

Community-acquired infectious pneumonia in puppies: 65 cases (1993–2002)

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Objective—To identify causative organisms, treatment, outcome, and prognosis for dogs < 1 year old with community-acquired infectious pneumonia.

Design—Retrospective case series.

Animals—65 dogs.

Procedures—Dogs were considered to have community-acquired infectious pneumonia if they had clinical signs of primary respiratory tract disease in conjunction with radiographic evidence of alveolar disease and positive results following bacterial culture of tracheal wash fluid.

Results—Most dogs were hypoxemic at the time of initial examination, with pulmonary function becoming worse during the first few days of hospitalization before improving; 57 (88%) dogs survived to discharge. *Bordetella bronchiseptica* was isolated from tracheal wash fluid from 32 (49%) dogs, and other organisms, predominantly gram-negative enteric bacteria, were isolated from the other 33 (51%). Dogs with *Bordetella* pneumonia were significantly younger (median, 14 vs 21 weeks), were significantly more likely to have been obtained from a pet store (19/31 vs 7/32), had been owned for a significantly shorter time prior to the onset of illness (median, 18 vs 90 days), had significantly higher PvcO₂ values at initial examination (median, 48.7 vs 41.3 mm Hg), were significantly more likely to receive supplemental oxygen (25/32 vs 16/33), and had significantly longer hospitalization times (mean, 7.2 vs 4.9 days) than did dogs with pneumonia caused by any other organism.

Conclusions and Clinical Relevance—Results suggested that a type of community-acquired infectious pneumonia could be identified in dogs < 1 year old, with disease being more severe in dogs with *Bordetella* pneumonia than in dogs with pneumonia caused by other bacterial organisms. (*J Am Vet Med Assoc* 2007;230:1493–1497)

In dogs, bacterial pneumonia is characterized by colonization of the airways or pulmonary parenchyma with bacteria, resulting in exudation and lung consolidation.^{1,2} Common causes of bacterial pneumonia include aspiration of gastrointestinal tract contents and infection with opportunistic pathogens secondary to immunosuppression. However, community-acquired infectious pneumonia has also been reported.^{3–6} Pneumonia that develops secondary to aspiration or opportunistic infection is typically caused by gram-negative enteric pathogens, whereas the most common cause of infectious pneumonia is *Bordetella bronchiseptica*.

In human medicine, community-acquired infectious pneumonia is defined as the development of new radiographic pulmonary infiltrates in conjunction with the presence of at least 1 major or 2 minor clinical signs suggestive of pneumonia in an individual who has not been treated in a health care environment for > 2 days immediately preceding the day of diagnosis.^{7–10} To the authors' knowledge, criteria for the diagnosis of com-

munity-acquired infectious pneumonia in dogs have not been developed. However, we believe that it can be defined as a contagious respiratory tract infection characterized by bronchopneumonia in a dog with a history of being housed in the community.

Clinical experience suggests that community-acquired infectious pneumonia is more common in puppies, whereas aspiration pneumonia and pneumonia secondary to opportunistic infection are more common in adult dogs with some underlying disease. Previous studies^{2,3,6,11,12} have reported on clinical findings and results of microbial culture of airway secretions in dogs of various ages, but to our knowledge, little has been published specifically on pneumonia in dogs that are < 1 year old. In particular, community-acquired infectious pneumonia has not been well documented in puppies, and there is little published information regarding causative organisms, treatment, outcome, or prognosis. In adult dogs with pneumonia, treatment and prognosis depend to a large extent on the underlying cause.¹³ Thus, findings for adult dogs with aspiration pneumonia or pneumonia secondary to opportunistic infection may not be applicable to puppies. The purpose of the study reported here, therefore, was to identify causative organisms, treatment, outcome, and prognosis for dogs < 1 year old with community-acquired infectious pneumonia. In this study, we were particularly interested in

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puppies with community-acquired infectious pneumonia caused by *B bronchiseptica*.

