

# Prevalence of and risk factors for leptospirosis among dogs in the United States and Canada: 677 cases (1970–1998)

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**Objective**—To determine whether there was a temporal trend in prevalence of leptospirosis among dogs in the United States and Canada and to determine whether age, sex, and breed were risk factors for the disease.

**Design**—Retrospective study.

**Animals**—1,819,792 dogs examined at 22 veterinary teaching hospitals between 1970 and 1998.

**Procedures**—The Veterinary Medical Data Base was searched for records of dogs in which a diagnosis of leptospirosis was made, and hospital prevalence was calculated. Logistic regression was used to examine the association between leptospirosis and age, sex, and breed.

**Results**—677 dogs with leptospirosis were identified. Thus, hospital prevalence was 37 cases/100,000 dogs examined. A significant increase in leptospirosis prevalence between 1983 and 1998 was identified. Male dogs were at significantly greater risk of leptospirosis than were female dogs; dogs between 4 and 6.9 years old and between 7 and 10 years old were at significantly greater risk than dogs < 1 year old; and herding dogs, hounds, working dogs, and mixed-breed dogs were at significantly greater risk than companion dogs.

**Conclusions and Clinical Relevance**—The prevalence of leptospirosis among dogs examined at veterinary teaching hospitals in the United States and Canada has increased significantly since 1983. Male dogs of working and herding breeds were at greater risk. (*J Am Vet Med Assoc* 2002;220:53–58)

Leptospirosis is a serious disease in dogs, with reported case-fatality rates ranging from 10 to 20%.<sup>1,3</sup> The disease may be characterized by acute renal and hepatic failure and coagulation abnormalities.<sup>1,3</sup> Dogs with leptospirosis are often examined because of vomiting, anorexia, severe weakness, and signs of depression; signs of renal insufficiency, such as azotemia, may become apparent only with laboratory testing.<sup>1,2</sup>

Leptospirosis is caused by many different *Leptospira* serovars, and at least 1 primary host species appears to serve as the reservoir for each serovar. Dogs are the reservoir for *Leptospira interrogans* serovar canicola; pigs, horses, and possibly dogs are the reservoir for *Leptospira interrogans* serovar bratislava; rats are the reservoir for *Leptospira interrogans* serovar icterohaemorrhagiae; voles, raccoons, skunks, and opossums are the reservoir for *Leptospira kirschneri* serovar grippoty-

phosa; and pigs, skunks, and opossums are the reservoir for *Leptospira interrogans* serovar pomona.<sup>2,7</sup> Reservoirs of *Leptospira* serovars may vary in different parts of the world.<sup>8</sup>

Following introduction of a bivalent vaccine against serovars canicola and icterohaemorrhagiae in the early 1970s, the incidence of leptospirosis in dogs in the United States decreased.<sup>2,4,9</sup> Beginning about 1990, reports<sup>2,4,8,10,11</sup> of leptospirosis in dogs caused by unusual serovars of *Leptospira*, including serovars bratislava, pomona, and grippotyphosa, began to appear. Dogs that received the bivalent vaccine were not protected from infection with these unusual serovars, because vaccine protection is serovar-specific. In addition, there appears to be more opportunity for contact between dogs and wildlife, such as skunks, raccoons, and opossums, which serve as reservoirs for some of these unusual serovars, and for contact between dogs and livestock or livestock waste.<sup>2,4,10</sup>

As a result, the epidemiology of leptospirosis among dogs in the United States and Canada appears to be changing,<sup>2,11</sup> and several reports<sup>2,3,5,9</sup> have suggested that the number of dogs with leptospirosis is increasing. However, this has not been verified. In addition, there are conflicting reports regarding whether age, sex, or breed are risk factors for leptospirosis in dogs.<sup>1,3,5,11</sup> Some hospital-based studies<sup>1,5,11-13</sup> of leptospirosis have reported that male dogs, young dogs, and hunting or large-breed dogs were overrepresented, but other studies<sup>3,10</sup> did not identify these risk factors. Many of these studies did not include an adequate comparison group and included low numbers of cases. The purposes of the study reported here, therefore, were to determine whether the hospital prevalence of leptospirosis among dogs in the United States and Canada has increased and to determine whether age, sex, and breed were risk factors for leptospirosis.

