pyothorax in the absence of an external thoracic wound, is a relatively uncommon condition and the underlying aetiology is poorly understood (Hawkins and Fossum 2009). Inhalation and migration of plant material in working dogs have been postulated as a possible cause (Frendin 1997); however, this theory has been disputed due to the lack of foreign material recovered from the majority of reported cases (Robertson and others 1983, Piek and Robben 2000, Demetriou and others 2002, Mellanby and others 2002, Rooney and Monnet 2002, Boothe and others 2010). Oesophageal perforation, necrotic pulmonary neoplasia and focal or haematogenous spread are also potential sources of bacterial contamination. Definitive diagnosis is based on cytological evaluation and bacteriological culture of pleural fluid.

The appropriate management of canine pyothorax is widely debated. Medical management options include single, unilateral needle thoracocentesis (Robertson and others 1983, Johnson and Martin 2007) and unilateral or bilateral indwelling thoracostomy tubes with intermittent or continuous (Turner and Breznock 1988) suction and thoracic lavage (Piek and Robben 2000) in combination with systemic antibiotic therapy and supportive care. Surgical management involves resection of affected tissues and thorough pleural space lavage via thoracotomy, followed by placement of thoracostomy tubes, systemic antibiotic therapy and supportive care (Rooney and Monnet 2002). The outcomes reported for these options are variable and broadly comparable, such that it is not possible to recommend one option over another on the basis of the available evidence.

Prompt instigation of an appropriate management protocol maximises the potential for a successful outcome. The presence of an underlying lesion, such as a parenchymal abscess or foreign body, on initial diagnostic imaging, a poor response to medical management after several days or the presence of a granular effusion suggestive of *Actinomyces* have been proposed as indicators for early surgical intervention (Rooney and Monnet 2002, Boothe and others 2010). Consequently, diagnostic imaging on initial presentation plays an important role in guiding case management. Thoracic radiography and ultrasonography have been used widely in this manner (Reichle and Wisner 2000, Demetriou and others 2002, Johnson and Martin 2007, Boothe and others 2010). However, the presence of residual pleural fluid following thoracocentesis often obscures thoracic structures and limits the use of radiography.

More advanced imaging modalities, such as computed tomography (CT), have been used in the diagnosis and management of human empyema. When compared to radiography and ultrasonography, CT can provide more accurate information regarding the extent and nature of thoracic pathology (Burk 1991, Prather and others 2005). CT evaluation of the normal (Smallwood and George 1993, De Rycke and others 2005) and diseased (Burk 1991, Johnson and others 2004, Prather and others 2005, Au and others 2006, Scherrer and others 2008, Joly and others 2009, Otoni and others 2010) canine thorax has been reported; however, the use of CT in canine pyothorax has not yet been described.

The aims of this study were to describe the CT findings in 12 dogs with canine spontaneous pyothorax and to correlate these findings with the surgical findings at exploratory thoracotomy in the 8 dogs managed surgically, in order to assess the utility of CT in guiding appropriate management.

MATERIALS AND METHODS

The medical records, CT images and surgery reports from dogs with spontaneous pyothorax, presenting between January 2003 and January 2010, were reviewed retrospectively. Criteria for inclusion were use of thoracic CT as part of the initial investigation and either pleural fluid or tissue analysis positive for any of the following: intracellular bacteria identified on pleural fluid cytology, bacterial growth on culture or pyogranulomatous inflammation identified on histopathology. Cases with a history of surgery or trauma to the thoracic cavity were excluded.

Animals were sedated (n=3) or anaesthetised (n=9) and positioned in sternal recumbency for the CT scan. CT scans were performed using a Picker PQ5000 single slice spiral CT scanner (Universal Medical Systems, OH, USA) (cases 1 to 9), GE Lightspeed 16 slice spiral scanner (case 10) or Philips MX8000IDT 16 slice spiral scanner (cases 11 and 12). Postcontrast scans were performed after manual intravenous administration of 600 mg iodine/kg iohexol (Omnipaque, GE, Buckinghamshire, UK; 300 mg iodine/mL). Images were acquired in the transverse plane and reformatted for dorsal and sagittal planes.

Management of individual cases was determined by the attending clinician. Medical management consisted of unilateral or bilateral intermittent thoracic drainage via indwelling chest drains and systemic antibiotic therapy. Empirical therapy most frequently comprised 20 mg/kg intravenous potentiated amoxicillin-clavulanic acid (Augmentin; GlaxoSmithKline, Middlesex, UK) every 8 hours and 10 mg/kg metronidazole (Metronidazole intravenous infusion; Baxter, Norfolk, UK) every 12 hours, with adjustments made when pleural fluid culture and sensitivity results became available. Surgical management consisted of resection of abnormal tissues and thoracic lavage via a median sternotomy, with postoperative management as described for the cases managed medically.

