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Despite high-risk exposures, no evidence of zoonotic transmission during a canine outbreak of leptospirosis

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Abstract

Leptospirosis is a bacterial zoonosis that affects many mammals, including humans and dogs; dogs can transmit the bacteria to humans, but the frequency of transmission and highest risk exposures are poorly understood. During 2016–2017, the Maricopa County Department of Public Health, Arizona Department of Health Services and Centers for Disease Control and Prevention investigated the zoonotic potential of a canine leptospirosis outbreak in the Phoenix metro area. We identified symptomatic persons exposed to canine leptospirosis cases by conducting active and passive surveillance. We tested dog owners (n = 9) and animal care providers (n = 109) for serological evidence of *Leptospira* spp. infection (via the microscopic agglutination test [MAT]) and interviewed these persons about their specific exposures to canine cases and general exposures to canine blood and urine. Through surveillance, seven symptomatic persons were identified; six were tested and all were negative by MAT, and of these six, four persons were negative by PCR (two did not have PCR testing). All serosurvey participants (n = 118) were also seronegative. Among animal care providers, bare skin contact with urine/blood from a canine case was reported by 23.2%; two persons reported dog urine splashing in their face. Veterinary technicians were more likely to have bare skin contact with blood from a canine case compared to veterinarians and boarding facility staff ($p < 0.001$). Infection control practices were

inconsistent; when working with specimens from a canine leptospirosis case, 44.6% of participants reported always wearing gloves when working with urine (i.e., collecting specimens), and 54.5% always wore gloves when working with blood. Veterinary technicians were also most likely to engage in all activities involving potential urine/blood contact, such as conducting laboratory tests ($p < 0.01$). We therefore recommend that veterinary technicians specifically receive targeted education about infection control practices. Our results suggest that dog-to-human transmission of leptospirosis is uncommon.

KEYWORDS
infection control, leptospirosis, occupational exposure, serology, veterinary clinics, zoonoses

1 | INTRODUCTION

Between February 2016 and June 2017 in Maricopa County, Arizona, there was a marked increase in canine cases of leptospirosis (more than 70 cases over 17 months, compared with historical reports of less than five cases per year) (H. Yaglom, personal communication, 13 February 2017). During this time, hundreds of people were potentially exposed to sick dogs. Leptospirosis is most commonly associated with tropical climates and heavy rainfall (Moore et al., 2006; Sykes et al., 2011), so its proliferation within the arid desert of Arizona is less expected than in other areas of the United States. This is concerning from a human health standpoint, as increased *Leptospira* spp. circulation in canines might offer more opportunities for zoonotic transmission, particularly in settings where humans are routinely exposed to infected dogs, such as in veterinary clinics, boarding facilities and people's homes.

The genus *Leptospira* consists of 10 pathogenic species, containing more than 250 pathogenic serovars (Adler & de la Pena Moctezuma, 2010; Bourhy, Collet, Brisse, & Picardeau, 2014). Virtually, all mammals are susceptible to *Leptospira* spp. infection, either as reservoir and/or incidental hosts. Human infection occurs from contact with an infected animal's urine or other body fluids, or urine-contaminated soil or water, and bacterial transmission occurs through broken skin or mucous membranes (Bharti et al., 2003). Symptoms are usually mild including fever, headache, myalgia, chills and gastrointestinal symptoms, although severe illness can occur in approximately 10% of patients, causing multi-organ dysfunction such as kidney or liver failure, meningitis, pulmonary haemorrhage and even death.

