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Signalment Changes in Canine Leptospirosis between 1970 and 2009

H.S. Lee, L. Guptill, A.J. Johnson, and G.E. Moore

Background: Previous studies have identified large breed, male, outdoor dogs of herding or working groups to be at increased risk for *Leptospira* infection. Exposure risk factors may change over time, altering the signalment of dogs most commonly diagnosed with leptospirosis.

Objectives: The objectives of this study were to evaluate possible signalment changes by decade in canine leptospirosis cases diagnosed at university veterinary hospitals in the United States and Canada using reports to the Veterinary Medical DataBase (VMDB) over a 40-year period (1970–2009).

Animals: One thousand and ninety-one dogs with leptospirosis diagnosed among 1,659,146 hospital visits.

Methods: Hospital prevalence of leptospirosis by decade was determined by age, sex, weight, and breed groups. Multivariable logistic regression models were created to evaluate the association between variables and the odds of disease for each decade.

Results: Veterinary Medical DataBase hospital prevalence of leptospirosis in dogs, after a marked decrease in the 1970s and low rates in the 1980s, began increasing in the 1990s. Hospital prevalence significantly increased in dogs between 2 and 9.9 years of age ($P < .05$) and in male dogs ($P < .05$) in each decade since the 1980s. Among weight groups in the most recent decade (2000–2009), dogs weighing <15 pounds had the greatest odds of being diagnosed with leptospirosis ($P = .003$).

Conclusions and Clinical Importance: Hospital prevalence rates by age, weight, sex, and breed groups differed by decade. These changes may reflect changes in exposure risk, *Leptospira* vaccination practices for dogs, or both.

Key words: Dogs; *Leptospira*; Prevalence; Temporal trends; Veterinary Medical DataBase.

Leptospirosis affects dogs, livestock, and other mammals.[1,2] The disease is caused by a Gram-negative spirochete *Leptospira*, which includes more than 200 pathogenic serovars and is maintained in nature by reservoir hosts.[1,3] Dogs typically become infected by contact with leptospires in urine from reservoir hosts, or from urine-contaminated water or soil.[3,4] Disease severity in infected dogs can be quite variable, from subclinical to mild illness to life-threatening disease. Common clinical findings include lethargy, anorexia, vomiting, diarrhea, fever, bleeding, and severe weakness.[5–7] Risk factors for leptospirosis in dogs at veterinary teaching hospitals in North America previously were investigated over a 3-decade period (1970–1998) using the Veterinary Medical DataBase (VMDB).[a,8] Dogs between 4 and 10 years of age were reported to be at higher risk than dogs <1 year of age, and male dogs were at greater risk than female dogs. Herding dogs, hounds, working dogs, and mixed breed dogs were determined to be at increased risk compared with a "companion dog" group. This conclusion summarized the 30-year period and may have been statistically influenced by time periods of differing prevalence. Overall hospital prevalence was reported to be high in the first few years of the study period, but decreased through the 1970s, remained low in the 1980s, and began increasing in the 1990s.[8]

Abbreviations:

AAHA	American Animal Hospital Association
AKC	American Kennel Club
CI	confidence interval
OR	odds ratio
VMDB	Veterinary Medical DataBase

Changes in reported disease may reflect changes in infecting serovars,[7,9–11] prompting additional infectious disease epidemiologic investigations. Published studies from Ontario,[12] Indiana,[13] and California[14] suggest a change in patient signalment and environmental risk factors in selected locations in the last 2 decades, with increased odds of disease noted in urban dogs.

The hypothesis of our study was that the temporal trend and patient signalment of canine leptospirosis differed by decade in the United States. Therefore, the objectives of this study were to evaluate prevalence and patient signalment by decade in canine leptospirosis cases diagnosed at university veterinary hospitals in the United States and Canada using reports to the VMDB between 1970 and 2009.

Materials and Methods

Data Source

In this extension of a previous study,[8] the VMDB was searched for records of dogs with a diagnosis of leptospirosis (VMDB diagnosis code: 010017200) made at any of the participating veterinary teaching hospitals in the United States and Canada during the 40-year period from 1/1/1970 to 12/31/2009. Only the first hospital visit per dog was used because subsequently entered diagnoses of leptospirosis could have represented

From the Departments of Comparative Pathobiology (Lee, Johnson, Moore); and the Department of Veterinary Clinical Sciences (Guptill), College of Veterinary Medicine, Purdue University, West Lafayette, IN.