Information collected from the medical records included age, breed, gender, management type and histopathology results. CT images were reviewed digitally on a computer work station (Image viewer, Visbion, Surrey, UK) by a board certified radiologist, blinded to all previous reports, for the presence of pleural fluid and gas, pleural thickening, pulmonary parenchymal abnormalities and mediastinal involvement (to include pleuritis, fluid accumulation or lymphadenopathy). Pleural fluid volume was graded subjectively as small, moderate or large. The extent of the abnormalities and a proposed underlying aetiology were also stated based on the CT findings. Surgery reports were reviewed by the author and surgical findings and procedures performed were recorded. Finally, CT and surgical findings were compared for the eight surgical cases.

RESULTS

Thirty-four dogs with spontaneous pyothorax were presented during the study period. In 22 cases, of which 13 were managed surgically and 9 were managed medically, a CT scan was not performed. Twelve dogs met the inclusion criteria during the study period (Table 1). Age at presentation ranged from 9 months to 8 years 4 months. Seven males (four entire and three neutered) and five females (three entire and two neutered) were included. Breeds represented were Labrador retriever (4), English springer spaniel (2), bassett hound (1), Neopolitan mastiff (1), lurcher (1), German shepherd (1), Hungarian vizla (1) and bichon frise (1).

All dogs underwent a plain CT scan and 10 underwent a postcontrast scan. Eight cases were managed surgically, three cases were managed medically and one case suffered a cardiopulmonary arrest immediately after CT, whilst under general anaesthesia.

Pleural fluid

Pleural fluid (Fig 1) was present in all 12 cases on CT and volume was graded as small (n=6), moderate (n=4) or large (n=2). Pleural fluid was present bilaterally in all 12 cases and the distribution between hemithoraces was asymmetric in 6 cases. Of these six cases, two of the four managed surgically had a pathological lesion detected at surgery in the hemithorax with the larger volume of fluid.

At surgery pleural fluid was present in all eight cases and volume was graded as small (n=0), moderate (n=2), large (n=1) or unstated (n=5). Distribution was bilateral in four cases, unilateral in three cases and unstated in one case. CT correctly identified the presence (8/8 cases) and stated volume (3/3 cases) of pleural fluid noted at surgery in all cases.

Pleural gas

Gas within the pleural space (Fig 2) was identified in 5 of 12 dogs on CT. The gas was present unilaterally in one case and bilaterally in four cases, of which two had an asymmetric distribution. All five cases with pleural gas had ipsilateral thoracocentesis or chest

Table 1. Case details, CT and surgical findings and overview of management

Case	Sig.	Postcontrast CT?	Pleural fluid		Pleural gas		Pleural thickening		Pulmonary parenchymal abnormality		Mediastinal involvement		Proposed cause		Case management
			CT	Sx	CT	Sx	CT	Sx	CT	Sx	CT	Sx	CT	Sx	
1	1y5m ME bassett hound	No	Small Bilat L>R	-	None	-	V	-	Single focus Lcau 3 cm	-	Fluid	-	Ab	-	Medical (antibiotic)
2	8y4m FN Labrador	No	Small Bilat R>L	-	Uni(R)	-	None	-	None	-	None	-	NU	-	Medical (bilat TT, antibiotic)
3	4y4m ME Neopol. mastiff	Yes	Large Bilat R=L	-	None	-	None	-	None	-	Fluid	-	NU	-	CPA before treatment
4	6y1m ME lurcher	Yes	Mod Bilat R>L	Mod Unilat	None	-	M	M V P	Single focus Acc 1 cm	Single focus Rcau/acc	Fluid Pleura	Pleura	Ab	GP	Surgical (Rcau/acc lobectomy)
5	3y0m ME springer spaniel	Yes	Small Bilat R>L	US Unilat	None	-	M V	M V P	Multiple foci Lcau/Lcr/ Rmid	Single focus Lcau	Pleura	Pleura	FB	FB	Surgical (Lcau lobectomy, FB present)
6	7y6m MN Labrador	Yes	Large Bilat R=L	Large Bilat	Bilat	-	None	M V P	Single focus Lcau 1.8 cm	None	None	Pleura	Ab	GP	Surgical (partial Rmid lobectomy)
7	9m FE GSD	Yes	Small Bilat R>L	US Bilat	None	-	None	P	Single focus Acc	Single focus Acc/Rcau	LN	None	GP	FB	Surgical (Rcau/acc lobectomy)
8	3y7m FE Labrador	Yes	Mod Bilat R=L	-	Bilat	-	V	-	Multiple foci Lcau/Rcau/ Rcr	-	LN	-	FB	-	Medical (bilat TT, antibiotic)
9	4y0m MN H. vizla	Yes	Mod Bilat R=L	Mod Bilat	None	-	M V	M V P	Multiple foci Rcr/Lcau/ Rcau/acc	None	Fluid Pleura LN	Pleura	GP	GP	Surgical (Rcrlobectomy)
10	1y1m FE springer spaniel	Yes	Mod Bilat L>R	US Unilat	None	-	M V	M V P	Single focus Rcau 0·8 cm	Single focus Rcau	Pleura	Pleura	GP	GP	Surgical (Rcau lobectomy)
11	4y6m FN Labrador	Yes	Small Bilat R=L	US Bilat	Bilat	-	M V	M V P	Multiple foci Rmid/Lcr/ Lcau/Acc	None	Pleura LN	Pleura LN	FB	Ab	Surgical (mediastinal resection)
12	2y0m MN bichon frise	Yes	Small Bilat R=L	US US	Bilat	-	M V P	V P	Multiple foci Lcr/Lcau	Single focus Lcr	Pleura LN	None	GP	GP	Surgical (Lcrlobectomy)

