

Influence of Infecting Serogroup on Clinical Features of Leptospirosis in Dogs

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The purpose of this study was to review recent cases of leptospirosis seen at referral centers in New York State and to identify differences in clinical or clinicopathologic aspects of the disease among different suspected infecting serogroups. Medical records at the Cornell University Hospital for Animals and the Animal Medical Center in New York City were reviewed to identify dogs diagnosed with leptospirosis from September 1996 to August 2002. Records of 55 dogs met the inclusion criteria for the study. The suspected infecting serogroups included 21 occurrences of Grippotyphosa, 12 of Pomona, 6 of Autumnalis, 5 of Bratislava, 2 of Hardjo, and 1 of Canicola. Five dogs had equal titers to serogroups Grippotyphosa and Pomona, and 3 had equal titers to 2 other serogroups. Common clinical signs included lethargy, anorexia, and vomiting. Common clinicopathologic findings included anemia, thrombocytopenia, azotemia, hyperphosphatemia, high liver enzyme activity, and hyperbilirubinemia. Forty-three of 55 dogs were discharged from the hospital. Serogroup-specific analysis indicated that dogs with suspected serogroup Pomona infection were more likely to suffer from vomiting ($P = .01$), thrombocytopenia ($P = .009$), severe azotemia ($P = .04$), and hyperphosphatemia ($P = .006$) than dogs with other serogroups and were less likely to be discharged alive from the hospital ($P = .03$). This study suggests that only minor clinically relevant differences exist among serogroups. *Leptospira* serogroup Pomona caused more severe renal disease and was associated with a worse outcome compared with disease caused by other serogroups.

Key words: Acute renal failure; Canine; Grippotyphosa; Pomona.

Leptospirosis is a worldwide zoonosis resulting from infection with pathogenic species of the spirochete bacterium *Leptospira*. Within a geographic region, *Leptospira* serovars are maintained by subclinical infections in both wild and domestic animals, referred to as maintenance hosts.¹ Maintenance hosts serve as a source of infection and disease for incidental hosts, both animal and human. Individual animals can be simultaneously infected with multiple serovars, but such infections are uncommon.^{2,3} Recognition of infection of dogs with host-adapted serovars usually is rare because the infection generally produces only mild clinical signs.² For this reason, it is believed that leptospiral infections are far more common than clinically evident.^{2,4–7} Predictably, the most severe cases of disease are those resulting from infection with non-host adapted serovars.²

The term “serovar” commonly is used to describe the specific strain of *Leptospira* bacteria that has been diagnosed in a specific case, but this term is valid only when the organism has been isolated. In veterinary medicine, the diagnosis is typically based on serology by the microscopic agglutination test (MAT). This test is thought to be serogroup and not serovar specific.¹ In the past, leptospirosis in dogs in North America has been

associated with infection by serovars *Leptospira icterohemorrhagiae* or *Leptospira canicola*, with dogs serving as maintenance hosts of the latter. Recent serologic evidence, however, demonstrates a shift in the predominant serovars implicated in leptospirosis in dogs to *Leptospira grippotyphosa*, *Leptospira pomona*, *Leptospira bratislava*, and more recently, *Leptospira autumnalis*.^{8–17}

Cases of leptospirosis in dogs share many common features, and although most pathogenic serovars tend to produce leptospiremia and vasculitis, organ system involvement has been thought to be somewhat serovar-specific.⁶ Numerous studies have suggested some correlation between clinical aspects of the disease and the infecting serovar.^{2,4,9,18} Infection with serovars *L. icterohemorrhagiae* or *L. canicola* has been associated with coagulopathies, hepatic disease, and renal failure, whereas infection with emerging serovars has been associated with acute renal failure rather than hepatic disease or coagulopathies.⁸ The relationship between infecting serovar and clinical disease, however, is not well defined. *L. bratislava* infection might be nonclinical,^{14,19} might cause acute renal failure,⁸ or could result in combined acute renal and hepatic failure.²⁰ Serovars *L. grippotyphosa* and *L. pomona* have both been associated with acute renal failure^{8,12,15,16,18,21,22} and mild to severe hepatic disease^{9,16,18,22,23} in dogs. Most reports of hepatic involvement indicate that renal failure is the primary clinical presentation in leptospirosis caused by serovars *L. grippotyphosa* or *L. pomona*.^{9,16,22}

