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Large animal veterinarians' knowledge, attitudes, and practices regarding livestock abortion-associated zoonoses in the United States indicate potential occupational health risk

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Abstract

OBJECTIVE—To understand large animal veterinarians' knowledge of select zoonotic diseases that cause livestock abortions and identify barriers to using personal protective equipment (PPE).

SAMPLE—A convenience sample of 469 veterinarians currently working with livestock.

PROCEDURES—We sent an electronic survey invitation to large animal veterinarians through various veterinary organizations. Respondents answered questions addressing knowledge and prior experience with select abortion-associated zoonotic diseases, resources available for infection control, attitudes and barriers to PPE use, and demographics.

RESULTS—Median participant age was 49 years (range, 22 to 82 years), and 54% (235/438) were male. Half of veterinarians (185/348) were contacted 5 or fewer times per year to consult on livestock abortions. No veterinarians surveyed answered all questions on zoonotic disease

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transmission correctly. Personal protective equipment access varied, from 99% (289/290) having access to gloves to 20% (59/290) having access to respirators. Concerns for spreading disease to other animals (136/289 [47%]) and to other humans (108/287 [38%]) ranked as the most common reported motivators for PPE use. Reported barriers to PPE use among survey participants were the inconvenience of taking PPE into the field (101/286 [35%]) and the inconvenience of wearing PPE (97/286 [34%]). Access to PPE was not correlated with PPE use.

CLINICAL RELEVANCE—Surveyed veterinarians had limited knowledge of transmission of select abortion-associated zoonotic diseases. Incomplete understanding might lead to inappropriate PPE selection, preventable disease exposure, or missed opportunities for client education. Inconvenience was a primary reason PPE was not used.

Veterinarians are exposed to a variety of health hazards during a typical day in clinical practice. Documented hazards include injury, mental distress, zoonotic diseases, radiation, and chemical exposure.[1-6] Veterinarians have an increased risk of contracting zoonotic diseases and might serve as a sentinel for emerging zoonoses.[1,7-10] Many reports document zoonotic diseases transmitted by food animal species.[11-15] Large animal veterinarians (those providing veterinary services for cattle, horses, swine, goats, and sheep) face additional challenges that might increase their risk of occupational exposure to zoonotic diseases. These challenges arise through working primarily in the field, which prevents the use of certain infection control measures within the hierarchy of controls that are more easily implemented in the veterinary clinic.[16] In the field, veterinarians examine herds instead of individual animals, have fewer handwashing opportunities, and need to wear personal protective equipment (PPE) outdoors, which can be perceived as an inconvenience, such as by causing discomfort in hot weather.[10,12]

Though veterinarians are often exposed to zoonotic diseases, zoonotic diseases are not always the primary cause of clinical illness in animals. Sick animals often present with nonspecific clinical signs that might be explained by various etiologies, including infectious and noninfectious diseases. For instance, livestock abortions occur from ingestion of toxic plants, dietary insufficiencies, genetics, heat stress, nonzoonotic infectious diseases (eg, bovine viral diarrhea, bluetongue, fungal placentitis, and trichomoniasis), and zoonotic diseases (eg, brucellosis, *Coxiella burnetii*, salmonellosis, leptospirosis, and campylobacteriosis; Supplementary Appendix S1).[17-22] With such a variety of differential diagnoses, veterinarians might not always suspect a zoonotic disease or take proper personal protective precautions.

Human brucellosis is a relatively uncommon bacterial infection in the US caused primarily by 4 species: *Brucella melitensis* from sheep and goats, *Brucella suis* from swine, *Brucella abortus* from cattle, and *Brucella canis* from dogs.[23] Transmission can occur via multiple routes including direct contact with the pathogen, aerosolization and subsequent inhalation, fomite transmission, or food- or water-borne spread. It is thought that human infections might be underdiagnosed because of nonspecific symptoms such as fever, malaise, anorexia, and myalgia and possible clinical disease manifesting in the bloodstream, spleen, liver, eyes, nervous system, heart, or musculoskeletal system.[23-25] Over 100 cases are reported in the US annually, with death occurring rarely.[25]

Coxiella burnetii infection, referred to as Q fever, is asymptomatic in about half of human infections.[26] Symptomatic humans most commonly have mild flu-like illness characterized by fever, myalgia, lethargy, cough, diarrhea, vomiting, or abdominal pain.[26,27] Severe manifestations of disease include, but are not limited to, pneumonia, acute hepatitis, and chronic endocarditis, and disease in pregnant women might result in miscarriage, stillbirth, or premature birth.[27] Humans are most often infected through contact with parturient animals, but the pathogen is easily spread via numerous routes of transmission including aerosolization, which allows it to be carried by the wind and might cause outbreaks in people with no animal contact.[27,28]

Salmonella is a common bacterium that can be harbored subclinically in the gastrointestinal tract of ruminants, poultry, and swine. Most human infections result from ingestion of the bacteria through contaminated food products or contact with animals and their environment. Mild illness can result in self-limiting diarrhea (sometimes bloody), abdominal pain, and fever. Severe infections can spread through the blood and result in meningitis or fatal septicemia.[29,30] Any *Salmonella* serovar capable of causing septicemia in large animals can catalyze an abortive event, but the risk of transmission to humans cannot always be predicted.[30] For example, *Salmonella enterica* serovar Abortusovis, an important cause of abortion in ewes, is considered nonpathogenic for humans, while *S enterica* serovar Dublin is the most common cause of abortion in cattle and has caused outbreaks in humans.[30,31]

Like *Salmonella, Campylobacter* spp cause human illness most commonly via food- and water-borne routes of transmission.[32,33] Contact with animals and their environment can also result in transmission of the bacteria.[34] Several species of *Campylobacter* can cause human infection; *Campylobacter jejuni, Campylobacter fetus* subsp *fetus*, and *C fetus* subsp *veneralis* are most likely to lead to reproductive disease in sheep and cattle.[34] Human disease manifests with diarrhea, vomiting, fever, abdominal pain, myalgia, and headache.[32-34] Estimates predict that up to 1.5 million people are affected in the US each year, with many cases remaining undiagnosed when symptoms are mild.[32]

Leptospira spp, a spirochete bacterium found ubiquitously in the environment and in numerous wild animal reservoirs, can cause a variety of diseases and symptoms in humans and animals.[35] Direct contact with this infectious agent (shed readily in the urine) or contaminated fomites are the most common routes of transmission, but food- and water-borne transmission has also been recognized.[35,36] The common progression of illness in humans begins with an initial phase characterized by acute fever, muscle ache, headache, diarrhea, and vomiting. Although some patients recover at this stage, others have symptoms resolve briefly only to relapse and potentially progress to liver or kidney failure, pneumonia, or meningitis.[35,36]

To understand the circumstances and challenges large animal veterinarians experience when working up an abortion event in livestock, we administered a knowledge, attitudes, and practices survey to a convenience sample of large animal veterinarians in the US. The objectives of this survey were to understand large animal veterinarians’ knowledge of select zoonotic diseases that cause livestock abortions and to identify barriers to using PPE.