## Criteria for Selection of Cases

The Veterinary Medical Data Base (VMDB) was used to identify records of dogs examined at veterinary teaching hospitals in the United States and Canada between Jan 1, 1970 and Dec 31, 1998. The VMDB was established in 1964 by the National Cancer Institute to collect, store, and retrieve veterinary clinical information<sup>14,15</sup> and contains a standardized abstract of every animal examined at the 24 participating veterinary teaching hospitals in the United States and Canada.

For the present study, the VMDB was searched to identify records of dogs examined each year of the study period at 22 veterinary teaching hospitals located at schools and colleges of veterinary medicine<sup>8</sup> in which a diagnosis of leptospirosis had been made

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(VMDB diagnosis code 010017200). Records from 2 schools were excluded because no records were submitted from these schools during the study period. The cutoff of Dec 31, 1998 was used because veterinary teaching hospitals have variable delays in reporting information to the VMDB. The following information was extracted from the record for each dog: veterinary teaching hospital, year of admission, age at admission (< 2 weeks, 2 to 8 weeks, 9 to 24 weeks, 25 weeks to 1 year, 1.1 to 1.9 years, 2 to 3.9 years, 4 to 6.9 years, 7 to 9.9 years, 10 to 15 years, > 15 years, unknown), sex (female, male), reproductive status (sexually intact, neutered, unknown), and breed (purebred [name of breed was recorded], mixed breed, unknown).

## Procedures

Hospital prevalence of leptospirosis and its 95% confidence interval (CI) were calculated for each year from 1970 through 1998 for each veterinary teaching hospital that examined and reported information to the VMDB on > 500 dogs. Hospital prevalence was calculated by dividing number of dogs with leptospirosis by total number of dogs examined at the veterinary teaching hospital. Data on annual hospital prevalence of leptospirosis were examined for normal distribution with the Wilks-Shapiro statistic.<sup>b</sup> A simple weighted linear regression model was used to test for linear changes in hospital prevalence of leptospirosis. In the model, year (1970 through 1998) was the independent variable, hospital prevalence of leptospirosis was the dependent variable, and number of dogs examined at the veterinary teaching hospitals was the weighting variable.

Associations (odds ratio [OR] and 95% confidence limits) between age, sex, and breed and the risk of leptospirosis were calculated by use of logistic regression.<sup>c</sup> All dogs examined at participating veterinary teaching

hospitals between 1970 and 1998 for which records were included in the VMDB were classified as cases (leptospirosis) or controls. Case-control status was used as the dependent variable, and age, sex, and breed were used as the independent variables. Age categories were < 1, 1 to 1.9, 2 to 3.9, 4 to 6.9, 7 to 9.9, and ≥ 10 years. Sex categories were sexually intact female, spayed female, sexually intact male, and castrated male. Breed categories were companion dogs, gun dogs, herding dogs, hounds, terriers, working dogs, and mixed-breed dogs; a general reference<sup>16</sup> on dog breeds was used to assign individual breeds to each of the breed categories. Separate logistic regression models were fitted to the data for age, sex, and breed. Fit of the model to the data was assessed by use of the Pearson  $\chi^2$  test. An all-possible-subsets regression procedure was used to determine whether more than 1 variable better explained the risk of leptospirosis. Interactions between all independent variables in the final multiple logistic regression model were assessed for an association with the risk of leptospirosis. The fit of the final model was assessed with the Hosmer-Lemeshow statistic.<sup>17</sup> If the model fit was inadequate, diagnostic procedures (standardized residual, leverage, distance, and outlier statistic) were used to identify reasons for lack of fit.<sup>b</sup> In each bivariate model, records were excluded if information on age, sex, or breed category was missing. In the multivariate models, records were excluded if information was missing for any of the variables included in the model. For all analyses, values of  $P < 0.05$  were considered significant.