Criteria for Selection of Cases

The patient database of the Matthew J. Ryan Veterinary Hospital at the University of Pennsylvania was searched to identify dogs < 1 year old that had been examined between 1993 and 2002 and in which both thoracic radiography and an endotracheal or transtracheal wash procedure had been performed. Dogs were included in the study if they had been examined because of clinical signs related to respiratory tract disease (ie, coughing, respiratory difficulty, or exercise intolerance), there was radiographic evidence of alveolar disease, and results of bacterial culture of endotracheal or transtracheal wash fluid were positive. Dogs were excluded from the study if pneumonia was determined to have developed secondary to some other condition or was obviously a result of aspiration or if the medical record was incomplete.

Procedures

Medical record review—Information obtained from the medical records for dogs included in the study consisted of history; physical examination findings; results of routine laboratory testing, including results of CBCs and blood gas analyses; results of bacterial culture and antimicrobial susceptibility testing of endotracheal or transtracheal wash fluid samples; treatment; clinical course; and outcome. All radiographs were evaluated by a board-certified radiologist to confirm the presence of pulmonary alveolar disease.

Data analysis—Data for all dogs were summarized. Dogs were then separated into 2 groups on the basis of results of bacterial culture of endotracheal or transtracheal wash fluid, with dogs positive for *B bronchiseptica* included in 1 group and dogs with bacterial pneumonia caused by any other organism included in the other group. Groups were compared with regard to history, clinical signs, results of laboratory testing, treatment, clinical progression, and outcome. The χ^2 test was used to compare categorical variables between groups. For continuous variables, visual inspection of graphs and the Shapiro-Wilk test were used to determine whether data were normally distributed. Unpaired *t* tests were used to compare continuous variables that were normally distributed between groups, and the Mann-Whitney test was used to compare continuous variables that were not normally distributed. Continuous data that were normally distributed are summarized as mean and SD; continuous data that were not normally distributed are summarized as median and range. Standard commercial software^a was used for all analyses. Values of *P* < 0.05 were considered significant.

Results

The search of the medical records yielded 87 cases, of which 65 fulfilled the criteria for inclusion in the study. Median age of the 65 dogs included in the study was 15 weeks (range, 4 to 49 weeks). There were 30 (46%) sexually intact males, 25 (38%) sexually intact

females, 7 (11%) spayed females, and 3 (5%) castrated males. Body weight at the time of initial examination ranged from 0.8 to 67 kg (1.8 to 147 lb; mean, 7.2 kg [15.8 lb]). Eight of the dogs were of mixed breeding, with the remainder representing a variety of breeds. The most common purebred dogs were Bulldogs (*n* = 4) and Weimaraners (4). Twenty-six (41%) of the dogs had been obtained from a pet store, 25 (40%) had been obtained from a breeder, 5 (8%) had been obtained from a shelter, and 7 (11%) had been obtained from other sources. Dogs had been acquired by their current owners a median of 31 days (range, 3 to 330 days; *n* = 57) prior to examination at the veterinary teaching hospital.

The most frequent historical complaints included cough (*n* = 49 [75%]), lethargy (40 [62%]), anorexia (35 [54%]), and dyspnea (31 [48%]). Although exercise intolerance was reported in only 4 dogs (6.2%), all 4 also had dyspnea. Antimicrobials administered prior to initial examination at the veterinary teaching hospital included amoxicillin-clavulanate (*n* = 18), amoxicillin (15), cephalexin (10), enrofloxacin (6), and trimethoprim-sulfonamide (2).

On initial examination, the most common physical examination abnormalities included tachypnea (*n* = 51 [78%]), increased bronchovesicular lung sounds (48 [74%]), increased respiratory effort (47 [72%]), and fever (31 [48%]).