Materials and Methods

Survey

We developed our survey using an electronic data capture tool utilized by the CDC and used the public survey function link for data collection (Supplementary Appendix S2).[37,38] We used a convenience sample design. We sent a survey invitation with the electronic link to large animal veterinarians through various veterinary organizations including species-specific specialty organizations, state public health veterinarians, and state agriculture departments. We also advertised the survey through the *JAVMA* and the 2019 AVMA Annual Convention. A snowball sampling technique developed, with some veterinarians advertising the survey through social media and membership in other veterinary associations not initially involved in survey distribution. Only veterinarians currently in practice with livestock were eligible to participate. The survey remained open from June 10, 2019, through October 31, 2019. Responses collected were anonymous and contained no personally identifiable information.

This survey underwent human subjects review at the CDC and was determined not to be research involving human subjects; approval from an institutional review board was not required. In accordance with the Paperwork Reduction Act, the Office of Management and Budget approved the new information collection "Knowledge, Attitudes, and Practices of US Large Animal Veterinarians Concerning Common Veterinary Infection Control Measures When Working with Animal Obstetric Cases" (Office of Management and Budget Control No. 0920-1251).

Respondents answered questions addressing knowledge and prior experience with select abortion-associated zoonotic infectious diseases, resources available for infection control practices, attitudes and barriers to PPE use, and demographics. We asked veterinarians to identify the transmission pathways of 5 zoonotic diseases associated with livestock abortions: brucellosis, Q fever, salmonellosis, leptospirosis, and campylobacteriosis. For each pathogen, respondents were instructed to select all possible routes of infection from a list including transmission by direct contact, contact with a contaminated fomite, inhalation via aerosol, ingestion of contaminated food or water, or transmission via unspecified vector. We also asked participants to indicate their awareness of the "Compendium of Veterinary Standard Precautions for Zoonotic Disease Prevention in Veterinary Personnel" (Compendium).[39] The Compendium provides guidance on personal protective actions and equipment during veterinary procedures. The recommendations in the Compendium are designed to prevent transmission of zoonotic pathogens from animal patients to veterinary personnel in private practice. The National Association of State Public Health Veterinarians developed the Compendium in 2008 and updated the document in 2015.[39,40]

Statistical analysis

We exported the survey data and conducted descriptive analysis using commercially available software (SAS statistical software version 9.4; SAS Institute Inc). Categorical variables were described as counts and proportions; continuous variables were described by use of medians and ranges. Confidence intervals were calculated by use of the Wilson (score) method. Answering each question was not mandatory; as such, denominators varied per question. Missing data were excluded from the analysis.

We consulted with CDC subject matter experts and reviewed available literature to identify all correct transmission pathways for each pathogen, and each respondent received a knowledge score out of 5 points possible for each pathogen based on selecting correct transmission routes and not selecting incorrect transmission routes. A Quasi-Poisson generalized linear model was used to test whether any demographic information collected in the survey was a useful predictor for the knowledge score of a given pathogen. Each pathogen knowledge score was analyzed separately. The following demographics were assessed for predictive value: age, sex, number of years practicing as a veterinarian, number of veterinarians at practice, number of hours per week working in practice, percentage of time in contact with livestock, classification of veterinary practice, practice type, and species primarily treated. For each pathogen, linear hypothesis tests were used to detect differences in pathogen knowledge score between categories of each possible predictor. Respondents were excluded from analysis if they indicated “not sure” instead of selecting transmission routes. Additionally, selecting “other” transmission for a pathogen and specifying (in writing) any other routes of transmission did not affect knowledge score and was not included in analysis. Statistical analyses were conducted by use of publicly available software (multcomp and Least-Squares Means; R Foundation for Statistical Computing).

Results

Demographics

Four hundred and sixty-nine (91%) of 518 veterinary survey respondents were currently practicing as livestock veterinarians and thus eligible to complete the survey. The median age of participating veterinarians was 49 years (range, 22 to 82 years), and just over half were men (235/438 [54%]). The median number of years post veterinary school was 21 years (range, < 1 to 57 years). Surveyed veterinarians practiced in all US geographic divisions (as defined by the US Census Divisions), with the largest number of veterinarians in West North Central (73/407 [18%]), West South Central (67/407 [16%]), and Mountain (62/407 [15%]) divisions followed by East North Central (57/407 [14%]), Pacific (47/407 [12%]), Middle Atlantic (39/407 [10%]), South Atlantic (37/407 [9%]), New England (16/407 [4%]), and East South Central (8/407 [2%]).[41] Most veterinarians worked ≥ 40 hours per week (304/406 [75%]) or 20 to 39 hours per week (65/406 [16%]) in large animal (181/409 [44%]) or mixed species practices (173/409 [42%]). The majority (211/411 [51%]) reported spending ≥ 75% of their workweek with livestock contact with 80 of 411 (19%) spending 50% of the time with livestock, 57 of 411 (14%) spending 25% of the time, and 63 of 411 (15%) spending < 25% of the time. Mixed mobile and clinic (223/402 [55%]) and mobile-only (130/402 [32%]) practices were the most common practice types reported. Surveyed veterinarians selected beef cattle (120/405 [30%]) and dairy cattle (109/405 [27%]) most frequently as the primary species they treated followed by equine (56/405 [14%]), companion animals (52/405 [13%]), small ruminants (37/405 [9%]), swine (24/405 [6%]), and other unspecified species (7/405 [2%]).

Examination or consultation on abortion cases

In the last 12 months, veterinarians reported that clients contacted them infrequently to consult on livestock abortions; 44% (153/348) described being asked 1 to 5 times a year, and 9% (32/348) did not consult on any abortion cases in the previous year. The most common reasons clients contacted the veterinarians were for 1 uncomplicated abortion (235/316 [74%]) or reproductive failure (223/316 [71%]). The percentage of abortions that veterinarians submitted for diagnostic testing was low, with 31% (107/347) of veterinarians submitting diagnostic specimens for only 1% to 5% of abortions and an almost equal number (104/347 [30%]) reported sending no diagnostics for abortion cases in the last year. The primary events that triggered a diagnostic workup were increased incidence of abortions over an extended period (160/243 [66%]) and an acute abortion storm (114/243 [47%]). Twenty-two percent (53/243) indicated that zoonotic concerns were a reason for diagnostic submission.