## Results

The 22 participating veterinary teaching hospitals in the United States and Canada submitted to the VMDB records on 1,819,792 dogs examined during the study period (Table 1). Veterinary teaching hospitals

Table 1—Hospital prevalence (No. of cases/100,000 dogs examined) of leptospirosis among dogs examined during 1970 through 1998 at 22 veterinary teaching hospitals in the United States and Canada that participated in the Veterinary Medical Data Base

Teaching hospital	Reporting period	Total years	Total No. of dogs	No. with leptospirosis	Hospital prevalence
Michigan State University	1970–1998	29	176,796	82	46
University of Missouri	1970–1998	29	94,919	27	28
University of Minnesota	1970–1998	29	109,137	7	6
Iowa State University	1973–1998	26	80,058	48	60
Cornell University	1982–1991	10	42,504	37	87
University of Guelph	1970–1978, 1983–1991	18	48,767	1	2
Purdue University	1970–1998	29	73,728	31	42
University of Georgia	1970–1998	29	113,813	35	31
University of California	1970–1987	18	106,219	83	78
Ohio State University	1970–1989	20	144,721	185	128
Kansas State University	1970–1993	24	92,728	3	3
University of Illinois	1970–1998	29	113,759	42	37
University of Saskatchewan	1970–1989	20	60,416	1	2
Colorado State University	1972–1998	27	147,210	5	3
Auburn University	1974–1998	25	98,200	9	9
Texas A&M University	1976–1980, 1983–1998	21	84,357	31	37
University of Tennessee	1977–1996	20	59,285	10	17
Louisiana State University	1980–1994	15	38,794	8	21
Virginia-Maryland Regional College of Veterinary Medicine	1988–1994	7	11,675	2	17
University of Wisconsin	1987–1997	11	39,463	23	58
University of Pennsylvania	1986–1994	9	49,226	6	12
University of Florida	1984–1995	12	34,017	1	3
<b>Total</b>		<b>457</b>	<b>1,819,792</b>	<b>677</b>	<b>37</b>

located at Michigan State University, Purdue University, and the Universities of Missouri, Minnesota, Georgia, and Illinois submitted records to the VMDB during each year of the study period, and 14 of the 22 institutions submitted records for 20 or more years. Mean number of years of reporting was 21.

Overall, mean and median numbers of records reported annually were 62,751 and 66,929 records/institution, respectively. The minimum (31,567) and maximum (77,166) numbers of records reported by all veterinary teaching hospitals were reported during 1998 and 1984, respectively.

**Temporal distribution of leptospirosis—**Leptospirosis was diagnosed in 677 of the 1,819,792 dogs examined during the study period (37 cases/100,000 dogs examined; 95% CI, 35 to 40 cases/100,000 dogs examined; Table 1). The Ohio State University had the highest hospital prevalence of leptospirosis (128 cases/100,000 dogs examined), and the Universities of Guelph and Saskatchewan had the lowest (2 cases/100,000 dogs examined).

Annual prevalence of leptospirosis ranged from 225 cases/100,000 dogs examined in 1971 to 7 cases/100,000 dogs examined in 1983 (Fig 1). Mean and median annual prevalences of leptospirosis were 43 and 26 cases/100,000 dogs examined, respectively. The distribution of annual prevalence of leptospirosis was right-skewed (Wilks-Shapiro statistic, 0.75;  $P < 0.01$ ), but transformation of the data to natural logarithms yielded a normal distribution (Wilks-Shapiro statistic, 0.97;  $P = 0.67$ ). No significant ( $P = 0.85$ ) linear trend in annual prevalence of leptospirosis was detected following transformation of the data. However, when the data were divided at the year of the lowest prevalence of leptospirosis (1983), a significant ( $P < 0.01$ ) linear decrease in annual prevalence (2.4 cases/100,000 dogs examined/y) was detected between 1970 and 1982, and a significant ( $P < 0.01$ ) linear increase in annual prevalence (1.2 cases/100,000 dogs examined/y) was detected between 1983 and 1998.