Occupation is one of the many recognized risk factors for human leptospirosis (Haake & Levett, 2015; Lau, Smythe, & Weinstein, 2010; Levett, 2001)—those at risk include veterinarians, farmers, abattoir workers and meat inspectors (Levett, 2001). Leptospirosis risk among large animal veterinarians has been well described (Acha & Szyfres, 2001; Kingscote, 1986), but less is known about the risk among small animal veterinarians, although they frequently contact animal body fluids. Contact with urine, reproductive fluid and blood are risk factors for transmission—urine poses significant risk because dogs and other animals can shed leptospires in their urine for weeks or longer following infection (Greene, Sykes, Brown, & Hartmann, 2008). There are a few case reports of possible dog-to-human transmission (Barkin & Glosser, 1973; Feigin, Lobes, Anderson, & Pickering, 1973; Fraser et al., 1973; Haunz & Cardy, 1952), but determining whether dog-to-human transmission occurred can be difficult when dogs and humans are in close contact because it is possible that both were infected from the environment or another animal source (Fraser et al., 1973).

In response to the canine outbreak, the Maricopa County Department of Public Health (MCDPH), the Arizona Department of Health Services (ADHS), Arizona Department of Agriculture (ADA) and Centers for Disease Control and Prevention (CDC) launched an investigation to (a) identify exposed persons with

Impacts

- Results from this serosurvey demonstrate a low probability of post-exposure *Leptospira* spp. transmission from dogs to people, which can help inform physicians in determining the need for post-exposure prophylaxis in persons exposed to infected dogs.
- Infection control practices in veterinary clinics should be a specific focus of training for all animal care staff, including training on transmission prevention for specific diseases. Veterinary technicians in particular should receive targeted education, as these persons are most likely to touch dog urine and/or blood.
- Enhanced surveillance was used to identify people exposed to canine leptospirosis cases, involving both active and passive approaches. Such surveillance methods might be applied to future canine leptospirosis outbreaks, but could also be applied to any zoonotic canine pathogen.

leptospirosis-consistent symptoms in order to provide timely diagnosis and treatment and (b) determine the risk of human infection by conducting a serosurvey and risk factor assessment among the exposed. To our knowledge, this is the first human leptospirosis serosurvey conducted in the context of a canine outbreak, and the first to focus specifically on employees of small animal veterinary clinics and boarding facilities in the United States. Results from this investigation have important implications for understanding the risk of dog-to-human *Leptospira* spp. transmission, which can inform decisions regarding the administration of post-exposure prophylaxis (PEP) following contact with infected dogs.

2 | MATERIALS AND METHODS

2.1 | Identification of canine cases

Canine leptospirosis cases were reported to the state veterinarian, MCDPH or ADHS. These cases were investigated and dogs were classified as either a confirmed, probable or suspect case. Confirmed cases had confirmatory laboratory evidence of infection (positive polymerase chain reaction [PCR] or a sufficient microscopic agglutination test [MAT] serology titre relative to leptospirosis vaccination status and timing). Probable cases had at least two of the following: (a) clinical signs/symptoms of leptospirosis, (b) supportive serologic results (IgM/IgG positive and/or MAT non-confirmatory positive, both interpreted in relation to vaccination status and timing) or (c) an epidemiological link (history of a shared facility or home) to a confirmed canine case. A suspect case had clinical signs of leptospirosis in the absence of both supportive/confirmatory laboratory results and an epidemiologic link.

Human surveillance and serosurvey activities (described below) were conducted concurrently with the canine outbreak investigation; therefore, persons identified as exposed to canine cases could have been exposed to a dog eventually classified as suspect, probable or confirmed.

2.2 | Enhanced human surveillance

Enhanced surveillance for symptomatic persons exposed to canine cases consisted of a combination of active and passive approaches, including.

1. Contacting dog owners and veterinary/boarding facilities caring for canine cases to identify any exposed persons with leptospirosis-consistent symptoms.
2. Receiving reports from dog owners/animal care providers about symptomatic persons.
3. Receiving reports from physicians treating patients who had exposure to a dog with leptospirosis.