Disease transmission knowledge

Veterinarians were most knowledgeable about the transmission of enteric diseases, with 39% (140/356) correctly identifying all salmonellosis transmission routes and 25% (88/356) correctly identifying all campylobacteriosis pathways (Table 1). The mean knowledge score for salmonellosis was 3.5 ± 1.2, which was the highest of all pathogens. Surveyed veterinarians were less familiar with the transmission pathways for leptospirosis, brucellosis, and Q fever. Sixteen percent (58/357) correctly selected all the transmission pathways for leptospirosis. Ten percent (36/358) correctly identified all the transmission pathways associated with brucellosis. Finally, veterinarians were the least familiar with Q fever transmission, with 9% (32/356) of veterinarians correctly identifying all Q fever transmission pathways. The mean knowledge score for Q fever was the lowest at 2.2 ± 1.3. No veterinarians correctly identified transmission routes for all 5 pathogens.

Most demographic variables tested had no predictive value on knowledge scores for any pathogen. No differences were detected for any pathogen knowledge score based on age, number of years practicing as a veterinarian, number of veterinarians at practice, number of hours per week working in practice, classification of veterinary practice, and practice type. Some variables inconsistently predicted differences in knowledge score between compared groups across different pathogens (Supplementary Table S1). For example, the scores of women were 1.12 times (95% CI, 1.02 to 1.24) that of men on Q fever–related transmission questions, but no differences across sex were detected for the 4 other pathogens. Similarly, veterinarians that reported working 75% of the time with livestock scored higher than veterinarians that reported working 25% of the time with livestock for Q fever (1.36 times; 95% CI, 1.04 to 1.78), salmonellosis (1.19 times; 95% CI, 1.03 to 1.38), and leptospirosis (1.17 times; 95% CI, 1.01 to 1.36). Those working > 75% of the time with livestock scored higher than veterinarians working 25% of the time with livestock for brucellosis (1.23 times; 95% CI, 1.02 to 1.47), salmonellosis (1.15 times; 95% CI, 1.03 to 1.29), and leptospirosis (1.14 times; 95% CI, 1.02 to 1.29). However, there were no differences in knowledge score for any pathogen between veterinarians working ≥ 75% of the time with livestock and those working < 25% of the time with livestock. Veterinarians working primarily with horses scored 0.68 times (95% CI, 0.51 to 0.92) lower than veterinarians working primarily with small ruminants for Q fever-related transmission questions. No other differences in knowledge score were detected between veterinarians based on the primary species treated.

Occupational health risks

Respondents were asked to describe their perceived occupational risk of acquiring certain zoonotic diseases in their primary work environment. Veterinarians selected the risk category of “slight risk” most frequently for *B abortus* (169/322 [53%]), *B suis* (154/315 [49%]), Q fever (148/318 [47%]), leptospirosis (162/321 [50%]), and campylobacteriosis (170/320 [53%]). However, almost half of the surveyed veterinarians (154/322 [48%]) believed they had a “moderate risk” for contracting salmonellosis (Figure 1). Despite these perceived occupational risks, 23 of the 292 (8%) respondents reported ever being diagnosed with one of these diseases. Among the 23 veterinarians, 9 (39%) were diagnosed with campylobacteriosis, 6 (26%) with salmonellosis, 5 (22%) with brucellosis, and 3 (13%) with Q fever. Eighteen of the 23 (78%) veterinarians with self-reported illnesses had their disease confirmed with laboratory diagnostics.

Personal protective equipment practices and perceptions

We asked veterinarians about the PPE accessible at their veterinary clinic. Personal protective equipment was reportedly always available for 69% (199/288) of veterinarians. Over 90% of veterinarians reported access to gloves (289/290 [99%]), obstetric sleeves (285/290 [98%]), rubber boots (278/290 [96%]), and reusable protective clothing (eg, cloth coveralls; 271/290 [93%]). The availability of surgical masks (232/290 [80%]), disposable shoe covers (174/290 [60%]), goggles (152/290 [52%]), and disposable protective clothing (152/290 [52%]) was less common. Fewer veterinarians reported access to face shields (100/290 [34%]) or respirators (59/290 [20%]). Of 59 veterinarians with access to respirators, 15 (15/59 [25%]) reported wearing respirators. Of these, the majority reported following OSHA respirator requirements, which include being medically cleared by a physician (13/15 [87%]), fit-tested for a respirator model (12/15 [80%]), and trained on how to wear a respirator (13/15 [87%]).[42]

We asked veterinarians to indicate what PPE they would wear for various scenarios involving the examination of healthy animals and animals with a suspected zoonotic disease (Table 2). Gloves (mean usage: healthy = 71%; zoonotic = 87%), protective outerwear (mean usage: healthy = 81%; zoonotic= 88%), rubber boots (mean usage: healthy = 78%; zoonotic = 86%), and obstetric sleeves (mean usage: healthy = 57%; zoonotic = 69%) were the PPE used the most in scenarios. Respirators (mean usage: healthy = 1%; zoonotic = 5%), face shields or goggles (mean usage: healthy = 3%; zoonotic = 12%), and surgical masks (mean usage: healthy = 4%; zoonotic = 17%) were worn infrequently. Gloves were the PPE with the highest increase (16%) in use when an animal ill with a suspected zoonotic disease was examined compared to healthy animals. Respirators had the smallest increase in usage (4%) between scenarios. When examining healthy animals, veterinarians indicated they wore the most PPE when performing a necropsy or cesarean delivery (mean = 3.6 PPE items used). The activities with the highest PPE use when an animal suspected of a zoonotic disease was examined were performing a necropsy (mean = 4.1 PPE items used) or cesarean delivery (mean = 4.0 PPE items used), handling birth products (mean = 3.8 PPE items used), and assisting with parturition (mean = 3.8 PPE items used).

Veterinarians also indicated their perceived level of importance of various motivators for PPE use (Figure 2). The largest number of veterinarians marked “concern for spreading the disease to other animals” (136/289 [47%]) and “concern for spreading the disease to other humans” (108/287 [38%]) as “very important” motivators for PPE use. Concern for personal safety (128/289 [44%]) and concern for liability (107/289 [37%]) were considered “important” reasons to wear PPE by most participants. Overall, 39% (111/285) of veterinarians considered concern about pregnancy or ability to conceive as “not important” motivator for PPE use. However, when analyzed by sex, concern levels differed. Male respondents still considered human ability to conceive “not important” (82/157 [52%]), but female respondents were divided nearly equally among those who considered it “very important” (35/124 [28%]), “important” (29/134 [22%]), and “not important” (29/134 [22%]).

