TREATMENT OF BACTERIAL PNEUMONIA
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INTRODUCTION
Although any portion of the respiratory tract is susceptible to bacterial infection, most life-threatening infections involve the gas exchange units of the lung; that is, bacterial pneumonia. Of course, not all bacterial pneumonia is life-threatening. Bacterial pneumonia may involve one lung lobe or many, may be acute or chronic, and may cause minimal clinical signs or may result in death. This presentation will deal primarily with severe bacterial pneumonia. Although we will focus on bacterial pneumonia, please keep in mind that not all pneumonia is infectious (e.g., aspiration pneumonia, lipid pneumonia), and not all infectious pneumonia is bacterial (e.g., viral pneumonia, fungal pneumonia).

As for humans, it is rare for young to middle aged adult animals to develop spontaneous bacterial pneumonia. Instead, pneumonia more often occurs in the very young, the very old, immune suppressed, injured, or debilitated animals. Reasonable efforts should be made to identify underlying predisposing factors (e.g., megaesophagus, immunodeficiency states) at the onset of treatment as these underlying conditions can make treatment of bacterial pneumonia all the more challenging. Dogs that present with pneumonia and have not had other known injury/illness are said to have community acquired pneumonia, which may be due to a primary respiratory pathogen such as *Bordetella* or a viral infection complicated by secondary bacterial infection. These pneumonias might also be associated with an unrecognized injury (e.g., airway foreign body). Bacterial pneumonia is much more common in dogs than in cats. Although the lungs can become infected via hematogenous spread of bacteria or from direct extension of pleural infection, it is more common via the airways, either as aerosolization of pathogen or aspiration.

Severe bacterial pneumonia causes clinical signs that are both 1) related to infection, and 2) related to hypoxemia. Anorexia, lethargy, cough, nasal discharge, tachypnea, and even dyspnea are typical, but respiratory signs are not always prominent (and may be absent in mild pneumonia). On examination, a mixed inspiratory-expiratory distress may be evident, as will increased bronchovesicular lung sounds. As pneumonia becomes more severe, crackles and sometimes wheezes will be heard on auscultation, often with a ventral distribution. Only about half of all animals with bacterial pneumonia have fever at presentation. Neutrophilic leukocytosis with or without left shift is common but not a uniform finding. Hypoxemia may be recognized via pulse oximetry or arterial blood gas analysis. Thoracic radiographs early on demonstrate an unstructured bronchointerstitial pattern that progresses to alveolar pattern as the process becomes more severe. Although a ventral distribution is typical, radiographic changes may be diffuse or may involve only some of the lung lobes, depending on the cause of pneumonia. Airway lavage typically reveals many degenerate neutrophils, often containing intracellular bacteria.

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Treatment of pneumonia must involve attempts to eradicate the causative bacterial agent, as well as supportive care.

Anti-Infective Therapy
Pathogens incriminated in bacterial pneumonia are often opportunistic, and include enteric pathogens (e.g., *E. coli*, *Klebsiella*), as well as *Pasteurella* spp., coagulase-positive *Staphylococci*, *Streptococci*, and *Mycoplasma* spp. *Bordetella bronchiseptica* is a very common cause of pneumonia in puppies, and is one of the few primary bacterial pathogens that can cause pneumonia. Because antimicrobial treatment is often prolonged, it is important to actually identify the offending pathogen(s) and determine susceptibility. Overly broad, toxic, or expensive treatment can be avoided simply to performing a timely culture and sensitivity from the airways. Transtracheal wash in larger dogs or transoral airway lavage in cats and small dogs provides material for cytologic exam and culture prior to initiation of broad-spectrum antibiotics.
All bacterial pneumonia should be treated with antimicrobial drugs, with the choice ideally based on culture and sensitivity results. However, antimicrobial drugs should be instituted before culture results become available, and then adjusted later. In some cases, owners will decline culture thus forcing the use of an “educated guess” as to the type of pathogen. In a recent retrospective study (Proulx et al), such guesses, made by clinicians in a veterinary medical teaching hospital, resulted in a resistant choice for 26% of pathogens! And in the same study, when animals had been given prior courses of antimicrobial within the last month, resistance to that previously used antimicrobial was around 57%. The organisms most commonly implicated in bacterial pneumonia include enteric pathogens (~ 50%) and anaerobes (~ 20–25%); polymicrobial infections are not uncommon. Especially if the dog is less than a year or in cases of community acquired pneumonia, be sure the guess includes an antimicrobial appropriate for B. bronchiseptica.

