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Retrospective Study

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In vitro bacterial isolate susceptibility to empirically selected antimicrobials in 111 dogs with bacterial pneumonia

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Abstract

Objectives – To determine the proportion of airway bacterial isolates resistant to both empirically selected and recently administered antimicrobials, and to assess the impact of inappropriate initial empiric antimicrobials selection on length of hospital stay and survival to discharge in dogs with bacterial pneumonia.
Design – Retrospective study.
Setting – University veterinary teaching hospital.
Animals – One hundred and eleven dogs with a clinical diagnosis of bacterial pneumonia that had aerobic bacterial culture and susceptibility testing performed from a tracheal wash sample.
Intervention – None.
Measurements and Main Results – Overall, 26% (29/111) of the dogs had at least 1 bacterial isolate that was resistant to empirically selected antimicrobials. In dogs with a history of antimicrobial administration within the preceding 4 weeks, a high incidence (57.4%, 31/54) of in vitro bacterial resistance to those antimicrobials was found: 64.7% (11/17) in the community-acquired pneumonia group, 55.2% (16/29) in the aspiration pneumonia group, and 50.0% (4/8) in the other causes of bacterial pneumonia group. No statistically significant association was found between bacterial isolate resistance to empirically selected antimicrobials and length of hospital stay or mortality.
Conclusions – The high proportion of in vitro airway bacterial resistance to empiric antimicrobials would suggest that airway sampling for bacterial culture and susceptibility testing may be helpful in guiding antimicrobial therapy and recently administered antimicrobials should be avoided when empirically selecting antimicrobials. Although no relationship was found between inappropriate initial empiric antimicrobial selection and length of hospital stay or mortality, future prospective studies using standardized airway-sampling techniques, treatment modalities, and stratification of disease severity based on objective values, such as arterial blood gas analysis in all dogs with pneumonia, would be needed to determine if a clinical effect of in vitro bacterial resistance to empirically administered antimicrobials truly exists or not.

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Introduction

Bacterial pneumonia is characterized as an acquired inflammatory lung disease caused by bacterial colonization of the lower airways and lung parenchyma.[1,2] Introduction of bacteria into the respiratory system occurs either by inhalation of aerosols, by aspiration of oropharyngeal or gastroesophageal contents, by extension of a local extra-pulmonary infection, or by hematogenous spread.[1] Anecdotally, aspiration- and community-acquired pneumonia appear to be the most common clinically encountered causes of pneumonia in dogs. In the former, aspiration of oropharyngeal or gastric material causes a chemical pneumonitis that may subsequently be colonized either by pathogenic bacteria that are carried

Abbreviation

MIC minimal inhibitory concentration

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down with the aspirated material or by normal respiratory flora.[3] In community-acquired pneumonia, a primary lung pathogen is contracted via close contact with a previously infected animal.[4]

A presumptive clinical diagnosis of bacterial pneumonia is based on a combination of historical data, clinical signs, physical examination findings, and thoracic radiographic abnormalities. Ideally, tracheal wash fluid analysis, bronchoalveolar lavage, or a pulmonary fine-needle aspirate is performed to confirm the diagnosis and allow for culture and antimicrobial susceptibility testing. Bronchoalveolar lavage has been suggested as the best clinical technique as it is selective, is less likely to lead to complications as compared with a transthoracic pulmonary fine-needle aspirate, and is more sensitive than tracheal wash techniques for diagnosis of alveolar and interstitial diseases.[5–7] However, this procedure is equipment- and expertise-dependent and therefore has limited availability. Although tracheal washes (transtracheal and endotracheal) provide less selective samples than other techniques, they are routinely used in clinical veterinary practice because they are easy to perform and minimally invasive. Once a clinical diagnosis of bacterial pneumonia has been established, treatment consists of antimicrobial administration along with general supportive therapy. Antimicrobial therapy based on the results of culture and susceptibility testing is desirable as it has been shown to hasten clinical and radiographic resolution of disease in previous studies in dogs with pneumonia.[8–10]