Ab Abscess, Acc Accessory lung lobe, CT Computed tomography, FB Foreign body, FE Female entire, FN Female neutered, GP Generalised pleuritis, GSD German shepherd dog, L Left, Lcr Left cranial lung lobe, Lcau Left caudal lung lobe, LN Lymphadenopathy, M Mediastinal pleura, ME Male entire, MN Male neutered, mod Moderate, NU No underlying disease, p Parietal pleura, R Right, Rcau Right caudal lung lobe, Rcr Right cranial lung lobe, Rmid Right middle lung lobe Sig Signalment, Sx Surgery, TT Thoracostomy tube, US Unstated, V Visceral pleura, CPA Cardiopulmonary arrest

drain placement before CT examination. The presence of pleural gas could not be assessed surgically.

Pleural involvement

CT identified pleural thickening (Fig 3) in 8 of 12 dogs, representing seven cases of visceral, one case of parietal and six cases of mediastinal pleural thickening.

At surgery, pleural thickening was detected in all eight cases representing seven cases of visceral, eight cases of parietal and six cases of mediastinal pleural thickening. Six of eight cases of pleural thickening detected surgically were identified by CT. Of the eight cases with pleural thickening identified on CT, six were managed surgically and all of these were found to have pleural thickening at surgery. Thickening of specific pleurae was detected by both CT and surgery in five of seven visceral cases, five of seven mediastinal cases and one of eight parietal cases.

Pulmonary parenchymal abnormalities

Abnormalities of the pulmonary parenchyma (Fig 4), defined as one or more focal soft tissue densities, were identified on CT in 10 of 12 dogs. Parenchymal abnormalities were detected on the precontrast scan in all 10 dogs and the postcontrast scan in 9 of these dogs that received contrast. The abnormality consisted of a single focus in five cases and multiple foci in five cases. Abnormalities were detected in the right cranial lung lobe in two dogs, the right middle lung lobe in three dogs, the right caudal lung lobe in three dogs, the accessory lung lobe in four dogs, the left cranial lung lobe in four dogs and the left caudal lung lobe in seven dogs.

Parenchymal abnormalities were detected in five of eight surgical cases, all of which were a single focus. The location of the single focus detected surgically in all five of these cases was correctly identified by CT. Of the eight surgical cases, CT identified

