Canine Pyothorax: Clinical Presentation, Diagnosis, and Treatment*

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ABSTRACT: Clinical presentation of canine pyothorax can be delayed and nonspecific. Fever, dyspnea, and weight loss are the most common physical examination findings. Diagnosis is made with radiographic findings and analysis of aspirated pleural fluid. Pleural infections have a high prevalence of polymicrobial infections. Antibiotic therapy without drainage and lavage is ineffective for pyothorax. Excessive delays in treatment can result in serious pulmonary dysfunction and may necessitate surgical intervention. Prognosis for canine pyothorax is fair to good with early diagnosis and aggressive medical and/or surgical treatment.

Pyothorax is an uncommon but important disease of dogs. Inflammatory conditions of the pleura and pleural space lead to alterations in capillary permeability and lymphatic function. An increase of septic fluid within the thoracic cavity leads to pulmonary dysfunction and systemic illness. This article discusses the clinical presentation, diagnosis, commonly isolated bacteria, proper treatment and management, and prognosis of canine pyothorax.

SIGNALMENT, HISTORY, AND PHYSICAL FINDINGS

In dogs, pyothorax most commonly occurs at a mean age of 3 to 4 years (range: 1 to 11 years). However, the first case report of pyothorax in a canine neonate was recently reported. Several studies show a male:female ratio of 2:1, whereas other reports have shown no sex predilection. Typically, medium to large breeds are affected, and affected breeds may differ on geographic location. Although no single breed predominates, dogs of the hunting/working type are overrepresented. An increased prevalence of grass awn cases were seen in springer spaniels, Labrador retrievers, golden retrievers, Brittany spaniels, and Airedale terriers. Most cases occur during the fall and winter, coinciding with training and hunting seasons.

Most dogs with pyothorax present with signs referable to accumulation of pleural effusion. Signs ensue because of decreased lung expandability and impaired gas exchange. Although some cases are insidious and nonspecific and

* A companion article entitled “Canine Pyothorax: Pleural Anatomy and Pathophysiology” appears on p. 172 of this issue.
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may go undetected for months, others can be associated with periodic flare-ups and periods of near-normal activity.\(^{11}\) Most owners consistently report exercise intolerance; poor performance in the field; and abnormal breathing patterns characterized by shortness of breath, open-mouth breathing with abducted elbows, extended head and neck, increased respiratory rates, and labored breathing. Additionally, reluctance to lay down, anorexia, and lethargy are reported.\(^{1,2,5,10,13–15}\) Cough, diarrhea, polyuria, and polydipsia are less frequently noted.\(^{3,16}\)

Fever, dyspnea in which the inspiratory phase is most difficult, and weight loss are the most common and consistent signs found on physical examination.\(^{2,3,13,17}\) Other findings include depression; dehydration; cyanosis; tachypnea; orthopnea; muffled heart sounds; decreased lung sounds; dull percussive sounds of the ventral thorax; and thoracic wall swellings, penetrations, or other trauma.\(^{5,10,15–18}\) In more severe cases, acute respiratory distress, shock, dehydration, pale mucous membranes, and hypothermia can occur.\(^{19}\)

**DIAGNOSTIC EVALUATION**

History, signalment, clinical signs, and radiography support a diagnosis of pleural effusion and may suggest pyothorax. However, the diagnosis of pyothorax is confirmed only by cytologic evaluation and culture of pleural fluid.

**Radiographic Evaluation**

In severely dyspneic patients, removal of pleural fluid via thoracocentesis is advised before taking radiographs. Oxygen supplementation, minimal handling, and taking only lateral views of the chest may also minimize respiratory compromise. A stable patient may undergo survey radiography that includes right and/or left lateral and either ventrodorsal or dorsoventral views.\(^{15,20}\) Fluid within the pleural cavity may be free or encapsulated, and encapsulated fluid is commonly associated with pyothorax.\(^{20}\) Fluid can become trapped by fibrinous adhesions, and large amounts of effusion can obscure the view of normal thoracic structures.\(^{20}\) Contrast studies or removal of large quantities of fluid can help with radiographic interpretation in these cases.\(^{21}\) Horizontal beam projections, with the animal either standing or in an erect position, and dorsoventral views can be helpful in some cases because these views are less stressful to dyspneic animals. Additionally, pooling of fluid in these views allows for a better differentiation between free pleural fluid, solid masses, or incarcerated “pockets” of fluid.\(^{20}\)