Diagnostic testing for the symptomatic people identified was conducted by CDC—combinations of MAT serology (acute and convalescent samples when possible), PCR on whole blood and/or urine, and whole blood or urine culture (Galloway & Hoffmaster, 2015; Stoddard, 2013), depending on the time of presentation post-illness onset. Each animal care facility or owner contacted was asked to advise all exposed persons in their facility or household to self-monitor for symptoms of leptospirosis for the duration of the 30-day incubation period and to seek medical attention and/or contact MCDPH if symptoms developed. They were educated regarding the signs/symptoms of leptospirosis, routes of infection and strategies to prevent exposure/infection.

2.3 | Human serosurvey enrolment

From the list of canine cases reported 1 October 2016 (onset of main canine community outbreak) through 5 February 2017, we identified 22 veterinary and boarding facilities that cared for cases. Veterinary clinics and animal boarding facilities provided a list of employees (collectively referred to as "animal care providers") present at the time dogs were treated/boarded between 1 October 2016 and 23 February 2017 (last serosurvey site visit). These individuals were invited to participate in a serosurvey. Dog owners were also invited to participate by voluntarily presenting to MCDPH.

2.4 | Serosurvey interviews

Participants were interviewed about post-exposure clinical symptoms, demographics, occupational characteristics, exposures to the canine cases and potential non-canine leptospirosis exposures. Animal care providers were also asked about routine daily workplace activities not specifically related to contact with the canine cases that might result in touching (direct skin contact) dog urine, blood or reproductive fluids.

2.5 | Serosurvey blood sample collection and testing

A 5-mL blood sample was collected from each participant and was tested at CDC's Bacterial Special Pathogens Branch for anti-*Leptospira* antibodies by MAT, using a 20-serovar panel (*L. interrogans* serovars Australis, Bratislava, Autumnalis, Bataviae, Canicola, Djasiman, Grippotyphosa, Icterohaemorrhagiae, Mankarso, Pomona, Pyrogenes and Wolffi; *L. borpeterenii* serovars Ballum, Javanica and Tarassovi; *L. weilii* serovar Celledoni; *L. kirschneri* serovar Cynopteri; and *L. santarosai* serovars Borincana, Georgia and Alexi).

MCDPH informed participants of their diagnostic results by phone and explained the interpretation of the serological results.

2.6 | Serosurvey data management and analysis

Data from paper interview questionnaires were input into Qualtrics and were anonymized and password-protected. Data management and cleaning were conducted in R 3.3.1 ("plyr" and "xlsx" packages; Dragulescu & Cole, 2014; Wickham, 2011), and analyses were conducted in SAS 9.3. Graphs were developed in the R base package.

The outcome variable of interest was "high-risk" exposures, defined as "touching" or bare skin contact with urine or blood from a dog with leptospirosis that could presumptively result in *Leptospira* spp. transmission. We compared persons with and without high-risk exposures by demographic characteristics, relationship to the dog (owner or animal care provider) and occupational traits like job title, facility type (boarding facility, veterinary clinic or combined facility) and the average hours worked per week (Fisher's exact test, significance cut-off $p < 0.05$). Animal care providers were classified as veterinarians, veterinary technicians and a third category of "other" workers encompassing groomers, receptionists and kennel staff.

Among animal care providers, we also characterized infection control practices and daily workplace activities (not specifically related to the canine cases) that might result in touching blood/urine such as collecting urine samples or cleaning urine-contaminated surfaces. We compared these behaviours and roles by occupation (Fisher's exact test, significance cut-off $p < 0.05$).

2.7 | Ethics statement

The serosurvey investigation was reviewed and given a non-research determination by the delegated authority at CDC's National Center for Zoonotic and Infectious Diseases. Written informed consent was acquired before interviews and blood sample collection, and risks and benefits were explained in both a group setting and on an individual basis.