We also inquired about the level of concern veterinarians had toward a variety of potential barriers to PPE use (Figure 3). Most veterinarians indicated they were “not concerned” about the following reasons as barriers to personal PPE use: uncertainty of how to wear PPE (215/286 [75%]), others’ negative perceptions of personal use of PPE (169/283 [60%]), belief that PPE is unnecessary (160/283 [57%]), uncertainty of what PPE to select (152/287 [53%]), and cost of PPE (130/287 [45%]). However, veterinarians did indicate they were “moderately concerned” about the inconvenience of taking PPE into the field (101/286 [35%]) and the overall inconvenience of wearing PPE (97/286 [34%]).

Awareness of the Compendium of Veterinary Standard Precautions

We queried veterinarians on their level of awareness of the Compendium, and most indicated “not aware” (115/288 [40%]) or “slightly aware” (81/288 [28%]); less than 5% (14/288) reported being “extremely aware” of the document. Over half of veterinarians (43/81 [53%]) who had graduated less than 10 years earlier had no awareness of the Compendium, compared with 35% (72/205) of veterinarians with clinical experience ≥ 10 years .

Discussion

Overall, the veterinarians in our convenience sample were contacted infrequently by their clients concerning livestock abortion events. Among those abortion events for which the veterinarians were consulted, few examinations led to diagnostic sample submissions. Concern that a zoonotic disease was the etiologic agent of the abortion was not a common motivator for sample submissions. Some veterinary reference guides suggest not pursuing an etiologic diagnosis for every abortion because diagnostic success is low and the costs associated with laboratory diagnostics are high.[21,43] Various published reports from veterinary diagnostic laboratories further illustrate this challenge; the etiologic agent was determined in only 29.5% (138/468) to 44% (786/1,784) of livestock abortions submitted.[17,20,44,45] The incidence of zoonotic diseases as the cause of abortions is often unknown and varies widely based on region.[17,18,20] With few abortions triggering a veterinary consultation and diagnostic samples infrequently submitted, it might be challenging for veterinarians to have a complete awareness of the circulating pathogens in their area of practice and select PPE to use based on potential pathogen exposure.

Understanding the pathogens causing abortions in their practice area might enable veterinarians to refresh their knowledge on transmission pathways for those specific diseases and take necessary steps to prevent occupational infections. Knowledge and understanding of disease transmission pathways are critical to implement infection control and prevention practices effectively.[46] Overall, surveyed veterinarians had limited knowledge of transmission pathways for brucellosis, Q fever, salmonellosis, leptospirosis, and campylobacteriosis. In particular, there was low awareness of the aerosol and food-borne transmission pathways for brucellosis and Q fever (Table 1). This incomplete understanding might lead to inappropriate PPE selection or missed staff and client education opportunities. A challenge of PPE selection, particularly for respiratory tract protection, is that it requires the user to determine the likelihood of exposure to certain pathogens. For instance, the Compendium recommends gloves or obstetric sleeves, facial protection, and impermeable outerwear be used in obstetrics cases. It further states, "Respiratory tract protection should be used when investigating abortions attributable to *C burnetii* infection (Q fever) or when other airborne pathogens are known or suspected risks."[39] In our study, half (174/355 [50%]) of survey participants knew about *C burnetii* aerosol transmission. In practice, food- and water-borne transmissions are potentially less important regarding PPE selection for veterinarians' occupational health risks in comparison to other transmission routes. However, it is challenging to rank transmission pathways as higher or lower risk for veterinarians and conclude that one transmission pathway is more important for a veterinarian to know than another. For instance, most survey respondents were aware of direct contact transmission for each of the 5 pathogens, but far fewer identified fomite transmission as a correct route of exposure. Even when an individual is infected from an animal carrying a zoonotic disease, it is frequently difficult to determine if the pathogen was contacted directly in a bodily secretion or indirectly via a fomite. There is further uncertainty for pathogens that can be inhaled or transmitted by other routes. As such, appropriate PPE selection is predicated on a complete understanding of disease transmission, and veterinarians should strive to decrease risk of exposure through all routes.[47]

Demographic variables mostly did not predict veterinarians' knowledge (Supplementary Table S1). For some pathogens, difference in knowledge score was detected between respondents on the basis of the percentage of time working with livestock, but a consistent relationship between amount of time with livestock and knowledge score was not detected. For instance, although veterinarians that work ≥ 75% of the time with livestock demonstrated greater knowledge of specific pathogens compared to veterinarians working 25% of the time with livestock, no differences in knowledge were detected between any groups and those that reportedly worked the least (< 25% of the time) with livestock. Other potential indicators of experience with large animals (eg, respondent age, number of years practicing as a veterinarian, and primary species treated) were not predictive of score for any pathogen, overall supporting that the analyzed demographic and experiential characteristics were not useful for explaining knowledge of abortion-related zoonoses in the studied population.

The veterinarians' overall access to PPE was high but varied by item. Participant-reported access to disposable shoe covers, disposable protective clothing, face shields, and respirators was lower than reported access to gloves, obstetric sleeves, and reusable protective outerwear. When the PPE veterinarians wore was evaluated, it appeared that veterinarians primarily focused on protecting their body using items such as gloves and cloth coveralls. Facial protection, through use of surgical mask, respirator, face shield, or goggles, had much lower reported use. The availability of PPE did not translate to PPE use for certain items; only 25% (15/59) of veterinarians with access to respirators reported wearing them. For examination of both healthy and ill animals, the activities where veterinarians were most likely to use PPE were necropsy and cesarean delivery. Veterinarians were more likely to wear PPE when they examined ill animals, and gloves were the items of PPE that saw the largest increase in use when unhealthy animals were examined compared to healthy animals.

Veterinarians indicated very few barriers to PPE use. Inconvenience was a major reason PPE was not used. Few veterinarians indicated they felt uncomfortable selecting what PPE to wear or were unsure how to wear PPE correctly. The barriers that concerned veterinarians most were decreased personal safety while wearing PPE due to reduced visibility or mobility, the inconvenience of wearing PPE, and the inconvenience of taking PPE into the field. Veterinarians' greatest motivator for PPE use was to prevent disease spread to other animals or humans.

Few standardized guidance protocols exist for infection prevention and control in veterinary medicine.[9] The guidance documents that do exist typically focus on small animal hospitals or clinics.[46,48] The Compendium is one of the available resources for infection control and prevention practices that addresses topics such as farm visits and obstetrics cases.[39] Of note, the Compendium groups direct contact, food- and water-borne, and fomite transmission routes collectively as contact transmission, thus not specifying transmission routes to the level of detail as was examined in this study.[39] Regardless of years of practice, awareness of the Compendium was low. Increased educational training on infection prevention and control is needed both during veterinary school and through continuing education. Innovative ways to provide information delivery from the Compendium to veterinarians are needed to aid in awareness and potential implementation of infection prevention activities through PPE use.