Definitive diagnosis of leptospirosis and identification of the infecting serovar or serogroup can be difficult in dogs. The MAT is the most commonly used test, but it does not distinguish natural exposure from vaccination, a problem confounded by the considerable cross-reactivity between serogroups, including serogroups included in vaccines. Paired titers can be used to document recent exposure, but MAT titers commonly decrease rapidly during treatment.¹² Other methods available but not commonly used commercially are

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specific *Leptospira* immunoglobulin M and G enzyme-linked immunosorbent assays (ELISAs), Western blots, and microscopic microcapsule agglutination testing (MCAT).⁷ Direct fluorescent antibody testing (FA), dark field microscopy, and bacterial culture and isolation are commercially available, specific, but non-sensitive modes of diagnosis.⁷ Polymerase chain reaction (PCR) testing recently has become available for the diagnosis of leptospirosis and might become available for widespread commercial use in the future.²⁴

The purpose of this study was to characterize *Leptospira* infections in dogs from 1996 to 2002 at 2 referral institutions in New York State. Our additional goal was to identify differences in the clinical and clinicopathologic aspects of the disease produced by different suspected infecting serogroups on the basis of MAT serology.

Materials and Methods

Criteria for Selection of Dogs

Medical records at the Cornell University Hospital for Animals (CUHA) and the Animal Medical Center (AMC) in New York City were reviewed to identify dogs for which leptospiral serologic or immunohistochemistry tests were conducted from September 1, 1996, to August 31, 2002. Criteria for inclusion in this study included any 1 or more of the following: a single positive serum antibody titer $\geq 1:800$ to nonvaccinal serogroups, a greater than 2-fold rise in convalescent titer to nonvaccinal serogroups, positive urine or tissue FA, or positive culture for *Leptospira* organisms. To avoid confusing interpretation of the data, dogs with serum antibody titers $\leq 1:3,200$ to vaccinal serogroups (*Canicola* or *Icterohemorrhagiae*) were excluded if $1:3,200$ was the highest titer that the dog demonstrated to any serogroup. Thus, dogs with titers $>1:3,200$ to vaccinal serogroups were considered positive for leptospiral infection. Additional exclusions included dogs with concurrent diseases.

History, Physical Examination, and Clinicopathologic Data

History, clinical signs, and physical examination data were obtained from the records of the CUHA and AMC. Only dogs with complete records were included. Complete blood counts, serum biochemistry, urinalyses, and coagulation profiles were performed at CUHA or AMC according to standard techniques. Only values obtained on presentation, before therapy, were included in the study. Urine protein was assessed by the sulfosalicylic acid method. Urine protein-to-creatinine ratios were not performed in most dogs. Isosthenuria was defined as urine specific gravity between 1.008 and 1.012, as measured by a refractometer. Hypersthenuria was defined as urine specific gravity over 1.012, as measured by a refractometer. Glycosuria was considered to be positive on the basis of a positive urine dipstick test result. Pyuria was defined as >5 white blood cells per high-power field on microscopic examination of the urine sediment. Appropriate reference ranges were used for each test at each institution. A marked increase or decrease in a clinicopathologic variable was defined as more than double the highest value of the reference range (marked increase) or less than 50% of the lowest value of the reference range (marked decrease).

MAT

MAT testing of all samples was performed at the Diagnostic Laboratory, College of Veterinary Medicine, Cornell University, as

previously described²⁵ with the whole-cell antigens of the following *Leptospira* serovars: *pomona*, *grippotyphosa*, *icterohaemorrhagiae*, *hardjo*, *canicola*, *autumnalis*, and *bratislava*.

Radiographic Evaluation

Thoracic radiographs were evaluated retrospectively. To avoid radiographic changes that might have occurred as a result of therapy, radiographs were included only if they were obtained at the time of presentation before therapy for leptospirosis. In addition, radiographs from 10 normal dogs were reviewed. All radiographic examinations (from dogs with leptospirosis and normal dogs) were evaluated once, in an order randomized by lottery, by a board-certified radiologist (PVS) in a blinded fashion. Each radiographic examination was evaluated for increased opacity of the lung attributed to disease.²⁶ Increased opacity of the lung was scored as (1) definitely detected, (2) questionably detected, (3) indeterminate, (4) questionably not detected, and (5) not detected.