**Risk factors for leptospirosis—**Age was recorded for 1,730,277 (95%) of the dogs (Table 2). Age was significantly associated with risk of leptospirosis, with dogs between 4 and 6.9 years old and dogs between 7 and 9.9 years at increased risk of leptospirosis, compared with dogs  $< 1$  year old.

Sex was recorded for 1,748,378 (96%) of the dogs (Table 2). Sex was significantly associated with risk of leptospirosis, with sexually intact male dogs at increased risk of leptospirosis, compared with sexually intact female dogs.

Breed was recorded for 1,742,110 (96%) of the dogs (Table 2). Breed was significantly associated with risk of leptospirosis, with herding dogs, hounds, working dogs, and mixed-breed dogs at increased risk of leptospirosis, compared with companion dogs.

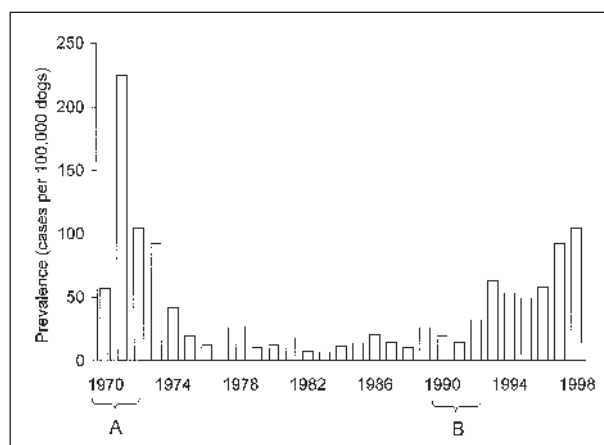


Figure 1—Annual prevalence of leptospirosis (No. of cases/100,000 dogs examined) among dogs examined at 22 veterinary teaching hospitals in the United States and Canada that participated in the Veterinary Medical Data Base between 1970 and 1998. A = Approximate time of the introduction of the first bacterin against leptospirosis approved for use in dogs. B = Approximate time of the first reports of *Leptospira interrogans* serovar bratislava, *Leptospira kirschneri* serovar grippotyphosa, and *Leptospira interrogans* serovar pomona as causes of leptospirosis in dogs.

Table 2—Risk factors for leptospirosis among dogs examined at veterinary teaching hospitals in the United States and Canada between 1970 and 1998

Variable	Category	No. of cases	No. of controls	Odds ratio	95% CI	P value
Age (y)	< 1	145	458,577	1.0	NA	< 0.001
	1–1.9	76	225,340	1.07	0.80, 1.40	
	2–3.9	120	297,641	1.28	1.00, 1.62	
	4–6.9	166	304,181	1.73	1.37, 2.14	
	7–9.9	107	234,834	1.44	1.11, 1.83	
	≥ 10	61	209,032	0.92	0.68, 1.23	
Sex	Sexually intact female	152	483,581	1.0	NA	< 0.001
	Spayed female	121	420,062	0.92	0.72, 1.16	
	Sexually intact male	336	655,350	1.63	1.35, 1.98	
	Castrated male	73	188,703	1.23	0.93, 1.63	
Breed	Companion dog	54	225,671	1.0	NA	< 0.001
	Gun dog	111	356,615	1.30	0.92, 1.76	
	Herding dog	136	214,022	2.66	1.90, 3.56	
	Hound	58	130,990	1.85	1.28, 2.67	
	Terrier	38	123,865	1.28	0.83, 1.90	
	Working dog	106	235,462	1.88	1.33, 2.55	
	Mixed-breed dog	174	454,808	1.60	1.17, 2.14	

CI = Confidence interval. NA = Not applicable.

