

Pyothorax in cats and dogs

Pyothorax bij de kat en de hond

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A BSTRACT

Pyothorax, or thoracic empyema, is an infection of the pleural space, characterized by the accumulation of purulent exudate. It is a life-threatening emergency in dogs as well as in cats, with a guarded prognosis. Dyspnea and/or tachypnea, anorexia and lethargy are the most typical clinical signs. Diagnosis is usually straightforward, based on the clinical symptoms combined with pleural fluid analysis, including cytology and bacterial culture. Most commonly, oropharyngeal flora is isolated in the pleural fluid. Treatment can be medical or surgical, but needs to be immediate and aggressive. In this article, an overview of the various causes of both feline and canine pyothorax with its similarities and differences is provided. Epidemiology, symptoms, diagnosis, treatment and prognosis are discussed.

SAMENVATTING

Pyothorax, of thoraxempyem, is een infectie van de pleurale holte, gekenmerkt door een accumulatie van purulent exudaat. Het is een levensbedreigende aandoening, zowel bij honden als bij katten, met een gereserveerde prognose. Dyspnee en/of tachypnee, anorexie en lethargie zijn de meest voorkomende symptomen. De diagnose is meestal gemakkelijk te stellen aan de hand van de klinische symptomen en onderzoek van het pleurale vocht, inclusief een cytologisch en bacteriologisch onderzoek. Meestal wordt orofaryngeale flora geïsoleerd in de pleurale effusie. De behandeling kan zowel medicamenteus als chirurgisch zijn, maar moet snel en agressief ingesteld worden. In dit artikel wordt een overzicht gegeven van de meest voorkomende oorzaken van zowel feliene als caniene pyothorax, waarbij gelijkenissen en verschillen worden besproken. Epidemiologie, klinische symptomen, diagnose, behandeling en prognose komen uitgebreid aan bod.

INTRODUCTION

In dogs as well as in cats, pyothorax can be a life-threatening disease. It is defined as the presence of septic exudate in the pleural space (Ettinger and Feldman, 2010). Patients with pyothorax are usually presented with dyspnea and/or tachypnea and it might be difficult to determine the underlying cause straight away (Murphy and Pappasoulitis, 2011a; Firth and Boag, 2012; Epstein, 2014). In general, the first step in dealing with dyspneic patients consists of providing a stress-free environment with sufficient oxygenation to maximize the breathing comfort of the animal. The clinical examination may have to be postponed, but a close inspection of the breathing pat-

tern will help in the initial localization of the problem (Beatty and Barrs, 2010; Murphy and Pappasoulitis, 2011a; Sigrist et al., 2011; Firth and Boag, 2012). On auscultation, pleural space disease is characterized by muffled heart and lung sounds. In case of pleural effusion, auscultation will be muffled ventrally, often in combination with increased lung sounds dorsally. The presence of air (pneumothorax) decreases dorsal lung sounds (Murphy and Pappasoulitis, 2011a; Firth and Boag, 2012; Epstein, 2014). After initial stabilization, appropriate measures should be taken to relieve the discomfort of the animal. In many cases, immediate thoracocentesis is necessary (Beatty and Barrs, 2010; Firth and Boag, 2012). This may be therapeutic as well as diagnostic, because pleural fluid provides im-

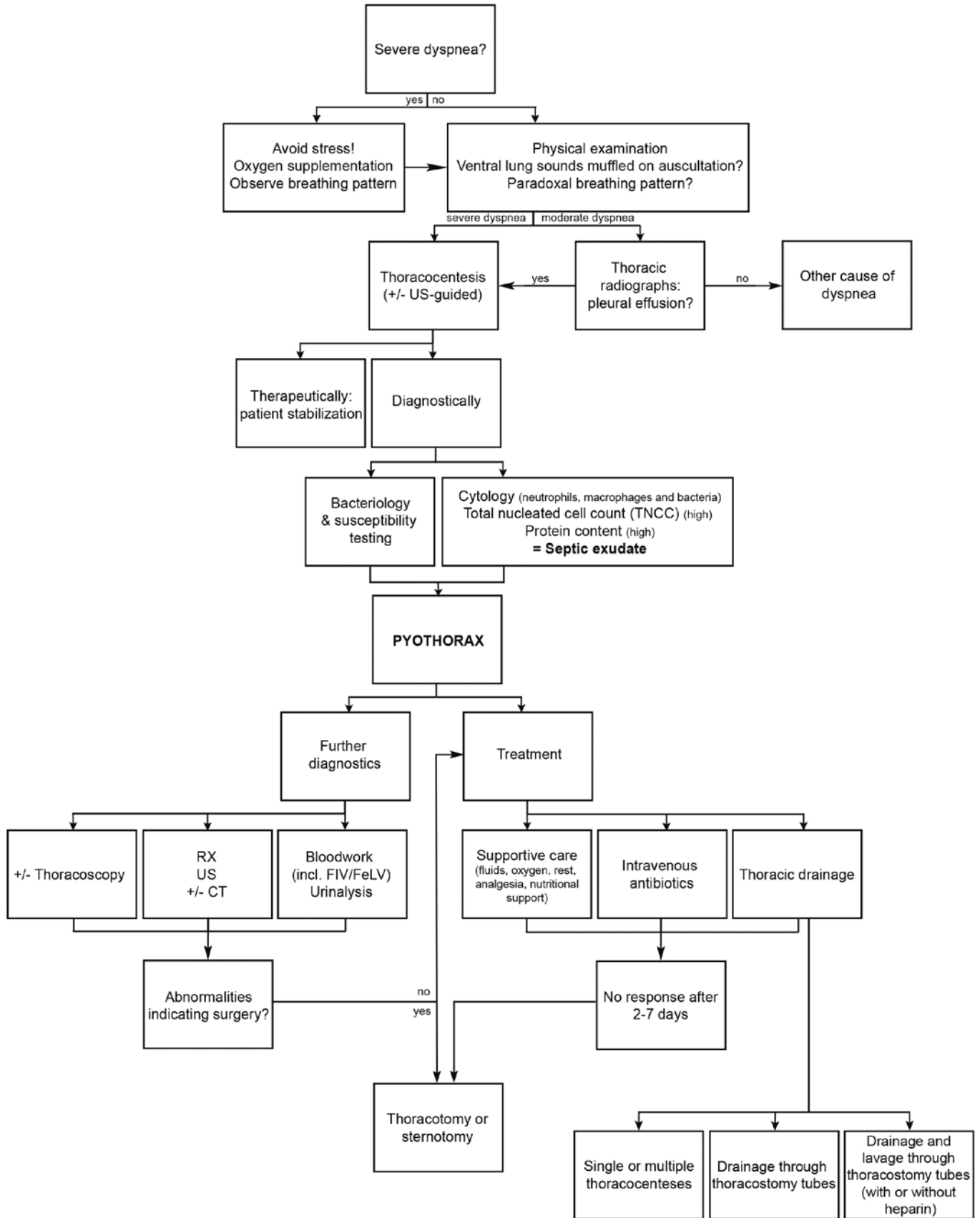


Figure 1. Flow chart for diagnostic and therapeutic management of pyothorax in dogs and cats.

portant information concerning the underlying cause (Murphy and Pappasoulitis, 2011a; Epstein, 2014).

Although the diagnosis of pleural space disease and pleural effusion is usually straightforward, long-term treatment may be more challenging and depends largely on the nature of the effusion (Murphy and Pappasoulitis, 2011a; Epstein, 2014). In case of pyothorax, pleural effusion is characterized by a septic exudate and medical management should at least consist of supportive care, systemic antibiotic therapy and drainage of the pleural fluid, which can be achieved through single or multiple thoracocenteses or through placement of thoracic drains, with or without thoracic lavage. Surgical management through thoracic surgery or thoracoscopy may be necessary in selected cases (Rooney and Monnet, 2002; Swinbourne et al., 2011). In this review, the general approach of pyothorax in clinical practice is focussed upon (Figure 1). The basic epidemiology and pathophysiology are briefly explained to better understand clinical signs and diagnostic measures, and different treatment options are discussed to aid the clinician in making the best therapeutic choices for each patient individually.

