Zoonoses-specific resources, collaborative networks, and enhanced communication can help US veterinarians tackle zoonotic diseases: results from a national survey

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ABSTRACT
Increased incidence of zoonoses, coupled with veterinarians’ occupational exposure, led to this study examining the knowledge of licensed US veterinarians on zoonoses and their disease prevention practices. This online survey supported by the National Association of State Public Health Veterinarians received 466 responses from 36 US states; 67% of the respondents were female, and 72.5% were small animal medicine practitioners. The One Health concept was familiar among 82% of respondents, 51.3% knew of continuing education training on zoonoses, and 68% had attended such a training in the last 5 years. Respondents were unaware of which zoonoses to report to public health departments. For 3 out of 8 questions on standard operating procedures, statistically significant differences in protocols followed among small, large, and mixed animal medicine practitioners were observed. Most respondents believed they played a critical role in zoonoses prevention but would like more information on zoonotic diseases. Results indicate that assisting veterinarians with regularly updated information on zoonoses, providing targeted education and training to adhere to standardized infection control measures, and increasing communication with public health agencies and physicians may help prevent and reduce incidence of zoonoses.

Keywords: veterinarians, zoonotic disease, knowledge, KAP survey, infection prevention

Introduction
Pathogens spread from animals to humans lead to zoonotic diseases or zoonoses.1 These pathogens include bacteria, viruses, parasites, and fungi and can be transmitted through direct and indirect contacts with animals, food, water, and arthropod vectors.1 Globally, about 1 billion cases of illness and millions of deaths occur every year from zoonoses, and approximately 75% of emerging infectious diseases are zoonotic.2,3 Ownership of companion animals and exposure to animals through occupations such as farming, animal husbandry, etc, can put people at risk for contracting various zoonotic diseases.4,5 In the US, 68% of households have pets, with 45 million dog and 77 million cat owners.6 There are also several nontraditional companion animals such as rodents, reptiles, and amphibians that spread zoonoses.4 Treating and preventing infections in domestic animals can help reduce zoonoses. Veterinarians are on the front lines of early detection, prevention, and diagnosis of these zoonotic diseases.7,8 Veterinarians create awareness and educate their clients and communities about necessary steps that can prevent illnesses among their companion or livestock animals, including transmission of pathogens to humans. Therefore, it is important to evaluate the current knowledge and prevention practices of licensed US clinical veterinarians on zoonotic diseases to determine whether appropriate measures are taken to leverage their unique position in the fight against zoonoses.

Previous cross-sectional studies performed in different states (Washington, Arizona, and Michigan) to determine the awareness of veterinarians on zoonotic diseases found that veterinarians were not engaging sufficiently with their clients on zoonotic disease information sharing, reported inadequate strategies to control zoonotic diseases, and were not sure of zoonotic disease–reporting procedures.9–11 As a follow-up to these studies, the goal of this study was to provide a representative national sample of licensed US clinical veterinarians to determine their awareness of zoonotic diseases and assess their ability to identify, diagnose, and prevent these diseases.
Utilizing these previously published articles in scientific literature, a knowledge, attitudes and practices (KAP)-style survey was designed to capture cross-sectional information on zoonoses from our target audience. Knowledge, attitudes, and practices surveys are increasingly utilized across varied disciplines.

Methods

Existing literature and consultations with Arizona state public health professionals were used in the survey design. The survey was divided into 4 main sections: (i) demographics (10 questions), (ii) communication (11 questions), (iii) experience with zoonotic diseases (4 questions), and (iv) prevention of zoonotic diseases (10 questions). The survey was administered online through Qualtrics. This study was ruled exempt by the University of Illinois Institutional Review Board (protocol No. 21577). Survey duration was approximately 15 minutes. Participation was voluntary, anonymous, and without incentives. Informed consent was obtained from each participant at the beginning of the survey. The survey was conducted from March 2021 to January 2022. The survey response goal was 1,000 responses from 25 states.