Table 3—Analysis of the fit of various multivariate models of the odds of leptospirosis among dogs examined at veterinary teaching hospitals in the United States and Canada between 1970 and 1998

Variables included in model	No. of observations	$\chi^2$ statistic	Degrees of freedom	P value
Age, sex	1,730,277	23.86	15	0.067
Age, breed	1,729,122	43.16	30	0.057
Sex, breed	1,735,847	25.86	18	0.103
Age, sex, breed	1,717,750	197.75	153	0.009

Sex and breed best explained ( $\chi^2$  goodness-of-fit, 25.86;  $P = 0.10$ ) the risk of a dog having leptospirosis (Table 3). Using sexually intact female companion dogs as a baseline, sexually intact male dogs of all breed categories except companion dog were at increased risk of leptospirosis, as were castrated male dogs in the herding dog, working dog, and gun dog categories; spayed female dogs in the hound, working dog, and herding dog categories; and sexually intact dogs in the herding dog category. Inclusion of an interaction term between sex and breed category did not significantly improve the fit of the model (likelihood ratio  $\chi^2$ , 25.58;  $P = 0.11$ ). The Hosmer-Lemeshow test statistic ( $\chi^2$ , 4.56;  $P = 0.80$ ) indicated that the model containing sex and breed fit the data adequately.

## Discussion

Results of the present study suggest that the prevalence of leptospirosis among dogs examined at veterinary teaching hospitals in the United States and Canada has increased since 1983. Age, sex, and breed were risk factors for leptospirosis in these dogs, with dogs in the herding, working, and gundog breed categories and sexually intact male dogs appearing to be at the greatest risk.

Many factors could be responsible for an increase in the prevalence of leptospirosis, including changes in diagnostic procedures and awareness, new patterns of *Leptospira* serovar transmission, and changes in the use of available vaccines. For purposes of this study, it was assumed that procedures used to diagnose leptospirosis in dogs examined at these veterinary teaching hospitals remained constant from 1970 through 1998. A combination of clinical signs and biochemical, hematologic, and serologic testing is used to diagnose leptospirosis, and this diagnostic approach appears to have remained constant between reports of leptospirosis published in the 1980s<sup>12</sup> and more recently published reports.<sup>3</sup> However, awareness of leptospirosis among clinicians is unlikely to have remained constant throughout the study period. For example, Prescott et al<sup>18</sup> suggested that leptospirosis is underdiagnosed among dogs in Ontario, and others have published reports<sup>3,10,19</sup> of leptospirosis associated with serovars previously considered unusual causes of disease in dogs. Awareness of leptospirosis in dogs probably increased among clinicians during the 1990s, and this increased awareness may partly explain the increase in annual prevalence of leptospirosis from 1983 to 1998.

The serovars causing leptospirosis were not reported in records submitted to the VMDB. However, a bivalent bacterin directed against serovars canicola and icterohaemorrhagiae has been available since the early

1970s, and the coincidence of introduction and widespread use of this bivalent bacterin in the early 1970s and the dramatic decrease in the prevalence of leptospirosis between 1970 and 1982 suggests a causal association. The increase in the prevalence of leptospirosis since 1983 could, in part, be a result of an increase in the number of infections with serovars other than canicola and icterohaemorrhagiae. Such a change in the epidemiology of leptospirosis in dogs would require establishment of new transmission patterns because of the role of wildlife and livestock as reservoirs for these serovars of *Leptospira*. The increase in prevalence of leptospirosis since 1983 could also be attributable, in part, to a decrease in the percentage of the dog population vaccinated against leptospirosis. The *Leptospira* bacterin is thought to cause a high rate of adverse reactions and to be immunosuppressive in dogs < 16 weeks of age,<sup>20,21</sup> and some veterinarians have suggested there is little indication for its use at present.<sup>20</sup> A vaccine providing protection against *L interrogans* serovar pomona and *L kirschneri* serovar grippityphosa, as well as *L interrogans* serovar canicola and *L interrogans* serovar icterohaemorrhagiae, was released during 2000.<sup>4</sup> If the increase in leptospirosis prevalence documented in this study is due to changing patterns of exposure of dogs to *L interrogans* serovar pomona and *L kirschneri* serovar grippityphosa and if the vaccine is effective and widely used, particularly in dogs at risk of infection, a decrease in leptospirosis prevalence can be expected.