Classic roentgen signs of pleural effusion include blurring of the cardiac silhouette, presence of interlobar fissure lines, rounding of the lung margins at the costophrenic angles, separation of the lung borders away from the thoracic wall, scalloping of the lung...
margins dorsal to the sternum, widening of the mediastinum, and dorsal elevation of the trachea\(^1\)\(^5\)\(^2\)\(^0\) (Figures 1A and 1B). Bilateral effusions are more common, and the pleura is usually not visible unless fibrous or calcified lesions are present.\(^2\)\(^2\)\(^0\) Pyopneumothorax can be found in some cases with horizontal and lateral beam projections, especially because these patients may have concurrent anaerobic gas-producing infections, possible rupture of lung parenchyma secondary to abscess formation and/or pneumonia, or iatrogenic pneumothorax from thoracocentesis.\(^2\)\(^4\)\(^2\)\(^0\) Furthermore, pleural effusion with signs of encapsulated fluid and mediastinal or pulmonary masses should be considered highly suspicious for *Actinomyces* spp infection.\(^2\)\(^2\)

**Hematologic Findings**

A complete blood cell count may reveal normocytic, normochromic anemia, which is common in patients with chronic disease.\(^2\)\(^1\)\(^4\)\(^1\)\(^8\) Neutrophilic leukocytosis, with or without a left shift, is the most common hematologic finding in dogs with pyothorax.\(^2\)\(^1\)\(^0\)\(^4\)\(^1\)\(^8\) Toxic neutrophil changes can be seen in severely affected patients.\(^3\)\(^1\)\(^4\) Leukogram results, however, do not correlate with the severity of infection, and leukocyte counts within or lower than normal can occur.\(^2\)\(^1\)\(^0\)

Biochemical and urinalysis findings are usually nonspecific and are typically not diagnostic for the disease.\(^2\) Hypoalbuminemia can occur secondary to effusive protein losses in the pleural cavity.\(^3\)\(^1\)\(^8\) Infections with *Actinomyces* spp have been associated with hyperglobulinemia and hypoglycemia.\(^1\)\(^7\)\(^1\)\(^8\) In addition, prerenal azotemia is possible in dehydrated patients.\(^2\)

**Thoracocentesis and Fluid Evaluation**

Thoracocentesis is a simple procedure that is both therapeutic and diagnostic. It should be performed immediately in patients with respiratory distress to relieve overt dyspnea. Exudative accumulation within the pleural space displaces functional lung tissue with fluid, causing atelectasis and reductions in tidal volume. Subsequently, hypoxia develops from ventilation–perfusion mismatch. Removal of fluid with thoracocentesis greatly improves the animal’s ability to ventilate by increasing the space available for pulmonary expansion, thus increasing tidal volume and reversing venous admixture. If considerable dyspnea is present after significant amounts of fluid are removed, the animal should be suspected of having pulmonary parenchymal disease, fibrosing pleuritis, or pneumothorax.\(^1\)\(^5\)

Numerous techniques for thoracocentesis have been described, and the materials needed for proper aspiration are minimal\(^1\)\(^5\)\(^1\)\(^9\)\(^2\)\(^3\)\(^2\)\(^3\)\(^2\)\(^8\) (Figure 2). Sedation is usually not necessary because local anesthesia is sufficient in most dogs. With the dog standing or placed in sternal recumbency, both sides of the thorax should be aseptically prepared and the ventral aspect aspirated. Removal of as much fluid as possible is recommended, and samples should be saved for fluid analysis.\(^2\)\(^4\)

Approximately 5 to 10 ml of aspirated fluid should be submitted aseptically for analysis. Samples should preferably be collected at the time of therapeutic thoracocentesis before beginning antibiotic therapy. A portion of the effusion should be placed into an EDTA (lavender-top) tube for total nucleated cell count, total protein count, specific gravity, and cytologic examination.\(^2\)\(^4\) The remainder of the sample should be placed into a serum (red-top) tube for biochemical analysis and in culture-transport media for aerobic, *Mycoplasma*, and anaerobic cultures.\(^2\)\(^4\)

Analysis of pleural fluid should include physical, chemical, and cytologic characteristics. Physical parameters of exudative fluid include volume, color, turbidity, viscosity, presence of sulfur granules, and odor.\(^1\)\(^3\)\(^1\)\(^5\)\(^2\)\(^4\) Septic effusions have increased turbidity, high viscosity, variable color (e.g., sanguineous, brown, tan, white/greenish, “tomato soup”), and a bad odor.\(^2\)\(^3\)\(^1\)\(^5\) Flocculent debris composed of bacteria and degenerating leukocytes can also be present in the sediment in the form of yellow flecks or sulfur granules.\(^1\)\(^5\) If present,
sulfur granules should be included in direct smears and submitted for culture.

Normal pleural fluid contains less than 1.5 g/dl of protein and less than 500 cells/µl. Inflammatory conditions of the pleura alter these measurements significantly. Exudative fluids typically contain more than 3 g/dl protein and more than 7,000 cells/µl with variable cell types and have a specific gravity greater than 1.025.