Few (23/292 [8%]) veterinarians reported being diagnosed with any of the zoonotic diseases about which we inquired. A survey among Canadian veterinarians found 14 of 775 (2%) reported previous diagnosis of campylobacteriosis and 1 of 775 (< 1%) reported previous diagnosis of brucellosis; none reported being diagnosed with Q fever, salmonellosis, or leptospirosis.[2] Early seroprevalence studies conducted among US veterinarians detected *Brucella* spp antibodies in 12% (48/392)[49] to 20% (68/340)[50] of veterinarians, *C burnetii* in 11% (44/392),[49] and *Leptospira* antibodies in < 1% (2/1301).[51] These data reflect that veterinarians might have a relatively low risk of acquiring an abortion-related zoonotic infection, which could suggest that knowledge (or the lack thereof) of transmission routes does not necessarily present an increased risk of infection. Alternatively, veterinarians' current usage of PPE or other behaviors not examined in this survey such as handwashing might be adequate to prevent infections despite rates of exposure. Our survey is not able to account for any previous mild or asymptomatic human infections that went undiagnosed and similarly cannot capture the number of disease exposure events that occurred in the surveyed population. More comprehensive surveillance of these infectious diseases in animals and monitoring of veterinary occupational health are needed to appropriately characterize the risk veterinarians face given their understanding of each disease. This would also help contextualize veterinarians' risk perceptions measured in this study; for all pathogens except *Salmonella*, over half of respondents considered abortion-associated zoonoses as presenting "slight" or no risk. Better appreciation of the incidence of these diseases in animal populations might aid in understanding if these zoonotic diseases present low risk to veterinarians or if veterinarians should instead practice with a greater degree of caution and perceive the risk of exposure to each pathogen as greater.

Limitations of this study included the convenience sample design, the findings of which were not representative of all US large animal veterinarians. We limited survey participation to those currently treating livestock and thus did not obtain the perspective of retirees and those that have transitioned away from large animal practice. The recruitment method for this survey likely led to selection bias, as not all large animal veterinarians are involved with the groups that advertised this survey. The snowball recruitment strategy prevented calculation of a response rate. The method of quantifying veterinarians' knowledge based on questions about pathogen transmission might not accurately reflect their complete understanding of zoonotic disease prevention.

While veterinary consultations for abortive events were infrequent, these types of examinations pose unique occupational risks in the veterinary profession and pathogen transmission from these events can adversely impact the health and well-being of veterinarians, veterinary staff, and clients. Knowledge of transmission mechanisms of select abortion-associated zoonotic diseases was low across demographics, and refresher training on zoonotic diseases might aid in the selection of appropriate PPE in the future. Given the variety of animal species and practice environments in veterinary medicine, a one-size-fits-all approach to infection control and prevention will not work. Infection control and prevention protocols are needed that provide innovative ways for veterinarians to overcome obstacles to behavior change and use of PPE.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Baker WS, Gray GC. A review of published reports regarding zoonotic pathogen infection in veterinarians. J Am Vet Med Assoc. 2009;234(10):1271–1278. [PubMed: 19442021]
2. Epp T, Waldner C. Occupational health hazards in veterinary medicine: zoonoses and other biological hazards. Can Vet J. 2012;53(2):144–150. [PubMed: 22851775]
3. Fowler HN, Holzbauer SM, Smith KE, Scheftel JM. Survey of occupational hazards in Minnesota veterinary practices in 2012. J Am Vet Med Assoc. 2016;248(2):207–218. [PubMed: 26720089]
4. Moore RM Jr, Davis YM, Kaczmarek RG. An overview of occupational hazards among veterinarians, with particular reference to pregnant women. Am Ind Hyg Assoc J. 1993;54(3):113–120. [PubMed: 8447254]
5. Rood KA, Pate ML. Assessment of musculoskeletal injuries associated with palpation, infection control practices, and zoonotic disease risks among Utah clinical veterinarians. J Agromedicine. 2019;24(1):35–45. [PubMed: 30362924]
6. Volk JO, Schimmack U, Strand EB, Lord LK, Siren CW. Executive summary of the Merck Animal Health Veterinary Wellbeing Study. J Am Vet Med Assoc. 2018;252(10):1231–1238. [PubMed: 29701527]
7. Hankenson FC, Johnston NA, Weigler BJ, Di Giacomo RF. Zoonoses of occupational health importance in contemporary laboratory animal research. Comp Med. 2003;53(6):579–601. [PubMed: 14727806]
8. Jackson J, Villarroel A. A survey of the risk of zoonoses for veterinarians. Zoonoses Public Health. 2012;59(3):193–201. [PubMed: 21884033]
9. Mendez DH, Kelly J, Buttner P, Nowak M, Speare R. Management of the slowly emerging zoonosis, Hendra virus, by private veterinarians in Queensland, Australia: a qualitative study. BMC Vet Res. 2014;10:215. [PubMed: 25224910]
10. Wright JG, Jung S, Holman RC, Marano NN, McQuiston JH. Infection control practices and zoonotic disease risks among veterinarians in the United States. J Am Vet Med Assoc. 2008;232(12): 1863–1872. [PubMed: 18598158]
11. Bonini S, Buonacucina A, Selis L, et al. Occupational hazards in veterinarians: an updating. J Vet Sci Tech. 2015;7(3):1000317. doi:10.4172/2157-7579.1000317
12. Poole AG, Shane SM, Kearney MT, McConnell DA. Survey of occupational hazards in large animal practices. J Am Vet Med Assoc. 1999;215(10):1433–1435. [PubMed: 10579036]
13. Proch V, Singh BB, Schemann K, Gill JPS, Ward MR Dhand NK. Risk factors for occupational Brucella infection in veterinary personnel in India. Transbound Emerg Dis. 2018;65(3):791–798. [PubMed: 29363286]
14. Siponen AM, Kinnunen PM, Koort J, et al. Toxoplasma gondii seroprevalence in veterinarians in Finland: older age, living in the countryside, tasting beef during cooking and not doing small animal practice associated with sero-positivity. Zoonoses Public Health. 2019;66(2):207–215. [PubMed: 30536784]
15. Vayr F, Martin-Blondel G, Savall F, Soulat JM, Deffontaines G, Herin F. Occupational exposure to human *Mycobacterium bovis* infection: a systematic review. PLoS Negl Trop Dis. 2018;12(1):e0006208. doi:10.1371/journal.pntd.0006208 [PubMed: 29337996]
16. Hierarchy of controls. CDC National Institute for Occupational Safety and Health. Accessed August 30, 2021. https://www.cdc.gov/niosh/topics/hierarchy/default.html
17. Anderson ML, Blanchard PC, Barr BC, Hoffman RL. A survey of causes of bovine abortion occurring in the San Joaquin Valley, California. J Vet Diagn Invest. 1990;2(4):283–287. [PubMed: 2095280]
18. Clothier K, Anderson M. Evaluation of bovine abortion cases and tissue suitability for identification of infectious agents in California diagnostic laboratory cases from 2007 to 2012. Theriogenology. 2016;85(5):933–938. [PubMed: 26679514]
19. Dubey JP, Kirkbride CA. Toxoplasmosis and other causes of abortions in sheep from north central United States. J Am Vet Med Assoc. 1990;196(2):287–290. [PubMed: 2298653]
20. Kirkbride CA. Etiologic agents detected in a 10-year study of bovine abortions and stillbirths. J Vet Diagn Invest. 1992;4(2):175–180. [PubMed: 1616982]