In the present study, age, sex, and breed category were identified as risk factors for leptospirosis in dogs. The risk of leptospirosis was greatest (OR, 1.44 to 1.73) in middle-aged (4 to 9.9 years old) dogs. In a study<sup>3</sup> of 36 dogs with leptospirosis treated at the Cornell University College of Veterinary Medicine, the median age at diagnosis was 7.4 years. In similar studies conducted at the Universities of California<sup>5</sup> and Wisconsin,<sup>13</sup> mean ages at diagnosis were 6.9 and 5.7 years, respectively. Middle-aged dogs may be more active outside their normal home environment than young or old dogs, increasing their potential exposure to *Leptospira* serovars. Alternatively, leptospirosis may more likely be correctly diagnosed in middle-age dogs, or middle-aged dogs may be less likely to be vaccinated against leptospirosis than young or old dogs.

Of all the logistic regression models assessed in the present study, the model containing sex and breed fit the data best. Male dogs of all breed categories (except companion dogs) had an increased risk (OR range, 1.29 to 2.13) of leptospirosis. Herding dogs had an increased risk (OR range, 1.32 to 2.13), regardless of sex, and hounds and working dogs of all sex categories except spayed female dogs had an increased risk (OR range, 1.16 to 1.58) of leptospirosis. In 2 case series, Baldwin and Atkins<sup>12</sup> and Rentko et al<sup>11</sup> reported that male dogs were affected by leptospirosis more often than female dogs. In a study of cases at the University of California, Adin and Cowgill<sup>5</sup> found that affected dogs were predominantly large-breed and male. Harkin et al<sup>1</sup> and Forrest et al<sup>15</sup> reported a breed predilection for German Shepherd Dogs. It has been suggested that large-breed dogs may be more likely to spend time out-



side their homes and be exposed to leptospiral organisms in the environment.<sup>5</sup> Findings from the present study confirm an increased risk of leptospirosis in male dogs and in dogs of breeds that are likely to be more active and spend more time outside the immediate vicinity of their home. There may be true causal links between breed and sex and the risk of leptospirosis, or this association may reflect a bias in diagnosing leptospirosis among dogs possessing certain characteristics. Follow-up longitudinal studies incorporating standard diagnostic criteria are necessary to confirm that sex and breed are causal factors for leptospirosis.

The VMDB, a secondary data source, was used to investigate trends in and risk factors for leptospirosis in the present study. Data analysis was limited to covariates recorded in the VMDB. It is possible that associations between leptospirosis and age, sex, and breed detected in this study were confounded by other variables that were not measured and, therefore, not included in analyses. Study findings may also be subject to bias in recorded information on risk factors and diagnosis of leptospirosis. Dogs for which age, sex, or breed was not reported to the VMDB were excluded from analysis. Age was categorized into broad categories on the basis of information from the VMDB. Although this categorization may have resulted in some loss of information, use of broad age categories reduces the likelihood of misclassification with respect to age of dogs included in the study. Similarly, records of dogs representing more than 160 breeds were reported to the VMDB, and to facilitate analysis and interpretation of results, we categorized breeds as companion dogs, gun dogs, herding dogs, hounds, terriers, working dogs, and mixed-breed dogs. Unfortunately, this categorization obscured high-risk breeds. For example, German Shepherd Dogs had the highest prevalence of leptospirosis (76 cases/100,000 dogs examined). However, use of breed categories rather than individual breeds allowed us to determine whether common risk factors, such as dog size and activity type, may explain the occurrence of leptospirosis. All dogs recorded in the VMDB in which a diagnosis of leptospirosis was made between 1970 and 1998 were included in this study. Because of the steps involved in making a diagnosis of leptospirosis (clinical examination and biochemical, hematologic, and serologic testing), it is unlikely that a dog examined at a veterinary teaching hospital would be falsely diagnosed as having leptospirosis when it did not. It is more likely that leptospirosis was not diagnosed in some dogs with the disease. This source of bias is unlikely to be substantial, because the number of dogs with undiagnosed leptospirosis is probably a very small proportion of all dogs examined at veterinary teaching hospitals. For example, if leptospirosis had been underdiagnosed by a factor of 10-fold, < 0.04% of the 1,819,792 dogs examined at veterinary teaching hospitals between 1970 and 1998 would have been classified as cases rather than controls. For the age category 4 to 6.9 years, this bias would result in a change in the estimated OR from 1.7259 to 1.7295 (a change of 0.21%), assuming equal proportions of misdiagnoses in the 4 to 6.9 years and < 1 year age categories. We do not expect