Lactate dehydrogenase (LDH), pH, and glucose levels may support the classification of septic effusions. LDH levels greater than 200 IU/L, acidic fluid, and glucose measurements less than 30 mg/dl have been shown to be consistent with exudative fluids in cats. In humans, increased levels of LDH in pleural fluid are consistent with cell damage or inflammation. However, there are currently no studies to determine the true usefulness of these chemical parameters in diagnosing canine pyothorax.

Exudative effusions are classified as either nonseptic or septic based on the cytologic appearance of neutrophils and presence or absence of bacteria. Neutrophils are the predominant cell type, and their morphology is helpful in classifying exudative effusions. Neutrophils are characterized as either nondegenerative or degenerative. Nondegenerative cells are indicative of a nonseptic process or low-grade sepsis. However, neutrophils may be nondegenerative in Nocardia and Actinomyces infections. Degenerative cells are indicative of sepsis, and the observer should look carefully for free or intracellular bacteria (Figure 3). Degenerative cell changes include nuclear swelling, karyolysis, pyknosis, toxic granules, and vacuolization of the cytoplasm. Macrophages and plasma cells, although not as numerous as neutrophils, increase with longstanding exudative effusions. Macrophages can also be seen engulfing debris and neutrophils. Moreover, the finding of acid-fast or non–acid-fast, gram-positive, branching filaments supports the presence of Nocardia or Actinomyces (Figure 4). Identification of these organisms is not always supported by positive cultures. Therefore, therapy aimed at both organisms is indicated if differentiation between the two organisms is not possible.

The lack of organisms and/or degenerative neutrophils on cytologic examination does not rule out an infectious cause. Not all bacteria produce strong or large amounts of toxin to induce neutrophil changes. Furthermore, absence of septic changes on cytology could also be due to prior antibiotic administration or the presence of organisms without cell walls (e.g., Mycoplasma).

Bacterial Culture

Exudative pleural fluid should be submitted for aerobic, Mycoplasma, and anaerobic cultures. Proper sample handling is crucial for optimum identification. Maximal anaerobic growth occurs with the use of anaerobic transport medium, avoidance of refrigeration, and submission of samples within 24 hours. Results may not be available for 24 hours for most facultative anaerobes and obligate aerobes and for 48 to 72 hours for most obligate anaerobes. Susceptibility testing can be delayed for an additional 24 to 48 hours. Determining susceptibility patterns of obligate anaerobes is difficult and expensive. Therefore, initial antibiotic therapy must be chosen on the basis of cytologic impressions and collected retrospective data.

It is not uncommon for bacterial culture and cytology findings to differ on the number and type of bacterial growth.
organisms present.\textsuperscript{10} Pleural infections have a high prevalence of polymicrobial infections.\textsuperscript{1,3,6,8,10,27} Obligate anaerobic bacteria alone or in combination with facultative aerobic or gram-positive, filamentous organisms are the most common bacterial isolates\textsuperscript{1,3,6,8,10,27} (see box on right). Recent evidence in dogs with pyothorax demonstrates that obligate anaerobes are present in 60% of positive cultures and one-third of those cultures are mixed with aerobic bacteria.\textsuperscript{8} The most common anaerobic isolates (approximately 73%) are \textit{Peptostreptococcus}, \textit{Bacteroides}, and \textit{Fusobacterium}, whereas most combined aerobes isolated are \textit{Escherichia coli}, \textit{Pasteurella}, \textit{Streptococcus}, and \textit{Staphylococcus}.\textsuperscript{8} Another recent study evaluating anaerobic infections in dogs found similar findings.\textsuperscript{27}

Gram-positive filamentous rods play an equally important role in the development of pyothorax, especially when grass awn migration is the suspected cause. \textit{Actinomyces} and \textit{Nocardia} spp are the most common organisms with a filamentous appearance.\textsuperscript{17} Culture results are often negative, and diagnosis is often based on cytologic or histologic identification in animals with appropriate clinical signs.\textsuperscript{17}

These microbes are part of the normal flora of the oral cavity and upper respiratory tract and depend on mechanical disruption of mucosal surfaces to initiate opportunistic infections.\textsuperscript{26} Once inoculation occurs, bacterial virulence and strength of local defense mechanisms subsequently determine the risk of infection.\textsuperscript{6,10} Synergistic activity between aerobic and anaerobic bacteria can further promote disease at the mucosal level. Aerobic bacterial scavenging systems along with inflammatory cells can substantially lower oxygen tension in traumatized tissue, thereby facilitating anaerobic growth.\textsuperscript{26} Moreover, avoiding phagocytosis and protecting against β-lactam antibiotics are additional ways in which aerobic and anaerobic bacteria support one another.\textsuperscript{26} These synergistic mechanisms necessitate that therapeutics target both populations for complete resolution of the infection.