Statistical Methods

Only dogs with titers that were of the highest magnitude for a single (not mixed) serogroup of serogroups Autumnalis ($n = 6$), Bratislava ($n = 5$), Grippotyphosa ($n = 21$), and Pomona ($n = 12$) were tested for serogroup-specific associations with clinical signs or clinical pathology. Because there were so few dogs with these 4 single infections, all signs or clinicopathologic data were tested 4 times—once for each serogroup (eg, Autumnalis yes/no, Bratislava yes/no, etc). Associations with yes/no data (clinical signs, death in the hospital) were tested by chi square analysis (or, if expected test frequency was <5 , Fisher's exact test). Associations with clinicopathologic data (ordinal or measurement) were tested with Wilcoxon's rank sum test. Because some data were ordinal and some measurement data were (by inspection) skewed, we used the nonparametric, rank-based, 2-group test. All tests were 2-tailed, and we used $P \leq .05$ to indicate significance despite multiple comparisons. This procedure was followed because of the limited number of dogs available for analysis. An odds ratio (OR) was calculated in a standard fashion:

	X+	X-
Y+	A	B
Y-	C	D

where, Y represents a serogroup and X represents the variable. A, B, C, and D are the numbers of dogs that fit each category. The OR was calculated as AD/BC .

Results

Records of 55 dogs met the inclusion criteria: 42 from CUHA and 13 from AMC. Thirty dogs (55%) were males (17 intact and 13 neutered). Of the 25 females included in the study, 2 were intact and 23 were spayed. Twenty-eight breeds were represented; among them were 5 German Shepherds, 4 Doberman Pinschers, and 3 Labrador Retrievers. Twelve dogs were mixed breed. Ages ranged from 1 to 15 years (median 7 years). Their weights ranged from 3 to 60 kg (median 25 kg). Forty-three dogs (78%) presented in the latter half of each year (months July–December; Fig 1). The suspected infecting serogroups included 21 dogs (38%) with only Grippotyphosa, 12 dogs (22%) with only Pomona, 6 dogs (11%)

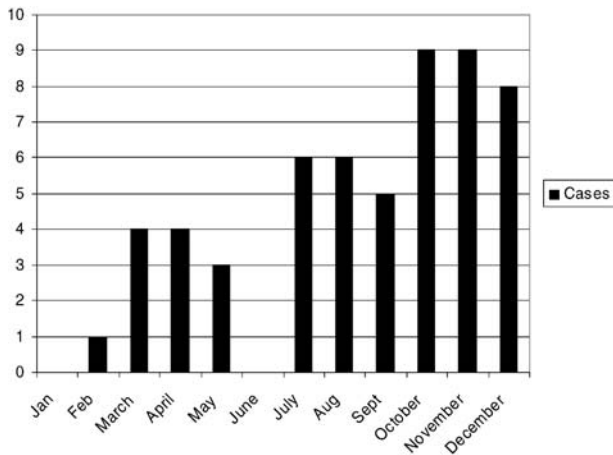


Fig 1. The number of cases with leptospirosis included in the study that presented during each month of the year to the Cornell University Hospital for Animals and the Animal Medical Center in New York City.

with only Autumnalis, 5 dogs (9%) with only Bratislava, 2 dogs (4%) with only Hardjo, and 1 dog (2%) with only Canicola. Five dogs had equal titers to Grippotyphosa and Pomona. Two dogs had equal titers to other serogroup combinations, and 1 dog was diagnosed on the basis of positive FA. Table 1 shows the signalment, clinical signs, and physical examination abnormalities in the dogs included in the study. Common (>50% of all dogs) clinical signs on presentation included lethargy, anorexia, and vomiting. Over 30% of the dogs also had

a history of diarrhea or had an audible cardiac murmur on auscultation. Table 2 shows the clinicopathologic abnormalities in these dogs. Pertinent clinicopathologic abnormalities that were present in >30% of the dogs included anemia, thrombocytopenia, azotemia, hyperphosphatemia, high liver enzyme activity, and hyperbilirubinemia. Table 3 shows duration of hospitalization and clinical outcome of dogs included in the study. Forty-three of 55 dogs (78%) were discharged from the hospital.