Corresponding author: Dr G.E. Moore, Department of Comparative Pathobiology, College of Veterinary Medicine, Purdue University, 725 Harrison Street, West Lafayette, IN 47907; e-mail: gemoore@purdue.edu.

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reevaluations of previous infections. Serovar information was not included in the VMDB. Signalment information extracted from the database included age group (<1, 1–1.9, 2–3.9, 4–6.9, 7–9.9, and ≥10 years), sex (intact female, neutered female, intact male, neutered male), breed (name of breed), and weight group (<15, 15–29.9, 30–49.9, 50–74.9, 75–99.9, and ≥100 pounds). Missing values for each variable were defined in a separate category as "not recorded (NR)." Signalment information, as noted in the categories above, also was obtained by year for first visits of all dogs in the VMDB without a diagnosis of leptospirosis in the same 40-year period as a noncase comparison group.

Procedures

All data were imported into Excel[b] and STATA[c] format for data analysis. Annual hospital prevalence per 100,000 examined dogs was calculated by dividing the number of dogs diagnosed with leptospirosis in a particular year by the total number of dogs examined for that year. In addition, the hospital prevalence per 100,000 examined dogs in each group, with a 95% binomial confidence interval (CI), was determined for each age, sex, weight, and breed group by decade (1970–1979, 1980–1989, 1990–1999, and 2000–2009). Breeds were classified as mixed, NR, or one of 7 purebred groups based on American Kennel Club group designations[15] (herding, hound, nonsporting, sporting, terrier, toy, working).

A multivariable logistic regression model was constructed for each decade to evaluate association between signalment variables and a diagnosis of leptospirosis. All 4 signalment variables (age, weight, sex, and breed) initially were included in each decade model with backward stepwise elimination of variables not significant at an alpha level of <0.05. The following subcategories: <1 year of age, intact female, ≥100 pounds, and mixed breed were used as the reference categories for the respective variable in each model. Odds ratios (ORs) and 95% CI were calculated by exponentiation of the regression coefficients. All logistic regression models were assessed for goodness of fit using the Hosmer–Lemeshow test.[16]

Results

Annual Hospital Prevalence of Leptospirosis

A total of 1,091 cases of leptospirosis were diagnosed among 1,659,146 dogs examined between 1970 and 2009 (Fig 1). The median and mean annual hospital prevalence rates were 62.5 and 65.8 per 100,000 per year, respectively. The highest prevalence was recorded in 1971 (296.5; 95% CI, 242.3–359.1) after which prevalence decreased to a low of 9.4 (95% CI, 3.1–21.9) in 1983. Hospital prevalence began increasing in the early 1990s. Compared with the decade of the 1970s, the odds of disease significantly decreased in the 1980s (OR, 0.3; 95% CI, 0.2–0.4), was unchanged in the 1990s (OR, 1.0; 95% CI, 0.9–1.2), and significantly increased in the 2000s (OR, 2.2; 95% CI, 1.9–2.6).

Patient Data in Signalment Analysis

Complete signalment data were available for 1,006 of 1,091 (92.2%) cases and for 1,465,333 of 1,658,055 (88.4%) noncases, constituting the dataset used for multivariate analysis. A missing entry for patient weight was the most common reason for exclusion from signalment factor analysis.

Prevalence and Signalment Factors in the 1970s

Hospital prevalence did not markedly differ among age groups in this decade (Fig 2A). Among sex categories, prevalence was highest in intact males at 89.3 cases (95% CI, 77.1–102.8; Fig 2B). The 30–49.9 pound (90.3 cases; 95% CI, 68.2–117.1) and the 50–74.9 pound weight groups (86.4 cases; 95% CI, 65.1–112.4) had the