Empiric antimicrobial therapy is generally instituted while awaiting the results of microbial testing. When choosing empiric antimicrobial therapy, a prudent approach consists of combining antimicrobials to provide broad spectrum coverage against the most commonly encountered bacteria.[1,2] Unfortunately, resistance to antimicrobials is increasingly common and the initial empiric antimicrobials may not be appropriate in all cases.[11] Human studies have shown that inappropriate initial empiric antimicrobial therapy increases morbidity, mortality, and length of hospitalization compared with the use of appropriate antimicrobial therapy in patients with severe bacterial pneumonia.[12–15] In addition, airway-sampling techniques for bacterial culture and susceptibility testing provides a means for de-escalation of antimicrobial therapy, which reduces both the healthcare costs and bacterial resistance selection pressure.[12] Comprehensive antimicrobial protocols based on epidemiologic data exist in people, which guide empiric antimicrobial clinical decisions.[12] The recommended empiric therapies are based on prediction of the most likely pathogen(s), knowledge of local susceptibility patterns, the patient's severity of disease, concurrent medical conditions, and recent antimicrobial therapy.[12] Such extensive, comprehensive, epidemiologic-based recommendations guiding empiric antimicrobial decisions are not yet available in veterinary medicine.

To the authors' knowledge, the frequency and clinical impact of inappropriate empiric antimicrobial therapy based on in vitro bacterial susceptibility testing in dogs with pneumonia has not been investigated to date. Therefore, the primary objective of this study was to determine the proportion of dogs with bacterial growth obtained from tracheal wash techniques that was resistant to initial empiric antimicrobial selection. The secondary objectives of this study were to determine the incidence of in vitro airway bacterial resistance to recently administered antimicrobials, and to assess the impact of inappropriate initial empiric antimicrobial selection on length of hospital stay and survival to discharge.

Materials and Methods

The patient computer database of the Ryan Veterinary Hospital, School of Veterinary Medicine, University of Pennsylvania was searched to identify records of dogs coded with a clinical diagnosis of "bacterial pneumonia," which had a sample from a tracheal wash submitted for aerobic bacterial culture testing from January 1, 2002 to December 31, 2009. Cases were excluded if the bacterial culture was negative (no bacterial growth) precluding an assessment of antimicrobial susceptibility or if the medical record was incomplete.

The medical records of these dogs were retrospectively reviewed and data were imported into a computer spreadsheet application.[a] The medical records of these patients were reviewed for: age, weight, medical history including recent anesthesia, vomiting, regurgitation, laryngeal or pharyngeal dysfunction, esophageal disease, neurologic disease, recent community exposure in the 10 days preceding presentation (eg, frequenting a boarding, training, doggie day care or grooming facility, or animal recently acquired), recent antimicrobial therapy (within the 4 weeks preceding presentation). Each case was assigned to 1 of the following clinical diagnosis groups: community-acquired pneumonia, aspiration pneumonia, or other causes of bacterial pneumonia. The community-acquired pneumonia group included every case with recent community exposure. The aspiration pneumonia group included dogs with a cranioventral radiographic abnormality distribution as well as at least one known risk factor for aspiration pneumonia: recent anesthesia, vomiting, regurgitation, laryngeal or pharyngeal dysfunction, esophageal disease or neurologic disease. The remaining dogs were assigned to the group of other causes of bacterial pneumonia.

Airway-sampling technique (transtracheal wash versus endotracheal wash), and both cytologic evaluation

and microbiologic testing results were also recorded. Cases were classified as susceptible if the bacterial culture isolate(s) was susceptible to at least one of the antimicrobials used empirically, based on the minimal inhibitory concentration (MIC). An intermediate susceptibility result based on MIC was classified as resistant for the purpose of statistical analysis. In dogs with more than 1 tracheal wash performed, only the culture result from the first sample and prior to initiation of mechanical ventilation in dogs with respiratory failure was recorded and included in statistical analysis.

The length of hospital stay was recorded as well as the outcome, survivor or nonsurvivor. Dogs were designated as survivor if they were discharged from the hospital and designated as nonsurvivor if they died or were euthanized while hospitalized.

Statistical methods

The Shapiro-Wilks test was used to determine whether continuous variables were normally distributed or not. Normally distributed continuous variables are described with mean ± SD while median (range) are used for non-normally distributed variables. The Student's *t*-test or the Wilcoxon rank sum test was used to compare continuous variables. Categorical data are described using ratios and percents and the Pearson χ^2 or Fisher's exact test (if the expected count in 1 of the cells of the contingency tables was < 5) was used to compare the categorical data. A P value < 0.05 was considered significant for all comparisons. A statistical software program was used for all analyses.[b]

Results

One hundred and fifty dogs with a clinical diagnosis of bacterial pneumonia, and that also had a tracheal wash sample submitted for aerobic bacterial culture, were identified through the medical database search. Of these, 18 dogs were excluded due to incomplete medical records and 21 dogs were excluded due to a negative bacterial culture result. A total of 111 dogs met the inclusion criteria of the study. Twenty-eight dogs were assigned to the community-acquired pneumonia group, 71 dogs to the aspiration pneumonia group and 12 dogs to the other causes of bacterial pneumonia group.

