

RISK OF ZOO NOTIC PATHOGEN EXPOSURE AMONG VETERINARY  
PROFESSIONALS AND STUDENTS AT VETERINARY SCHOOLS AND BEST  
PRACTICES TO MINIMIZE THIS RISK ON INDIVIDUAL AND INSTITUTIONAL  
LEVELS

by

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## **Abstract**

The College of Veterinary Medicine (CVM) environment is a place where veterinarians, veterinary staff, and veterinary students may have increased risk of exposure to zoonotic pathogens. This exposure may occur in classrooms or laboratories where pre-clinical veterinary students and non-clinical staff frequent. Exposure may also occur in the veterinary teaching hospital (VTH) and may impact veterinary patients, clinicians, interns, residents, veterinary technicians, veterinary students, animal caretakers, and others. This thesis is divided into 3 chapters. The first chapter describes a current review of the literature involving risk of zoonotic pathogen exposure at VTHs including descriptions of the most commonly documented zoonotic pathogens and their transmission, environmental sources of zoonotic pathogens at VTHs, and ways to prevent zoonotic pathogen exposure at individual and institutional levels. The second chapter describes an original research study of hand hygiene behavior among pre-clinical veterinary students at a CVM. The purpose of this study was to determine if a campaign could improve hand hygiene among veterinary students at extracurricular meetings serving meals. Campaign interventions included a 3.5 minute educational video and a novel motivational poster. The video was presented to all 1st, 2nd, and 3rd year veterinary students. Posters encouraging hand sanitization were displayed on doors and tables alongside sanitizers at each meeting. Observational hand hygiene data were collected immediately after introduction of interventions and again 3 months later. Environmental sampling for presence of bacteria in and around meeting locations was also performed. Observed hand hygiene was lowest during baseline (11.0% +/- 1.7), improved significantly post-intervention (48.8% +/- 3.2), and remained improved at 3-month follow-up (33.5% +/-4.0). Females had higher probability of hand-

sanitizing ( $35.9\% \pm 2.2$ ) than males ( $21.4\% \pm 2.4$ ) ( $p < 0.01$ ). *Clostridium perfringens* was isolated from 2/42 samples, and *Salmonella* spp. were isolated from 4/42 samples. This study documented that a short-term public health campaign targeting veterinary students successfully improved hand hygiene before meals. The final chapter discusses future areas of research in the realm of risk of zoonotic pathogen exposure and risk mitigation at CVMs.

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## List of Abbreviations

CVM – College of Veterinary Medicine  
EAEC – Enteroaggregative *E. coli*  
EHEC – Enterohemorrhagic *E. coli*  
EIEC – Enteroinvasive *E. coli*  
EPEC – Enteropathogenic *E. coli*  
ESBL – Extended Spectrum  $\beta$ -lactamase  
ETEC – Enterotoxigenic *E. coli*  
ExPEC – Extraintestinal pathogenic *E. coli*  
HAI – hospital-associated infection  
ICU – Intensive Care Unit  
IRB – Institutional Review Board  
KSU – Kansas State University  
KSU-CVM – Kansas State University College of Veterinary Medicine  
MDR – multi-drug resistant  
MRSA – Methicillin-resistant *Staphylococcus aureus*  
MRSP – Methicillin-resistant *Staphylococcus pseudintermedius*  
PBP – Penicillin binding protein  
PFGE – Pulsed-field gel electrophoresis  
SIG – *Staphylococcus intermedius* Group  
UTI – urinary tract infection  
VTH – Veterinary Teaching Hospital

# **Chapter 1 - A Review of the Risk of Zoonotic Pathogen Exposure among Veterinary Professionals and Students in Veterinary Teaching Hospitals**

## **Introduction**

An accepted risk in practicing veterinary medicine is that of exposure to zoonotic pathogens, which by definition can be transmitted from non-human animals to human beings.<sup>1</sup> The number of known zoonotic pathogens is quite large. A comprehensive literature review found that of 1415 known human pathogens, 868 (61%) are considered zoonotic.<sup>2</sup> The severity of disease caused by zoonotic pathogens can range from subclinical to fatal; therefore veterinarians should be cognizant of this occupational risk and take precautions to minimize exposure throughout their careers.