EPIDEMIOLOGY

Pyothorax is most frequently seen in middle-aged dogs and cats with a mean age of three to six years (Demetriou et al., 2002; Waddell et al., 2002; Barrs et al., 2005; Boothe et al., 2010). In some studies, outdoor male dogs and cats were more frequently affected, probably because young, male animals have a greater likelihood to roam and fight, and therefore obtain penetrating injuries more easily (Demetriou et al., 2002; Waddell et al., 2002; Malik et al., 2006; Boothe et al., 2010). There is no clear data available concerning the actual incidence of pyothorax in dogs or in cats. Potential underlying causes include penetrating trauma or bite wounds, migrating foreign bodies, parasites, neoplasia, hematogenous spread of extra-thoracic or intra-thoracic infections and iatrogenic causes, e.g. thoracic surgery, thoracocentesis (Demetriou et al., 2002; Waddell et al., 2002; Barrs et al., 2005; Klainbart et al., 2005; Malik et al., 2006; Doyle et al., 2009; Boothe et al., 2010; Ettinger and Feldman, 2010).

In dogs, pyothorax is not frequently encountered (Piek and Robben, 2000; Rooney and Monnet, 2002; Johnson and Martin, 2007). The cause of pyothorax is only found in 2 to 19% of canine cases. The most common cause is the migration of foreign bodies. In 40% of dogs with pyothorax that were managed surgically, a foreign body, e.g. grass awn, was the underlying cause (Demetriou et al., 2002). The incidence and type of foreign bodies vary depending on the local geographical flora (Piek and Robben, 2000). English Springer spaniels, Border collies, Labrador retrievers and their crosses are overrepresented due to their large airways, scenting habits, outdoor nature and thus

frequent exposure to plant material (Demetriou et al., 2002; Johnson and Martin, 2007; Doyle et al., 2009).

Pyothorax is more frequently seen in cats than in dogs (Waddell et al., 2002; Barrs et al., 2005). A definitive cause is found in 35 to 67% of feline cases. The most common route of infection is thought to be through penetrating bite wounds and abscesses that rupture towards the thoracic cavity, causing bacterial contamination and ultimately pyothorax. Data supporting this hypothesis include a history of wounds in 14 to 40% of cases (Jonas, 1983; Waddell et al., 2002), a seasonal association with more cases in late summer and fall due to increases in fighting behavior (Waddell et al., 2002; MacPhail, 2007) and the isolation of similar bacteria in pyothorax as in bite wound abscesses (Waddell et al., 2002). Increased neutering, confinement and routine treatment with antibiotics after a catfight seem to reduce the incidence of pyothorax (Barrs and Beatty, 2009a). Cats affected by pyothorax are predominantly young outdoor cats from multi-cat households, probably because there is more inter-cat aggression (Waddell et al., 2002). However, these cats also have a greater exposure to upper respiratory tract infections, which is a predisposing event in up to 26% of the feline pyothorax cases. In more recent studies, it has been suggested that aspiration of oropharyngeal flora with parapneumonic spread might be a more frequent cause of pyothorax than bite wounds (Waddell et al., 2002; Barrs et al., 2005; Barrs and Beatty, 2009a).

PATHOGENESIS AND CLINICAL SIGNS

The pleural space and pathophysiology of pleural effusion

The pleural space is a potential space, lined by the visceral and parietal pleura. These serous membranes cover the outer surface of the lungs and inner surface of the thoracic cavity, dividing the pleural space into a left and a right hemithorax, separated by the mediastinum. A thin layer of glycoprotein-rich fluid separates the pleura and allows the different intrathoracic structures to slide freely during respiration (Ettinger and Feldman, 2010). The pleural space of normal cats and dogs contains 0.1 and 0.3 mL/kg of fluid respectively (Epstein, 2014). The production and absorption of this fluid represent a continuous process controlled by Starling's forces. Hydrostatic pressure forces fluid out of the vasculature, while oncotic pressure maintains fluid within the vasculature. Any process that disrupts capillary or interstitial hydrostatic or oncotic pressures, lymphatic drainage or vessel integrity may result in fluid accumulation (Ettinger and Feldman, 2010). The presence of 30 mL/kg of pleural effusion is assumed to cause mild breathing discomfort, while volumes up to 60 mL/kg result in severe dyspnea (Beatty and Barrs, 2010).

Pathogenesis and bacteria associated with feline and canine pyothorax

Bacteria may enter the pleural space through compromised lung parenchyma, bronchi, esophagus or thoracic wall (Light, 2001; MacPhail, 2007). When the pleural space is faced with an infectious organism, it responds with edema and exudation of fluid, proteins and neutrophils into the pleural space. Mesothelial cells then act as phagocytes and trigger an inflammatory response. This results in the release of chemokines, cytokines, oxidants and proteases. The rapidity and extent of progression depend on the type and virulence of the organism, the patient's host defences and the timing and effectiveness of antibiotic treatment. If initial effusion remains untreated, fibropurulent effusions or complex parapneumonic effusions develop. Fibrin is formed in the pleural fluid and results in the formation of adhesions and loculations. A complex parapneumonic effusion progresses to pyothorax when the concentration of leukocytes becomes sufficient to form pus, consisting of fibrin, cellular debris and viable or dead bacteria. If untreated, eventually, an organizing phase occurs with the influx of fibroblasts and the formation of dense fibrous adhesions (Light, 2001; Sevilla et al., 2009; Christie, 2010).

In general, it can be stated that bacteria isolated from canine and feline pyothorax are largely the same and most commonly consist of gram-negative, facultative anaerobic rods and/or obligate anaerobic bacteria, representing oropharyngeal flora (Walker et al., 2000; Demetriou et al., 2002). An important difference between both is the fact that isolated gram-negative, facultative anaerobic rods are predominantly non-enteric in origin in cats, e.g. *Pasteurella* spp., *Pseudomonas* spp., *Actinobacillus* spp., while they are mostly of enteric origin in dogs, e.g. *Escherichia* spp., *Enterobacter* spp., *Klebsiella* spp. (Love et al., 1982; Walker et al., 2000). A common mechanism of infection is the aspiration of oropharyngeal flora and the subsequent colonization of the lower respiratory tract (Piek and Robben, 2000; Barrs et al., 2005; MacPhail, 2007; Barrs and Beatty, 2009a). Oropharyngeal flora may also gain access to the pleural space by aspiration during dental procedures, migrating foreign bodies, e.g. grass awns, penetrating thoracic wounds, e.g. bite wounds, stick injury, hematogenous spread from a distant wound or extension from underlying pulmonary infection (Piek and Robben, 2000; Demetriou et al., 2002; Rooney and Monnet, 2002; Barrs et al., 2005; Doyle et al., 2005; Johnson and Martin, 2007; MacPhail, 2007; Barrs and Beatty, 2009a).

About 20% of feline pyothorax cases are caused by infectious agents other than oropharyngeal flora, including *Rhodococcus equi*, *Nocardia* spp., *Klebsiella* spp., *Proteus* spp. and *Pseudomonas* spp. (Walker et al., 2000; Demetriou et al., 2002; Barrs and Beatty, 2009a). There is no clear data available concerning the prevalence of pyothorax caused by non-

oropharyngeal flora in dogs.

Further, it should be mentioned that filamentous bacteria, e.g. *Nocardia* spp., *Actinomyces* spp., seem to be isolated from pyothorax more often in dogs than in cats (Walker et al., 2000; Sivacolundhu et al., 2001; Demetriou et al., 2002; Barrs et al., 2005). Isolation of *Nocardia* spp. has been reported in 12.5% of feline cases, while it was found in 19% of canine cases (Demetriou et al., 2002). *Actinomyces* spp. are identified in the pleural fluid of 10 to 15% of cats with pyothorax but are present in up to 49% of dogs with pyothorax, although *Actinomyces* spp. form part of the normal oropharyngeal flora in both species. The higher prevalence of *Actinomyces* spp. in canine pyothorax than in feline pyothorax might be explained by its association with grass awn migration in dogs (Sivacolundhu et al., 2001; Rooney and Monnet, 2002; Waddel et al., 2002; Barrs et al., 2005; Doyle et al., 2009).