Inclusion criteria were that participants (i) had to be 18 years of age, (ii) were a licensed clinical veterinarian practicing in the US, and (iii) had English-language proficiency. For recruitment, a partnership with the National Association of State Public Health Veterinarians facilitated dissemination of the study information and survey link to all state public health veterinarians in the US. In turn, they could disseminate the information to all licensed veterinarians in their respective states. After the first study explanatory letter, 3 reminder emails were sent out monthly to the National Association of State Public Health Veterinarians. To increase recruitment, the amended institutional review board allowed partnership with state veterinary medical associations to further disseminate study information. Two reminder emails were sent to the state veterinary medical associations.

Veterinarian respondents provided what type of medicine they currently practice (selecting up to 9 options) and were grouped into 4 large practice categories. The categories were small animal (ie, small animal, small animal and exotic, shelter, or specialty if small animal), large animal (ie, production animal, equine medicine, or specialty if large animal), mixed animal (ie, selected small animal and large animal or mixed animal), and “other” (ie, zoo/wildlife medicine, other, specialty not including large or small animal specific). These subjective categories follow accepted categories of veterinary practice in the US and have similarities in the environments in which they practiced and disease exposures from species with which they worked.

Anonymous survey results were exported from Qualtrics into Microsoft Excel. Data were cleaned, and any identifiers present were excluded from analysis. Duplicate and incomplete responses were removed. Data analysis was performed in R Studio, version 4.1.1. Descriptive statistics were performed, and any open/free-text responses were qualitatively analyzed. For contingency tests, a Pearson χ² test was utilized with simulated P value. The level of significance was set at α = 0.05.

Results

Demographics

The survey received 601 responses from 36 states, with most responses from the states of Louisiana, Illinois, Arkansas, and Arizona (Figure 1). Responses that did not meet inclusion criteria, were incomplete, or were from nonlicensed veterinarians were removed (n = 135). After exclusion, 466 responses were analyzed. The demographics of the study participants included the following: a majority female (67% [312/466]), small animal practitioners (72.5% [338/466]), did not have an advanced degree (70.6% [329/466]), and practiced in suburban areas (52.8% [246/466]) and the highest number graduated between 2011 and 2020 (24% [112/466]) and 2001 and 2010 (23.2% [108/466]; Table 1). The survey was a good representation of the general population of licensed clinical veterinarians in the US.

Knowledge

As the term One Health was first used in 2003 to 2004, 82% (382/466) of the participants were aware of this concept. Comparing One Health knowledge with practice location, suburban veterinarians reported the highest One Health knowledge (86.2% [212/246]), whereas rural veterinarians were lowest (80.2% [97/131]). Comparing knowledge about One Health by veterinary medicine type, veterinarians categorized as “other” tended to be most familiar (85% [17/20]), followed by small animal practitioners (83.4% [282/338]), large animal practitioners (79.4% [27/34]), and mixed animal practitioners (76.7% [56/73]). Familiarity with the One Health concept trended higher among younger practitioners.

Regarding knowledge of availability of continuing education (CE) training on zoonotic diseases, in

![Figure 1—Map of a nationally representative survey assessing licensed clinical veterinarians by practice state on knowledge of zoonotic diseases and One Health in the US. Created with Datawrapper.](image-url)
The frequency of zoonotic disease reporting to public health agency/department by veterinarians was generally observed to be weekly (0.4% [2/466], monthly (2.8% [13/466]), yearly (7.5% [35/466]), rarely (58.2% [271/466], and never (29.4% [137/466]). Regarding knowledge of which diseases to report to a local public health agency, rural veterinarians were more likely to self-report as very knowledgeable (18.3% [24/131]), followed by suburban veterinarians (15.9% [39/246]) and urban veterinarians (10.2% [9/88]). Most veterinarians, regardless of practice location, were somewhat knowledgeable about which diseases to report (urban, 71.6% [63/88]; rural, 68.7% [90/131]; suburban, 67.5% [166/246]). However, 15.9% of both suburban (39/246) and urban (14/88) veterinarians reported not being knowledgeable about which diseases to report, while only 11.5% (15/131) of rural veterinarians were not.