Radiographic analysis identified mild pulmonary opacities in 2 of 22 dogs with leptospirosis that had radiographs available for review and none in the radiographs of normal dogs. Because so few dogs with leptospirosis had radiographic abnormalities when assessed in a blinded fashion, the accuracy of these findings in evaluating dogs for possible leptospirosis was not evaluated further.

Serogroup-specific analysis included 44 dogs. Because of the small numbers in a group or the inability to assess the infecting serogroup, 11 dogs of the original 55 were excluded from this analysis. The serogroup-specific analysis indicated that dogs with suspected Pomona infection were >7 times more likely to suffer from vomiting ($P = .01$, OR = 7.1; Table 1) and >5 times more likely to be thrombocytopenic ($P = .009$, OR = 5.5). They also were more likely to have marked increases in blood urea nitrogen concentration ($P = .002$), serum creatinine concentration ($P = .04$), and serum phosphorus concentration ($P = .006$) compared with dogs in the study that were infected with other

Table 1. Signalment, clinical signs, and physical examination abnormalities in dogs suspected to be infected with different *Leptospira* serogroups.

	Grippo	Pomona	Autumnalis	Bratislava	Pomona + Grippo ^a	All Dogs Analyzed
No. of dogs	21	12	6	5	5	55
AMC	7	2	0	0	2	13
CUHA	14	10	6	5	3	42
Intact male	7 (33%)	2 (17%)	3 (50%)	0	2 (40%)	17 (31%)
Neutered male	7 (33%)	3 (25%)	1 (17%)	0	1 (20%)	13 (24%)
Intact female	1 (5%)	1 (8%)	0	0	0	2 (4%)
Neutered female	6 (29%)	6 (50%)	2 (33%)	5 (100%)	2 (40%)	23 (42%)
Lethargy	17 (80%)	9 (75%)	6 (100%)	3 (60%)	4 (80%)	43 (78%)
Anorexia	13 (62%)	10 (83%)	5 (83%)	4 (80%)	4 (80%)	41 (75%)
Vomiting	14 (67%)	10 (83%)	2 (33%)	3 (60%)	5 (100%)	35 (64%)
Weight loss	7 (33%)	2 (17%)	1 (17%)	2 (40%)	3 (60%)	19 (35%)
Cardiac murmur	3 (14%)	5 (42%)	5 (83%)	2 (40%)	2 (40%)	17 (31%)
Polyuria and polydipsia	7 (33%)	3 (25%)	2 (33%)	2 (40%)	1 (20%)	17 (31%)
Diarrhea	5 (24%)	4 (33%)	4 (67%)	1 (20%)	2 (40%)	16 (29%)
Dehydration	3 (14%)	4 (33%)	1 (17%)	2 (40%)	2 (40%)	14 (26%)
Abdominal pain	6 (29%)	5 (42%)	0	0	1 (20%)	12 (22%)
Pale mucus membranes	5 (24%)	3 (25%)	3 (50%)	0	0	12 (22%)
Prostatomegaly	4 (19%)	0	1 (17%)	0	2 (40%)	9 (16%)
Icterus	2 (10%)	2 (17%)	0	1 (20%)	1 (20%)	7 (13%)
Melena	1 (5%)	3 (25%)	1 (17%)	0	0	6 (11%)
Peripheral edema	3 (14%)	2 (17%)	0	0	0	5 (9%)
Renomegaly	3 (14%)	0	1 (17%)	0	1 (20%)	5 (9%)
Fever	0	1 (8%)	1 (17%)	2 (40%)	0	5 (9%)

AMC, Animal Medical Center (New York); CUHA, Cornell University Hospital for Animals; Grippo, Grippotyphosa.

^aThe Pomona + Grippo column includes dogs with equal MAT titers to serogroups Grippotyphosa and Pomona.

Table 2. Clinicopathologic abnormalities in dogs suspected to be infected with different *Leptospira* serogroups.