Mean \pm SD WBC count on initial examination was $22.9 \pm 11.6 \times 10^3$ cells/ μ L (reference range, 5.3 to 19.8×10^3 cells/ μ L). Mean neutrophil count was $16.9 \pm 9.9 \times 10^3$ cells/ μ L (reference range, 3.1 to 14.4×10^3 cells/ μ L), and mean band neutrophil count was $0.8 \pm 1.8 \times 10^3$ cells/ μ L (reference range, 0 to 0.2×10^3 cells/ μ L). Only 30 of 52 (57%) dogs had evidence of leukocytosis or a left shift. Mean platelet count was $307 \pm 146 \times 10^3$ platelets/ μ L. Examination of the results of venous blood gas analyses, pulse oximetry, and measurement of blood lactate concentration suggested that dogs were typically hypoxemic and hypercarbic at the time of initial examination and that pulmonary function tended to deteriorate during the early hospitalization period before improving (Table 1).

Bacterial culture of endotracheal or transtracheal wash fluid samples yielded *B bronchiseptica* in 32 of the 65 (49%) dogs. Other organisms were isolated in the remaining 33 (51%) dogs, including *Staphylococcus* spp (*n* = 9), *Escherichia coli* (7), *Klebsiella pneumoniae* (4), *Enterobacter* spp (4), *Pseudomonas aeruginosa* (4), *Streptococcus* spp (4), *Enterococcus faecalis* (3), *Acinetobacter* spp (3), *Pasteurella multocida* (2), and other organisms (3). In 10 dogs, 2 organisms were isolated, and in 2 of these 10, one of the organisms isolated was *B bronchiseptica*. For purposes of data analysis, these 2 dogs were grouped with the 30 other dogs from which *B bronchiseptica* was isolated. In both groups, isolates were susceptible to most antimicrobials tested (Table 2).

Forty-one of the 65 (63%) dogs received supplemental oxygen while hospitalized; mean \pm SD duration of supplemental oxygen administration was 4.4 ± 2.6 days (range, 1 to 11 days). In 40 of the 41 dogs that received supplemental oxygen, oxygen saturation, as determined by means of pulse oximetry (ie, SpO₂) was $\leq 92\%$. Antimicrobials administered during hospital-

Table 1—Results of pulse oximetry and venous blood gas analyses in 65 dogs < 1 year old with community-acquired infectious pneumonia.

Variable	Initial value	Worst value	Time to worst value (d)	Reference range
Spo ₂ (%)	91 (82–96) n = 21	87 (81–96) n = 36	2 (1–6) n = 36	> 92
PvcO ₂ (mm Hg)	43.8 (25–72) n = 48	57 (28–76) n = 43	2 (1–7) n = 43	33–43
Venous pH	7.36 (7.24–7.46) n = 48	7.31 (6.87–7.42) n = 46	2 (1–10) n = 45	7.35–7.47

Data are given as median (range), followed by the number of dogs for which information was available. Data represent values obtained at the time of initial examination, the worst value recorded for each dog during the hospitalization period, and the time between initial examination and recording of the worst value.

Table 2—Results of bacterial culture and susceptibility testing of endotracheal or transtracheal wash samples from 65 dogs < 1 year old with community-acquired infectious pneumonia caused by *Bordetella bronchiseptica* or some other bacterial organism.

Antimicrobial	Causative organism	
	<i>B bronchiseptica</i> (n = 32)	Other bacteria (n = 33)
Amoxicillin-clavulanate	25/25	21/27
Ticarcillin	23/24	13/27
Amikacin	31/32	19/27
Gentamicin	31/32	19/27
Enrofloxacin	26/27	17/27
Doxycycline	23/23	11/27
Chloramphenicol	21/22	15/27
Trimethoprim-sulfonamide	9/31	14/27

Data are given as No. of susceptible isolates/No. of isolates tested.

ization included ampicillin (n = 34), aminoglycosides (31), ticarcillin-clavulanate (12), enrofloxacin (7), and cefazolin (1). Nebulization and coupage were used in 49 of the 65 (75%) dogs. Bronchodilators were used in 16 of the 65 (25%) dogs, with 13 of the 16 that received bronchodilators having Spo₂ values ≤ 92%. Fluid therapy was administered IV in 49 (75%) dogs. Mean duration of hospitalization was 6.1 ± 2.1 days (range, 0 to 14 days), and 57 (88%) dogs survived and were discharged.