Comparing by veterinary medicine type, fewer respondents reported being very knowledgeable about which diseases to report. Large animal practitioners (38.2% [13/34]) reported being very knowledgeable followed by “other” practitioners (25% [5/20]), mixed animal practitioners (21.9% [16/73]), and, lastly, small animal practitioners (11.2% [38/338]). Most participants were somewhat knowledgeable about which diseases to report to their local health agency (small animal, 70.1% [237/338]; “other,” 70% [14/20]; mixed animal, 65.8% [48/73]; large animal, 58.8% [20/34]). Large animal practitioners reported no knowledge gap on reporting, while small animal (17.2% [58/338]), mixed animal (12.3% [9/73]), and “other” (5% [1/20]) had no knowledge of which diseases to report to local health agencies, indicating a key knowledge gap.

Zoonotic disease risk
In general, 46.8% (218/466) of respondents indicated diagnosing a zoonotic disease weekly, 33.9% (158/466) monthly, 6% (28/466) yearly, 11.8% (55/466) rarely, and 0.9% (4/466) never. In the past year, 2.6% (12/466) respondents diagnosed a zoonotic disease once among their patients, 23.6% (110/466), 2 to 5 times; 12.2% (57/466), 6 to 10 times; 47.2% (220/466), > 10 times; and 4.9% (23/466) did not diagnose any zoonotic disease.

When asked how often veterinarians were diagnosed with a zoonotic disease that originated in their practice, 74.9% (349/466) indicated not being diagnosed with a zoonotic disease. Among those respondents who indicated yes to being diagnosed with a zoonotic disease, those in mixed animal practice (31.5% [23/73]) and urban veterinarians (28.4% [25/88]) reported the highest number of personal diagnoses. The number of veterinarians who reported the name(s) of zoonotic disease(s) that they were diagnosed with from their practice location was 88 of 466 (18.9%). Some diseases were reported more frequently than others, (eg, dermatophytosis or ringworm, bartonella infections, etc). Some veterinarians mentioned > 1 zoonotic disease that they were diagnosed with in the past year, and some indicated infections that had a frequency of < 3 occurrences, so
they were categorized as “other zoonotic diseases” (Supplementary Figure S2). No statistical difference was found for personal diagnosis of zoonotic diseases by veterinary medicine type or practice location. Given the risk of exposure to zoonotic infections in veterinarians, a follow-up question on what licensed veterinarians thought about the risk of zoonotic diseases among pet and livestock owners was asked. Overwhelmingly, veterinarians responded yes to these groups being at risk of acquiring zoonoses from their animals (risk to pet owners, 92.5% [431/466]; risk to livestock owners, 89.9% [419/466]). There were few survey participants who did not respond to whether these groups were at risk or not (risk to pet owners, 7.3% [34/466]; risk to livestock owners, 9.9% [46/466]), indicating room for education.

**Attitudes**

Regarding whether veterinarians had professional relationships with physicians to consult on zoonotic diseases, only 27% (126/466) responded yes whereas 69.5% (324/466) indicated no, suggesting a lack of communication between human and veterinary practitioners. Of those who mentioned having discussions with a physician, 20.6% (26/126) indicated doing so once a month, 26.2% (33/126) said once every 6 months, 11.9% (15/126) said once a year, 39.7% (50/126) responded rarely, and 1.6% (2/126) indicated never discussing with a physician.

Most (90.1% [420/466]) of the licensed veterinarians in this survey believed that they play a vital role in promoting zoonotic disease prevention. A majority (73% [341/466]) of respondents believed that advising clients on zoonoses is very important, 15.9% (74/466) said moderately important, 4.5% (21/466) said somewhat important, and 0.6% (3/466) said it is of little importance.

When asked how often respondents would initiate conversations about zoonotic diseases with their clients, 35.6% (166/466) indicated daily, 38.8% (181/466) weekly, 11.4% (55/466) monthly, 12.9% (60/466) occasionally, and 1.1% (5/466) never do so. Conversely, regarding the number of times clients have initiated conversations with their veterinarians about zoonotic diseases, 5.2% (24/466) of respondents said daily, 18.7% (87/466) weekly, 15.5% (72/466) monthly, 54.7% (255/466) occasionally, and 4.3% (20/466) never (Figure 2).