Clinical signs and findings on physical examination

The duration of clinical signs prior to diagnosis is typically one to two weeks, but it may take months (Barrs and Beatty, 2009a). In dogs, the disease is thought to be chronic at the time of presentation, because of its insidious nature and vague clinical signs (Rooney and Monnet, 2002). Cats are usually presented even later, and by the time clinical signs of respiratory compromise become obvious, minimal respiratory reserve remains (Barrs and Beatty, 2009a).

Both in cats and in dogs, clinical signs include partial or complete anorexia and lethargy or weakness in 80% of cases, followed by dyspnea and/or tachypnea (Demetriou et al., 2002; Mellanby et al., 2002; Rooney and Monnet, 2002; Waddel et al., 2002; Barrs et al., 2005; Doyle et al., 2009; Boothe et al., 2010). The dyspnea of feline patients with pyothorax may be surprisingly subtle and is not noticed by 40% of the owners (Barrs et al., 2005). It is widely accepted that pleural effusion causes a restrictive pattern of respiration, characterized by an increase in respiratory rate and effort (MacPhail, 2007; Murphy and Papsouliotis, 2011a; Sigrist et al., 2011; Firth and Boag, 2012). However, a large study investigating breathing patterns of different causes of dyspnea, revealed that pleural space disease is typically associated with either an asynchronous (inspiration with inward movement of the abdominal wall combined with outward movement of the thoracic wall) or an inverse (inspiration with outward movement of the abdominal wall combined with inward movement of the thorax) breathing pattern (Sigrist et al., 2011). Cats typically adopt a crouched, sternally recumbent posture with abducted elbows and often show open-mouth breathing (Beatty and Barrs, 2010).

Pyrexia and/or exercise intolerance have been reported in almost half of canine cases, while only 28.6% of cats are presented with fever and hardly any

Table 1. Classification of pleural fluid based on total protein (TP) concentration, total nucleated cell count (TNCC) and cytology (Light, 2001; Beatty and Barrs, 2010; Ettinger and Feldman, 2010; Murphy and Pappasoulitis, 2011a; Nelson and Couto, 2014; Zoia and Drigo, 2015).

	TP (g/L)	TNCC (/μL)	Cytology	Common causes
Transudate	< 25	< 1 500	Macrophages, mesothelial cells, lymphocytes and non-degenerative neutrophils	Decreased oncotic pressure (e.g. liver disease, protein losing nephropathy, protein losing enteropathy), mildly increased hydrostatic pressure (e.g. right-sided heart failure, pericardial disease)
Modified transudate	25 - 75	1 000 – 7 000	Macrophages, mesothelial cells, lymphocytes and nondegenerative neutrophils	Increased hydrostatic pressure (e.g. right-sided heart failure, pericardial disease), chronic lymphatic obstruction (e.g. neoplasia, diaphragmatic herniation)
Exudate	> 30	> 7 000		Increased vascular permeability
(1) Nonseptic			1. Nondegenerative neutrophils, eosinophils, lymphocytes and macrophages	1. Feline infectious peritonitis (FIP), neoplasia, lung lobe torsion
(2) Septic			2. Degenerative neutrophils, intracellular/extracellular bacteria and macrophages	2. Bacterial pneumonia, penetrating thoracic or esophageal wounds, migrating foreign bodies
Chylous effusion	> 25	< 10 000	Small lymphocytes, nondegenerative neutrophils and macrophages	Leakage from thoracic duct (e.g. neoplasia, idiopathic, congenital, traumatic, pericardial disease, cardiac disease, dirofilariosis, lung lobe torsion)
Hemorrhagic effusion	> 30	< 10 000	Similar to peripheral blood	Hemorrhage (e.g. trauma, coagulopathy, neoplasia, lung lobe torsion)
Neoplastic effusion	> 25	Variable	Inflammatory and reactive mesothelial cells, neutrophils, macrophages and possibly neoplastic cells	Neoplasia of intrathoracical structures (e.g. mediastinal lymphoma, pulmonary carcinoma)

cat shows signs of exercise intolerance (Demetriou et al., 2002; Boothe et al., 2010). Because cats are mostly presented in a very late stage of disease, they are often in a poor body condition (Demetriou et al., 2002; Waddel et al., 2002; Barrs et al., 2005). Coughing has been reported in 14% to 30% of feline cases and up to 15% of cats with pyothorax have concurrent clinical signs of upper respiratory tract infection (oculonasal discharge and/or third eyelid prolapse) (Barrs et al., 2005). Pyothorax is the most common cause of sepsis in cats, and hypothermia, present in 15% of feline cases, should alert for sepsis, particularly when accompanied by bradycardia (Brady et al., 2000; Barrs and Beatty, 2009a). Nevertheless, the absence of bradycardia does not rule out sepsis or pyothorax, since in a study of Barrs et al. (2005), 20% of the cats had tachycardia, whereas bradycardia was not observed. Other clinical presentations occurring in a number of individual cats and dogs are submandibular abscesses, halitosis, cyanosis, lameness and pneumothorax (Demetriou et al., 2002).

On thoracic auscultation, respiratory sounds are

decreased to absent. This is more pronounced ventrally and may be asymmetrical (Beatty and Barrs, 2010; Murphy and Pappasoulitis, 2011a; Sigrist et al., 2011). Based on auscultation, the initial thoracocentesis should be performed on the side that is most affected (Beatty and Barrs, 2010). Pleural effusion may also create muffled heart sounds (Beatty and Barrs, 2010; Murphy and Pappasoulitis, 2011a). The combination of auscultation along with percussion may be helpful in the diagnostic work-up of pleural space disease. On percussion, the presence of free fluid results in a low-pitched resonance (Murphy and Pappasoulitis, 2011a).

DIAGNOSIS

The diagnostic approach of pyothorax is based on the clinical signs, thoracocentesis, the evaluation of the effusion and thoracic radiographs (MacPhail, 2007; Beatty and Barrs, 2010; Murphy and Pappasoulitis, 2011a). Other medical imaging studies, such