The median age of the community-acquired pneumonia dogs was 0.4 years (range 0.2–9.1 y) and median body weight was 15.0 kg (range 0.44–65.4 kg). The median age of the aspiration pneumonia dogs was 8.2 years (range 0.2–14.2 y) and median body weight was 26.9 kg (range 3.5 – 75.0 kg). The median age of the other causes of pneumonia dogs was 8.1 years (range 1.5–13.3 y) and median body weight was 40.3 kg (range 8.8–71.8 kg). Endotracheal wash was the most common technique from which an airway sample was obtained (Table 1). One hundred and eight dogs (108/111) had cytologic evaluation of the airway sample obtained from tracheal wash and these results are summarized in Table 2.

Table 1: Numbers of each tracheal wash technique performed in each group

Tracheal wash technique	Community-acquired pneumonia (%)	Aspiration pneumonia (%)	Other causes of pneumonia (%)
Endotracheal wash	26 (93)	62 (87)	11 (92)
Transtracheal wash	2 (7)	9 (13)	1 (8)

Various bacterial isolates were obtained as shown in Table 3. The most commonly isolated bacterial organism was *Bordetella bronchiseptica* in dogs with community-acquired pneumonia; whereas *Escherichia coli*, *Klebsiella* sp., *Streptococcus* sp., and *Staphylococcus* sp. were most commonly identified in both dogs with aspiration pneumonia and other causes of bacterial pneumonia. Overall, 26.1% (29/111) of the dogs had at least 1 bacterial isolate that was resistant to empirically selected antimicrobials. Of these dogs, 69.0% (20/29) received antimicrobials within the 4 weeks prior to presentation and 50.0% (10/20) of those were empirically prescribed the same antimicrobial(s) they had been recently receiving. After assigning the dogs to groups based on their clinical diagnosis, the percentage of dogs with at least 1 bacterial isolate that was resistant to empirically selected antimicrobials was: 28.6% (8/28) in the community-acquired group, 28.2% (20/71) in the aspiration pneumonia group, and 8.3% (1/12) in the other causes of pneumonia group. The antimicrobials were empirically selected at the attending veterinarian's discretion and these are summarized in Table 4.

Within the 4 weeks preceding presentation, 62 dogs (62/111) received antimicrobials: 61% (17/28) of the dogs in the community-acquired pneumonia group, 50% (36/71) of the dogs in the aspiration pneumonia group, and 75% (9/12) of the dogs in the other causes of pneumonia group; 23.5% (4/17) of the dogs in the community-acquired pneumonia group, 47.2% (17/36) of the dogs in the aspiration pneumonia group, and 66.7% (6/9) of the dogs in the other causes of pneumonia group were empirically prescribed the same antimicrobial(s) they had been recently receiving. Six dogs were being treated for a skin infection, 4 dogs were being treated for a urinary tract infection, 1 dog was being treated for septic arthritis, and the remaining 51 dogs were being treated for respiratory tract infections. The previously administered antimicrobials are summarized in Table 5.

Table 2: Airway sample cytologic evaluation ($n = 108$)

Groups	Severe neutrophilic inflammation (%)	Mild neutrophilic inflammation (%)	No inflammation (%)	Oropharyngeal material* (%)
Community-acquired pneumonia ($n = 27$)	27 (100)	0 (0.0)	0 (0.0)	2 (7.4)
Aspiration pneumonia ($n = 69$)	60 (87.0)	7 (10.1)	2 (2.9)	18 (26.1)
Others ($n = 12$)	10 (83.3)	1 (8.3)	1 (8.3)	1 (8.3)

*Oropharyngeal material was present in addition to the underlying type of cytologic findings.