Dogs from which *B bronchiseptica* was isolated were significantly (P = 0.004) younger (median, 14 weeks; range, 7 to 35 weeks) than were dogs with pneumonia caused by other organisms (median, 21 weeks; range, 4 to 49 weeks). Dogs with pneumonia caused by *B bronchiseptica* had also been owned for a significantly (P < 0.001) shorter time (median, 18 days; range, 3 to 120 days; n = 28) than had dogs with pneumonia caused by other organisms (median, 90 days; range, 2 to 330 days; n = 29). Median body weight of dogs with pneumonia caused by *B bronchiseptica* (6.9 kg [15.2 lb]; range, 0.8 to 24.5 kg [1.8 to 53.9 lb]) was not significantly (P = 0.097) different from median body weight of dogs with pneumonia caused by other organisms (12 kg [26.4 lb]; range, 0.8 to 67 kg).

Dogs with pneumonia caused by *B bronchiseptica* were significantly (P = 0.01) more likely to have been acquired from a pet store (n = 19/31) than were dogs with pneumonia caused by other organisms (7/32). Dogs with pneumonia caused by *B bronchiseptica* were significantly (P = 0.027) less likely to have been ac-

quired from a breeder (n = 8/31) than were dogs with pneumonia caused by other organisms (17/32).

Comparison of historical findings and results of laboratory testing between dogs with pneumonia caused by *B bronchiseptica* and dogs with pneumonia caused by other organisms revealed only 2 significant differences. Median venous partial pressure of CO₂ (ie, PvcO₂) at the time of initial examination was significantly (P = 0.015) higher in dogs with pneumonia caused by *B bronchiseptica* (48.7 mm Hg; range, 32.8 to 65.8 mm Hg; n = 25) than in dogs with pneumonia caused by other organisms (41.3 mm Hg; range, 24.7 to 70.2 mm Hg; n = 23), and median Hct at the time of initial examination was significantly (P = 0.014) lower in dogs with pneumonia caused by *B bronchiseptica* (32.6%; range, 17.8% to 45.2%; n = 31) than in dogs with pneumonia caused by other organisms (37.8%; range, 23.6% to 56.6%; n = 29).

Dogs with pneumonia caused by *B bronchiseptica* were significantly (P = 0.013) more likely to receive supplemental oxygen (n = 25/32 [78%]) than were dogs with pneumonia caused by other organisms (16/33 [48%]). However, mean duration of oxygen supplementation for dogs with pneumonia caused by *B bronchiseptica* (4.8 ± 2.7 days; range, 1 to 11 days) was not significantly different from mean duration for dogs with pneumonia caused by other organisms (3.9 ± 2.4 days; range, 1 to 9 days). Bronchodilators were administered in a significantly (P = 0.018) higher proportion of dogs with pneumonia caused by *B bronchiseptica* (n = 12/32 [38%]) than dogs with pneumonia caused by other organisms (4/33 [12%]).

Mean duration of hospitalization for dogs with pneumonia caused by *B bronchiseptica* (7.2 ± 3.7 days; range, 2 to 14 days) was significantly (P = 0.014) longer than mean duration for dogs with pneumonia caused by other organisms (4.9 ± 2.7 days; range, 0 to 12 days). Proportions of dogs that survived to discharge were not significantly (P = 0.258) different between dogs with pneumonia caused by *B bronchiseptica* (n = 30/32 [94%]) and dogs with pneumonia caused by other organisms (27/33 [82%]).