Veterinary teaching hospitals (VTHs) have several characteristics that may impact occupational risk from zoonotic pathogens. VTHs provide case management and care with a team approach including a student, intern/resident, faculty member, and several technicians, which increases the number of people with exposure from a single case as compared to most private veterinary practices. With complicated cases, a single patient may be evaluated by multiple services within the VTH (including internal medicine, surgery, ophthalmology, anesthesia, and radiology), thus potentially exposing students, clinicians, and technicians from those services as well. As students who are less experienced are often the first to examine patients in VTHs, education about recognizing and mitigating zoonotic risk exposure is important in the veterinary curriculum. Furthermore, as tertiary hospitals, patients treated at VTHs often require intensive care and prolonged hospitalization, which increases the opportunity for zoonotic transmission as compared with less ill patients. Although there are many potential

opportunities for zoonotic transmission, literature examining actual incidence and risk of zoonotic transmission within VTHs is lacking. The goals of this literature review are: 1) to review the most common zoonotic pathogens that have been documented to be spread in VTHs, 2) to investigate potential sources of zoonotic pathogens in VTHs, and 3) to examine ways to minimize risk of exposure to zoonotic infections in VTHs at both individual and institutional levels.

### **Documented Zoonotic Pathogens at Veterinary Teaching Hospitals**

VTHs are places where veterinary personnel may come in contact with several different zoonotic pathogens. Such pathogens may include *Leptospira* spp., Rabies virus, *Bartonella* spp., Influenza viruses, Methicillin-resistant *Staphylococcus aureus* (MRSA), Methicillin-resistant *Staphylococcus pseudintermedius* (MRSP), *Salmonella* spp., *Escherichia coli*, *Cryptosporidium parvum*, and many others. Although the zoonotic potential of many of these pathogens may be common knowledge, this review is limited to pathogens in which zoonotic transmission has been documented specifically in VTHs.

#### ***Cryptosporidium parvum***

*Cryptosporidium parvum* is an obligate intracellular parasite that can infect both humans and animals. The only stage capable of prolonged survival outside of the host is the infective oocyst stage.<sup>3</sup> There is a significant amount of epidemiological evidence supporting the association between contact with infected livestock, especially pre-weaned calves, and infection of *C. parvum* in humans.<sup>4-6</sup> Humans or other animals may become infected with *C. parvum* through ingestion of oocysts either by direct contact with an infected host or indirectly from contaminated water, food, or other environmental fomites.<sup>3</sup>

There have been several documented outbreaks of *C. parvum* among veterinary students at VTHs caused by contact with clinically infected pre-weaned calves.<sup>7-12</sup> One case report documented a confirmed case of cryptosporidiosis lasting 11 days in a 25 –year-old veterinary student after overseeing the supportive care of 2 infected calves.<sup>13</sup> The student began having symptoms 5 days after initial contact that included diarrhea, fever, abdominal pain, chills, and sweating; diagnosis was confirmed via fecal floatation.<sup>13</sup> Two separate outbreaks were caused by contact with infected calves used in required practical laboratories.<sup>8, 10</sup> In one report, *C. parvum* was found in 10 of 20 fecal samples (50%) submitted by students who had worked with the calves in a practical laboratory where students performed physical exams on the calves without knowing the calves had been diagnosed with *C. parvum* via fecal flotation.<sup>10</sup> In another report, identical *C. parvum* isolates were found in 4/7 student fecal samples following an outbreak of gastrointestinal illness in a veterinary class of 96 students after they attended a practical class performing physical exams on bovine patients.<sup>8</sup> Among these students, 25/80 respondents to a questionnaire met the case definition of *C. parvum*. An outbreak of diarrhea among 5 veterinary students one week after they had all cared for calves experimentally infected with *C. parvum* was reported to be cryptosporidiosis as confirmed by fecal flotation.<sup>11</sup> It is interesting to note that this outbreak occurred even after students had been informed of their risk of zoonotic pathogen exposure and the need for proper hand hygiene.<sup>11</sup> These reports emphasize the risk of transmission of *C. parvum* from infected livestock to students and personnel in VTHs, and reinforce the need for practicing proper hand hygiene when working with these animals.