Table 3: Bacterial isolates obtained from tracheal washes for each group

	Number of isolates		
Bacteria	**Community-acquired pneumonia (%)**	**Aspiration pneumonia (%)**	**Other causes of pneumonia (%)**
Gram-negative enteric			
Escherichia coli	5 (17.8)	36 (50.7)	6 (50.0)
Klebsiella sp.	1 (3.6)	15 (21.1)	3 (25.0)
Enterobacter sp.	0	8 (11.3)	1 (8.3)
Proteus sp.	1 (3.6)	2 (2.8)	0
Morganella morganii	0	0	2 (16.7)
Gram-negative nonenteric			
Bordetella bronchiseptica	20 (71.4)	0	0
Pseudomonas aeruginosa	2 (7.1)	7 (9.9)	0
Pasteurella sp.	0	2 (2.8)	0
Other*	4 (14.3)	3 (4.2)	1 (8.3)
Gram-positive			
Staphylococcus sp.	2 (7.1)	14 (19.7)	3 (25.0)
Streptococcus sp.	2 (7.1)	15 (21.1)	2 (16.7)
Enterococcus sp.	1 (3.6)	8 (11.3)	1 (8.3)

*Species names for isolates that were cultured only once are not listed and are categorized as "other."

Susceptibility data to previously administered antimicrobials were available for 54 of these dogs (54/62, 87.1%): 17/17 (100%) dogs in the community-acquired pneumonia group, 29/36 (80.6%) dogs in the aspiration pneumonia group, and 8/9 (88.9%) dogs in the other causes of pneumonia group. Overall, 57.4% of these dogs (31/54) had a bacterial isolate that was resistant to the previously prescribed antimicrobial: 11 dogs (11/17, 64.7%) in the community-acquired pneumonia group, 16 dogs (16/29, 55.2%) in the aspiration pneumonia group, and 4 dogs (4/8, 50.0%) in the other causes of pneumonia group.

The median length of hospital stay for all the dogs included in our study was 2.75 days (range 0–28). In dogs with community-acquired pneumonia, the median length of hospital stay was 3 days (range 0–17) for bacterial isolates that were sensitive to the empirically selected antimicrobials and 5 days (range 3–8) for bacterial isolates that were resistant to the empirically selected antimicrobials. Although there was a trend for a longer length of hospital stay in dogs with bacterial isolates that were resistant to the empirically selected antimicrobial(s), this did not reach statistical significance ($P = 0.0729$). In dogs with aspiration pneumonia, the median length of hospital stay was 3 days (range 0–13) and 2 days (range 0–28) for bacterial isolates that were susceptible and resistant to empirically selected antimicrobials therapy respectively, but this difference was not found to be statistically significant ($P = 0.3602$). In dogs with other causes of bacterial pneumonia, the median length of hospital stay was 1 day (range 0–6) for all dogs, independent of the bacterial isolate antimicrobial susceptibility.

The overall survival rate was 87.4% for all dogs included in our study. All nonsurvivor dogs (14/111) were euthanized at the owner's request. The survival rate for the community-acquired pneumonia group was 96.4% (27/28). The only nonsurvivor dog within this group had *Bordetella bronchiseptica* isolated from the airway sample that was resistant to the empirically selected antimicrobials, ampicillin, and enrofloxacin. The survival rate for the aspiration pneumonia group was 83.1% (59/71). Only 1 (1/12) of the nonsurvivor dogs within this group had a bacterial isolate (*E. coli*) resistant to the empirically selected antimicrobials (amoxicillin/clavulanate and enrofloxacin). The survival rate for the dogs in the other causes of bacterial pneumonia group was 91.7% (11/12). The only nonsurvivor dog within this group had a bacterial isolate (beta hemolytic *Streptococcus*) susceptible to the empirically selected antimicrobials (ampicillin and enrofloxacin). No association was found between

Table 4: Empirically selected antimicrobials for each group

Antimicrobials	Community-acquired pneumonia	Aspiration pneumonia	Other causes of pneumonia
β-lactam* and fluoroquinolone	3	37	4
Ampicillin and amikacin	5	1	
Clindamycin and cefotaxime	2	3	
Clindamycin, cefotaxime, and azithromycin	2		
Clindamycin and fluoroquinolone	1	1	
Ampicillin/sublactam and azithromycin	1	1	
Ampicillin, enrofloxacin, and metronidazole		1	
Ampicillin, enrofloxacin, and clindamycin		1	
Clindamycin, enrofloxacin, and doxycycline		1	
Ampicillin and cefotaxime		1	
Cefazolin and amikacin		1	
Ticarcillin/clavulanate and azithromycin	1		
Enrofloxacin and azithromycin	1		
Amoxicillin/clavulanate	3	7	5
Fluoroquinolones		7	3
Azithromycin	5	1	
Ticarcillin/clavulanate	2	4	
Aminoglycosides		2	
Doxycycline	1		
Cefotaxime		1	
Imipenem		1	
Chloramphenicol	1		

*β-lactam includes ampicillin, amoxicillin/clavulanate, and ticarcillin/clavulanate.