**TREATMENT**

Management of pyothorax involves drainage, lavage, and antibiotics along with supporting the cardiovascular and systemic needs of the patient. Some patients may need immediate fluid therapy to correct shock, dehydration, acid–base imbalances, and electrolyte abnormalities. Although uncommon, patients with severe pyothorax can present with systemic inflammatory response syndrome.\textsuperscript{28} Excessive delays in treatment may increase the formation of fibrosis and adhesions that may impair drainage and increase the need for surgical intervention.\textsuperscript{10,23}

Thoracic drains are necessary to treat accumulations of purulent material and remove debris within a closed space. Patients will not improve unless drainage is
Thoracic drains are usually placed once the animal is stable and initial fluid samples have been taken. Bilateral drainage is often required because adhesions are common in pyothorax. Radiography should be used to verify position. Tubes should run along the lateral thoracic wall to the level of the second or third rib. Removal of thoracostomy tubes is possible when exudative effusions change to a modified transudate and repeat cultures are negative. Additionally, the fluid volume should decrease to 0.5 to 2.0 ml/kg/day. If there is doubt about the proper time for tube removal, a radiograph can be taken to evaluate tube patency or existence of fluid pockets. If no problems are noted on radiography, the tube can be removed. We encourage readers to seek additional resources on materials, anesthesia, management, and proper technique concerning thoracostomy tube placement.

Infections in closed spaces require drainage to rinse pleural surfaces; remove accumulated debris, pus, and bacteria; and make additional medical therapy more productive. Although intermittent thoracocentesis is an option in certain cases, it is not the therapy of choice and is less effective than closed chest tube drainage. Mortality is higher in patients treated with multiple thoracocenteses and antibiotics than in those treated with tube thoracostomy alone. Risks associated with tube thoracostomy include improper maintenance of the chest tube, premature removal, pneumothorax, and chest wall infection. Advantages include installation of lavage solutions, avoidance of repeated needle thoracocentesis, and ease of sampling pleural fluid to monitor treatment response. Radiographs should be taken within 1 to 8 hours after tube placement to verify proper positioning, evaluate effects of initial drainage, and assess for possible complicating thoracic disease.

### Table 1. Drainage in Dogs with Pyothorax: Reports of Intermittent and Continuous Suction

<table>
<thead>
<tr>
<th>Investigators</th>
<th>Number of Cases</th>
<th>Drainage Time (days)</th>
<th>Follow-Up</th>
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<tbody>
<tr>
<td><strong>Intermittent Suction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campbell and Scott¹⁴</td>
<td>1</td>
<td>12</td>
<td>Disease free at 1 year</td>
</tr>
<tr>
<td>Robertson et al¹</td>
<td>6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Median: 5 (range: 4–9)</td>
<td>6 weeks to 3 years&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Edwards et al¹⁸</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8</td>
<td>Disease free at 4 years</td>
</tr>
<tr>
<td>Fredin⁵</td>
<td>8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Median: 9 (range: 5–18)</td>
<td>5 of 8 patients were disease free for a median of 5.3 years (range: 3.5–9 years)&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Piek and Robben⁶</td>
<td>9</td>
<td>Median: 9 (range: 7–12)</td>
<td>8 of 9 patients had no relapse at 6 months</td>
</tr>
<tr>
<td><strong>Continuous Suction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bauer²</td>
<td>42&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Mean: 5.4 ± 1.4</td>
<td>41 of 42 patients survived&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Turner and Breznock³</td>
<td>15</td>
<td>Mean: 5.6 ± 1.6</td>
<td>8 of 15 patients were free from clinical signs and were receiving no antibiotics for a mean of 33.7 ± 22.8 months (range: 7–62.4 months)&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Two patients underwent thoracotomy after 9 and 4 days of drainage, respectively. Their survival times were 10 months and 3 years, respectively.

<sup>b</sup>Thoracostomy tube placed initially after exploratory transsternal thoracotomy.

<sup>c</sup>One patient had an initial drainage for 18 days, a recurrence after 8 months, a second drainage for 8 days, subsequent antibiotic therapy for 6 months, and then died 2 months later.

<sup>d</sup>One patient died 1 day into treatment. One patient was euthanized because of an inoperable intrathoracic mass diagnosed 3.5 months after primary pleural drainage for 5 days. One patient died 2 months after completing antibiotics following a second drainage treatment (see c).

<sup>e</sup>Cats and dogs combined. The actual number of dogs was not reported.

<sup>f</sup>One dog did not survive. Length of survival time for remaining cases was not reported; “Patients were restored to their former state of health without functional limitation.”