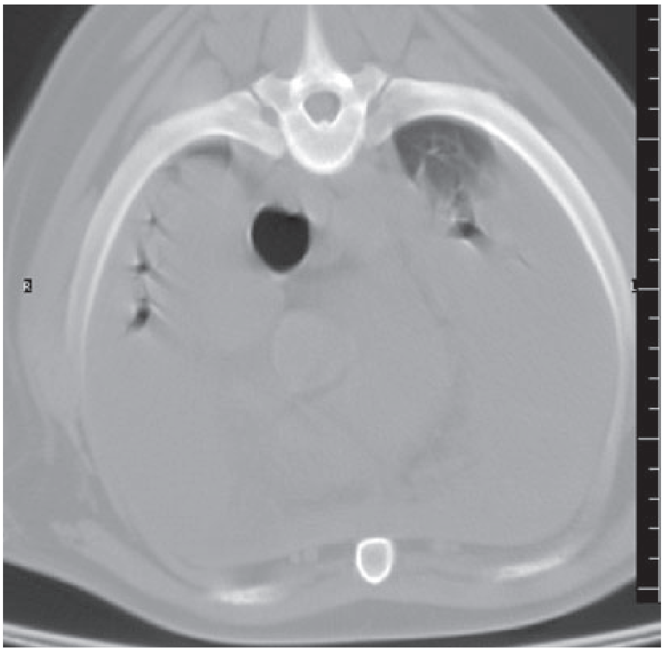

FIG 1. Precontrast transverse computed tomographic image (window width 2000 HU, window level –200 HU) at the level of the heart-base demonstrating large volume bilateral pleural effusion (Case 3)

extra lesions not reported at surgery in seven cases and surgery detected extra lesions not reported on CT in one case.

Mediastinal involvement

Mediastinal involvement (Fig 5) was identified on CT in 10 of 12 dogs, including six cases of mediastinal pleuritis, five cases of lymphadenopathy and four cases with mediastinal fluid present.

Six of eight surgical cases had mediastinal involvement, including six cases of mediastinal pleuritis, one case of lymphadenopathy and no cases of mediastinal fluid. CT correctly identified mediastinal involvement present at surgery in five of six cases. Of the eight surgical cases, CT identified mediastinal involvement not reported at surgery in two cases and surgery detected mediastinal involvement not reported on CT in one case. Both CT and surgery detected mediastinal pleuritis in five of seven cases, lymphadenopathy in one of four cases and mediastinal fluid in zero of two cases.

Proposed aetiology

On the basis of CT evaluation, no evident underlying cause was found in two cases, chronic and generalised pleuritis was suspected in four cases and a focal lesion was suspected in six cases (solitary abscess in three cases and migrating foreign body in three cases).

Surgical and histopathological findings combined concluded that five cases had evidence of chronic, generalised pleuritis and three cases had evidence of a focal lesion (solitary abscess in one case and migrating foreign body in two cases). Foreign material, consistent with a black thorn, was recovered from one dog at surgery.

Of the eight surgical cases, CT correctly predicted the extent of the pathological changes in five cases (generalised process in

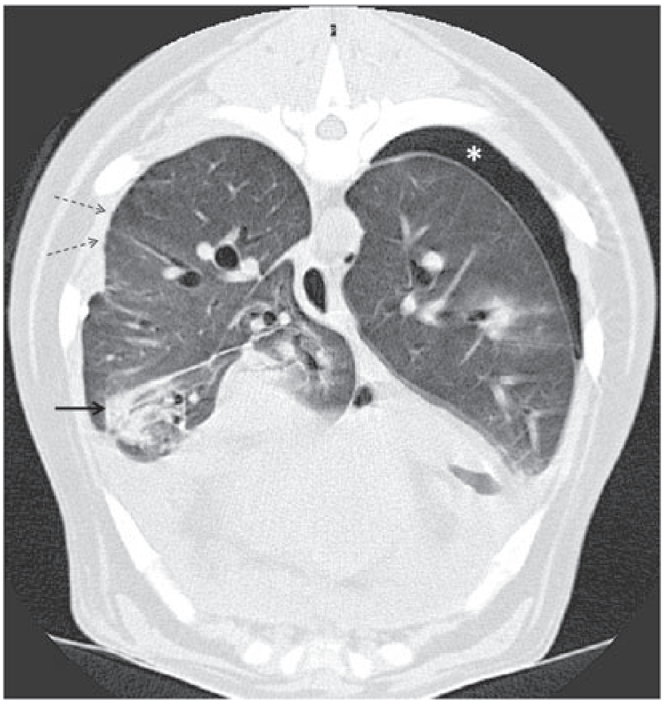

FIG 2. Precontrast transverse computed tomographic image (window width 1600 HU, window level –599 HU) at the level of the accessory lobe demonstrating unilateral small pneumothorax (asterisk). In addition, pulmonary parenchymal infiltrates can be seen in the right caudal lobe (black arrow) and there is visceral pleural thickening (dotted arrows) and a small volume of pleural fluid (Case 11)