21. Tibary A Abortion in large animals In: The Merck Veterinary Manual. 11th ed. Merck & Co Inc; 2016.
22. Urie NJ, Highland MA, Knowles DR Branan MA, Herndon DR, Marshall KL. *Mycoplasma ovis* infection in domestic sheep (*Ovis aries*) in the United States: prevalence, distribution, associated risk factors, and associated outcomes. Prev Vet Med. 2019:171:104750. doi:10.1016/j.prevetmed.2019.104750 [PubMed: 31472359]
23. Sauret JM, Vilissova N. Human brucellosis. J Am Board Fam Pract. 2002;15(5):401–406. [PubMed: 12350062]
24. Boschiroli ML, Foulongne V, O'Callaghan D. Brucellosis: a worldwide zoonosis. Curr Opin Microbiol. 2001;4(1):58–64. [PubMed: 11173035]
25. Brucellosis. GDC. Accessed June 9, 2021. https://www.cdc.gov/brucellosis/index.html
26. Q fever. CDC. Accessed June 9, 2021. https://www.cdc.gov/qfever/index.html
27. Spickler A Q fever. The Center for Food Security and Public Health. Accessed June 9, 2021. https://www.cfsph.iastate.edu/DiseaseInfo/factsheets.php
28. Roest HI, Tilburg JJ, van der Hoek W, et al. The Q fever epidemic in the Netherlands: history, onset, response and reflection. Epidemiol Infect. 2011;139(1):1–12. doi:10.1017/S0950268810002268 [PubMed: 20920383]
29. Salmonella. CDC. Accessed June 9, 2021. https://www.cdc.gov/salmonella/index.html
30. Spickler A, Leedom KL. Salmonellosis. The Center for Food Security and Public Health. Accessed June 9, 2021. https://www.cfsph.iastate.edu/Diseaselnfo/factsheets.php
31. Spickler A Salmonella abortusovis. The Center for Food Security and Public Health. Accessed June 9, 2021. https://www.cfsph.iastate.edu/DiseaseInfo/factsheets.php
32. Campylobacter (Campylobacteriosis). CDC. Accessed June 9, 2021. https://www.cdc.gov/campylobacter/index.html
33. Lee S, Lee J, Ha J, et al. Clinical relevance of infections with zoonotic and human oral species of Campylobacter. J Microbiol. 2016;54(7):459–467. [PubMed: 27350611]
34. Spickler A. Campylobacteriosis. The Center for Food Security and Public Health. Accessed June 9, 2021. https://www.cfsph.iastate.edu/DiseaseInfo/factsheets.php
35. Leptospirosis. CDC. Accessed June 9, 2021. https://www.cdc.gov/leptospirosis/index.html
36. Haake DA, Levett PN. Leptospirosis in humans. Curr Top Microbiol Immunol. 2015;387:65–97. [PubMed: 25388133]
37. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: building an international community of software platform partners. J Biomed Inform. 2019;95:103208. doi:10.1016/j.jbi.2019 [PubMed: 31078660]
38. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009;42(2):377–381. [PubMed: 18929686]
39. Williams CJ, Scheftel JM, Elchos BL, Hopkins SG, Levine JF. Compendium of veterinary standard precautions for zoonotic disease prevention in veterinary personnel: National Association of State Public Health Veterinarians: Veterinary Infection Control Committee 2015 (Erratum published in *J Am Vet Med Assoc*. 2016;248(2):171). J Am Vet Med Assoc. 2015;247(11):1252–1277. [PubMed: 26594810]
40. Elchos BL, Scheftel JM, Cherry B, et al. Compendium of veterinary standard precautions for zoonotic disease prevention in veterinary personnel. J Am Vet Med Assoc. 2008;233(3):415–432. [PubMed: 18673027]
41. Census Regions and Divisions of the United States, 2021. US Census Bureau. Accessed April 3, 2021. https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf
42. Hospital Respiratory Protection Program Toolkit. OSHA. Accessed July 9, 2021. https://www.osha.gov/sites/default/files/publications/OSHA3767.pdf
43. Mee JF. Investigation of bovine abortion and stillbirth/perinatal mortality - similar diagnostic challenges, different approaches. Ir Vet J. 2020:73:20. doi:10.1186/s13620-020-00172-0 [PubMed: 32944225]

44. Kirkbride CA. Diagnoses in 1,784 ovine abortions and stillbirths. J Vet Diagn Invest. 1993;5(3):398–402. [PubMed: 8373854]
45. Moeller RB Jr. Causes of caprine abortion: diagnostic assessment of 211 cases (1991-1998). J Vet Diagn Invest. 2001;13(3):265–270. [PubMed: 11482610]
46. Stull JW, Bjorvik E, Bub J, Dvorak G, Petersen C, Troyer HL. 2018 AAHA infection control, prevention, and biosecurity guidelines. J Am Anim Hosp Assoc. 2018;54(6):297–326. [PubMed: 30376377]
47. Dowd K, Taylor M, Toribio JA, Hooker C, Dhand NK. Zoonotic disease risk perceptions and infection control practices of Australian veterinarians: call for change in work culture. Prev Vet Med. 2013;111(1-2):17–24. [PubMed: 23664739]
48. Stull JW, Weese JS. Hospital-associated infections in small animal practice. Vet Clin North Am Small Anim Pract. 2015;45(2):217–233. [PubMed: 25559054]
49. Schnurrenberger PR, Masterson RA, Russell JH. Serologic surveys for selected zoonoses in Ohio veterinarians. J Am Vet Med Assoc. 1964;144:381–383. [PubMed: 14118024]
50. Schnurrenberger PR, Walker JF, Martin RJ. Brucella infections in Illinois veterinarians. J Am Vet Med Assoc. 1975;167(12):1084–1088. [PubMed: 1194115]
51. Schnurrenberger PR, Grigor JK, Walker JF, Martin RJ. The zoonosis-prone veterinarian. J Am Vet Med Assoc. 1978;173(4):373–376. [PubMed: 567636]