<sup>g</sup>Three patients were lost during follow-up. One patient died 7 weeks after completing 7 months of antibiotics. Three patients were euthanized because of recurrence (two were euthanized 6 weeks after completing drainage and one was euthanized 1.5 years after completing drainage).
Drainage of the pleural space occurs through either intermittent or continuous suction. Minimal expense and management associated with intermittent suction make this method more ideal and safe for most practice situations. It is initially performed every 2 to 4 hours for the first 24 to 48 hours, and if this frequency cannot be carried out overnight, referral to an emergency clinic for 24-hour monitoring is necessary. Within the first few days, the amount of fluid drained often decreases and the frequency of drainage can then be decreased to one to two times a day. If animals with thoracic drain placement must be unattended for any period of time, it is imperative to prevent chewing or dislodgement of the chest tube through proper bandaging and application of an Elizabethan collar. The activity of the patient should also be restricted. A summary of case reports of intermittent suction drainage is represented in Table 1.

Continuous suction is achieved with either commercial units or a three-bottle water-seal collection system (Figure 6). It offers the advantage of maximal drainage. Tube thoracostomy without continuous drainage is a less-than-ideal means of pleural drainage. Although continuous drainage may facilitate a more complete resolution of the pyothorax, it does not necessarily decrease the time needed to manage the infection. Continuous drainage can be expensive and necessitates 24-hour monitoring. Problems with obstructions (i.e., from fibrin and debris), kinking of tubing, and accidental dislodgement can be rapidly fatal. A summary of case reports of continuous suction drainage is represented in Table 1.

Before thoracic lavage, maximal drainage of exudative fluid should be attempted. A 10 to 20 ml/kg solution of warmed isotonic 0.9% sodium chloride or lactated Ringer’s solution should be slowly instilled into the pleural cavity over 5 to 10 minutes at least two to four times daily. Asepsis should be maintained at all times to prevent entrance of hospital pathogens. If respiratory difficulty occurs, instillation should be stopped, fluid aspirated, and a smaller volume of lavage solution used during the next lavage. Rolling the patient from side to side may maximize the “rinsing” of pleural surfaces. The solution should be left in the pleural cavity for 3 to 5 minutes. Longer times of up to 1 hour can be used, but the patient should be monitored closely for respiratory difficulty. Seventy-five percent of the volume infused should be retrieved; decreased amounts of recovered fluid suggest inadequate drainage of loculated fluid. The amount of fluid drained with each attempt should be recorded. Length of drainage time is highly dependent on frequent monitoring of fluid. This includes repeat cytology and cultures of aspirated pleural fluid.

Despite recommendations, no firm evidence of positive effects on morbidity or mortality has been reported on the use of antibiotics instilled into the chest during lavage. If instilled, however, the choice of antibiotic should be based on culture and sensitivity results, and systemic doses should be decreased to avoid toxicity. Administering one-half the systemic

![Figure 6](image-url) — The setup of a commercially available continuous suction system in a dog.
dose and infusing the remainder into the chest during lavage has been recommended. Enzymatic breakdown of fibrous material can result in febrile reactions and is not recommended. Heparin (1,500 U/100 ml of lavage) can be beneficial in reducing clotting, fibrin deposition, and fluid loculation.

A combination of thoracic radiographs every 24 to 48 hours and cytologic examination of aspirated fluid every 36 to 48 hours may be used to monitor the success of lavage treatment. Removed fluid should be relatively clear and free of inspissated material. Decreasing cell counts, loss of degenerative changes in neutrophils, and the absence of bacteria on cytologic examination are indications of improvement.

Antibiotic therapy without drainage and lavage is an ineffective therapy for pyothorax. It is known that 80% of specimens from dogs with anaerobic infections contain both obligate anaerobes and aerobic bacteria. No single antibiotic is effective against the mixture of obligate anaerobic and facultative bacteria commonly isolated from dogs with pyothorax, thus combination antimicrobial therapy targeting both populations is necessary.

Initially, antibiotics should be given IV until the patient is alert and eating. Once clinical improvement is noted, oral therapy can begin for long-term treatment. Antibiotics should be continued for at least 4 to 6 weeks after chest tube removal. Nocardia infections should be treated for up to 6 to 12 months.

Antibiotics available for use in dogs with pyothorax and spectrum of activity as it applies to the disease are listed in Table 2.