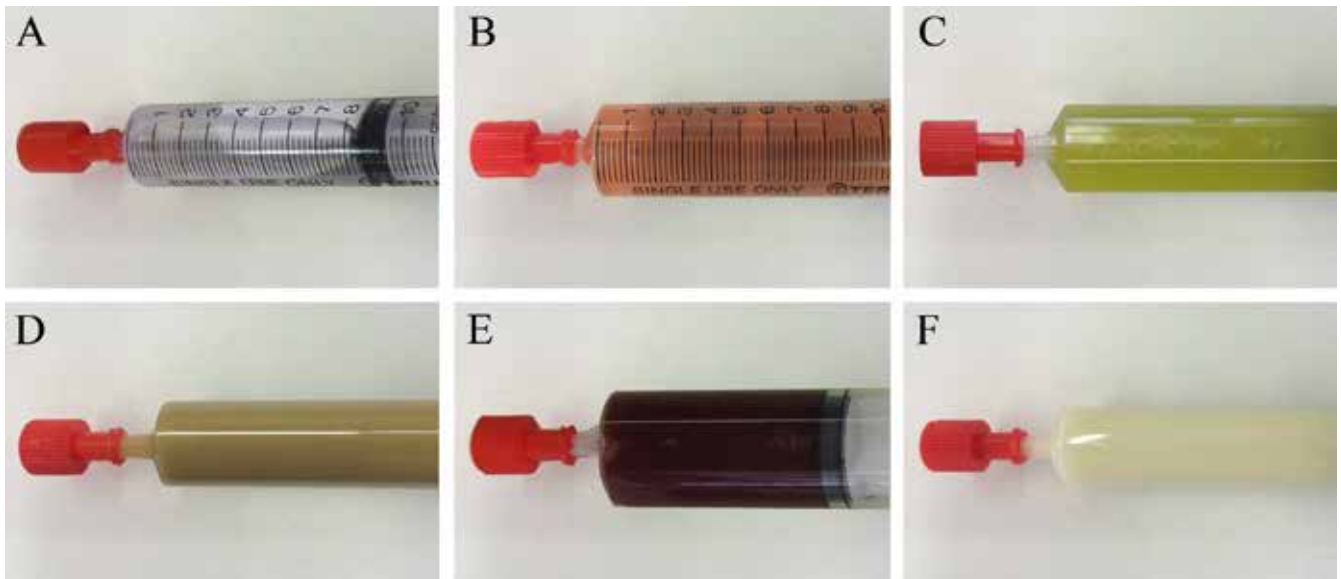


Figure 2. Macroscopic appearance of different types of effusion. A. Transudate secondary to protein losing enteropathy. B. Modified transudate caused by right-sided heart failure. C. Non-septic exudate caused by feline infectious peritonitis (FIP). D. Septic exudate from pyothorax. E. Hemothorax caused by mediastinal lymphoma. F. Idiopathic chylothorax.

as ultrasound (US) and computed tomography (CT), may be necessary to search for underlying causes. Complete blood count (CBC), serum biochemistry and urinalysis should form part of the minimum database to assess the general clinical condition of the patient and to guide the management. However, they are not crucial for the diagnosis itself (Beatty and Barrs, 2010). Cats should always be tested for feline immunodeficiency virus (FIV) and feline leukemia virus (FeLV) (Waddell et al., 2002; Malik et al., 2006; Barrs and Beatty, 2009a).

Pleural fluid evaluation

The examination of pleural fluid is fundamental in the diagnostic work-up of animals with pleural space disease. Pleural effusion is classically divided in different categories based on protein content, total nucleated cell count (TNCC) and appearance on cytology (Ettinger and Feldman, 2010; Nelson and Couto, 2014) (Table 1). However, in one study, it has been suggested that Light's classification of pleural fluid in human medicine would be superior in cats as well. This classification is based on lactate dehydrogenase concentration in the pleural fluid, pleural fluid/serum lactate dehydrogenase ratio and pleural fluid/serum total protein ratio and is thought to classify transudate, modified transudate and exudate more accurately than the classical categorization, but further studies are needed (Zoia and Drigo, 2015). Aerobic and anaerobic culture should always be included (Love et al., 1982; Beatty and Barrs, 2010; Murphy and Pappasoulis, 2011a). The fluid should be collected in ethylene diamine tetra-acetic (EDTA) tubes for cell count and cytology, while a sterile container should be used for culture. For reliable anaerobic culture results,

oxygen must be excluded from the transport specimen (Demetriou et al., 2002; Barrs and Beatty, 2009a).

In some cases, macroscopic evaluation may give a first indication towards the type of effusion (Figure 2). The purulent exudate in pyothorax is associated with a malodorous smell in up to 80% of cases (Piek and Robben, 2000; Waddell et al., 2002; Barrs et al., 2005; Barrs and Beatty, 2009a). The fluid is usually opaque and creamy, but it can also be pink, green tinged or serohemorrhagic. Flocculent particles are often present (MacPhail, 2007; Beatty and Barrs, 2010; Murphy and Pappasoulis, 2011a).

Cytological examination generally shows a large population of predominantly degenerate neutrophils, polymorphic inflammatory cells, a small proportion of mononuclear cells and large numbers of pleomorphic, intracellular and/or extracellular bacteria (Demetriou et al., 2002; Barrs et al., 2005; MacPhail, 2007; Ettinger and Feldman, 2010). The macrophages demonstrate phagocytosis of debris and bacteria. In general, most cases of pyothorax are characterized by a polymicrobial infection on cytology (Waddell et al., 2000; Demetriou et al., 2002; Rooney and Monnet, 2002; Barrs et al., 2005; Klainbart et al., 2007). In one case series in 27 cats, 7% showed no bacteria on cytology, while 78% were presented with a polymicrobial infection and 15% showed a single type of bacterium (Barrs et al., 2005). In another case series in 14 cats and 36 dogs, no bacteria were seen in 20% of cases, 37.5% showed a polymicrobial infection and 42.5% was characterized by a single type of bacterium (Demetriou et al., 2002). Some bacteria, such as *Nocardia* spp. and *Actinomyces* spp., have a filamentous shape and acid-fast stains may aid in their differentiation (Demetriou et al., 2002; Malik et al., 2006; Doyle et al., 2009).

Infectious agents may not always be present cytologically due to prior antimicrobial therapy. The cytological results should therefore always be compared to the culture results (Barrs and Beatty, 2009a). Unfortunately, culture of pleural fluid may be false negative due to prior antibiotic therapy or insufficient growth of certain isolates *in vitro*. Positive bacterial cultures of pleural fluid have been reported in 68.7% of canine and feline cases with pyothorax (Demetriou et al., 2002). However, in other studies, a positive culture in less than half of the examined dogs has been reported (Johnson and Martin, 2007), whereas 78% of cats have a positive culture (Barrs et al., 2005). Low canine positive culture results may be explained by prior antibiotic therapy or by losing strictly anaerobic bacteria prior to culture, as a result of air contamination during sample collection and transport (Love et al., 1982; Piek and Robben, 2000; Johnson and Martin, 2007).

Complete blood count (CBC) and serum biochemistry

Complete blood count (CBC) generally shows a neutrophilic leukocytosis with a left shift, i.e. an increased concentration of nonsegmented or band neutrophils, as expected for pyogenic infections, but a degenerative left shift or leukopenia may be indicative for sepsis (Brady et al., 2000; Demetriou et al., 2002; Waddel et al., 2002; Barrs et al., 2005; Klainbart et al., 2007). A mild to moderate anemia is seen in up to 20% of feline and canine cases (Brady et al., 2000; Demetriou et al., 2002; Barrs and Beatty, 2009a). In 86% of feline cases with anemia, the anemia is non-regenerative and mostly normocytic and normochromic (Ottjenann et al., 2006).

The most common abnormalities on serum biochemistry are hypoalbuminemia, hyperbilirubinemia, hyponatremia, hypochloremia and mild elevations of aspartate aminotransferase (AST) (Barrs et al., 2005; Klainbart et al., 2007; MacPhail, 2007; Barrs and Beatty, 2009a). Hypoalbuminemia and hyperbilirubinemia are both common findings in sepsis (Brady et al., 2000). The decrease in albumin may be caused by increased vascular permeability, decreased hepatic synthesis and loss of protein in the pleural fluid in severe acute infections (Waddel et al., 2002; Barrs et al., 2005; Barrs and Beatty, 2009a). Hyponatremia and hypochloremia may be explained by decreased intake due to anorexia or may be attributed to the loss of fluid into the thoracic cavity. AST is commonly increased due to hepatocellular or myocyte damage. Possible mechanisms include hypoxia-induced damage secondary to poor perfusion due to hypovolemia or sepsis, inflammation from concurrent processes, e.g. pancreatitis, and infection within the liver caused by hepatic abscesses (Waddel et al., 2002).

Medical imaging

The importance of gentle handling of animals in respiratory distress cannot be overemphasized. Some procedures, such as medical imaging, may need to wait until the patient is stable enough, e.g. after thoracocentesis. Severe hypoxemia may occur if the animal is placed in lateral or dorsal recumbency. Reducing oxygen requirements and stress through minimal handling or fixation, combined with anxiolytic drugs and/or sedation and supplementation of oxygen are the first steps in stabilization to obtain better respiratory comfort (Beatty and Barrs, 2010).