	Grippe	Pomona	Autumnalis	Bratislava	Pomona + Grippe ^a	All Dogs Analyzed
No. of dogs	20	12	6	5	5	54
Anemia	11 (55%)	9 (75%)	4 (67%)	2 (40%)	0	29 (53%)
Leukocytosis	8 (40%)	6 (50%)	1 (17%)	2 (40%)	3 (60%)	20 (37%)
Neutrophilia	11/20 (55%)	6 (50%)	2 (33%)	2 (40%)	5 (100%)	27 (50%)
Thrombocytopenia	3/15 (20%)	5/8 (63%)	0/5	2 (40%)	2 (40%)	13/44 (30%)
Increased BUN and serum creatinine	19 (95%)	12 (100%)	5 (83%)	3 (60%)	5 (100%)	50 (93%)
Hyperphosphatemia	16 (80%)	12 (100%)	4 (67%)	2 (40%)	5 (100%)	42 (78%)
Hypoalbuminemia	7 (35%)	4 (33%)	3 (50%)	2 (40%)	2 (40%)	19 (35%)
Hyperglobulinemia	9 (45%)	2 (17%)	3 (50%)	2 (40%)	1 (20%)	17 (31%)
Increased ALT	6 (30%)	5 (42%)	2 (33%)	2 (40%)	1 (20%)	17 (32%)
Increased AST	10 (50%)	9 (75%)	3 (50%)	2 (40%)	5 (100%)	30 (56%)
Increased ALP	11 (55%)	8 (67%)	2 (33%)	4 (80%)	5 (100%)	31 (57%)
Increased total bilirubin	7 (35%)	8 (67%)	2 (33%)	2 (40%)	2 (40%)	22 (41%)
Hyponatremia	3 (15%)	2 (17%)	3 (50%)	0	0	9 (17%)
Hypokalemia	6 (30%)	5 (42%)	3 (50%)	3 (60%)	3 (60%)	22 (41%)
Hypochloremia	9 (45%)	7 (58%)	2 (33%)	2 (40%)	4 (80%)	25 (46%)
Low serum bicarbonate	10 (50%)	6 (50%)	5 (83%)	1 (20%)	1 (20%)	26 (48%)
Prolonged PT	2/10 (20%)	1/6 (17%)	0/5	0/3	0/1	3/27 (11%)
Prolonged PTT	1/10 (10%)	3/6 (50%)	0/5	0/3	0/1	4/27 (15%)
Isosthenuria	6 (30%)	6 (50%)	3 (50%)	3 (60%)	4 (80%)	24 (44%)
Hypersthenuria	10 (50%)	5 (42%)	3 (50%)	2 (40%)	1 (20%)	24 (44%)
Pyuria	5 (25%)	1 (8%)	2 (33%)	1 (20%)	0	9 (17%)
Proteinuria	15 (75%)	9 (75%)	5 (83%)	4 (80%)	3 (60%)	41 (76%)
Glycosuria	4/18 (22%)	5/12 (42%)	1/3 (33%)	1/3 (33%)	0/5	13/44 (30%)

BUN, ; ALT, ; ASP, ; ALP, ; PT, ; PTT, ; Grippe, Grippotyphosa.

^a The Pomona + Grippe column includes dogs with equal MAT titers to serogroups Grippotyphosa and Pomona.

serogroups (Table 2). ORs could not be calculated for these variables because 100% of dogs suspected to be infected with Pomona were positive. Dogs infected with Pomona also were almost 5 times less likely to be discharged from the hospital ($P = .03$, OR = 4.8; Table 3).

Discussion

The serogroups that were most commonly suspected to have caused clinical disease from 1996 to 2002 at 2 large referral centers in New York State were Grippotyphosa and Pomona. This finding appears to be unchanged from a previous study at Cornell University that evaluated occurrences between 1980 and 1995.¹² *L. grippotyphosa* also was the most common serovar identified in a study that evaluated occurrences in Illinois between 1996 and 2001.²⁷ In that study, the 2nd most common serovar was *L. bratislava*. A study from California that evaluated dogs from 1990 to 1998

identified *L. pomona* as the most common serovar, with *L. bratislava* the 2nd most common.⁸ These discordant results during similar time periods suggest regional differences in the importance of different serovars. Unlike previous studies, we identified several suspected Autumnalis cases in the northeastern United States. Autumnalis was the 3rd most common serogroup identified in our study. This number likely underestimates the true prevalence of this serogroup because only dogs seen at Cornell University from 2000 to 2001 were evaluated for it. Dogs seen at the AMC during the time period of this study were not evaluated for this serogroup. The previous study at Cornell University¹² and the recent studies from Illinois²⁷ and California also did not evaluate the prevalence of Autumnalis.⁸ Future studies could identify the true prevalence and possible clinical relevance of this emerging serogroup. Increased numbers of Autumnalis cases more likely are a result of

Table 3. Hospitalization and clinical outcome of dogs suspected to be infected with different *Leptospira* serogroups.