3 | RESULTS

3.1 | Enhanced human surveillance

Enhanced surveillance identified seven exposed persons with leptospirosis-compatible symptoms; all were exposed to dogs eventually classified as confirmed or probable cases. Most symptomatic persons (6/7) had a mild illness (combination of subjective or measured fever, chills, headache, myalgia, gastrointestinal symptoms and

TABLE 1 Select demographic characteristics of serosurvey participants who touched urine and/or blood from a canine leptospirosis case. Among all participants (both animal care providers and dog owners), no variables were significantly associated with touching urine/blood. Touching is defined as bare skin contact in the absence of gloves or other protection

Demographic variables	Total (%), *N* = 121	Did not touch urine/blood *n* = 91 (75.2%) *n* (%)	Touched urine/blood *n* = 30 (24.8%) *n* (%)	Fisher's *p*
Sex				
Women	103 (85.1)	77 (74.7)	26 (25.2)	1.0
Men	18 (14.9)	14 (77.8)	4 (22.2)	
Age group (years)				
<20	2 (1.7)	2 (100)	0 (0)	0.49
21–30	48 (39.7)	38 (79.2)	10 (20.8)	
31–40	27 (22.3)	20 (74.1)	7 (25.9)	
>40	38 (31.4)	25 (65.8)	13 (34.2)	
No response	6 (5.0)			
Race				
American Indian/Alaskan Native	4 (3.3)	4 (100)	0 (0)	0.70
Asian	2 (1.7)	2 (100)	0 (0)	
Black/African American	2 (1.7)	1 (50.0)	1 (50.0)	
White	100 (82.6)	74 (74.0)	26 (26.0)	
Other	10 (8.3)	7 (70.0)	3 (30.0)	
No response	3 (2.5)	3 (100)	0 (0)	
Ethnic group				
Latino or Hispanic	13 (10.7)	11 (84.6)	2 (15.4)	0.59
Not Latino or Hispanic	93 (78.9)	67 (72.0)	26 (28.0)	
Other/unknown	11 (9.1)	9 (81.8)	2 (18.2)	
No response	4 (3.3)	4 (100)	0 (0)	
Relationship to dog				
Animal care provider	112 (92.6)	86 (76.8)	26 (23.2)	0.22
Owner	9 (7.4)	5 (55.6)	4 (44.4)	

TABLE 2 Characteristics of animal care providers touching urine and/or blood from a canine leptospirosis case. No variables were significantly associated with touching urine/blood. Touching is defined as bare skin contact in the absence of gloves or other protection

		Did not touch urine/blood *n* = 86 (76.8%)	Touched urine/blood *n* = 26 (23.2%)	
Occupational variables	**Total (%), *N* = 112**	***n* (%)**	***n* (%)**	**Fisher's *p***
Occupation				
Veterinarian	17 (15.2)	14 (82.4)	3 (17.7)	0.86
Veterinary technician	67 (59.8)	50 (74.6)	17 (25.4)	
Other	28 (25.0)	22 (78.6)	6 (21.1)	
Facility type				
Boarding facility	9 (8.0)	6 (66.7)	3 (33.3)	0.46
Veterinary clinic	68 (60.7)	51 (75.0)	17 (25.0)	
Combined facility	35 (31.3)	29 (82.9)	6 (17.1)	
Average hours worked per week				
≤25	9 (8.0)	7 (77.8)	2 (22.2)	0.85
25–40	44 (39.3)	32 (72.7)	12 (27.3)	
41–55	51 (45.5)	41 (80.4)	10 (19.6)	
≥56	8 (7.4)	6 (75.0)	2 (25.0)	

conjunctivitis), and one person was hospitalized for meningitis. Six of these persons (including the patient with meningitis) were tested for leptospirosis with all negative results; all six had convalescent serum samples tested by MAT (and therefore were considered to have leptospirosis ruled-out as best as possible), four had whole blood or urine tested by PCR, and four also had acute serum tested by MAT.