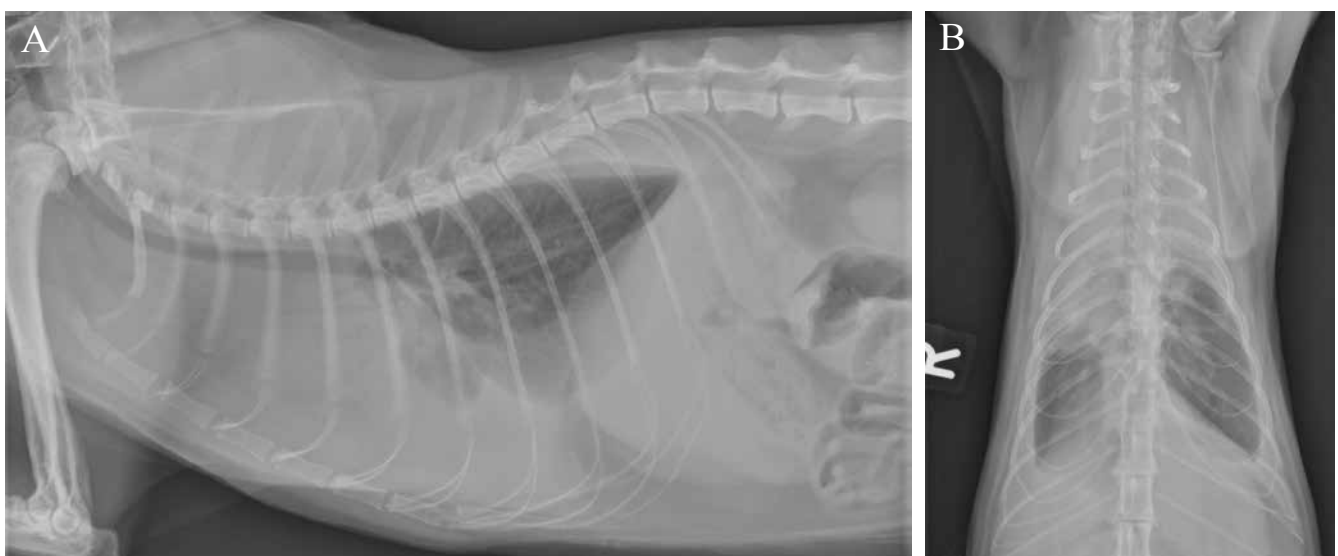


Figure 3A. Right lateral and dorsoventral thoracic radiographs of a cat with severe pyothorax. **B.** The radiographs were taken after left-sided thoracocentesis, through which 180 mL of yellow, opaque fluid had already been removed. The lung lobes are retracted from the thoracic wall by a soft tissue opacity in both left and right hemithorax. The effusion is asymmetrical, showing more severe effusion in the right hemithorax, which might be a consequence of previous left-sided thoracocentesis. There is scalloping of the ventral lung lobes.

Radiography (RX)

A single dorsoventral projection confirms the presence of pleural effusion (Beatty and Barrs, 2010), while a lateral projection helps to detect loculations (Christie, 2010). If the volume of effusion is small and more information is desired, other projections may be indicated. A ventrodorsal radiograph is more sensitive for the detection of small-volume effusions. However, there is a considerable risk of serious respiratory compromise if a patient has a moderate- to large-volume effusion. Therefore, this projection is not routinely advised (Murphy and Papasouliotis, 2011a). To assess if there is any underlying bronchopulmonary disease present, a complete set of thoracic radiographs should be obtained after pleural fluid removal, because they may have been effaced by fluid or obscured by atelectasis (Barrs and Beatty, 2009a; Beatty and Barrs, 2010; Epstein, 2014). It can take some time for the lungs to re-expand fully; hence, taking radiographs immediately after fluid removal may not be ideal (Murphy and Papasouliotis, 2011a).

Radiographically, a small volume of pleural effusion is characterized by the presence of interlobar fissure lines, though this may also be caused by pleural thickening (Murphy and Papasouliotis, 2011a). In cases with moderate to large amounts of free fluid, the retraction of the lobar borders from the thoracic wall, resulting in rounded lung borders, is particularly obvious in the caudodorsal areas of the lung. Other signs include lung collapse due to incomplete expansion, dorsal displacement of the trachea, widening of the mediastinum, obscuring of the cardiac silhouette and diaphragm, and scalloping of the lung margins at the sternal border (Barrs and Beatty, 2009a; Beatty and Barrs, 2010; Murphy and Papasouliotis, 2011a) (Figures 3A and B).

In dogs and cats, communication between the left and the right hemithorax may vary individually and can be influenced by concurring disease (Epstein, 2014). In a case study of 76 cats, a bilateral pleural effusion in 76%, a unilateral left-sided pleural effusion in 16% and a unilateral right-sided pleural effusion in 8% were reported (Barrs et al., 2005). The presence of unilateral effusion on radiographs should in any case raise the index of suspicion for pyothorax (or chylothorax) (Beatty and Barrs, 2010). Overall, cats with pyothorax have a higher frequency of unilateral effusion with up to 29% of cases, compared to 14% of cases in dogs with pyothorax (Demetriou et al., 2002; Barrs et al., 2005).

Ultrasonography (US)

Although thoracic radiography is more sensitive than ultrasonography in detecting small-volume pleural effusions, thoracic ultrasonography is a less invasive technique for the confirmation of a moderate to large volume of pleural effusion (Beatty and Barrs, 2010). Thoracic ultrasonography may also be indicated

to identify consolidated lung masses, mediastinal masses and abscedated or neoplastic lung nodules. It can also be used for guided thoracocentesis when only a small amount of pleural fluid is present (MacPhail, 2007). The exudate in pyothorax is hypoechoic or complex echoic (Beatty and Barrs, 2010).

Computed tomography (CT)

With a computed tomography (CT) scan, the severity and the location of the pleural effusion can be determined and a detailed assessment of underlying parenchymal and pleural abnormalities can be provided (Swimbourne et al., 2011). In cases of migrating intrathoracic grass awns in dogs, CT has been reported to detect more sites of abnormalities and traces the foreign body pathway more accurately than radiographs (Swimbourne et al., 2011; Jiménez Peláez and Jolliffe, 2012; Vansteenkiste et al., 2014). Currently, CT is mostly used after patient stabilization to determine whether surgical intervention is indicated (MacPhail, 2007; Swimbourne et al., 2011). In contrast to what is mostly assumed, CT does not necessarily require general anesthesia and could therefore be used in more critical phases of diagnosis as well. While dogs require at least a deep sedation, cats tend to be fixated very well in a transparent container, e.g. VetMouseTrap, which allows quick and safe scanning without sedation (Oliveira et al., 2011; Schwarz and O'Brien, 2011).

TREATMENT

In some studies, death has been reported during clinical examination or shortly after (Mellanby et al., 2002; Barrs et al., 2005), highlighting the importance of minimal, careful handling and immediate supplementary oxygen (Barrs and Beatty, 2009b). The emergency patient should receive immediate intravenous fluid therapy if indicated. Afterwards, the level of pain should be assessed. Pleuritis and thoracic visceral pain are associated with a moderate to severe level of pain and a multimodal approach is advised (Lemke and Dawson, 2000; Mathews et al., 2014). In many cases, opioids are the initial drug of choice, e.g. buprenorphine; 0.01-0.02 mg/kg IV tid-qid. However, caution should be taken in patients with respiratory distress (Mathews et al., 2014). After stabilization, non-steroidal anti-inflammatory drugs, e.g. meloxicam; 0.1 mg/kg IV sid in dogs and 0.05 mg/kg SC in cats, can be added if there are no contraindications. Additionally, a CRI of ketamine, e.g. bolus of 0.5-1 mg/kg and CRI at 0.12-0.6 mg/kg/h in dogs; bolus of 0.5 mg/kg and CRI at 0.3-1.2 mg/kg/h in cats, may help in controlling severe pain (Mathews et al., 2014). If persisting thoracic visceral pain is suspected, the use of intrapleural blocks can be considered (Lemke and Dawson, 2000; Mathews et al., 2014). Treatment with systemic antibiotics alone usually does not over-

come the infection and removal of the exudate will be necessary (Piek and Robben, 2000). This drainage can take place through single or multiple thoracocenteses or through placement of thoracostomy tubes, with or without lavage of the pleural cavity (Piek and Robben, 2000; Demetriou et al., 2002; Rooney and Monnet, 2002; Boothe et al., 2010). In patients that are medically managed for two to three days without improvement, surgery should be considered (Monnet, 2009).