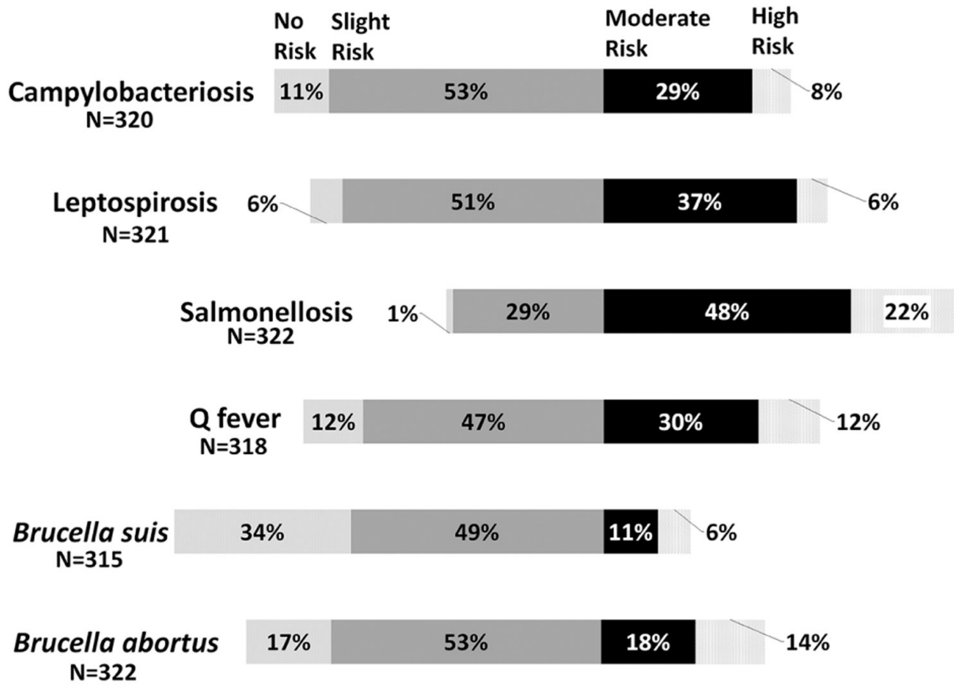

Figure 1—.

Perceived occupational risk of acquiring select zoonotic diseases in the primary work environment among large animal veterinarians administered a web-based survey on knowledge, attitudes, and practices regarding livestock abortion-associated zoonoses in the US from June 10, 2019, through October 31, 2019. Survey participants were asked to indicate their level of perceived risk of acquiring campylobacteriosis, leptospirosis, salmonellosis, Q fever, and brucellosis (*Brucella suis* and *Brucella abortus*) in their primary work environment. The number of respondents is denoted beneath each question. Gray represents "no risk," dark gray is "slight risk," black is "moderate risk," and light gray is "high risk." Salmonellosis was the zoonotic disease that veterinarians reported as the highest risk of acquiring.

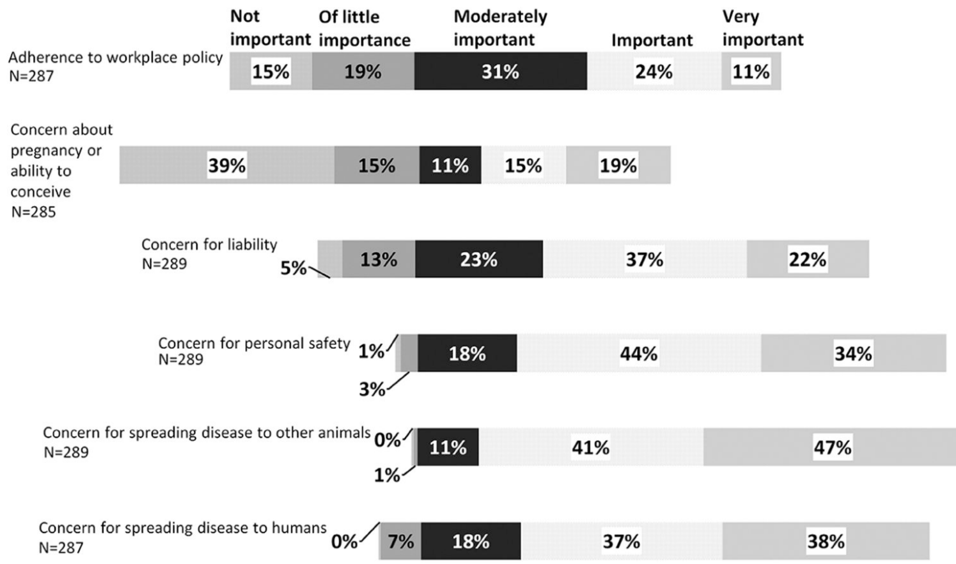

Figure 2—.

Level of perceived importance of motivators for using personal protective equipment (PPE) among respondents described in Figure 1. The number of respondents is denoted beneath each question. Gray represents “not important,” dark gray is “of little importance,” black is “moderately important,” light gray is “important,” and medium gray is “very important.” The largest number of veterinarians marked “concern for spreading the disease to other animals” and “concern for spreading the disease to other humans” as “very important” motivators for PPE use.

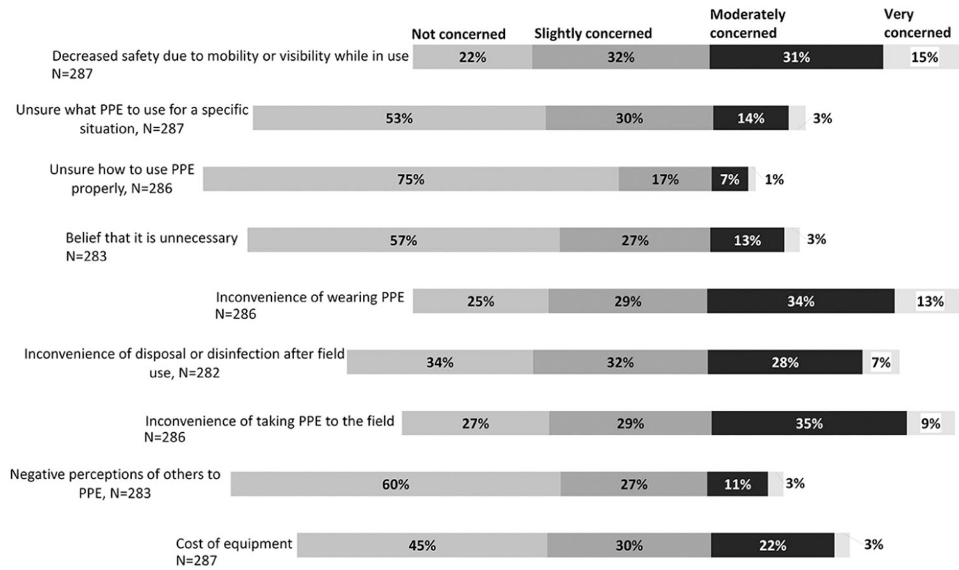

Figure 3—.