3.2 | Serosurvey population and results

We enrolled 121 persons in the serosurvey, including nine dog owners and 112 employees from 17 animal care facilities, including: boarding facilities (9 persons), veterinary clinics (68 persons and combined facilities (35 persons). We visited each participating facility at a prearranged date and time between 10 February and 23 February 2017, within 17 weeks (mean: 63 days) of the first detected canine case at each given site. Participating facilities provided either boarding or veterinary care services, or both, and were widely distributed throughout Maricopa County, in six cities including Phoenix, Scottsdale, Avondale, Gilbert, Litchfield Park and Fountain Hills.

Participation ranged from 11% to 100% per animal care facility and employees of veterinary clinics were more likely to participate than boarding facility staff (chi-square = 13.68, $p = 0.0002$). Participating facilities cared for the majority (65%) of confirmed/probable canine cases identified. In total, 110 participants were exposed to confirmed or probable canine cases of leptospirosis and five were likely exposed to confirmed/probable cases; six were not exposed to confirmed/probable cases. Participants could definitively recall being exposed to 50 dogs (26 confirmed cases, 18 probable cases, 1 suspected case and 5 dogs that did not fit a case definition).

Thirty participants (24.8%) reported having touched (without gloves) urine and/or blood from a canine leptospirosis case (Table 1). Notably, two individuals specifically reported dog urine (from confirmed canine cases) splashing in their face.

Among the 118 participants from which serum was successfully collected, all had negative MAT serology results. Eleven participants met the Council of State and Territorial Epidemiologists clinical case definition for leptospirosis—the most common symptoms were fever, headache, myalgia and conjunctivitis (CSTE, 2013). Five of the eleven symptomatic participants identified in the serosurvey were also identified through enhanced surveillance.

3.3 | Animal care providers' exposures to canine leptospirosis cases

The remainder of our findings are focused on the 112 participating animal care providers, including 17 (15.2%) veterinarians, 67 (59.8%) veterinary technicians and 28 (25.0%) persons of other occupations (groomers, kennel staff, receptionists, other not specified). Twenty-six providers (23.2%) touched (without gloves) urine and/or blood from a canine case, but there were no significant differences for this exposure by occupation (Table 2). When comparing touching urine and blood independently, however, veterinary technicians were significantly more likely to touch dog blood relative to other participants ($p < 0.0005$; Table 3). One veterinary technician and one kennel worker reported dog urine splashing in their face.

Infection control procedures were inconsistent among animal care providers. Both veterinarians and veterinary technicians were more likely to report "always" wearing gloves when working with blood specimens from a dog with known or suspected leptospirosis, compared with blood from any dog (chi-square = 25.3, $p < 0.0001$) (Figure 1). In contrast, no differences in glove use were observed among those working with urine from these dogs.

TABLE 3 Touching urine or blood from a canine leptospirosis case by occupation. Among persons reporting bare skin contact with blood, most were veterinary technicians (Touching is defined as bare skin contact in the absence of gloves or other protection)

		Veterinarian *n* = 17 (15.2%)	Veterinary technician *n* = 67 (59.8%)	Other *n* = 28 (25.0%)	
	Total (%), *N* = 112	*n* (%)	*n* (%)	*n* (%)	Fisher's *p*
Touched urine	56 (50)	9 (16.1)	34 (60.7)	13 (23.2)	0.93
Touched blood	51 (45)	9 (17.7)	38 (74.5)	4 (7.8)	**<0.0005**

Note. Bolded *p*-values denote statistical significance by Fisher's exact test. The total number of providers that touched urine or blood do not sum to 112 because they may have touched both (or neither) types of body fluids