Antimicrobial therapy

Initial antimicrobial therapy is based on the cytology of the pleural fluid. Single antimicrobial therapy in dogs has a 35%-risk of inefficacy. Therefore, a combined antimicrobial treatment seems prudent (Demetriou et al., 2002; Barrs and Beatty, 2009b; Boothe et al., 2010). A gram-stain of the fluid sample should be made and may help the clinician in choosing an appropriate antimicrobial agent for initial treatment (Love et al., 1982; Murphy and Pappasoulitis, 2011b). Therapy should be altered afterwards, based on the results of culture and susceptibility testing (Walker et al., 2000; Klainbart et al., 2007; Barrs and Beatty, 2009b; Murphy and Pappasoulitis, 2011b). Initial antibiotics should be administered parenterally, preferably intravenously. Once the patient is eating well, oral antibiotics may be substituted (Barrs and Beatty, 2009b).

Given that the majority of cases is characterized by synergistic polymicrobial infections caused by oropharyngeal flora, antibiotics should ideally be effective against anaerobes as well as gram-positive and gram-negative aerobes (Walker et al., 2000; Barrs and Beatty, 2009b). Penicillins and their derivatives, e.g. amoxicillin-clavulanic acid, 10-40 mg/kg bid or tid, are reliably effective against obligate anaerobes, such as *Bacteroides* spp., and are especially a good treatment in cats, as enterobacteriaceae are not frequently isolated in the pleural fluid (Demetriou et al., 2002; Barrs et al., 2005; Barrs and Beatty, 2009b). Alternatively, fluoroquinolones, e.g. enrofloxacin, 5-7 mg/kg sid, or cephalosporins, e.g. cefazolin, 20-30 mg/kg tid, could be used as first-choice antibiotics (Demetriou et al., 2002; Greene, 2006; Barrs and Beatty, 2009b). Monotherapy with pradofloxacin has a high activity against isolates of anaerobic bacteria in dogs as well as in cats, but should be used with care because of the increasing resistance in treating human anaerobic infections (Stein and Goldstein, 2006). A combination of β -lactam antibiotics with fluoroquinolones for more than six weeks is advised to treat *Actinomyces*-infections (Sivacolundhu et al., 2001; Rooney and Monnet, 2002; MacPhail, 2007). Other antibiotics that can be used against *Actinomyces* spp. are clindamycin, chloramphenicol and gentamicin (Sivacolundhu et al., 2001; MacPhail, 2007; Barrs and Beatty, 2009b).

Metronidazole (15-50 mg/kg bid) can be used because of its lipophilic qualities. It is well distributed throughout the body and diffuses well into abscesses (Johnson and Martin, 2007). It is mostly used in combination with other antibiotics, because it is only effective against anaerobic bacteria (Piek and Robben, 2000; Murphy and Pappasoulitis, 2011b). In high dosages or when administered for a long period of time, which is often necessary in the treatment of pyothorax, neurological side effects such as generalized muscle weakness can be seen (Piek and Robben, 2000).

Sulphonamides, e.g. trimethoprim-sulphamethoxazole (TMP-SDX), 5-10 mg/kg trimethoprim and 25-50 mg/kg sulfamethoxazole sid, are effective for high percentages of *Nocardia* isolates (Peabody and Seabury, 1960; Yildiz and Doganay, 2006; MacPhail, 2007; Malik et al., 2006; Sullivan and Chapman, 2010; Murphy and Pappasoulitis, 2011b). This dosage of TMP-SDX is often effective, but not always well tolerated, resulting in excessive salivation due to the bitter taste, vomiting and partial to complete anorexia. In cats, high dosages may induce anemia and neutropenia due to bone marrow suppression (Malik et al., 2006). In dogs, severe neurological signs, such as generalized muscle weakness, may occur (Piek and Robben, 2000).

The appropriate duration of treatment in veterinary patients with pyothorax has not been well studied, but should be long-term, i.e. at least 4-6 weeks. In cases with isolation of filamentous organisms, treatment must be continued longer, since these infections are associated with devitalized tissue and tend to relapse if therapy is discontinued prematurely (Demetriou et al., 2002; Barrs et al., 2005; Malik et al., 2006; MacPhail, 2007). Treatment is necessary for a minimum of three months and can be prolonged for as long as one year in patients with disseminated disease (Sivacolundhu et al., 2001; Yildiz and Doganay, 2006).

Thoracic drainage

Needle thoracocentesis

Thoracocentesis can be diagnostic as well as therapeutic (MacPhail, 2007). Single or repeated needle thoracocentesis can be performed prior to tube thoracostomy. The removal of as much of the fluid as possible gives considerable relief (Barrs and Beatty, 2009b). Typically, a 20- or 22-gauge needle or butterfly catheter, connected to an extension tube with a three-way stop valve, is used. Using a sterile technique, the needle is advanced into the pleural cavity at the level of the ventral third of the thorax, mostly in the seventh or eighth intercostal space (ICS), cranial to the rib. Multiple thoracocenteses spread in time are generally not recommended and often ineffective (Barrs et al., 2005; MacPhail, 2007). However, one study performed by Johnson and Martin (2007) in



Figure 4. Placement and fixation of a thoracostomy tube in a dog. A. The eleventh intercostal space is localized. B. A skin incision is made in the dorsal third of the eleventh intercostal space. C. The skin is pulled cranially, bringing the skin incision at the level of the eighth intercostal space. D. The thoracic drain is inserted perpendicular to the thoracic wall. E. The thoracic drain is advanced in cranoventral direction. F. The skin is moved caudally. G. This results in subcutaneous tunnelling. H. The thoracic drain is attached to the skin using a purse-string suture and a Chinese finger trap.

Note: These pictures were taken on a euthanized dog. Sterile preparation and surgical draping are required to provide a sterile working field, but were disregarded in this case.

15 dogs without inhaled foreign body or pyogranulomatous effusion, showed a successful treatment of pyothorax in all 15 dogs through single unilateral thoracocentesis along with long-term antibiotic therapy.

Thoracostomy tubes and thoracic lavage

If needle thoracocentesis fails to stabilize or manage the clinical signs, chest drain placement is recommended (Valtolina and Adamantos, 2009). It can also be used in therapeutic procedures such as pleural lavage or in surgical cases following a thoracotomy (Murphy and Pappasoulotis, 2011a). In complex cases with numerous pleural adhesions or in animals with a complete mediastinum, bilateral chest tubes are more likely to provide effective drainage than unilateral chest tubes (Barrs et al., 2005; Barrs and Beatty, 2009b).