Table 2. Antibiotics for Treating Canine Pyothorax

<table>
<thead>
<tr>
<th>Drug</th>
<th>Spectrum</th>
<th>Dosage</th>
</tr>
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<tbody>
<tr>
<td>Amikacin</td>
<td>A–, N, M</td>
<td>5–10 mg/kg IV, IM, or SC q8–12h</td>
</tr>
<tr>
<td>Amoxicillin–clavulanate</td>
<td>A–, A+, Ac, An</td>
<td>22 mg/kg PO q8–12h</td>
</tr>
<tr>
<td>Ampicillin (amoxicillin)</td>
<td>A+, few A–, Ac, An</td>
<td>20–40 mg/kg IV, IM, SC, or PO q6–8h</td>
</tr>
<tr>
<td>Ampicillin–sulbactam</td>
<td>A–, A+, An</td>
<td>22 mg/kg IV or IM q6–8h</td>
</tr>
<tr>
<td>Cefazolin</td>
<td>A+, Ac</td>
<td>15–25 mg/kg IV, IM, or SC q4–8h</td>
</tr>
<tr>
<td>Cefotaxime</td>
<td>A–, A+, An, N</td>
<td>20–80 mg/kg IV, IM, or SC q6–8h</td>
</tr>
<tr>
<td>Ceftriaxime</td>
<td>A–, A+, An’</td>
<td>25–50 mg/kg IV, IM q8h</td>
</tr>
<tr>
<td>Cefoxitin</td>
<td>A–, A+, An’</td>
<td>30 mg/kg IV, IM, or SC q6–8h</td>
</tr>
<tr>
<td>Cephalexin</td>
<td>A+, Ac</td>
<td>25–60 mg/kg PO q8h</td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>A+, few A–, Ac, An’, M</td>
<td>50 mg/kg IV, IM, SC, or PO q6–8h</td>
</tr>
<tr>
<td>Clindamycin</td>
<td>A+, Ac, An’, M</td>
<td>5–11 mg/kg IV, IM, SC, or PO q8h</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>A–, M</td>
<td>5–20 mg/kg IV, IM, SC, or PO q24h</td>
</tr>
<tr>
<td>Erythromycin</td>
<td>A+, Ac, N, M</td>
<td>10–20 mg/kg PO q8h</td>
</tr>
<tr>
<td>Gentamicin</td>
<td>A–, M</td>
<td>6 mg/kg IV, IM, or SC q24h</td>
</tr>
<tr>
<td>Imipenem–cilastatin</td>
<td>A–, few A+, Ac, N</td>
<td>2–5 mg/kg IV q6–8h</td>
</tr>
<tr>
<td>Metronidazole</td>
<td>An’</td>
<td>10–15 mg/kg IV or PO q12h</td>
</tr>
<tr>
<td>Minocycline</td>
<td>Ac, N</td>
<td>5–12 mg/kg IV or PO q12h</td>
</tr>
<tr>
<td>Penicillin G</td>
<td>A+, Ac, An</td>
<td>20,000–100,000 U/kg IV, IM, SC, or PO q4–8h</td>
</tr>
<tr>
<td>Penicillin V</td>
<td>Ac, N</td>
<td>5.5–40 mg/kg PO q6–8h</td>
</tr>
<tr>
<td>Rifampin</td>
<td>Ac</td>
<td>10–20 mg/kg IV, IM, or PO q12–24h</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>few A–, few A+, Ac, M</td>
<td>20–50 mg/kg PO q8–12h</td>
</tr>
<tr>
<td>Ticarcillin–clavulanate</td>
<td>A–, A+, An, N</td>
<td>40–50 mg/kg IV q6–12h</td>
</tr>
<tr>
<td>Trimethoprim–sulfamethoxazole</td>
<td>A–, N</td>
<td>30–60 mg/kg IV or PO q12h</td>
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</table>

*Good activity against *Pseudomonas* spp.
*Effective against *B. fragilis*.
*Ineffective against *Nocardia* spp and *B. fragilis*; variable activity against other *Bacteroides* spp.
*Resistance to some *Staphylococcus* spp possible.
*E. coli* isolates appear to be growing less sensitive to enrofloxacin; greater susceptibility achieved with amikacin, gentamicin, and ceftriaxime.
*A–* = gram-negative aerobes; *A+* = gram-positive aerobes; *Ac* = *Actinomyces* spp; *An* = anaerobes; *M* = *Mycoplasma* spp; *N* = *Nocardia* spp.
acid, chloramphenicol, and metronidazole. Initial therapy for anaerobic bacteria should begin with one of these antimicrobials, especially given that culture and sensitivity testing for anaerobic bacteria is difficult and expensive. Ampicillin also possesses good activity against many anaerobes but is ineffective against some Bacteroides isolates, especially those of the Bacteroides fragilis group. This resistance stems from the production of cephalosporinase by members of the B. fragilis group, which inactivates ampicillin as well as amoxicillin. Clindamycin, however, is more effective against B. fragilis when compared with ampicillin or amoxicillin and is active against many anaerobic species, including Peptostreptococcus, Fusobacterium, and some Clostridium spp. If an IV preparation is needed for treatment, ampicillin–sulfactam can be used in place of amoxicillin–clavulanic acid. Although not extensively reported in the veterinary literature, ticarcillin–clavulanic acid, another IV formulation, has been shown to be effective in human anaerobic infections. Additionally, the trimethoprim–sulfonamides have questionable efficacy against anaerobic bacteria because of inhibitory thymidine production in vivo, despite favorable susceptibility testing in vitro. The effects of tetracycline against anaerobes are unpredictable as well.