### ***Methicillin-Resistant Staphylococcus aureus (MRSA)***

*Staphylococcus aureus*, members of the Staphylococcaceae family, are facultative anaerobic, Gram-positive, catalase-positive, cocci-shaped bacteria that are differentiated from

other staphylococci by gold colored colonies and positive reactions for coagulase, mannitol-fermentation, and deoxyribonuclease.<sup>14</sup> *Staphylococcus aureus* are important pathogens in both human and veterinary medicine, capable of causing a wide variety of clinical syndromes ranging from mild skin infections to deadly bacteremia and toxic-shock. Over 80% of *S. aureus* strains naturally produce penicillinases, enzymes that can inactivate beta-lactams and thereby reduce efficacy of several beta-lactam drugs. This led to extensive use of methicillin in the 1950s to treat penicillin-resistant *S. aureus* infections leading to the emergence of methicillin resistance among *S. aureus* which remains a serious health threat today.<sup>15</sup> MRSA are resistant to all beta-lactam antibiotics, commonly mediated by the *mecA* gene that encodes production of a modified penicillin binding protein (PBP), and many isolates are resistant to other classes of antibiotics as well.<sup>15</sup>

Humans are natural reservoirs for *S. aureus* in skin and mucous membranes; a recent United States general population survey found a prevalence rate for *S. aureus* colonization of 31.6% and a MRSA prevalence rate of 0.84%.<sup>16</sup> Veterinary personnel have been documented to have higher MRSA prevalence rates than the general population; a study of attendees of an annual American College of Veterinary Internal Medicine forum found increased prevalence of MRSA when compared to the general population in veterinarians (23/345, 7%) and veterinary technicians (4/34, 12%).<sup>17</sup> Although much less common than from humans, MRSA has been reported in many domestic animals including dairy cattle, sheep, pigs, chickens, horses, dogs, and cats.<sup>15</sup>

MRSA may be spread by direct contact, contact with infected fomites, or possibly airborne transmission.<sup>18</sup> Transmission of MRSA by direct contact between veterinary staff and animal patients (including horses<sup>19-23</sup> and dogs<sup>24, 25</sup>) in VTHs has been documented in several

studies. Of these studies, two included veterinary students as part of the population of personnel being tested.<sup>19,24</sup> Among the studies involving horses, 3 studies described possible horse to human transmission of MRSA<sup>19-21</sup> including one study that found identical isolates of MRSA in both a foal (from nasal swab at admission and as the causative agent of subsequent arthritis and omphalophlebitis) housed in the intensive care unit and 3 veterinary students (from skin lesions on their hands, and nose, and from a groin swab from one student) assigned to care for the foal.<sup>20</sup> The remaining 2 studies demonstrated a common MRSA strain in isolates from horses and humans but were less clear on how the infections occurred.<sup>22,23</sup> Among the studies involving dogs, one study statistically analyzed nasal swabs from veterinary personnel and veterinary students, VTH environmental samples, known MRSA isolates from clinically ill canine patients at the VTH, and results of a survey of VTH personnel that included questions about behaviors that may increase MRSA risk. The analysis found that contact with MRSA infected patients was an independent factor associated with MRSA carriage among veterinary personnel.<sup>24</sup> Another study in a VTH isolated MRSA from nasal and oral mucosa of veterinary staff (14/78, 17.9%), nasal and oral mucosa of canine patients (4/45, 9%), and from the VTH environment (3/30, 10%); MRSA isolates from these 3 groups were found to be identical (56%) or closely related (26%) through pulse-field gel electrophoresis (PFGE) analysis.<sup>25</sup> These studies show that MRSA may be present within VTHs and that veterinary personnel may be at risk for contacting MRSA, including through interaction with their animal patients.