The most frequently reported zoonoses or conditions for which clients initiated the conversation with the veterinarian were feeding raw foods, external parasitism, toxoplasmosis, Lyme disease, methicillin-resistant *Staphylococcus aureus* (MRSA) infection, dermatophytosis, cat scratch disease, animal bite prevention, psittacosis, internal parasitism, feeding raw foods, *Escherichia coli* infection, MRSA infection, and dermatophytosis. Finally, the most frequently reported zoonosis or condition for which either veterinarians or clients initiated the conversation were external parasitism, dermatophytosis, internal parasitism, animal bite prevention, psittacosis, Lyme disease, rabies, feeding raw foods, MRSA infection, and giardiasis (Figure 2).

Veterinarians were asked whether they provided their clients with any information on zoonotic diseases and what kind. Sixty-six percent (307/466) reported having some educational materials for their clients, while 27.5% (128/466) of veterinarians reported not providing any educational materials to their clients and 6.7% (31/466) did not provide any response. Among those who did provide educational materials, these were in the form of handouts; information through resources like Veterinary Information Network; websites like that of the US CDC, Companion Animal Parasite Council, and veterinarypartner.com; and pamphlets from drug manufacturers.

### Standard operating procedures

To reduce the occurrence of zoonotic diseases in occupational settings, following standard operating procedures (SOPs) is important. Responses to which SOPs were followed by licensed veterinarians in general by type of veterinary medicine and practice location are provided in Table 2.

In general, veterinary practices insufficiently followed SOPs. Only 40.3% (188/466) indicated having written infection control guidelines for staff. About 49.1% (229/466) washed hands after handling individual animals, and 25.8% (120/466) indicated having an assigned employee that oversaw infection control measures. Only 41.4% (193/466) of the veterinarians were up-to-date on their rabies vaccinations, and 44.4% (207/466) of the time, staff members were restricted to access animals in isolation or quarantine.

When analyzing these responses by veterinary medicine type, just 35.3% (12/34) of mixed animal practitioners were washing their hands between handling individual animals. Generally, 82.6% (385/466) indicated using soap and water to wash their hands, and large animal practitioners were the highest group that reported doing so (86.7% [293/336]). Mixed animal practitioners had the lowest reporting of having written infection control measures (28.8% [21/73]). Notably, only a small proportion of clinics had an assigned employee to oversee infection control measures (small animal, 25.4% [86/336]; large animal, 26.5% [9/34]; mixed animal, 24.7% [18/73]; and other, 35% [7/20]). Rabies vaccination was least updated among large animal practitioners (35.3% [12/34]) and “other” practitioners (35% [7/20]).

Three SOP situations were statistically significant between veterinary practice types (small animal, large animal, and mixed animal). These SOP questions were (a) “How often are exam tables, treatment tables, and animal handling equipment disinfected between patients?” (χ² = 14.237; P = .038), (b) “I use soap and water when washing my hands” (χ² = 26.076; P = .002), and (c) “Does your practice have written infection control guidelines for the staff?” (χ² = 13.048; P = .003).
Participant responses to situations when personal protective equipment (PPE) is worn in clinical settings were assessed, both in general and by veterinary medicine type (Supplementary Table S1). Veterinarians reported low levels of PPE use during necropsy (50.2% [234/466]), while handling sick animals (49.4% [230/466]), during animal birth (49.4% [230/466]), and while encountering animal blood/saliva (34.5% [161/466]), indicating several points at increased exposure risk.

Analyzing the responses by veterinary medicine type, 63% (46/73) of mixed animal practitioners wore PPE during surgery and only 48.2% (163/338) of
small animal practitioners wore PPE during necropsy. Among small animal practitioners, 47.3% (160/338) wore PPE during animal birthing and 43.2% (146/338) while encountering animal urine or feces. While encountering animal blood and saliva, 29.6% (100/338) of small animal practitioners and 35.3% (12/34) of large animal medicine practitioners wore PPE. Lastly, 46.2% (156/338) of small animal practitioners wore PPE while handling sick animals. Small animal practitioners wore PPE the least as compared to their other colleagues, indicating a key gap.