Discussion

Results of the present study suggest that a type of community-acquired infectious pneumonia can be identified in dogs < 1 year old. For purposes of the present study, dogs were considered to have commu-

nity-acquired infectious pneumonia if they had clinical signs of primary respiratory tract disease in conjunction with radiographic evidence of pulmonary alveolar disease and positive results following bacterial culture of endotracheal or transtracheal wash fluid. Surprisingly, only 30 of 52 (57%) dogs had an inflammatory leukogram characterized by leukocytosis, neutrophilia, and band neutrophilia, and for many, CBC results were unremarkable despite severe bronchopneumonia. These findings emphasize the importance of performing thoracic radiography in dogs with systemic signs of disease and a primary complaint related to the respiratory tract. Most dogs in the present study were hypoxemic at the time of initial examination, with pulmonary function becoming worse in most dogs during the first few days of hospitalization. However, most dogs eventually improved, with 57 of the 65 (88%) dogs surviving to discharge.

In 32 of the 65 (49%) dogs in the present study, *B bronchiseptica* was isolated from endotracheal or transtracheal wash fluid, whereas a variety of antimicrobial species were identified in the remaining dogs. The source of the bacteria isolated from these dogs could not be determined, although many of the isolates were enteric organisms. In dogs with infectious tracheobronchitis, progression to bronchopneumonia, likely as a result of impairment of respiratory tract immune function, has been documented.^{4,14} In studies¹⁴⁻¹⁷ of dogs with infectious tracheobronchitis, although *B bronchiseptica* is the most commonly identified bacterial cause, other bacterial organisms such as *Streptococcus* spp, *Staphylococcus* spp, *Pasteurella* spp, *E coli*, and *Klebsiella* spp may also play a role.^{4,18-20} Thus, in some dogs in this study, isolation of organisms other than *B bronchiseptica* may have been a reflection of opportunistic infection, and we suspect that many of these dogs had infectious tracheobronchitis or pneumonia at the time of adoption or purchase.

Bordetella organisms attach to cilia in the respiratory tract, releasing exotoxins that induce variable degrees of ciliostasis, depending on the virulence of the strain.²¹ Adhesins facilitate binding of the organism to specific receptors on respiratory epithelial cells. Thus, host defenses are disrupted both as a result of direct cell death and as a result of inhibition of ciliary function.²² Further complicating factors may include damage to tissues, suppression of humoral and cell-mediated immunity, and inhibition of phagocytic functions of WBCs by other exotoxins.²²

A previous short-term (14 days) study⁵ of dogs experimentally infected with *B bronchiseptica* found only limited alveolar involvement. In contrast, a separate study²³ of experimentally infected dogs found evidence of pneumonia in all untreated dogs and some treated dogs that were euthanized between 6 and 16 days after inoculation.²³ Thus, in susceptible individuals, *B bronchiseptica*, in conjunction with other components of infectious tracheobronchitis, can impair host defenses sufficiently to allow invasion of the lower respiratory tract and development of pneumonia.

In the present study, we compared findings for dogs with pneumonia caused by *B bronchiseptica* with findings for dogs with pneumonia caused by other organ-

isms and found significant differences in disease signs and severity. Dogs with pneumonia caused by *B bronchiseptica* were younger, had been owned for a shorter time prior to the onset of respiratory tract disease, and were more likely to have been acquired from a pet store than were dogs with pneumonia caused by other organisms. In addition, dogs with pneumonia caused by *B bronchiseptica* had higher PvcO₂ values at the time of initial examination, were more likely to require supplemental oxygen, were more likely to be treated with bronchodilators, and had longer hospitalization times, suggesting that they had more severe disease than did dogs with pneumonia caused by other organisms. Although PvcO₂ is dependent, in part, on adequacy of tissue perfusion, we suspect that the high values that were seen in these dogs were attributable to compromised respiratory function, in that none of the dogs had any clinical evidence of inadequate tissue perfusion. Unfortunately, blood lactate concentration, which can be used to assess tissue perfusion, was not routinely measured during hospitalization in these dogs.