the proportion of dogs with leptospirosis in which the disease is not diagnosed at veterinary teaching hospitals to be greater than 10-fold that recorded in the VMDB, so bias from misclassification of leptospirosis status was unlikely to be substantial in this study. Similarly, the error rate associated with recording and transposing data from clinical records to the VMDB is unlikely to be > 5%<sup>22</sup> and probably did not have an important effect on results of the present study. Finally, referral bias may exist in data extracted from the VMDB. Dogs examined at veterinary teaching hospitals may not be representative of all dogs in the United States and Canada or of all dogs examined by veterinarians. In particular, more dogs with leptospirosis may be examined at veterinary teaching hospitals than in general veterinary practices. Assuming that this source of bias was constant between 1970 and 1998, the trends identified in this study are still valid. Also, if this bias is nondifferential, estimates of the association between age, breed, and sex and the risk of leptospirosis should be valid. From data available in the VMDB, it is not possible to determine whether differential bias with respect to age, breed, or sex and diagnosis of leptospirosis is present.

Information on risk factors for leptospirosis in dogs is needed to develop effective control strategies. Knowledge of risk factors assists veterinarians in identifying dogs with leptospirosis and can be used by dog owners to modify exposure of their dogs to *Leptospira* serovars. Sex and breed (and probably age) risk factors may operate through environmental exposure of dogs. Further research is needed to identify these specific factors. For example, flooding has been associated with outbreaks of leptospirosis in humans and animals,<sup>11</sup> and rainfall may be useful in predicting the number of dogs with leptospirosis.<sup>3</sup> Preventing exposure of dogs to areas of land that have been flooded recently and to natural water features that are contaminated with *Leptospira* serovars could be effective in reducing the occurrence of leptospirosis. Before such advice can be given to owners of dogs, the importance of environmental variables as risk factors for leptospirosis needs to be confirmed. In addition, veterinarians need to be aware of the risks of leptospirosis in dogs in their practice and the risks of adverse reactions to leptospirosis vaccination so that their clients can make an informed decision on the need to have their dogs vaccinated.

Information on the infecting *Leptospira* serovars was not available in the VMDB. Knowledge of the prevalence of different serovars would enable the reasons for the increase in leptospirosis prevalence since the early 1980s to be better understood. In addition, identification of different associations between *Leptospira* serovars and risk factors could assist in the development of more targeted control programs. Studies carried out using serovar information at specific institutions could provide valuable insights into the changing epidemiology of leptospirosis among dogs in the United States and Canada. Further understanding of the epidemiology of leptospirosis will require studies in which infecting leptospirae are isolated and identified. Because results of serologic tests make it difficult to identify infecting serovars with confidence, molecular typing techniques may be useful for further epi-

demographic studies of leptospirosis in dogs and identification of the reservoir host species of isolated leptospires.

<sup>a</sup>Auburn University, Colorado State University, Cornell University, Iowa State University, Kansas State University, Louisiana State University, Michigan State University, Purdue University, Texas A&M University, The Ohio State University, University of California, University of Florida, University of Georgia, University of Guelph, University of Illinois, University of Minnesota, University of Missouri, University of Pennsylvania, University of Saskatchewan, University of Tennessee, University of Wisconsin, and Virginia-Maryland College of Veterinary Medicine.

<sup>b</sup>Statistix Analytical Software, version 7, Tallahassee, Fla.

<sup>c</sup>SPSS for Windows, version 10.1.0, SPSS Inc, Chicago, Ill.

<sup>d</sup>Duramune LGP, Fort Dodge, Overland Park, Kan.

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