Table 5: Previous antimicrobial therapy among the population ($n = 111$)

Antimicrobials*	Community-acquired pneumonia	Aspiration pneumonia	Other causes of pneumonia
Ampicillin	1	1	
Ampicillin/sublactam		1	
Amoxicillin	1	1	
Amoxicillin/clavulanate	10	14	5
Meropenem		1	
Cephalexin	2	4	1
Cefpodoxime		4	
Enrofloxacin		10	6
Marbofloxacin		1	
Ciprofloxacin		4	
Metronidazole	1	1	
Doxycycline	2	3	2
Clindamycin		3	
Azitrhomycin	3	1	1
Gentamicin	1		
Amikacin	1	4	
Trimethoprim sulfa	1	1	
Chloramphenicol	1		

*Those antimicrobials were used as a single agent or in various combinations.

bacterial isolate resistance to empirically selected antimicrobials and survival in the aspiration pneumonia group ($P = 0.158$). The low number of nonsurvivors in the community-acquired pneumonia (1/28) and in the other causes of bacterial pneumonia (1/12) groups precluded meaningful statistical analysis.

Discussion

The bacterial culture and susceptibility testing results from airways-sampling techniques in dogs with suspected pneumonia are used clinically to confirm the presence of infection and guide antimicrobial therapy.[1,2] Identification of in vitro bacterial antimicrobial resistance can lead to alterations of antimicrobial therapy due to concerns for possible increased morbidity and mortality if the resistance is also occurring in vivo. To the authors' knowledge, there is limited information of the true clinical effect of in vitro antimicrobial resistance on morbidity and mortality in dogs with bacterial pneumonia. In people, the clinical effect of in vitro bacterial resistance to empirically selected antimicrobials on morbidity and mortality is well documented and therefore the assumption is made that the bacterial antimicrobial resistance is also occurring in vivo.[12–15]

In this study, 26.1% of dogs with pneumonia had a bacterial isolate from an airway sample obtained via tracheal washing that was resistant to the empirically selected antimicrobials. However, we did not find an association between bacterial resistance to empiric antimicrobial therapy and mortality or length of hospitalization in this population of dogs. This does not entirely refute a possible clinical effect of in vitro bacterial resistance to empiric antimicrobials on morbidity or mortality. Although it did not reach statistical significance, there was a trend toward an increased duration of hospitalization in dogs with community-acquired pneumonia in which a bacterial isolate was resistant to the empirically selected antimicrobials. In addition, the overall high survival to discharge rate (87.4%) along with the relatively low number of cases in this study may have also precluded finding an effect of inappropriate empiric antimicrobial therapy on mortality. As all nonsurvivor dogs were euthanized this may have created a euthanasia bias. Finally, due to the retrospective nature of our study, determination of the specific cause (ie, whether due to worsening clinical condition or for other reasons such as financial restrictions) for nonsurvival could not be determined. Although we did not find a correlation between bacterial isolate resistance to empirically selected antimicrobials and length of hospital stay in our study, there is the possibility that an association with increased morbidity may still exist as we did not evaluate other outcome

parameters such as time to clinical improvement or radiographic resolution of pneumonia.

In our study, we did find a high incidence of in vitro bacterial resistance to antimicrobials that had been recently administered. Although standardized protocols guiding empiric antimicrobial therapy do not currently exist in our hospital, the antimicrobials empirically chosen for treatment of pneumonia in this study, as reported in Table 2, are very similar to the ones used in previous studies of dogs with pneumonia and adhere to current antimicrobial recommendations.[1,2,4,16,17]

To the authors' knowledge, this is the first study in dogs with pneumonia reporting the incidence of in vitro susceptibility of airway bacterial isolates to recently administered antimicrobials. Any antimicrobial administration can increase resistance-selection pressure allowing for resistant bacterial strains to thrive while susceptible bacteria die. These resistant bacterial strains can then potentially perpetuate infection or contribute to the development of new infection.[18–22] The high incidence of in vitro bacterial resistance to recently administered antimicrobials suggest that this resistance-selection pressure may be occurring in our patients. Therefore, similar to current recommendations in human medicine, it may be prudent to avoid recently administered antimicrobials as part of the initial empiric antimicrobials pending the results of airway microbial testing despite the possibility that the in vitro bacterial susceptibility may not correlate with in vivo bacterial susceptibility.[12]