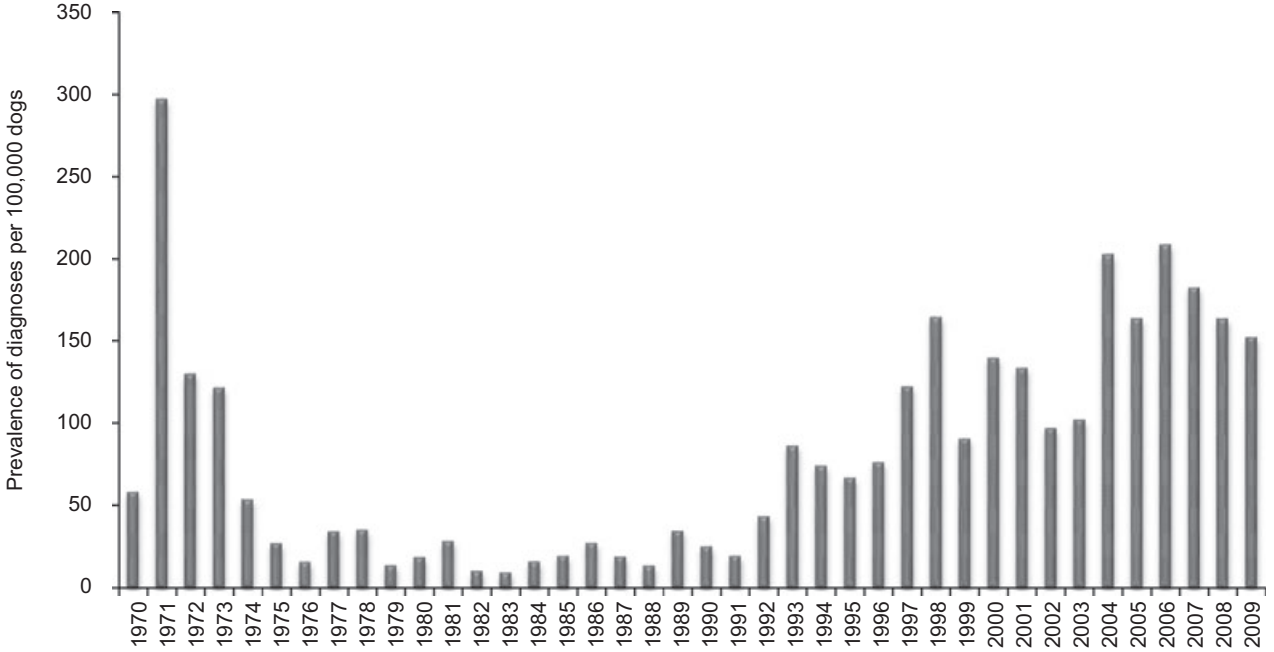

Fig 1. Hospital annual prevalence (per 100,000 examined dogs) of canine leptospirosis at 26 veterinary teaching hospitals in North America from 1970 to 2009.