The placement of thoracostomy tubes is simple and is generally well tolerated. Sedation or anesthesia may be necessary for uncooperative or stressed patients. The thoracostomy tube of the greatest diameter that can fit comfortably in the intercostal space (ICS) should be used, since wider bore tubes facilitate drainage of pus (Rahman and Gleeson, 2006; Barrs and Beatty, 2009b). The placement of chest tubes is preferably done with the animal standing or in sternal position (Frendin and Obel, 1997; MacPhail, 2007; Barrs and Beatty, 2009b; Murphy and Pappasoulotis, 2011b). To minimize pneumothorax from leakage of air around the tube, subcutaneous tunneling of the drain should be achieved by entering the chest tube through the skin two or more ICS caudal to where the tube enters the thoracic cavity. After extensive clipping, aseptic preparation and local anesthesia, a small skin incision is made in the dorsal third of the tenth to twelfth ICS, lateral to the longissimus dorsi muscle. The skin is pulled cranially and the tube is inserted in the chest perpendicular to the thoracic wall around the eighth ICS. Afterwards, the drain is moved in cranio-ventral direction. The tube needs to be clamped or a three-way valve has to be placed to prevent iatrogenic pneumothorax (Frendin and Obel, 1997; Barrs and Beatty, 2009b). Thoracostomy tubes without stylets can be placed, using large hemostats to perforate the intercostal muscles. After placement, tubes should be secured to the thoracic wall by a purse-string suture and a Chinese-finger trap to prevent the tube from slipping (Figures 4A-H). Finally, a bandage is needed to prevent the animal from manipulating the tube. The bandage should be changed at least once daily (Barrs and Beatty, 2009b; Murphy and Pappasoulotis, 2011b). Control radiographs should be taken immediately after drain placement to assess its position. The tip of the drain should end in the ventral 2nd-3rd ICS to be positioned correctly (Barrs et al., 2005).

Chest tubes can be drained continuously or intermittently, e.g. every 4 hours. Continuous suction offers the advantage of maximal drainage, but gives more severe complications if the system detaches,

which would remain unrecognized. Intermittent suction is easier, less expensive, requires less monitoring and is sufficient in most cases (Barrs and Beatty, 2009b; Murphy and Pappasoulotis, 2011b). Hygienic procedures should be respected when draining the tube to prevent infection. Analgesia is necessary and usually includes systemic opioids. Interpleural use of bupivacaine is controversial. Some authors state that interpleural analgesia should be avoided in patients with poor respiratory reserves because of the potential diaphragmatic paralysis (Kowalski et al., 1992; Barrs and Beatty, 2009b). In other reports, it is described that, when using the correct dosages, e.g. 1.5 mg/kg, it can provide sufficient analgesia for up to eight hours with minimal risks of cardiovascular or pulmonary side effects (Lemke and Dawson, 2000; Glowaski, 2002).

Drainage should ideally be combined with intermittent thoracic lavage. This facilitates exudate drainage and prevents obstruction of the thoracostomy tubes by reducing pleural fluid viscosity. It also allows hydraulic debridement of the pleura, including breakdown of adhesions and dilution of bacteria and inflammatory mediators (Barrs and Beatty, 2009b; Boothe et al., 2010). Thoracic lavage must be carried out every four hours for the first two days. Afterwards, two to three times daily is usually adequate. As lavage solution, 0.9% sodium chloride or Hartmann's solution (to prevent hypokalemia), heated to body temperature, can be safely used in volumes of 10-25 mL/kg/lavage. Slow and hygienic infusion is necessary, combined with close monitoring of the patient. Recovery of 75% or more of the lavage solution after 30-60 minutes is expected, preferably after walking or moving the patient (Barrs and Beatty, 2009b; Boothe et al., 2010).

Complex loculated effusions or cases with advanced fibrinous or fibrous adhesions can be treated with subsequent administration of fibrinolytic agents through the tube (Rahman and Gleeson, 2006). Reported side effects include fever and bleeding. Fibrinolytic agents that can be used are heparin (10-15 IU/mL of lavage fluid), streptokinase, urokinase and tissue plasminogen activator (Demetriou et al., 2002; Boothe et al., 2010; Christie, 2010). Scientific evidence in veterinary medicine is still scarce, but in one study, improvement of both short- and long-term survival in dogs that were lavaged with a heparin-containing solution has been reported. No adverse effects were registered, but blood coagulation profiles were not monitored (Boothe et al., 2010).

In one study of 98 dogs, up to 22% of dogs developed some type of complication after the placement of thoracostomy tubes (Tattersall and Welsh, 2006). This is especially important in cases of pyothorax (and chylothorax), given that the tubes usually stay in place longer than in cases of other pleural space diseases. Therefore, complications occur more often (Tattersall and Welsh, 2006). Described complications include pneumothorax, serohemorrhagic dis-

charge from around the drain/skin interface, subcutaneous emphysema or edema, blockage of the drain with fibrin clots, infection of the thoracic wall with abscesses, lung tissue irritation or trauma, re-expansion pulmonary edema, arrhythmias, phrenic nerve irritation and hemorrhage from laceration of intercostal vessels (Tattersall and Welsh, 2006; Barrs and Beatty, 2009b; Valtolina and Adamantos, 2009). In cats, the incidence of complications after thoracostomy tube placement is even higher, with a reported prevalence of 58% (Barrs et al., 2005).

Constant monitoring to observe changes in respiratory pattern and frequent clinical examination are advised. The volume of lavage solution administered and aspirated should be noted carefully and daily cytology of the fluid is recommended to assess therapeutic response. Regular monitoring with thoracic radiographs, preferably every two or three days, is necessary to detect failure of drainage due to incorrect tube placement, tube kinking or adhesions (Barrs and Beatty, 2009b; Murphy and Pappasoulitis, 2011b). Thoracostomy tubes are generally removed after four to six days, but the ideal time of removal should be evaluated individually. Factors indicating possible removal are the reduction of the pleural effusion to 2-4 mL/kg/day, minimal amounts of remaining pleural effusion on thoracic radiographs and resolution of infection on cytology. Cytological examination of the pleural fluid should gradually contain less bacteria and less neutrophils with decreasing degenerative appearance (Demetriou et al., 2002; Klainbart et al., 2007; Barrs and Beatty, 2009b; Marques et al., 2009; Murphy and Pappasoulitis, 2011b).

Surgical approach

The advantage of surgical treatment lies in a thorough exploration and removal of the primary cause with lavage and debridement of the pleural space. However, this must be weighed against the risks of general anesthesia in a compromised patient, the increased costs and prolonged hospital stay (Doyle et al., 2005; MacPhail, 2007). Common indications for early surgical intervention are the detection of an underlying lesion, e.g. abscess, foreign body, extensively loculated effusions or poor response to medical treatment after two to seven days (Rooney and Monnet, 2002; Barrs and Beatty, 2009b; Boothe et al., 2010). Surgery is also indicated when pneumothorax or drain obstruction caused by pleural adhesions, develops (Barrs and Beatty, 2009b). In dogs, a surgical approach is recommended if *Actinomyces* spp. is isolated, because of the poor outcome associated with medical therapy only, given the frequent association with migrating grass awns (Rooney and Monnet, 2002; Doyle et al., 2009). In cats however, the medical treatment of pyothorax caused by *Actinomyces* spp. (in combination with other oropharyngeal flora) is often sufficient, because it is less likely to be associated with grass awn foreign bodies (Barrs and Beatty, 2009b).

Intercostal thoracotomy or median sternotomy

Because surgical treatment of pyothorax usually requires exposure and exploration of both hemithoraces, median sternotomy is the most common surgical approach. It is used when preoperative workup reveals generalized disease or when no clear underlying cause can be found (Tattersall and Welsh, 2006; MacPhail, 2007; Boothe et al., 2010). Intercostal thoracotomy is not commonly used for exploratory purposes, but it may be a good approach when preoperative diagnostics reveal a focal lesion in a specific region (Tattersall and Welsh, 2006). It also enables more accurate positioning of thoracostomy tubes than median sternotomy (MacPhail, 2007; Barrs and Beatty, 2009b; Crawford et al., 2011). Affected lung tissue can be removed by pneumectomy. Acute loss of up to 50% of lung tissue is followed by compensatory changes in the contralateral lung. The removal of the entire right or left lung is usually well tolerated in cats. However, in dogs, right-sided pneumectomy is not well tolerated, because the right lung accounts for 58% of all lung tissue. Samples for bacteriology and, if indicated, histology must be taken during the surgical procedure. Postoperative oxygen supplementation, analgesia, careful monitoring and management of chest drainage are essential for successful recovery (Crawford et al., 2011).