In a recent study by Epstein et al,[11] comparing airway bacterial resistance patterns in dogs with respiratory diseases of varying severity, the bacterial isolates obtained from dogs and cats requiring positive-pressure ventilation were found to be more resistant to commonly used antimicrobials compared to dogs without respiratory failure.[11] The authors concluded that the severity of disease should be taken into consideration when empirically selecting antimicrobials in the treatment of dogs with respiratory diseases. Interestingly, 81% of the dogs in the respiratory failure group were reported to have received antimicrobials prior to airway sampling. The frequency of antimicrobial administration prior to airway sampling in their control group was not reported and therefore, it is unknown whether this increased antimicrobial resistance in the respiratory failure group was solely associated with worse clinical disease or whether there was an association with previous antimicrobial administration as may be suggested by the results of the present study. Further prospective studies investigating bacterial resistance in all dogs with pneumonia with varying severity of disease would be useful in definitively establishing whether severity of disease and recently administered antimicrobials are independently associated with increased bacterial resistance.

The bacterial species isolated from the tracheal washes in this study were similar to previous reports of dogs with pneumonia.[4,11,16,17] Of particular interest, multiple dogs with aspiration pneumonia had a combination of gram-positive and enteric gram-negative isolates. Similarly, multiple dogs with community-acquired pneumonia had various gram-positive and gram-negative bacteria isolated in addition to *Bordetella bronchiseptica*. Currently, several authors have suggested single-agent antimicrobial therapy for mild, noncomplicated pneumonia as opposed to broad spectrum antimicrobial combinations.[1,2] However, the findings of our study would support the use of broad-spectrum antimicrobial therapy, independent of the severity of the pneumonia, until the results of airway sample culture and susceptibility are available. Once these results are available, de-escalation of antimicrobial therapy may be possible. Although the pathogenic role of anaerobic bacteria in canine bacterial pneumonia is currently poorly understood, anaerobic antimicrobial coverage as part of the empiric antimicrobial selection should also be considered.

The presence of oropharyngeal material on cytologic evaluations may support aspiration of oropharyngeal secretions or may represent contamination during the sampling procedure. Due to the retrospective nature of this study, it was not possible to blind the clinical pathologist's cytological evaluation. Hence, a known tentative diagnosis of aspiration pneumonia and knowledge of airway-sampling technique may have resulted in a higher reported frequency of the presence of oropharyngeal material. Although care is usually taken as to avoid oropharyngeal contamination during endotracheal intubation, it is possible that oropharyngeal contamination was more frequent within the aspiration pneumonia group and may have affected the culture results. Additionally, tracheal washes are suspected of not effectively sampling the cranioventral lung fields. Therefore, it is possible that if a directed technique such as bronchoscopically assisted bronchoalveolar lavage had been performed rather than tracheal washes, the bacterial isolate results may have been differentiating, especially for dogs with aspiration pneumonia. Also, 3 tracheal wash samples did not reveal any inflammation but the bacterial isolate susceptibility results were included in the statistical analyses. The isolated bacteria from those samples may not represent the causal agent of the pneumonia but due to the low number of cases, it is unlikely to have affected our results.

An inherent limitation of our study is its retrospective nature. Group assignments were performed based on available data and some dogs may not have been assigned to the appropriate group due to lack of historical data. However, this does not affect the overall rate of

in vitro antimicrobial resistance found. Similarly, some dogs may have received antimicrobials prior to presentation to our hospital that were not recorded at the time of admission and therefore possibly affected our results. This is, however, unlikely to have significantly affected our results.

In conclusion, the results of the present study show that recent antimicrobial therapy is associated with a high incidence of in vitro airway bacterial resistance to these antimicrobials and the overall rate of bacterial resistance to initial empirically selected antimicrobials was 26% in dogs with bacterial pneumonia. Therefore, avoidance of recently administered antimicrobials may be warranted while awaiting results of culture and susceptibility testing. Although we did not find an effect of this in vitro antimicrobial resistance on mortality or duration of hospitalization in this study, the possibility for an effect on clinical outcome still exists. Additional prospective studies are needed using standardized airway-sampling techniques, treatment modalities, and stratification of disease severity based on objective values such as arterial blood gas analysis in all dogs with pneumonia to determine if a clinical effect of in vitro bacterial resistance to empirically selected antimicrobials truly exists or not.

Footnotes

[a] Excel, Microsoft Inc, Redmond, WA.
[b] Stata, version 11.0 for Windows, Stata Corporation, College Station, TX.

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