	Grippe	Pomona	Autumnalis	Bratislava	Pomona + Grippe ^a	All Dogs Analyzed
No. of dogs	21	12	6	5	5	55
Mean duration of hospitalization	8.1 ± 1.6	7.6 ± 1.5	9.2 ± 1.7	10 ± 2.4	5.4 ± 1.3	8.0 ± 0.8
Range of hospitalization	0–27	1–16	2–10	4–16	0–16	0–27
Survival—left the hospital	17 (81%)	6 (50%)	6 (100%)	5 (100%)	4 (80%)	43 (78%)
Died/euthanized	4 euth	1 died 5 euth	0	0	1 died	2 died 10 euth

Grippe, Grippotyphosa; euth, euthanized.

^a The Pomona + Grippe column includes dogs with equal MAT titers to Grippotyphosa and Pomona.

prior lack of diagnosis and not an actual increase in the occurrence of this serogroup. In 2001 a new vaccine was introduced to veterinary medicine that includes the 4 serovars *L. canicola*, *L. icterohemorrhagiae*, *L. grippityphosa*, and *L. pomona*.^a Future studies could determine whether the addition of the 2 serovars to the vaccine will change the prevalence of serovars in dogs presenting with clinical disease. Because most of the dogs included in this study were evaluated before the use of the new vaccine, the effect of inclusion of these serovars in the vaccine cannot be assessed in this study.

It cannot be assumed that the serogroup with the highest MAT is always the infecting serogroup. At the present time, another readily available method of serogroup or serovar recognition is not available. In one study in human patients performed in Barbados, only an approximately 50% correlation existed between the estimate of the infecting serogroup on the basis of MAT and what was considered to be the actual infecting serovar on the basis of bacterial culture and isolation.²⁸

The seasonality in the number of incidences identified is consistent with previous studies performed in similar geographic areas,¹² with more occurrences seen in the late fall and early winter than previously described. The signalment and breed distribution also are similar to those of previous studies.^{12,16} Clinical signs and results of physical examination, CBC, and serum biochemistry panel were in agreement with those of previous studies.^{8,12,16} The most common clinical signs identified in this study were lethargy, anorexia, and vomiting. Leukocytosis, thrombocytopenia, anemia, azotemia, hyperphosphatemia, increased liver enzyme activity, and hyperbilirubinemia were the most common clinicopathologic abnormalities identified. Almost all the dogs in this study, as well as in previous studies,^{8,12,16} were azotemic and suffered from acute or acute on chronic renal failure. This observation might be more a consequence of the decision to test for leptospirosis than a reflection of the true scope of the pathophysiology of leptospirosis in dogs. Urinalysis identified a high percentage of dogs with proteinuria. Quantification of proteinuria was not performed in most cases, and differentiating between glomerular, preglomerular, and postglomerular proteinuria was not possible. Acute tubular damage can explain proteinuria in many of these dogs on the basis of additional findings such as glycosuria.

Only 2 of 22 dogs with leptospirosis had clinically relevant changes on thoracic radiographs taken at presentation. This finding differs from the results reported in previous studies. In a previous study from Cornell University,⁸ abnormalities were identified in at least 4 of 17 dogs. In a study from New Jersey and Michigan,¹⁶ 1 of 3 dogs had radiographic abnormalities. In both studies, it is not clear when in the course of the disease radiographs were taken, and the radiographs were reviewed retrospectively and not reassessed in a blinded fashion by a single radiologist. In a recent paper from Switzerland assessing radiographic changes in the thorax of dogs with leptospirosis, 5 of 5 dogs reviewed appeared to have radiographic changes.²⁹ In this study, the criteria used for dog selection were not clear, and whether the