Several aerobic gram-negative and -positive species (e.g., E. coli, Staphylococcus) commonly associated with canine pyothorax are inherently resistant to amoxicillin, ampicillin, and first-generation cephalosporins because of β-lactamase production. The clavulanic acid component of the amoxicillin–clavulanic acid and ticarcillin–clavulanic acid preparations inactivates β-lactamase. Moreover, recent evidence demonstrates that nonenteric gram-negative bacteria (most commonly Pasteurella spp) comprise 37% of all aerobic bacteria isolated with anaerobes from mixed pyothorax infections in dogs, and these bacteria are 92% to 100% susceptible to amikacin, gentamicin, enrofloxacin, amoxicillin–clavulanic acid and ticarcillin–clavulanic acid, cefoxime, and trimethoprim–sulfamethoxazole. Furthermore, only 75% of the E. coli strains isolated from the same group of dogs were sensitive to enrofloxacin compared with an earlier report by the same authors in which more than 95% of E. coli isolates were found to be susceptible to enrofloxacin. This growing resistance to enrofloxacin should be considered when choosing antibiotics before receiving culture and sensitivity results. Greater susceptibility for 80% or more of E. coli isolates can be achieved with amikacin, gentamicin, and cefoxime.

The presence of dense granulomatous sulfur granules in aspirated fluid and cytologic evidence of gram-positive branching filamentous rods dictates long, high-dose antibiotic therapy. Culture and/or acid-fast staining should be used to differentiate between Actinomyces and Nocardia spp. Penicillin G (benzyl penicillin) or penicillin V (phenoxymethyl penicillin) is recommended for Actinomyces infections. Most Actinomyces spp isolates are susceptible to the penicillins, and poor responses to penicillin treatment may be due to poor thoracic drainage and/or the presence of associated bacteria. Relapses can be common if long-term treatment (weeks to months) for Actinomyces is not provided. Other effective antibiotics include erythromycin, clindamycin, ampicillin, tetracycline, minocycline, doxycycline, chloramphenicol, imipenem, and first-generation cephalosporins. Sulphonamides and the trimethoprim–sulfonamide combinations are the recommended therapeutics for Nocardia infections. Others reported to be effective include amikacin, erythromycin, imipenem, minocycline, and ofloxacin. Severely affected animals may warrant initial combination therapy.

**THORACOTOMY**

Underlying cause, etiologic agents, and the duration of clinical disease are important factors to consider when determining the need for surgery. Exploratory thoracic surgery should be considered if clinical and radiographic signs have not responded to intense medical therapy in 3 to 7 days or if underlying disease (i.e., lung abscess, lung lobe torsion, foreign body) is present. In some cases, surgery may be necessary for complete resolution of pyothorax, especially if foreign body involvement is suspected. However, foreign material can be difficult to locate intraoperatively. Better outcomes have been achieved when surgery is performed on dogs with initial radiographic evidence of mediastinal or pulmonary lesions. Moreover, isolation of Actinomyces spp from pleural fluid may warrant early surgical intervention because these organisms are associated with grass-awn type foreign bodies.

Typical approaches include intercostal thoracotomy if disease can be isolated to one hemithorax or median sternotomy to give access to both sides of the thorax for bilateral disease. Objectives for surgery include breakdown of adhesions and pockets of loculated fluid, localizing and removing any foreign material, resection of affected tissue, and copious lavage of the thoracic cavity. Mediastinectomy, pericardectomy, and/or lobectomy may be necessary if the surfaces are thickened and abscessed. Removal of necrotic and inflamed tissue may help to reduce bacterial numbers and also allow better penetration of antimicrobials. Nevertheless, excised tissue should be scrutinized for foreign bodies and submitted for histopathologic examination. Microscopic foreign bodies may be detected only with
A chest tube should be placed during surgery for continued suction drainage after surgery. The tube can be removed once the criteria indicated under medical management have been met.