We did not identify any factors that could be used to predict whether dogs had pneumonia caused by *B bronchiseptica* versus some other organism. The lower Hct in dogs with pneumonia caused by *B bronchiseptica* was most likely attributable to the younger age of these dogs, and there were no significant differences between groups in regard to sex or neuter status.

Cytologic examination and bacterial culture of tracheal wash fluid are useful in the diagnosis of bacterial pneumonia and the selection of appropriate antimicrobial treatment. In general, we found that *Bordetella* isolates from these dogs were susceptible to a wide variety of antimicrobial agents, with the exception that only 9 of 31 *B bronchiseptica* isolates were susceptible to trimethoprim-sulfonamide. There have been conflicting reports in the literature regarding the susceptibility of *B bronchiseptica* isolates to trimethoprim-sulfonamide combinations, with some studies^{20,23} finding these combinations to be effective and others^{3,12} finding them to be ineffective.

Twenty-four of the 32 dogs with pneumonia caused by *B bronchiseptica* had been treated with various antimicrobials PO prior to referral to the veterinary teaching hospital, yet in all of these dogs, the disease had apparently progressed to bronchopneumonia. Even though 20 of these 24 dogs had been treated with amoxicillin or amoxicillin-clavulanate, all 25 *Bordetella* isolates that were tested were found to be susceptible to amoxicillin-clavulanate in vitro. Although penicillin derivatives achieve good penetration into the pulmonary parenchyma, they have relatively poor ability to penetrate the blood-bronchus barrier and, therefore, may not reach therapeutic concentrations in the airways.^{4,24-26} Variability in enteral absorption of orally administered drugs in sick puppies combined with variability in owner compliance in regard to drug administration may also have contributed to treatment failure. After admission to the veterinary teaching hospital, most of these puppies were treated by means of parenteral antimicrobial administration.

In clinical practice, infectious tracheobronchitis is most common among dogs housed in high-density situations,^{14,16,19} and most dogs in which infectious

tracheobronchitis progresses to pneumonia are young, often < 1 year old.^{2,4} However, numerous questions remain about etiologic factors related to the development of infectious tracheobronchitis in young dogs. One issue relates to whether puppy origin is associated with the risk of infectious tracheobronchitis. In the present study, dogs with pneumonia caused by *B bronchiseptica* were significantly more likely to have been acquired from a pet store and significantly less likely to have been acquired from a breeder than were dogs with pneumonia caused by other organisms. Puppies obtained from pet stores may be at greater risk for developing infectious tracheobronchitis, with subsequent progression to bronchopneumonia, because they are in closer contact with other puppies; under greater stress because of concurrent bacterial, viral, or parasite infections or greater changes in environment and diet; and young enough to have immature immune systems. In contrast, puppies obtained from breeders may have been maintained in a single environment during the first few months of life. Puppies adopted from shelters tended to be older in the present study and seemed less susceptible to *Bordetella bronchopneumonia*; however, the small number of dogs that had been acquired from shelters precluded meaningful analysis. It would have been interesting to know how long puppies had been held in the pet store or shelter prior to purchase or adoption, as well as their vaccination and treatment histories, but this information was unavailable owing to the retrospective nature of the study.

A few other limitations of the present study should also be considered. Importantly, the frequency with which bronchopneumonia develops in animals with infectious tracheobronchitis is unknown. Furthermore, the number of puppies in which infectious tracheobronchitis resolves uneventfully is unknown, precluding any objective evaluation of the true incidence of this disease. Because a number of dogs in the present study were lost to follow-up, we cannot form any conclusions regarding the long-term consequences of *Bordetella pneumonia*. Thus, more studies are needed to further characterize the short- and long-term impact of infectious pneumonia in puppies.

a. Stata, version 8.0 for Windows, Stata Corp, College Station, Tex.

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