presence of radiographic abnormalities was necessary for inclusion was not addressed. As in the previous studies, it is unknown when in the disease process radiographs were obtained. In human medicine, pulmonary pathology does play a role in the pathophysiology of leptospirosis. Pulmonary hemorrhage is likely a result of vasculitis and appears to occur more in epidemics of leptospirosis than in endemic disease.³⁰ The lack of pulmonary lesions in the dogs reviewed in our study could be explained by several factors, one of which might be that we did not rely on the radiographic diagnosis given at the time of treatment but had the radiographs reviewed in a blinded fashion by a single radiologist. Unlike the radiologist assessing the radiographs as part of the routine work-up and trying to identify pathology in a dog known to be ill, the radiologist in our study assessed specific radiographic criteria in radiographs from the dogs included in the study, as well as radiographs from normal dogs in a blinded fashion. The other likely factor is that we only evaluated radiographs taken on presentation and before antibiotic or fluid therapy. We felt this would be important to minimize the effect of treatment on radiographic findings, including the possible effects of antibiotics, recumbency, and fluid overload. Antibiotic treatment could cause toxin release from dying bacteria and, hence, transiently worsen vasculitis, and fluid overload might result from aggressive fluid therapy in oliguric dogs, especially in the presence of abnormal vascular integrity. A 3rd explanation could be that the lack of abnormalities on thoracic radiographs was coincidental and the result of the small numbers of dogs studied or geographic distribution, as occurs in human medicine, in which the incidence of pulmonary involvement varies considerably from region to region and from epidemic to epidemic.¹ Therefore, results of our study indicate that in our population, abnormalities on thoracic radiographic are uncommon at presentation and findings consistent with leptospirosis usually cannot be identified.

All dogs in our study eventually were treated with doxycycline when the diagnosis of leptospirosis was confirmed. Some of the dogs also were treated with penicillin derivatives concurrently before beginning doxycycline therapy. Survival of 78% of the affected dogs with aggressive medical management is similar to previously reported survival rates.^{8,12}

We attempted to identify differences in the clinical presentation, clinicopathologic data or clinical outcome in dogs infected with different serogroups of leptospira. This task is difficult for a number of reasons, including the need for strict criteria for the diagnosis of leptospirosis and differentiation among serogroups, as well as the requirement for large numbers from each suspected serogroup to achieve statistical significance. Consequently, serogroup-specific analysis in our study was limited to the common serogroups *Grippityphosa*, *Pomona*, and *Autumnalis*. Dogs suspected to be infected with other serogroups or with equal MAT titers to 2 serogroups were excluded from analysis in many instances. This difficulty was, in addition to the inherent problems associated with the use of the highest MAT, to predict the infecting serogroup, as discussed earlier. We

did not identify major differences among serogroups that could explain differences in the pathophysiology of the disease. For example, we did not identify a serogroup that primarily causes liver disease and another that causes primarily pulmonary disease or vasculitis. Failure to find such differences could be a result of the limited number of affected dogs, or possibly because such differences do not exist. Despite these difficulties, the serogroup-specific analysis did identify some potentially clinically relevant and statistically significant differences, primarily related to disease severity and prognosis. These differences related to Pomona when compared with other serogroups. Infection with Pomona was found to cause more severe clinical signs (eg, vomiting), and more severe clinicopathologic abnormalities (eg, thrombocytopenia, azotemia, hyperphosphatemia) when compared with dogs suspected to be infected with other serogroups. Pomona infection also was associated with a worse outcome. Only 50% of dogs thought to be infected with Pomona were discharged from the hospital compared with 81% of those thought to be infected with Grippotyphosa and 78% of all cases. It is unlikely that the worse outcome associated with this serovar was a function of bias of owners or clinicians causing dogs with Pomona infections to be euthanized more frequently or given a worse prognosis.

The number of dogs studied, however, was relatively small, and conclusions about clinical differences among serovars should not be definitively made until additional information is available. At the present time in New York State, it appears that dogs thought to be infected with Pomona should be considered more severely affected than those infected with other serogroups, and early aggressive medical management should be offered to owners. A more guarded prognosis might be warranted in these dogs compared with dogs infected with other serogroups.

Footnotes

^a Duramune Max 5-CvK/4L, Fort Dodge Animal Health. Fort Dodge, IA 50501

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