Finally, respondents were asked what would be most helpful in assisting them with management of zoonotic diseases. In general, the main measures that
would be helpful for all licensed US veterinarians were written information for veterinarians on zoonotic disease recognition and control, written information for clients on zoonoses awareness and prevention, and websites with zoonotic disease information for veterinarians. The top 3 measures by veterinary medicine type and practice location that would assist veterinarians, based on their self-reporting, are captured in Figure 3. Other measures reported by veterinarians that would be useful for management of zoonosis are provided in Supplementary Material S1.

**Discussion**

Veterinarians are a crucial part of the public health taskforce as they sound the alarm for zoonotic diseases, manage disease outbreaks, and form a bridge between animal and human health. It is critical that veterinarians are informed about emerging and reemerging zoonoses and appropriate zoonosis prevention measures to reduce the incidence and prevalence of such diseases. In this study, survey results from a nationally representative sample of licensed US clinical veterinarians provide insights into their knowledge of One Health, zoonoses, and prevention practices.

**One Health knowledge**

Most participants reported knowledge of One Health. By veterinary medicine type, “other” professionals reported the highest knowledge, due to the wide range of animals and patients that they treat on a regular basis. On analyzing responses by practice location, rural practitioners reported low knowledge of One Health. This can be an important gap since rural veterinarians along with other stakeholders in agricultural and remote areas provide much needed care to animals and humans and are often the only source of medical information and advice for rural communities. Their lower knowledge of One Health and lack of access to resources and training can hamper the fight against zoonoses.
Engagement with physicians and public health agencies

Similar to prior studies,9,10,20 this study found that licensed US veterinarians were not very knowledgeable about which zoonotic diseases to report to public health departments/agencies. Most participants responded to being somewhat knowledgeable (68.4% [319/466]) about which diseases to report, with large animal and rural practitioners having the highest knowledge about which zoonotic diseases to report. Confusion and lack of clarity on reporting strategies can serve as barriers when it comes to zoonoses reporting and timely response.20 Less than a third of the veterinarians in this survey had professional relationships with physicians to consult on zoonotic diseases, and among them, the frequency of conversations occurring between the professions was low. The insufficient interaction between veterinarians and other medical professionals has been documented in other studies9,10,21 and indicates a missed opportunity for collaboration and control of zoonotic diseases. If veterinarians are informed of which zoonotic diseases in their patients are reportable to public health agencies, that will strengthen zoonotic disease surveillance and better inform human healthcare professionals about potentially impactful disease outbreaks in the area. Lack of communication between veterinarians and physicians can stem from confusion on ways to collaborate, absence of resources, and a paucity of occasions that could lead to better exchange of ideas, collaboration, and capacity building.22,23

Additionally, as several zoonotic pathogens can arise from companion animals and the majority of our survey respondents were small animal practitioners (reflecting the demographics of licensed veterinarians in the US), this continued gap in communication and disease reporting limits information exchange between healthcare professionals and local public health agencies. Ultimately, this leads to delays in disease control and prevention. A clear recommendation is the creation of increased opportunities for communication and information sharing between veterinarians, physicians, other healthcare professionals, researchers, and county and state health entities on a regular basis to reduce zoonotic disease occurrence.

Veterinary communication

Even though 73% (341/466) of veterinarians believed they should provide essential information on zoonoses to their clients, only about 66% (307/466) of the veterinarians reported doing so, indicating another gap. In general, participants responded that they spoke more often about zoonoses with their clients than vice versa. However, those zoonotic diseases that veterinarians thought important to discuss did not completely overlap with the disease concerns that clients wanted to talk about. Since veterinarians have demonstrated more knowledge about zoonoses than human healthcare professionals,24-26 not having frequent conversations with clients on this topic can hinder zoonotic disease prevention efforts. Several studies27,28 have recommended providing courses on communication as part of veterinary education, and curriculum to help veterinarians communicate effectively with their clients and colleagues on zoonotic diseases would be beneficial.