Several studies have documented MRSA colonization in the VTH environment,<sup>18, 24, 26-28</sup> including documentation of MRSA being carried on stethoscopes,<sup>29</sup> cell phones<sup>30</sup> and clothing<sup>31</sup> of veterinary personnel in VTHs. One study of seven VTHs across the United States found MRSA in six of the seven hospitals, and found that of 65 patients found to be infected with *S.*

*aureus*, 14% of them were clinically ill with a MRSA infection.<sup>32</sup> A year-long active MRSA surveillance program at a VTH found that MRSA strains introduced by carrier dogs can be maintained and spread in the hospital environment for up to 9 months.<sup>26</sup> Increased length of hospital stay has been shown to be associated with increased risk of a dog acquiring MRSA<sup>33</sup> and an outbreak of MRSA among dogs in an intensive care unit of a VTH has been reported.<sup>34</sup> A year-long surveillance program from the equine center of a VTH showed maintenance strains of MRSA lasting for up to 2 months at a time in certain parts of the hospital.<sup>35</sup> A separate study has calculated nosocomial colonization of MRSA incidence of 23 per 1,000 admissions of horses in a VTH<sup>36</sup> and a case series of 4 horses from the same VTH hospital being infected with MRSA has also been reported.<sup>37</sup>

### ***Methicillin-Resistant Staphylococcus pseudintermedius (MRSP)***

*Staphylococcus pseudintermedius* are very similar to *Staphylococcus aureus* (members of the Staphylococcaceae family, are facultative anaerobic, Gram-positive, catalase-positive, cocci) but may be differentiated by lack of gold pigment of colonies, lack of clumping factor, weak, delayed mannitol fermentation, and positive reaction of pyrrolidiny arylamidase test.<sup>38</sup>

*Staphylococcus pseudintermedius* was first described in 2005<sup>39</sup> and since that time it has been shown that many isolates formerly classified as *Staphylococcus intermedius* based on phenotypic characteristics are actually one of a group (*Staphylococcus intermedius* group, SIG) consisting of *Staphylococcus intermedius*, *Staphylococcus pseudintermedius*, and *Staphylococcus delphini*.<sup>40</sup> This new grouping has revealed that *S. pseudintermedius* is the true species that predominantly colonizes and infects dogs and cats<sup>41-43</sup> and it has been recommended that traditionally identified SIG strains collected from dogs should be assumed to be *S. pseudintermedius* unless otherwise proven by further genomic testing.<sup>43</sup>



Similar to *S. aureus* in humans, *S. pseudintermedius* are considered opportunistic pathogens. *S. pseudintermedius* are commensal organisms that may be isolated from several body sites including the forehead, nares, mouth, pharynx, groin, and anus of healthy dogs and cats;<sup>44, 45</sup> however, *S. pseudintermedius* are also the leading cause of skin and post-operative infections in dogs and cats.<sup>46</sup> Methicillin resistance of *S. pseudintermedius* is mediated in much the same way as MRSA, through the *mecA* gene that encodes for a modified PBP.<sup>47</sup> The *mecA* gene is located on a mobile element of the bacterial chromosome called “staphylococcal chromosomal cassette” (SCCmec) that has been shown to be transferrable between staphylococcal species.<sup>48</sup>

*Staphylococcus pseudintermedius* colonization in humans appears to be uncommon, although in a study of 13 dogs with deep pyoderma the occurrence of *S. pseudintermedius* in the dogs’ owners was significantly higher than that of controls and 46% of owners carried *S. pseudintermedius* strains identical to those isolated from their dogs.<sup>49</sup> *S. pseudintermedius* are also common pathogens found in dog-bite wounds of humans.<sup>50</sup> Proper identification and reporting of staphylococci are important to guide appropriate treatment and management recommendations. One report discovered that methicillin-susceptible *S. pseudintermedius* isolates from 4 unrelated human cases were mis-identified as MRSA<sup>51</sup> and another report re-analyzed isolates from human dog-bite wounds to show that 3/14 previously classified *S. aureus* isolates were found to be *S. pseudintermedius*.<sup>52</sup> This evidence indicates that *S. pseudintermedius* may be a more frequent zoonotic pathogen than what previous work has shown.