Thoracoscopy

Video-assisted thoracoscopic surgery (VATS) is a recent diagnostic and therapeutic tool, which provides minimal invasive access to the thoracic cavity. It allows exploration of the entire pleural space, biopsies and culture samples, and debridement of the mediastinum and other tissues involved in the infectious process (Kovak et al., 2002; MacPhail, 2007; Monnet, 2009; Jiménez Peláez and Jolliffe, 2012). The disadvantages include the need for specific instrumentation and possible technical difficulties. Although there is little scientific evidence in veterinary medicine, thoracoscopy seems to be a safe and effective procedure in dogs and cats with rapid patient recovery, high success rates with shorter duration of chest tube drainage, less postoperative pain and shorter hospital stay than more invasive surgery (Christie, 2010; Jiménez Peláez and Jolliffe, 2012). If thoracoscopic exploration reveals multiple adhesions with severe involvement of lung lobes or pericardium, the conversion from thoracoscopy to sternotomy is advised (Monnet, 2009).

PROGNOSIS

The prognosis in cats and dogs with pyothorax is variable, ranging from excellent to extremely guarded, often resulting in death or euthanasia (Murphy and Pappasoulitis, 2011a). The underlying cause, the extent of the disease and the rate of progression have an influence on both clinical signs and prognosis. Medi-

cal treatment fails in up to one third of all patients with pyothorax, but guidelines to when surgical intervention should be performed remain unclear and surgery is often disregarded due to financial concerns (Waddell et al., 2002; Rahman and Gleeson, 2006; MacPhail, 2007; Boothe et al., 2010).

One of the most common complications of pyothorax is recurrence (Demetriou et al., 2002; Waddell et al., 2002; Barrs et al., 2005). Recurrence rates are usually low, but vary greatly according to the type of treatment and the underlying cause (Demetriou et al., 2002; Rooney and Monnet, 2002; Waddell et al., 2002; Boothe et al., 2010). Cases involving *Nocardia* spp. or *Actinomyces* spp. tend to relapse most frequently, especially when treated without surgery, because they are often associated with complex pyogranulomatous disease (Peabody et al., 1960; Sivacolundhu et al., 2001; Malik et al., 2006; Doyle et al., 2009).

In cats, 50-100% of the non-survivors die or are euthanized within the first 48 hours after presentation. It is therefore considered that survival of the first 48 hours can serve as a good prognostic indicator (Demetriou et al., 2002; Waddell et al., 2002). Survival rates vary greatly according to the type of treatment. In one study of 80 cats, 66% of the cats survived, each of them receiving an appropriate type of treatment (Waddell et al., 2002). In 19 cats treated with intravenous fluids combined with antimicrobial therapy and drainage through thoracostomy tubes, a 95% success rate has been reported (Barrs et al., 2005). In contrast, mortality rates as high as 80% have been reported in cats when drainage was achieved through single or multiple thoracocenteses, without placement of chest tubes (Bauer, 1986). On average, cats that have undergone surgery, are generally hospitalized for six days prior to surgical intervention. They have higher survival rates than cats that have been treated more conservatively, probably due to more effective drainage postoperatively (Waddell et al., 2002). The available data in cats shows a recurrence rate between 5 and 8% in general, but it could increase up to 23% in cases of pyothorax caused by *Nocardia* infections (Demetriou et al., 2002; Waddell et al., 2002; Barrs et al., 2005; Malik et al., 2006).

In dogs, a good outcome is often seen when therapy includes intravenous antibiotic therapy and drainage of the pleural fluid, with or without the placement of thoracostomy tubes and lavage (Piek and Robben, 2000; Demetriou et al., 2002; Johnson and Martin, 2007). It should be noted that in these cases, foreign bodies or filamentous bacteria are usually not included (Piek and Robben, 2000; Demetriou et al., 2002; Johnson and Martin, 2007). Short-term survival rates of dogs undergoing surgical therapy are thought to be about five times higher than dogs treated conservatively (MacPhail, 2007; Boothe et al., 2010). Survival rates vary between 29 and 100% for medical treatment and up to 92% for surgical treatment (Melanby et al., 2002; Rooney and Monnet, 2002; Boothe et al., 2010; Lee, 2014).

DISCUSSION

Pyothorax is an uncommon disease in dogs and cats, but can potentially be life-threatening. At the moment, there is no data available concerning the actual incidence of pyothorax in dogs and cats, but it appears to occur more frequently in cats (Demetriou et al., 2002; Rooney and Monnet, 2002; Barrs et al., 2005; MacPhail, 2007; Boothe et al., 2010). An immediate and appropriate diagnostic and therapeutic approach is essential to obtain a good outcome (Barrs and Beatty, 2009b; Firth and Boag, 2012). The time between the occurrence of the clinical signs and the start of therapy are of great importance. Treatment should minimally consist of careful handling, supportive care, antibiotic treatment and drainage of the pleural fluid (Rooney and Monnet, 2002; Barrs et al., 2005; Boothe et al., 2010). It is recommended to place bilateral thoracostomy tubes in all bilateral cases of pyothorax, although there is no clear consensus in the literature as to whether bilateral drainage is superior to unilateral drainage. In cases with multiple loculations of fluid, however, bilateral thoracostomy tubes seem to be necessary for adequate drainage of the pleural fluid (Demetriou et al., 2002; Barrs and Beatty, 2009b; Boothe et al., 2010; Christie 2010; Epstein, 2014; Lee, 2014).

Careful clinical and radiographic monitoring is important to assess therapeutic response. There is no clear data available as to whether or not surgery is indicated. However, it should be considered when there is poor response to medical therapy, in the presence of structural lesions or pneumothorax and in cases where involvement of filamentous organisms is suspected (Doyle et al., 2009; Murphy and Pappasoulotis, 2011b). Thoracoscopy seems to be a very promising technique that can be used both diagnostically and therapeutically (Kovak et al., 2002; MacPhail, 2007). In some cases, with thoracoscopy, the cause of pyothorax can be resolved, but conversion to thoracotomy or sternotomy may still be necessary (Monnet, 2009).

A good first choice of antibiotic therapy consists of amoxicillin-clavulanic acid (10-40 mg/kg bid or tid) in cats and a combination of amoxicilline (20-40 mg/kg bid or tid) and enrofloxacin (5 mg/kg sid) should be considered in dogs, based on the susceptibility of the most commonly isolated organisms in both species (Greene, 2006). It should be emphasized that the appropriate antibiotic therapy should always be altered according to the results of cytology and gram-stain, and if necessary, changed again according to the results of the bacteriological examination and susceptibility testing.

The optimal duration of antibiotic therapy in cases of pyothorax still needs to be elucidated. A sufficient duration of treatment may prevent recurrence of infection, which is a common and serious complication. Finally, veterinarians must take effort in preventing pyothorax by adequately treating bite wounds and local infections. Given that oropharyngeal bacteria are

the most common source of infection of the pleural space, it is recommended that cats undergoing dental surgery, cats suffering from upper respiratory tract infections and cats that have been involved in a catfight should be treated with antibiotics as a prophylactic measure (Barrs et al., 2005; Barrs and Beatty, 2009b). Whether this will actually reduce the incidence of pyothorax still needs to be investigated, and the potential benefits must be weighed against the risk of increasing antimicrobial resistance.

CONCLUSION

Pyothorax is thought to be an uncommon disease, but there is few data available regarding incidence, and most common underlying causes are yet to be further investigated. Treatment should always consist of supportive care, long-term antibiotics and drainage of the effusion, but it should be emphasized that there is no golden standard, and treatment approach should always be evaluated individually. Although the results of one canine study were promising, the addition of thoracic lavage is yet to be studied, as there is no clear scientific advice regarding the amount, the frequency and/or the type of lavage. In addition, further research regarding possible complications is indicated. Regarding the treatment of complex cases, video-assisted thoracoscopic surgery is a promising technique. However, further studies are needed to assess its advantages and disadvantages in comparison to more invasive thoracic surgery.

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