Training on zoonoses and zoonosis risk

About half of respondents knew about availability of CE on zoonotic diseases, and only 68% (317/466) had attended such a training in the last 5 years. The lack of sufficient knowledge on zoonotic diseases should be addressed both in veterinary education as well as in clinical and professional settings29 to reduce the zoonotic disease risk among veterinarians, their staff, and their patients. A clear recommendation to fill this gap is making easily accessible information and resources on zoonotic diseases available in veterinary student curricula and part of the protocols of clinics and teaching hospitals. The addition of short and updated modules on zoonoses every 2 years for every staff member in veterinary practices and enforcement of appropriate infection control measures can help protect and update veterinarians on new zoonotic diseases, treatments, and management options.

Veterinarians are at risk of contracting various zoonotic diseases through their patients. About half of participants diagnosed zoonotic diseases weekly in their patients, and a quarter reported contracting a zoonosis that originated from their practice. Related results were observed by Garcia-Sanchez et al30 among Spanish veterinarians along with the most commonly diagnosed zoonosis (ie, dermatophytosis). Veterinarians’ risk of exposure and zoonotic pathogen contraction can be due in part to insufficient SOPs,31-33 This study found veterinarians were not following appropriate SOPs and were not using PPE to protect themselves and staff from potential zoonotic disease threats as frequently as recommended. There were statistical differences among various veterinary groups regarding specific SOPs, indicating another gap. Additionally, small animal practitioners reported the lowest frequency of wearing PPE during various clinical activities and following proper SOPs. Sykes and Weese32 specifically laid out infection control measures that should be followed in small animal clinics, as these could be easy areas where both clients and veterinarians are at risk of contracting zoonoses.

Results indicate there need to be several areas of improvement in SOPs to reduce transmission of zoonotic pathogens within clinics. The fact that insufficient and improper infection control practices in veterinary clinics continues to be found across several studies and countries for several years10,32-34 is a real sign of concern. Different studies have suggested people’s personal perceptions, funding, availability of resources, failure to implement standardized infection control measures, lack of regulations, and lack of knowledge as key reasons behind insufficient hygiene practices followed in veterinary clinics, which drive veterinarians’ increased risk of zoonotic diseases.
Management of zoonosis
Given the lack of infection control measures and differences in SOPs followed in veterinary clinics along with insufficient knowledge on zoonotic disease reporting, infrequent consultation with physicians, and insufficient attendance of zoonotic disease training, there is a need for solutions that will help fill these gaps. Veterinarians are aware of some of these gaps, and all respondents, regardless of veterinary medical sector and practice location, felt that written information for clients, updated websites, resources on zoonoses for veterinarians, information on local regulations, and availability of more CE trainings by local public health agencies are key measures that can assist them in disease management. Creating accessible and updated resources with tangible information on zoonoses, best reporting, diagnosis, and treatment practices that can be retrieved by veterinarians irrespective of location and practice type would be valuable. Additionally, trusted, easily accessible sources of information on zoonoses that veterinarians can provide to their clients at every visit would be beneficial. Ensuring the availability of standardized information on SOPs by veterinary medicine type so that the same set of standardized infection control practices are followed across the veterinary profession is essential to reduce cross-contamination and risk of zoonoses.

Recommended solutions
There are several highlighted gaps that need to be addressed through 4 recommendations. First, develop an easily accessible and updated resource of educational materials on zoonoses for all US veterinarians. Second, develop open channels of collaboration and communication on zoonoses between veterinarians, physicians, and public health officials. Third, improve communication skills of veterinarians with their clients to effectively address zoonotic disease concerns and prevent future outbreaks. Finally, establish standardized and mandatory infection control measures across all veterinary clinical settings to minimize disease risk (Supplementary Figure S3).

Limitations
Since this was a cross-sectional survey examining licensed clinical veterinarians at a specific time without follow-up, there were several limitations. Responses were not received from all states in the US due to difficulties in survey distribution. There may have been response bias, as respondents who participated were already interested in this topic. Responses may have been affected by social desirability bias. Despite these limitations, this study provides important results that can help improve knowledge, communication, and existing practices of licensed clinical veterinarians in the US (Supplementary Figure S4).

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References

Supplementary Materials

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