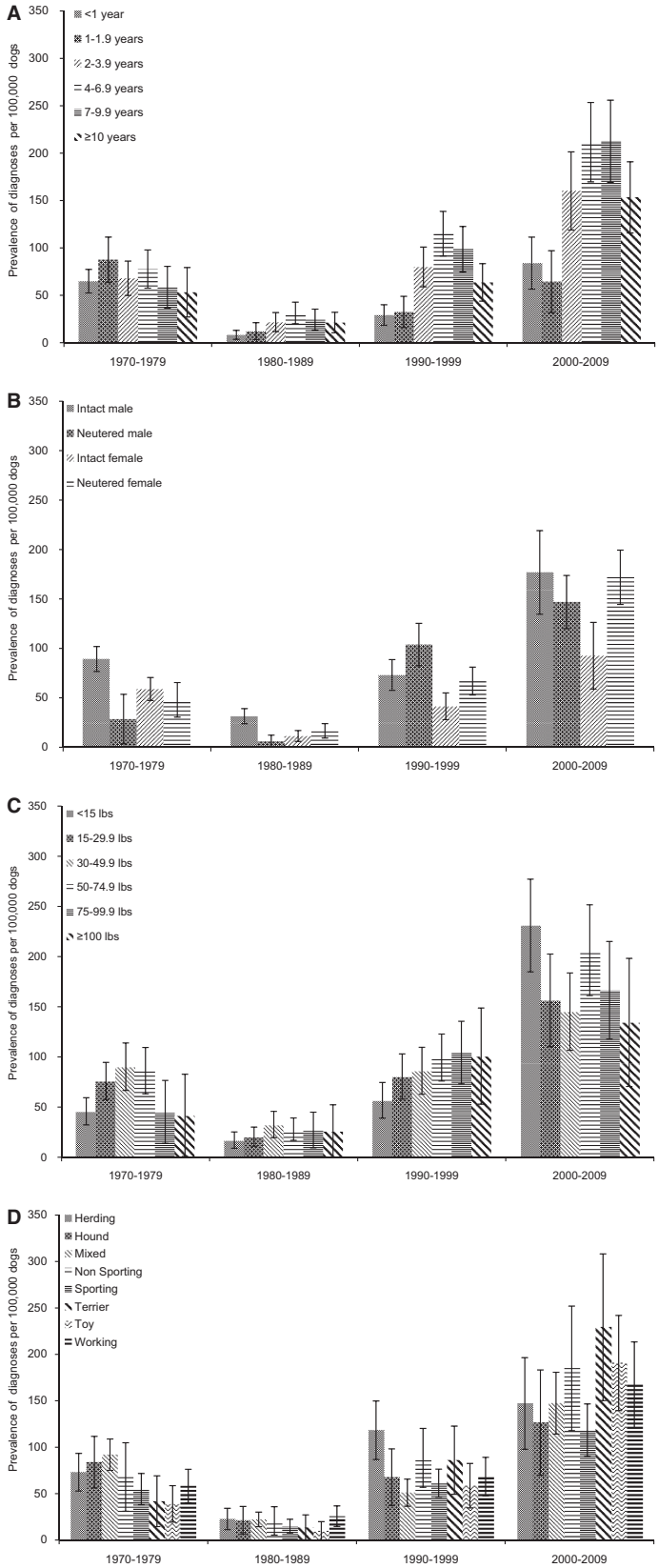

Fig 2. Hospital prevalence per 100,000 dogs for leptospirosis (1970–2009) by age **(A)**, sex **(B)**, weight **(C)**, and breed group **(D)**. Bars represent 95% confidence intervals.

Table 1. Multivariable logistic regression analysis of the adjusted odds of leptospirosis in dogs by decade from 1970 through 2009, reporting only signalment variables with statistical significance after backward stepwise procedure ($P < .05$). Models adjusted for patient age, gender, weight, and breed group.

Variable	Category	Cases	Noncases	Odds Ratio	95% CI	*P*-Value
1970–1979						
Breed group	Herding	50	68,396	0.79	0.57–1.11	.176
	Hound	35	41,718	0.91	0.62–1.33	.635
	Nonsporting	13	19,137	0.74	0.42–1.31	.301
	Sporting	41	74,665	0.60	0.42–0.85	.005[a]
	Terrier	9	21,489	0.46	0.23–0.90	.023[a]
	Toy	15	38,557	0.42	0.25–0.72	.002[a]
	Working	40	68,664	0.63	0.44–0.91	.013[a]
	Mixed	114	123,964	1	NA	NA
1980–1989						
Age (years)	<1	12	143,890	1.00	NA	NA
	1–1.9	7	57,507	1.46	0.57–3.71	.427
	2–3.9	18	82,606	2.61	1.26–5.42	.010[a]
	4–6.9	29	92,272	3.77	1.92–7.39	<.001[a]
	7–9.9	18	74,166	2.91	1.40–6.04	.004[a]
	≥10	15	70,422	2.55	1.20–5.46	.015[a]
1990–1999						
Age (years)	<1	26	72,066	1.00	NA	NA
	1–1.9	13	33,650	1.00	0.51–1.96	.994
	2–3.9	52	49,544	2.72	1.69–4.38	<.001[a]
	4–6.9	83	59,971	3.60	2.30–5.63	<.001[a]
	7–9.9	62	50,285	3.19	2.01–5.08	<.001[a]
	≥10	31	47,223	1.73	1.03–2.93	.040[a]
2000–2009						
Age (years)	<1	35	32,532	1.00	NA	NA
	1–1.9	15	17,525	0.87	0.48–1.61	.663
	2–3.9	48	27,001	1.85	1.19–2.88	.006[a]
	4–6.9	88	34,749	2.69	1.80–4.02	<.001[a]
	7–9.9	79	32,712	2.59	1.72–3.89	<.001[a]
	≥10	58	30,622	1.97	1.28–3.01	.002[a]
Weight (lb)	<15	96	41,282	2.18	1.29–3.67	.003[a]
	15–29.9	44	27,861	1.34	0.76–2.35	.311
	30–49.9	41	27,976	1.26	0.71–2.22	.429
	50–74.9	80	38,550	1.67	0.99–2.82	.055[a]
	75–99.9	45	26,868	1.25	0.72–2.20	.430
	≥100	17	12,604	1	NA	NA

CI, confidence interval; NA, not applicable for referent group.
[a] $P < .05$.

highest prevalence (Fig 2C). Prevalence was highest in mixed breed dogs (91.9 cases; 95% CI, 75.8–110.4) followed by hounds (83.9 cases; 95% CI, 58.4–116.7; Fig 2D). In multivariable analysis, the odds of leptospirosis significantly differed across breed groups but not age, weight, or sex groups. Four breed groups (sporting [$P = .005$], terrier [$P = .023$], toy [$P = .002$], and working dogs [$P = .013$]) were at significantly decreased odds of being diagnosed with leptospirosis compared with mixed breed dogs (Table 1).