Level of perceived concern toward potential barriers to PPE among the respondents described in Figure 1. The number of respondents is denoted beneath each question. Gray represents "not concerned", dark gray is "slightly concerned", black is "moderately concerned", and light gray is "very concerned." Most potential barriers were not or were slightly concerning for surveyed veterinarians.

Table 1—

Zoonotic disease transmission mechanisms reported among large animal veterinarians administered a web-based survey of knowledge, attitudes, and practices regarding livestock abortion-associated zoonoses in the US from June 10, 2019, through October 31, 2019.

Zoonotic disease and survey answer options for routes of transmission	No. of respondents reporting	%	Mean ± SD score
Brucellosis†	358		2.4 ± 1.3
Direct contact	337	94	
Fomite	127	36	
Aerosol	106	30	
Food/water-borne	168	47	
Vector-borne	11	3	
Other	16	5	
Not sure	4	1	
Q fever	356		2.2 ± 1.3
Direct contact	247	69	
Fomite	107	30	
Aerosol	174	49	
Food/water-borne	105	30	
Vector-borne*	96	27	
Other	9	3	
Not sure	31	9	
Salmonellosis	356		3.5 ± 1.2
Direct contact	299	84	
Fomite	232	65	
Aerosol	64	18	
Food/water-borne	322	90	
Vector-borne	12	3	
Other	7	2	
Not sure	1	0.3	
Leptospirosis	357		3.2 ± 1.0
Direct contact	287	80	
Fomite	93	26	
Aerosol	63	18	
Food/water-borne	298	84	
Vector-borne	19	5	
Other	13	4	
Not sure	1	0.3	
Campylobacteriosis	356		3.2 ± 1.1
Direct contact	281	79	
Fomite	126	35	
Aerosol	46	13	

Zoonotic disease and survey answer options for routes of transmission	No. of respondents reporting	%	Mean ± SD score
Food/water-borne	252	70	
Vector-borne	10	3	
Other	11	3	
Not sure	23	7	

†Respondents could choose as many transmission pathways as they believed to be correct for a given pathogen, and the correct routes of transmission are underlined.

*Vector-borne transmission occurs for Q fever through transmission by tick bite and potentially other vectors. However, it is uncommon for ticks to transmit the pathogen between domesticated animals and humans, particularly in the US.[27] As such, this route was considered correct for all respondents regardless of answer when total scores were calculated and during statistical analysis.

Table 2—

Numbers (percentages) of respondents described in Table 1 who reported the use of various personal protective equipment (PPE) during routine veterinary examinations and examinations for a suspected zoonotic disease.

PPE used during the following routine veterinary examination scenarios	Gloves	Rubber boots	Obstetric sleeves	Coveralls	Surgical musk	Respirator	Goggles or face shield	Do not wear PPE	Mean number of PPE types used
Handling a neonate (n = 299)	198 (66)	224 (75)	35 (12)	223 (75)	1 (0.3)	1 (0.3)	3 (1)	25 (8)	2.5
Handling an adult animal (n = 299)	144 (48)	218 (73)	36 (12)	224 (75)	1 (0.3)	0 (0)	3 (1)	52 (17)	2.5
Conducting a rectal examination (n = 300)	154 (51)	230 (77)	284 (95)	239 (80)	0 (0)	0 (0)	4 (1)	0 (0)	3
Conducting a vaginal examination (n = 299)	168 (56)	225 (75)	266 (89)	240 (80)	0 (0)	0 (0)	4 (1)	2 (1)	3
Assisting with parturition (n = 298)	176 (59)	242 (81)	264 (89)	257 (86)	0 (0)	3 (1)	4 (1)	9 (3)	3.2
Performing a cesarean section (n = 294)	261 (89)	245 (83)	236 (80)	261 (89)	52 (18)	5 (2)	7 (2)	2 (1)	3.6
Handling an animal with hemorrhage (n = 299)	261 (87)	225 (75)	65 (22)	235 (79)	8 (3)	0 (0)	8 (3)	11 (4)	2.8
Handling birth products/aborted fetus (n = 302)	274 (91)	236 (78)	162 (54)	246 (82)	16 (5)	6 (2)	16 (5)	1 (0.3)	3.2
Performing a necropsy (n = 302)	286 (95)	251 (83)	195 (65)	268 (89)	39 (13)	7 (2)	37 (12)	1 (0.3)	3.6
PPE used during scenarios when conducting an examination for a suspected zoonotic disease									
Handling a neonate (n = 285)	262 (92)	246 (86)	95 (33)	251 (88)	46 (16)	10 (4)	28 (10)	6 (2)	3.4
Handling an adult animal (n = 285)	246 (86)	245 (86)	90 (32)	249 (87)	38 (13)	11 (4)	24 (8)	6 (2)	3.2
Conducting a rectal examination (n = 283)	211 (75)	242 (86)	266 (94)	248 (88)	26 (9)	8 (3)	27 (10)	0 (0)	3.6
Conducting a vaginal examination (n = 283)	215 (76)	243 (86)	260 (92)	250 (88)	33 (12)	11 (4)	28 (10)	0 (0)	3.7
Assisting with parturition (n = 289)	221 (77)	247 (86)	263 (91)	252 (87)	47 (16)	14 (5)	32 (11)	1 (0.3)	3.8
Performing a cesarean section (n = 278)	257 (92)	243 (87)	242 (87)	252 (91)	77 (28)	15 (5)	35 (13)	0 (0)	4
Handling an animal with hemorrhage (n = 282)	266 (94)	238 (84)	132 (47)	246 (87)	45 (16)	12 (4)	32 (11)	1 (0.4)	3.5
Handling birth products/aborted fetus (n = 282)	271 (96)	241 (86)	185 (66)	251 (89)	59 (21)	20 (7)	44 (16)	0 (0)	3.8
Performing a necropsy (n = 284)	273 (96)	250 (88)	221 (78)	253 (89)	73 (26)	20 (7)	63 (22)	0 (0)	4.1