An initial antibacterial choice depends on the disease severity; the more severe the disease, the more aggressive should be the therapy. To achieve broad spectrum coverage it is common to use combination therapy. The author typically begins with a fluoroquinolone combined with a beta-lactam, but other drugs or combinations could be used (e.g., beta lactams plus aminoglycosides or second generation cephalosporin; ticarcillin; meropenem). Parenteral administration is used as the initial delivery route for severely affected animals (e.g., enrofloxacin plus ampicillin). For cats with pneumonia, oral pradofloxacin provides broad spectrum coverage, including an anaerobic spectrum of activity and thus is a good initial choice. Typically if the animal’s condition has improved after several days an oral route of administration is adopted.

For pets with moderate to mild pneumonia, oral therapy may be fine initially, and it is reasonable to use a bit less of a broad net for empiric treatment. Cultures should be done, however, as “wrong” guesses are quite common. A 2014 study by Proulx et al documented that at U Penn, 26% of all empiric antibiotic choices were “wrong” based on pathogen MIC, and this went up to 57.5% “wrong” choice for dogs that had received any antibiotic within the past 4 weeks. Once antimicrobial susceptibilities have been determined, the antibiotic with the narrowest effective spectrum of action should be used. Duration of therapy is usually at least one week past an apparent radiographic cure, or a minimum of 3 weeks. However, humans are treated for much much shorter times when they have pneumonia...perhaps we could do with shorter antibiotic durations as well. However, most human pathogens are primary bacterial respiratory pathogens, whereas bacterial pneumonia in dogs is more likely to be due to enteric secondary pathogens after aspiration (Bordetella being an important exception in pups).

Although in the treatment of tracheobronchitis strong consideration should be given to the “blood bronchus barrier” that effects penetration of systemic antibiotics into the airway lumen. Some drugs penetrate well (e.g., fluoroquinolones, tetracyclines, azithromycin), and others do not (e.g., beta lactams, including amoxicillin and cephalosporins). However, severe inflammation that accompanies bacterial pneumonia should allow the penetration of drugs that otherwise would not reach adequate airway concentrations in the airway lining fluid.

Some veterinarians use nebulized antimicrobials in the treatment of bacterial pneumonia. Nebulized antibiotics will only reach the airway lumen, and not the deep tissue sights of infection. For this reason, the use of nebulized antibiotics for the treatment of pneumonia must never be used to replace systemic therapy, but can be considered as an adjunct to systemic antimicrobials. This form of therapy is certainly used in the treatment of some forms of bacterial pneumonia in humans, especially in patients with cystic fibrosis. There are no published studies on the efficacy or safety of nebulized antibiotics for the treatment of pneumonia in dogs or cats. In humans, nebulized antibiotics are specially formulated for that route of administration. They do not contain additives or preservatives that might cause bronchoconstriction, and are formulated to achieve the correct particle size in a nebulizer to reach the distal airways. Unfortunately, these formulations (i.e., tobramycin for aerosol administration) are prohibitively expensive for veterinary use. Few liquid antimicrobials are appropriate to even consider for nebulization; the author has used both gentamicin and amikacin for this purpose.

Supportive Therapy
Dogs with severe bacterial pneumonia are often hypoxemic. Ideally, PaO₂ is determined via arterial blood gas, or alternatively, SpO₂ is used as a rough correlate. Oxygen supplementation should be provided when PaO₂ is < 80 mmHg or the SpO₂ is < 94%. The most practical means of delivery is placement of a
nasal cannula, or oxygen cages for cats or small dogs (cages use far more oxygen). Oxygen should be humidified prior to delivery to prevent drying of the airways with resultant impaired mucociliary clearance. The FIO₂ should be kept at a minimum effective level since oxygen is itself toxic in high concentration over time. Ideally, a maximum of 40% FiO₂ should be used. On occasion higher concentrations are required but should be used for less than 2 days if at all possible. For animals that remain markedly hypoxemic, fail to adequately eliminate CO₂, or are threatened with respiratory exhaustion ventilator therapy may be the only option for continued care.