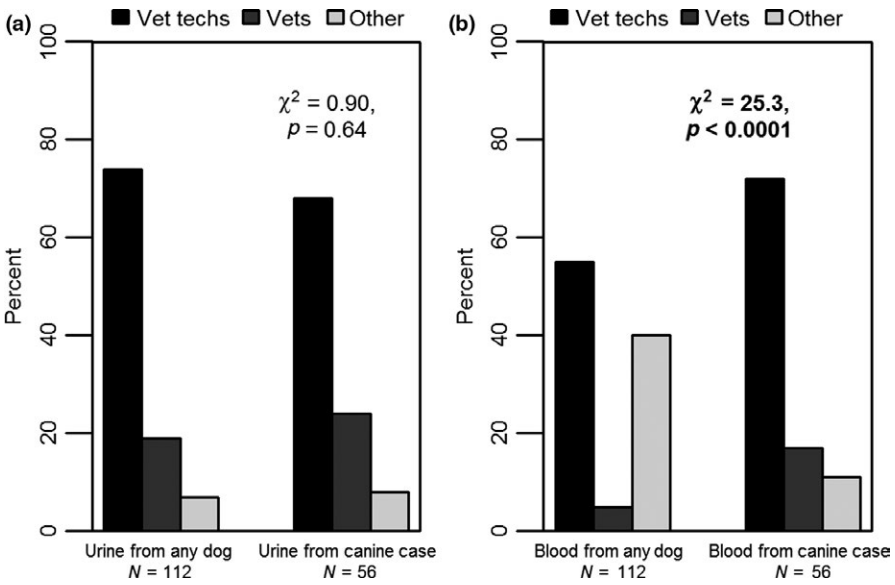

FIGURE 1 Consistency of glove use when working with urine (a) and blood (b) in general vs. urine/blood from a canine leptospirosis case. There were no differences in the number of persons reporting "always" wearing gloves when working with urine in general in comparison with urine from a known canine case. When working with blood, veterinarians and veterinary technicians were significantly more likely to wear gloves when working with specimens from a dog suspected or known to have leptospirosis. Individuals in "other" occupations (i.e., receptionists) were proportionally less likely to wear gloves when handling blood from a canine case

3.4 | Animal care providers' daily workplace activities

Veterinary technicians were most likely to engage in all standard daily activities (not specifically related to the canine cases) associated with exposure to urine or blood (indicating higher theoretical risk of *Leptospira* spp. exposure), including urine/blood collection and testing (Fisher's $p < 0.01$ for all variables; Table 4). Among all animal care providers, common urine exposures included performing laboratory tests on dog urine or blood (78, 69.6%), and collecting urine via free catch (75, 67.0%) or cystocentesis (70, 62.5%). Placing intravenous catheters and collecting blood samples were also frequently performed (79, 70.5% and 85, 75.9%, respectively). Many providers reported cleaning surfaces (103, 92.0%) and cages (97, 86.6%), which could be contaminated with dog urine and/or blood. Most participants reported eating in the break room (75, 67.0%), office (26, 23.6%) or the patient treatment area (22, 19.6%). (Multiple eating locations could be reported by a single person.)

4 | DISCUSSION

This leptospirosis investigation is the first of its kind in the United States. We evaluated seropositivity among small animal veterinary clinic employees, boarding facility staff and dog owners recently exposed to canine cases—the first time this has been done during a canine outbreak.

Despite exposures to urine and blood from canine cases in nearly one quarter of participants, all individuals tested were seronegative, including symptomatic persons identified through enhanced surveillance. These results are consistent with findings from previous investigations (Barmettler, Schweighauser, Bigler, Grooters, & Francey, 2011). Some seroepidemiologic studies among veterinarians (including small, large and mixed-practice) have demonstrated low rates of seropositivity, but only when the tested participants included veterinarians with definite or potential large animal exposures and therefore were not limited to canine case exposures (Fang et al., 2014; Schnurrenberger, Grigor, Walker, & Martin, 1978; Whitney, Ailes, Myers, Saliki, & Berkelman, 2009). Although historical case reports (Barkin & Glosser, 1973; Feigin et al., 1973; Haunz & Cardy, 1952) have documented possible dog-to-human transmission of *Leptospira* spp., our findings lend further support to the hypothesis that such events are uncommon (Barmettler et al., 2011). Still, the potential variability in dog-to-human transmission by different *Leptospira* serovars warrants further attention. In our investigation, *Leptospira* serovar Canicola was likely the most common serovar affecting the canine population, based on MAT highest reacting serovars (Iverson et al., 2019). It would therefore be appropriate to conduct similar