Chronic exposure of the pleural surfaces to exudate effusions leads to formation of a tissue layer rich in fibroblasts and inflammatory cells. Fibrosing pleuritis subsequently develops, causing both constriction of pulmonary parenchyma and restriction of pulmonary expansion. Compromise of normal pulmonary function necessitates removal of this fibrous peel via decortication. The procedure is difficult in animals, and complications include pulmonary hemorrhage and edema, pneumothorax, and pulmonary fistulas. Decortication should ideally be performed as soon as possible after diagnosis but before the fibrous tissue adheres to the pleura and becomes vascularized. Adhesions between the parietal and visceral pleura and adjacent lung lobes can also form. These adhesions can tear with forceful inspirations, causing pain and pneumothorax.

PROGNOSIS

The prognosis for pyothorax is fair to good. Early diagnosis and aggressive therapy with tube thoracostomy, frequent drainage, lavage, and appropriate antimicrobials improve long-term outcome. Reviews of early studies show a 50% to 60% success rate. More recent reports show a survival rate close to 90%, which may be attributable to earlier diagnosis, different underlying pathogenesis, and more aggressive treatment. Treatment with antibiotics alone or in combination with infrequent thoracic drainage can increase the likelihood of adhesion formation and the need for surgical management. If the degree of fibrosis is severe and affected lung lobes are unable to expand normally, the prognosis may be poor. Until recently, the role of thoracic surgery in managing canine pyothorax was not well documented. It may still be unclear whether all cases of pyothorax require surgery; however, evidence from a recent retrospective study demonstrates that in cases in which it is indicated, a more favorable outcome is associated with thoracotomy when compared with medical therapy. Moreover, early surgical intervention may be warranted in patients with radiographic signs of mediastinal or pulmonary lesions and/or with pleural fluid in which Actinomyces spp have been positively identified. Additionally, earlier reports indicate that cure rates of at least 90% are possible with long-term antibiotics and/or surgery in patients with Actinomyces spp. In contrast, mortality with nocardiosis is high and attributable to predisposing conditions, delayed diagnosis, and inappropriate therapy. It is possible that earlier diagnosis and combination antimicrobial therapy in animals with Nocardia spp may lower mortality rates as it does in humans.

REFERENCES


**ARTICLE #2 CE TEST**

The article you have read qualifies for 1.5 contact hours of Continuing Education Credit from the Auburn University College of Veterinary Medicine. Choose the best answer to each of the following questions; then mark your answers on the postage-paid envelope inserted in *Compendium*.

1. The most common signs seen on physical examination of dogs with pyothorax are
   a. anorexia and polyuria.
   b. tachypnea and hypothermia.
   c. dehydration and cyanosis.
   d. fever, dyspnea, and weight loss.

2. Complications of thoracocentesis include
   a. pneumothorax.
   b. hemothorax.
   c. pulmonary hemorrhage.
   d. all of the above.
3. Which of the following anaerobic bacteria are not commonly isolated in canine pyothorax?
   a. *Fusobacterium*  
   b. *Clostridium*  
   c. *Bacteroides*  
   d. *Peptostreptococcus*

4. The best method to prevent hypoproteinemia during treatment of pyothorax is to
   a. decrease the amount of lavage solution.
   b. provide adequate nutrition.
   c. increase the time between drainage.
   d. initiate transfusion therapy with whole blood or plasma.

5. The antibiotic of choice for *Nocardia* infections is
   a. ticarcillin–clavulanate acid.
   b. enrofloxacin.
   c. chloramphenicol.
   d. trimethoprim–sulfonamides.

6. Which of the following thoracic radiographic views and/or procedures provides the most diagnostic information after thoracocentesis in severely dyspneic animals?
   a. ventrodorsal
   b. right lateral
   c. standing horizontal beam projection
   d. pleural space contrast study

7. Proper analysis of pleural fluid includes
   a. aerobic and anaerobic cultures.
   b. volume, color, and presence of sulfur granules.
   c. cytologic examination.
   d. all of the above

8. What percentage of *Actinomyces* infections respond with appropriate treatment?
   a. 90%  
   b. 20%  
   c. 10%  
   d. 60%

9. Aspirated pleural fluid should be placed in ___________ tubes for biochemical analysis and ___________ tubes for cell counts, total protein determination, and cytologic examination.
   a. heparin (green-top); serum (red-top)
   b. EDTA (lavender-top); serum (red-top)
   c. sodium fluoride (gray-top); EDTA (lavender-top)
   d. serum (red-top); EDTA (lavender-top)

10. Which of the following statements regarding canine pyothorax is false?
    a. Young and middle-aged dogs from hunting/working breeds are more affected.
    b. Lack of degenerative neutrophils and/or bacterial organisms does not totally rule out a septic effusion.
    c. Continuous suction drainage decreases the time needed to manage pleural infections.
    d. Exploratory thoracic surgery is not usually successful in isolating foreign material in cases refractory to medical treatment.