A study at a VTH examining methicillin-resistant *Staphylococcus pseudintermedius* (MRSP) and MRSA isolated both pathogens from veterinary staff, veterinary students, hospitalized companion animals, and the hospital environment.<sup>24</sup> An analysis of MRSP strains

collected from veterinary staff, hospitalized dogs, and out-patient dogs in the same VTH found these strains shared three major clones.<sup>42</sup> An environmental surveillance study<sup>28</sup> found that MRSP was a frequent contaminant in veterinary hospitals in Ontario, and another study showed that the incidence of colonization with MRSP significantly increased in dogs after surgery and hospitalization at a VTH in Sweden.<sup>53</sup> These findings indicate that veterinarians, veterinary staff, and veterinary students may be exposed to and at risk for becoming infected with MRSP through direct contact with infected animals, animal bites, or contact with fomites in the VTH environment.

### ***Salmonella enterica subspecies enterica***

*Salmonella* are facultative anaerobic, non-lactose fermenting, Gram-negative rod-shaped bacteria that are pathogens of many vertebrates and significant zoonotic pathogens worldwide. *Salmonella enterica* subspecies *enterica* predominantly infect mammals and are commonly transmitted through contaminated food and water or through a fecal-oral route.<sup>54</sup> Although *Salmonella enterica* subspecies *enterica* have many different serovars, human infection is usually limited to only a few. In the CDC's 2011 National *Salmonella* Surveillance Annual Report the top 4 serotypes infecting humans in the United States were Enteritidis (17%), Typhimurium (13%), Newport (11%) and Javiana (6%) (<http://www.cdc.gov/nationalsurveillance/salmonella-surveillance.html>).

Contact with animals of several different species is a well-recognized risk factor for acquiring salmonellosis in humans.<sup>55</sup> *Salmonella* spp. commonly colonize the skin of reptiles, amphibians, and fish and may be shed in the feces of all mammals.<sup>56</sup> One study directly linked 2 of 8 temporal clusters of bovine *Salmonella* outbreaks to nosocomial transmission within a VTH.<sup>57</sup> Another 11-year retrospective cohort study of bovine salmonellosis in cattle admitted to

a VTH found the most common serovars in bovine fecal samples were Typhimurium (33%), Newport (23%), and Agona (12%).<sup>58</sup> One nosocomial outbreak in a large animal VTH demonstrated 8 animals infected with the same strain of *Salmonella* Newport that was also recovered in 15% of environmental samples collected at the hospital.<sup>59</sup>

There are many documented reports of *Salmonella* outbreaks among equine patients at VTHs.<sup>60-65</sup> One study documented an outbreak of *Salmonella* Oranienburg at a VTH which affected 20 horses, 5 alpacas, and 3 cattle and which spread through the hospital from an index case of a mare presenting for a chronic draining tract involving her right hind sole.<sup>61</sup> An outbreak of antimicrobial resistant *Salmonella* Anatum was documented at a private practice veterinary clinic that spread through infected foals referred to a VTH and was documented in environmental cultures from both locations.<sup>63</sup> Outbreaks of *Salmonella* Typhimurium<sup>64</sup> and Infantis<sup>65</sup> have also been documented in equine patients at VTHs. In the *Salmonella* Typhimurium outbreak,<sup>64</sup> one veterinary student was infected with *Salmonella* that shared identical antimicrobial resistance and had a similar PFGE pattern to the isolate from the point-source foal. These two similarities suggest the student isolate was related to the foal outbreak strain and was the result of zoonotic transmission.<sup>64</sup> Two outbreaks of multi-drug resistant *Salmonella* Typhimurium<sup>66</sup> and Newport<sup>62</sup> among horses were notable in their impact on their VTHs, causing extended closure and significant financial costs to the institutions.<sup>62, 66</sup>

Salmonellosis is not only a concern for the large animal departments of VTHs. Fecal shedding of *Salmonella* spp. has been documented in dogs<sup>67-71</sup> with documented dog to human transmission via fecal-oral route.<sup>70, 72</sup> Chronic carriage of *Salmonella* has also been documented in cats.<sup>73, 74</sup> Environmental culture sampling described in two separate studies conducted at separate VTHs found *Salmonella enterica* subspecies *enterica* throughout the hospitals,

including both large and small animal wards.<sup>75,76</sup> One study reported 4 separate outbreaks of multi-drug resistant *Salmonella* Typhimurium in 3 companion animal veterinary clinics and 1 animal shelter affecting a total of 18 people and 36 animals (including both dogs and cats).<sup>77</sup> This study did not identify VTHs being involved in the outbreaks; however, it demonstrates the severe impact and zoonotic potential of *Salmonella enterica* subspecies *enterica* in causing disease.