TABLE 4 Normal occupational duties performed that risk exposure to canine body fluids

Activities	Total (%), *N* = 112	Veterinarian *n* = 17 (15.2%) *n* (%)	Veterinary technician *n* = 67 (59.8%) *n* (%)	Other *n* = 28 (25%) *n* (%)	Fisher's *p*
Urine exposures					
Collecting free catch urine samples	75 (67.0)	6 (35.3)	63 (94.0)	6 (21.4)	**<0.0001**
Collecting urine by cystocentesis	70 (62.5)	16 (94.1)	51 (76.1)	3 (10.7)	**<0.0001**
Placing urinary catheter	53 (47.3)	14 (82.4)	39 (58.2)	0 (0)	**<0.0001**
Blood exposures					
Placing IV catheters	79 (70.5)	15 (88.2)	61 (91.0)	3 (10.7)	**<0.0001**
Blood collection	85 (75.9)	15 (88.2)	64 (95.5)	6 (21.4)	**<0.0001**
Urine or blood exposures					
Performing lab tests on urine or blood	78 (69.6)	10 (58.8)	65 (97.0)	3 (10.7)	**<0.0001**
Other possible body fluid exposures					
Assisting in animal birthing procedures	44 (39.3)	12 (70.6)	31 (46.3)	1 (3.6)	**<0.0001**
Handling/bagging dead bodies	89 (79.5)	11 (64.7)	66 (98.5)	12 (42.9)	**<0.0001**
Laundering soiled bedding/towels	85 (75.9)	4 (23.5)	60 (89.6)	21 (75.0)	**<0.0001**
Cleaning cages	97 (86.6)	7 (41.5)	66 (98.5)	24 (85.7)	**<0.0001**
Cleaning surfaces	103 (92.0)	11 (64.7)	67 (100)	25 (89.3)	**<0.0001**
Other					
General animal care	96 (85.7)	7 (41.2)	66 (98.5)	23 (82.1)	**<0.0001**
Performing or assisting with exams	93 (83.0)	17 (100)	66 (98.5)	10 (35.7)	**<0.0001**
Restraining animals	104 (92.9)	15 (88.2)	67 (100)	22 (78.6)	**0.0004**
Bathing animals	57 (50.9)	3 (17.7)	40 (59.7)	14 (50.0)	**0.0075**

Note. Bolded *p*-values denote statistical significance between occupation and urine/blood exposure by Fisher's exact test. Column percentages are reported

investigations with canine outbreaks involving serovars that are non-canine-adapted and/or are thought to be more pathogenic in humans (i.e., Icterohaemorrhagiae).

Even if the risk of dog-to-human transmission of *Leptospira* spp. is low, infection control practices remain important for the prevention of leptospirosis and other zoonotic diseases. Our results showed inconsistencies between formal veterinary infection control guidelines and day-to-day practice in the participating animal care facilities (National Association of State Public Health Veterinarians, 2015). Animal care providers were more likely to report consistent glove use when working with blood specimens from a canine case of leptospirosis (in comparison with blood specimens any dog), yet no significant differences were found in glove use for handling urine specimens from a canine case vs. any dog. Accordingly, animal care providers should handle every specimen as potentially infectious, but infection control education should emphasize that urine is the most important transmission vehicle for *Leptospira* spp. During canine leptospirosis outbreaks, education efforts should target all animal care providers, but with particular focus on veterinary technicians, as these persons were significantly most likely to experience urine and/or blood exposures in general.