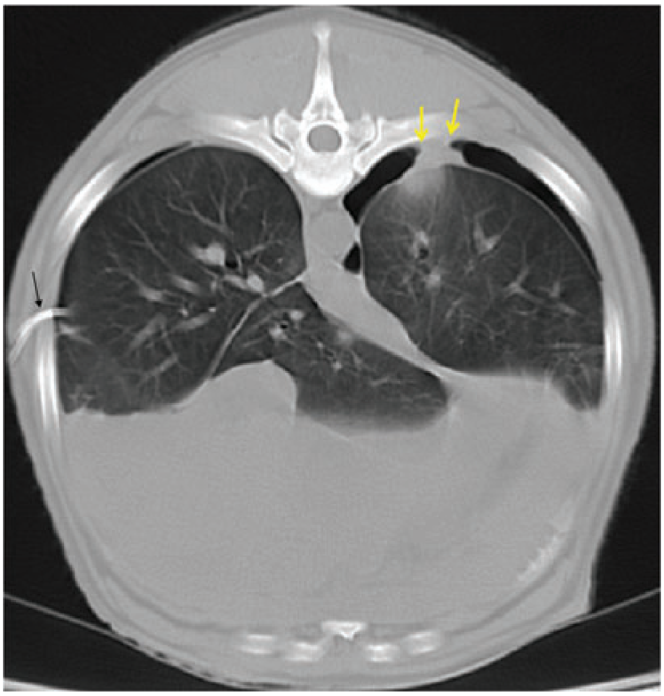

FIG 3. Precontrast transverse computed tomographic image (window width 2000 HU, window level –299 HU) at the level of the accessory lobe demonstrating pleural adhesion dorsally in the left hemithorax (yellow arrows). Adjacent to the adhesion is a poorly defined soft tissue attenuating lesion which represents pulmonary involvement and could be seen on contiguous slices. There is a small pneumothorax, worse on the left than the right, moderate pleural effusion and a chest drain can be seen passing through the intercostal space on the right (black arrow) (Case 8)

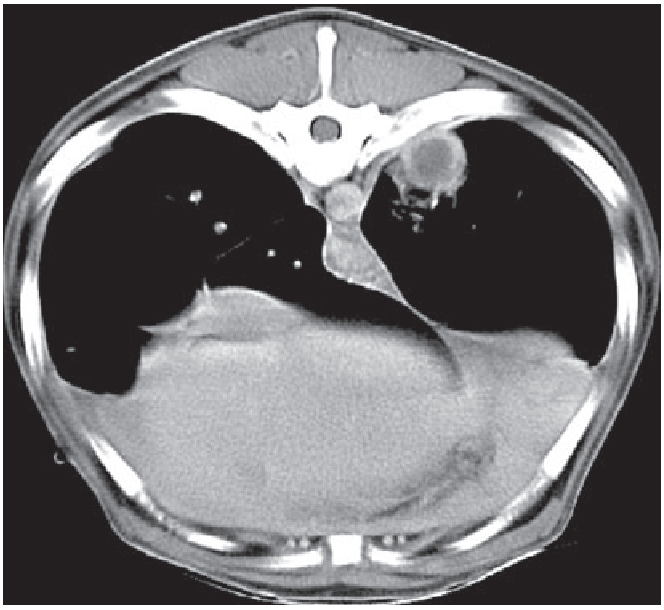

FIG 4. Postcontrast transverse computed tomographic image (window width 350 HU, window level 50 HU) at the level of the accessory lobe demonstrating a peripherally enhancing, focal parenchymal abnormality in the left caudal lobe with associated pleural thickening. A pulmonary abscess was confirmed surgically. There is a small volume of pleural fluid (Case 5)

FIG 5. Postcontrast transverse computed tomographic image (window width 300 HU, window level 50 HU) at the level of the second sternebra demonstrating sternal lymphadenopathy (yellow arrows). There is some swirling, enhancing material in the ventral thorax consistent with inflammation of the mediastinal pleura (asterisk) (Case 11)

three of five cases and a focal process in two of three cases) and the correct underlying cause in four cases (chronic pleuritis in three cases and a migrating foreign body in one case).

DISCUSSION

The results of this study provide a guide to the CT findings that can be expected in canine pyothorax, an assessment of how these compare to the surgical findings and enable the utility of CT in the management of these cases to be assessed.