Prevalence and Signalment Factors in the 1980s

Hospital prevalence in the 4–6.9 years age group was higher compared with other age groups (Fig 2A). Dogs ≥2 years old ($P < .004$) were at higher odds of being diagnosed than dogs <1 year old (Table 1). Among sex categories, prevalence was highest in intact males in the 1980s with 31.5 cases (95% CI, 24.4–40.1; Fig 2B). There was, however, no significant difference in odds of disease among sex, weight, or breed group categories in multivariable analysis.

Prevalence and Signalment Factors in the 1990s

Hospital prevalence in the 4–6.9 years group was higher compared with other age groups with 115.0 cases (95% CI, 92.7–141.0; Fig 2A). Dogs ≥2 years old were at significantly higher odds for leptospirosis than dogs <1 year old ($P \leq .040$). Among weight groups, prevalence was higher in dogs ≥50 pounds (Fig 2C) and among herding dogs (118.2 cases; 95% CI, 88.8–154.1; Fig 2D). As in the previous decade, there was no significant difference in odds of disease among sex, weight, or breed group categories in multivariable analysis.

Prevalence and Signalment Factors in the 2000s

The 7–9.9 years age group (212.6 cases; 95% CI, 171.1–260.7) had the highest hospital prevalence

followed closely by the 4–6.9 years age group (211.6 cases; 95% CI, 171.8–257.9; Fig 2A). Dogs ≥2 years of age were at increased odds of being diagnosed compared with dogs <1 year old ($P \leq .006$; Table 1). Intact males (176.6 cases; 95% CI, 136.9–224.2) and spayed females (172.0 cases; 95% CI, 145.6–201.8) had comparable prevalence rates (Fig 2B). Prevalence was highest in <15 pound dogs (230.5 cases; 95% CI, 186.7–281.4; Fig 2C), and odds of diagnosis was higher for this group than for other weight groups compared with dogs weighing ≥100 pounds ($P = .003$, Table 1). The terrier breed group had the highest hospital prevalence in this decade (Fig 2D). Among small breeds, Yorkshire Terriers (part of the toy group) had the highest prevalence.

Discussion

The results of this study indicate that the hospital prevalence of leptospirosis diagnosed in dogs at university teaching hospitals has increased since the 1990s. The signalment of affected dogs varied by decade. The variations in prevalence over time are likely because of individual susceptibility and environmental risk factors, such as vaccine status, amount of outdoor activity of the dog, frequency of contact with urine from reservoir hosts or urine-contaminated environment, and annual precipitation.[17–19] Increased hospital prevalence in dogs <15 pounds and in the terrier group in 2000–2009 represents a distinct change from other decades.

Although certain exposures may be more common for some breeds, the impact of exposure cannot be extrapolated from this study. However, another study showed that certain activities such as spending time outdoors, exposure to wild animals, and exposure to water were associated with risk of leptospirosis.[14] Urbanization is likely to provide more opportunities for contact between wildlife reservoir hosts and dogs owing to the high density of urban wildlife,[12,13] but that risk should not differ among breeds unless some breeds are less likely to go outside. Vaccine-associated adverse events have been documented to occur more frequently in small versus large dogs,[20] and the increase in leptospirosis in small breeds might reflect a tendency of owners and veterinarians not to vaccinate smaller dogs against this disease. Higher rates of disease in small breeds thus may reflect perceptions of risk of exposure and risk of vaccine adverse events.