This investigation raises questions about the appropriate public health response to canine leptospirosis outbreaks and individuals exposed to infected dogs. People exposed to a canine case of leptospirosis should be contacted to (a) notify them that they had contact with an infected dog; (b) provide education on leptospirosis symptoms and encourage them to seek medical attention as soon as possible if they develop any of those symptoms in the 30 days (maximum incubation period) after their last exposure; and (c) provide education on *Leptospira* spp. transmission and prevention, especially if they continue to be exposed to a dog with leptospirosis. Exposed persons who have immunocompromising conditions, are pregnant, or experienced high-risk body fluid exposures should consult a physician, even if asymptomatic. During canine outbreaks, some jurisdictions might additionally choose to monitor persons with high-risk exposures during and/or at the end of their 30-day

incubation period. CDC currently recommends that persons with known or potential leptospirosis exposures should only pursue diagnostic testing if they develop compatible symptoms—testing of asymptomatic persons is not recommended. Further research is needed to develop evidence-based recommendations about appropriate use of leptospirosis PEP. Existing studies about PEP efficacy and dosing regimens are limited and often inconclusive (Brett-Major & Lipnick, 2009), and notably, none examined PEP after exposures to infected animals. The findings of this investigation may be used by physicians to help inform decisions regarding the use of PEP in persons with exposures to dogs with leptospirosis, as the likelihood of dog-to-human transmission appears to be low.

The detection of symptomatic individuals in this study who did not have any or adequate leptospirosis testing conducted meant that we could not definitively rule out the possibility of zoonotic transmission. MAT is considered the reference standard for serological confirmation of leptospirosis (Musso & La Scola, 2013), but it is insensitive in the acute phase of infection, and therefore, testing paired (acute and convalescent) samples or a convalescent sample alone is important for accurate test interpretation. Among the eleven symptomatic persons identified through the serosurvey, two only had acute samples collected and were therefore not adequately tested for possible seroconversion. Additionally, one person identified through enhanced surveillance did not have any testing completed. It is therefore possible that some symptomatic patients in our investigation tested negative despite potential infection with *Leptospira* spp. Insufficient immune response or antibiotic treatment may also delay or prevent seroconversion, which could result in undetected zoonotic transmission events. The cross-sectional study design also would not have detected illness or infection in participants that were re-exposed to canine cases after testing, possibly a more common occurrence among dog owners than animal care providers. In addition, some serosurvey participants were still in the post-exposure incubation period at the time of testing, and therefore, potential later seroconversion would have been missed. Small numbers of some categories of participants (kennel staff, groomers, receptionists, owners) limited our ability to draw inferences about exposures and infection control behaviours in these groups independently. Among animal care providers, participation might have been limited by scheduling (only 1 day/time per site), and only dog owners that agreed to independently visit MCDPH were interviewed and tested, resulting in a low participation rate in this group of exposed persons. Further, our serosurvey was carried out in the Phoenix metropolitan area, and our results might not reflect broader patterns of infection control behaviours across the United States. It is plausible, for example, that veterinary clinic employees in states where canine leptospirosis is more common (e.g., the Midwest, East, other parts of the Southwest; White et al., 2017) may be more likely to use gloves when working with body fluid specimens from a canine case. Even so, past research (Wright, Jung, Holman, Marano, & McQuiston, 2008) has pointed to the need for improved infection control practices in veterinary clinic settings across the nation.

Our findings contribute to the body of evidence suggesting that dog-to-human transmission of leptospirosis, while possible, is likely uncommon. The analysis of daily workplace exposures to dog urine/blood reveals that veterinary technicians are presumptively most at-risk for exposure to *Leptospira* spp. compared with veterinarians and boarding facility staff, implying that while infection control education should be provided to all animal care professionals, veterinary technicians should be specifically targeted.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

DISCLAIMER

The findings and conclusions in this manuscript have not been formally disseminated by the Centers for Disease Control and Prevention and should not be construed to represent any agency determination or policy.

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