Bilateral pleural fluid evident on CT in all cases is comparable to the previously reported high incidence of bilateral effusion in canine pyothorax using radiography and ultrasonography (Piek and Robben 2000, Demetriou and others 2002, Johnson and Martin 2007, Boothe and others 2010). The lower incidence of bilateral effusion reported at surgery may be explained by the lack of detail recorded in surgical reports. CT correctly identified the presence and volume (if stated) of pleural fluid in all eight surgical cases and therefore can be used to reliably predict the presence of fluid. However, asymmetric fluid distribution on CT correlated with lesion location at surgery in only two of four cases; hence, pleural fluid distribution on CT may not reliably predict lesion location.

Pleural gas presence could always be explained by pre-CT thoracocentesis or chest drain placement ipsilaterally. Pleural gas was not present in any case which did not undergo preimaging thoracocentesis, confirming the presence of gas as iatrogenic rather than secondary to the pyothorax or its aetiology.

Thickening of the pleura was present on CT in the majority of cases with visceral and mediastinal thickening being the most common and parietal thickening being the least common. If CT identified any form of pleural thickening, then it was always present at surgery. However, CT did not identify pleural thickening in two of eight cases where it was detected at surgery and therefore CT does not identify the presence of pleural thickening reliably in every case. The agreement between CT and surgical findings was higher for visceral and mediastinal pleura than it was for parietal pleura.

Pulmonary parenchymal abnormalities were identified by CT in the majority of dogs. All lung lobes were variably involved with the left caudal lung lobe being involved most commonly, as has been previously reported (Rooney and Monnet 2002). If a single focal lesion was present at surgery, CT correctly identified the location of the lesion in all cases and may be reliably used to guide the surgeon to the location of pathology. CT also detected lesions which were not reported at surgery in seven cases. These lesions consisted of one or more focal soft tissue densities and were 1 cm or greater in diameter in three cases. It is difficult to determine the significance of these lesions. They might not have been detected at surgery due to a deep parenchymal position or may have been observed but deemed insignificant and therefore not recorded. Preoperative CT can be used to identify lesions that may otherwise go undetected at surgery and their significance can then be determined. In one case, a tract through the right caudal lung lobe was detected at surgery but not reported on CT. This suggests that a median sternotomy and thorough exploration of the thoracic cavity should be performed in all surgical cases, rather than relying on CT findings to guide a more localised approach. All cases of parenchymal abnormality were identified on precontrast CT but were enhanced following contrast administration, supporting the use of contrast to further characterise lesions.

Mediastinal involvement was commonly identified on CT. CT identified mediastinal involvement present at surgery in most cases. The agreement between CT and surgical findings was higher for mediastinal thickening than it was for lymphadenopathy and mediastinal fluid. All cases of lymphadenopathy were identified on precontrast CT but were better characterised following the administration of contrast.

CT correctly predicted the extent of the pathological changes in five of eight cases. CT predicted generalised disease when focal disease was found at surgery in one case and focal disease when generalised disease was found at surgery in two cases. As focal disease is an indicator for early surgical intervention, the error in categorising these three cases is potentially of significance. CT correctly predicted the underlying cause in four of eight cases. No underlying cause was detected on CT in two cases and as these were managed medically it was not possible to identify any lesions missed by CT. Foreign material was recovered in one of eight surgical cases and this incidence is comparable to previous reports (Frendin 1997, Piek and Robben 2000, Demetriou and others 2002, Mellanby and others 2002, Rooney and Monnet 2002).

Limitations of the study include its retrospective nature. This made objective interpretation of clinical data difficult and resulted in differences between cases including type of CT scanner used, use of contrast, timing between CT and surgery and extent of tissue analysed histologically. It was not possible to determine the attending clinician's criteria for opting for CT or radiography and medical or surgical management. The three cases managed medically were influenced by financial constraints and early response to medical management but it is not possible to determine the impact that the CT findings had on case management. Only the eight cases managed surgically could be used to compare CT and surgical findings; however, the four cases managed medically were included in the study as the CT findings of 12 cases are more informative than those of 8 cases. The small sample size prohibited statistical analysis of the data. A prospective study with more animals, objective assessment of CT and surgical findings and case follow-up is required in order to define CT criteria which can be used to guide the appropriate management of canine pyothorax.

In conclusion, CT findings are similar to surgical findings in most cases of canine spontaneous pyothorax. Consequently, CT may be a useful diagnostic tool for evaluating the nature and extent of the intra-thoracic pathological changes and guiding the management of these cases. Preoperative CT may identify lesions that would otherwise not be detected at surgery, aiding selection of the most appropriate surgical technique, but not eliminating the necessity to explore the entire thorax.

Conflict of interest

None of the authors of this article has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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