Fluid therapy is an important part of the treatment of animals with severe bacterial pneumonia. These animals are weak, depressed and often febrile and therefore susceptible to dehydration. In addition to the systemic effects of dehydration, dehydration can cause the mucus layer of airway secretions to become dehydrated as well. The mucociliary escalator functions to trap particulates and bacteria, move them cranial via directional movement of cilia, and allow particulates to reach the oropharynx where they can be expelled through coughing swallowing. The mucus itself is made of two layers - the watery sol layer through with the cilia move, and the overlying gel layer that traps the particulates. If the sol layer becomes dehydrated, the cilia themselves can become entrapped in the gel layer impeding the free movement of the cilia and thereby effectively inhibiting the mucociliary escalator. Both systemic fluid therapy and airway nebulization can contribute to the more effective action of the mucociliary escalator by allowing the sol layer to perform as required.

Importantly, cough suppressants should NOT be used to treat animals with bacterial pneumonia. Instead, the goal should be to encourage cough and subsequent removal of infected sputum. This is the reasoning behind the use of physical therapy techniques such as coupage. Using a cupped hand clapping motion on either side of the chest several times a day, combined with frequent turning of recumbent patients and encouraging short walks may help induce cough and encourage clearance of sputum. Nebulization of the airways will help make the mucus layer thinner and more able to be moved by the mucociliary escalator. Nebulizers should secrete particles between 0.5 and 3.0 micrometers, a feat that is not accomplished with simple room humidifiers. Saline nebulization is effective alone, although sometimes other agents such as mucolytics (N-acetylcysteine) or antibiotics (often aminoglycosides) are added to the nebulization solution. When products are added to the nebulization solutions that were not made for that purpose (e.g., non-respiratory formulations of gentamicin or amikacin) it must be recognized that a percentage of animals may develop bronchoconstriction in response to additives or preservatives in the product. Bronchoconstriction commonly follows nebulization of N-acetylcysteine too, so the author does not use this product by the inhalant route. The routine use of bronchodilators in the treatment of bacterial pneumonia remains controversial. The author does not use bronchodilators on a routine basis, but may consider the use of either albuterol inhalers or oral methylxanthine type drugs (e.g., theophylline) in animals that remain hypoxemic despite oxygen supplementation.

In cases of severe bacterial pneumonia involving a single lung lobe that fail to clear in response to standard therapy, strong consideration should be given to lobectomy. Often, such infections are due to an underlying physical problem in that single lobe such as bronchial foreign body or tumor. Removal of the lobe may result in cure in such cases. The removed lung should be submitted both for tissue culture and for histopathology.

The author’s typical management of a dog suffering from severe bacterial pneumonia would include intravenous crystalloid fluids at a rate to provide maintenance needs, correct dehydration, and account for ongoing losses. Parenteral broad spectrum antimicrobials would be initiated pending culture results, most often consisting of ampicillin (20 mg/kg IV TID) and enrofloxacin (5 mg/kg IV diluted 50:50 in saline and given slowly BID). Saline nebulization and coupage would each be performed QID. Oxygen would be supplied, typically by nasal cannula, if PaO₂ is < 80 mmHg or SpO₂ is < 94%. If the animal remains anorectic for more than 3 days, nutritional support either via tube feeding or parenteral nutrition would be initiated.

**SPECIAL INFECTIONS**

There are specific bacterial causes of infectious pneumonia worth mention. Both *Ehrlichia* and *Rickettsia rickettsii* may cause pulmonary manifestation due to vasculitis. Mycoplasma, fastidious microbes that lack a cell wall, may play a primary or secondary role in pulmonary infection of dogs and cats. They are resistant to many commonly used antibiotics, but are generally susceptible to macrolides, tetracyclines,
chloramphenicol, and fluoroquinolones. Dogs and cats are rarely diagnosed with acid-fast mycobacterial infections. Basset hounds and Siamese cats have been most often reported to have M. avium infections. M. bovis (tuberculosis) is a reverse zoonoses, which dogs acquire from and infected human. Because of the typical hilar lymphadenomegaly and nodular or interstitial nodular lung patterns, mycobacterial infections may mimic pulmonary neoplasia. Cats in the southwestern USA may develop pneumonia as a result of Yersinia pestis infection. Although uncommon, this is extremely important as a potentially fatal zoonosis.

REFERENCES