Leptospirosis in dogs in the 1990s was largely attributed to nonvaccinal serovars (serovars other than Canicola and Icterohemorrhagiae) in some reports.[7,9–11,21] The exact role of each serovar cannot be determined for any dogs with leptospirosis because cross-reactivity on serologic tests occurs with several serovars.[3] The potential impact of failure to vaccinate or of vaccine failure, versus infection by nonvaccinal serovars, remains undefined. Four-serovar leptospiral vaccines have been commercially available since 2001, and 2-serovar vaccines are not recommended in current guidelines.[22] *Leptospira* is listed as a noncore vaccination in the current American Animal Hospital Association (AAHA) vaccination guidelines, and the guidelines state that vaccination should be based on whether leptospirosis is documented in the geographic area, and "exposure risk" of the dog.[22] Exposure risk is not clearly defined in the AAHA guidelines. Changes in patient signalment as reported here suggest that exposure risk for different types of dogs is not consistent over time.

The high odds identified in dogs between 4 and 9.9 years of age over the last 3 decades were consistent with other studies.[8,23] In addition, this study found that young adult dogs 2–3.9 years old were also at increased odds of diagnosis compared with dogs <1 year old. The reasons for this observed lower prevalence in dogs <1 year old is not known. Hypotheses include decreased risk caused by less outdoor activity, or more controlled outdoor activity, compared with other age groups or better immunologic protection as a result of puppy vaccinations and maternally acquired antibodies. Maternal antibodies to leptospirosis are not long lived in puppies,[5] and protection conceivably could be ascribed to vaccination as a puppy. Differences in observed rates, if related to vaccination, may indicate that *Leptospira* vaccine was included in a puppy vaccination series but not subsequently in adult booster vaccinations. However, vaccination of young puppies may be unlikely if practitioners perceive lower exposure risk, higher vaccine reaction risk, or both in young dogs.

Although this study was an extension of a previous study of VMDB data,[8] there were some differences in methodology that may have impacted data interpretation. The total number of examined dogs was slightly different from the previous study's total number of examined dogs. In this study, an individual dog was included only once in the analysis, versus up to once per year in the previous study. In addition, there has been a change in VMDB database structure in the last decade (personal communication, Ellis, WK, VMDB), breed group classification was slightly different, and the previous study assessed the proportion of dogs in each age, sex, and breed class across the entire 3-decade study period, thus assuming or inferring that risk was homogenous throughout the 30-year period. Because it is possible that proportions of infected dogs in each age, sex, and breed category changed over time, data were evaluated by decade to identify potential changes in estimated risk at different points in time. Logistic regression models produce ORs, which also are appropriate for retrospective case–control studies. Although relative risk cannot be calculated, the ORs can be good approximations of risk ratios when disease prevalence is low and cases and noncases are representative of their respective general populations.

Use of VMDB-determined age and weight groups allows a comparison between groups without an assumption of linear changes per year of age or weight, but risk may not be homogeneous within predetermined subgroups. The use of categorical subgroups and the conversion of continuous variables (eg, age and weight) into these subgroups has limitations. Different selection of cut-off points for subgroups might lead to different findings and conclusions. Use of recognized breed groups allows inclusion of many breeds without fragmenting data into an excessive number of individual breed entries, but these groups

do not necessarily represent dogs that are phenotypically similar or have similar exposures.

Limitations of VMDB records include the fact that record submission and diagnostic methods are not standardized across hospitals, *Leptospira* serovars are not available, and vaccination information is not included in VMDB patient record. Therefore, we were not able to determine whether the increase in hospital prevalence was related to lack of protection by vaccines or exposure to nonvaccinal serovars. Most university hospital patients are referred from primary practices (especially in latter decades), and therefore a referral bias may exist with the VMDB limited in its representativeness of dogs seen in general practices. This potential referral bias suggests that the prevalence of leptospirosis in dogs in the general population should not be estimated numerically from this study. Misclassification or misdiagnosis bias also is possible, but the magnitude of this bias is uncertain. Although diagnoses were made by clinical specialists at university teaching hospitals, there are no inclusion or exclusion criteria established entering a disease diagnosis into the VMDB.

In summary, temporal changes in the signalment of dogs with leptospirosis seen at hospitals reporting to the VMDB have occurred in the last 4 decades. Increased hospital prevalence in the last decade in small dogs may be because of lack of vaccination in these patients as well as increased exposure risk. Practitioners should consider leptospirosis as a possible diagnosis when a dog is presented with clinical signs consistent with the disease, regardless of patient signalment.

Footnotes

[a] Veterinary Medical DataBases, www.vmdb.org, Urbana, IL
[b] Microsoft Office Excel 2007, Microsoft Corp, Redmond, WA
[c] STATA/IC version 11.2; STATA Corp, College Station, TX

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