Although many of these studies did not report zoonotic spread of *Salmonella enterica* subspecies *enterica* from hospitalized animals to veterinary personnel in VTHs, it is important to consider that salmonellosis may be underreported among veterinary personnel due to the sometimes transient and non-specific symptoms associated with such infection. More research needs to be done to more fully assess the risk of zoonotic transmission of *Salmonella* in VTHs. However, given the documented nosocomial spread between animals, ability of *Salmonella enterica* to contaminate the hospital environment, and known zoonotic potential of *Salmonella enterica*, there is evidence of increased risk of salmonellosis to veterinary personnel and students in VTHs.

### ***Multi-drug resistant Escherichia coli***

*Escherichia coli* are facultative anaerobic, lactose fermenting, Gram negative rod-shaped bacteria included in the family Enterobacteriaceae. *E. coli* are considered an opportunistic pathogen as they are found as commensal organisms in the gastrointestinal tract of humans and animals but are also an important cause of urinary tract infections (UTIs), enteric infections, and systemic infections of both animals and humans.<sup>78</sup> There are several different “pathotypes” of *E. coli* based on unique sets of virulence factors; enteropathogenic *E. coli* (EPEC), enterohemorrhagic *E. coli* (EHEC), enterotoxigenic *E. coli* (ETEC), enteroaggregative *E. coli*

(EAEC), enteroinvasive *E. coli* (EIEC), and some forms of extraintestinal pathogenic *E. coli* (ExPEC) are known to cause disease in humans and animals.<sup>78, 79</sup> Animals with or without clinical signs of enteric disease may harbor pathogenic *E. coli* and shed it in their feces so that humans may become infected through direct routes such as fecal-oral, or touching an animal whose fur, hair, skin, or saliva may contain fecal organisms, or through indirect routes such as contact with infected fomites including clothes, shoes, floors, animal bedding, or other environmental surfaces.<sup>80</sup> Sharing of *E. coli* between animals and people in close contact has been documented in a longitudinal study within one family's household where a single strain of *E. coli* was found to be the cause of a UTI in both a woman and a dog.<sup>81</sup> Another study found prevalence of *E. coli* sharing between dog owners and their pets to be 9.8% from a sample population of 61 healthy dog-owner pairs.<sup>82</sup> These studies highlight the importance of certain pathotypes of *E. coli* as potential zoonotic pathogens.

In a VTH in Australia, 2 separate clones of MDR *E. coli* were identified and both clones were found in rectal swab cultures from hospitalized dogs (129/409, 16.5%). One clone was also cultured in human rectal swabs from apparently healthy veterinary staff (2/16, 12.5%), and the other clone was also cultured in the hospital environment (43/220, 19.5%) (swabs were taken from various areas including bedding, drains, cages, and respirators from the VTH intensive care unit (ICU) and floor drains and air vents from a small dog ward).<sup>83</sup> This study is an important example of the risk of sharing of MDR *E. coli* between veterinarians and hospitalized patients in VTHs. Several studies have linked risk of carriage of MDR *E. coli* with length of hospitalization of horses<sup>84, 85</sup> and small animals.<sup>33, 86-88</sup> One study demonstrated that odds of culturing MDR *E. coli* from rectal swabs of dogs in an intensive-care-unit (ICU) increased 1.5 times for every day spent in ICU.<sup>87</sup> MDR *E. coli* have been documented in environmental culture samples of several

VTHs.<sup>28, 83, 88</sup> Two separate environmental studies<sup>83, 88</sup> have each documented separate occasions in different VTHs where the strain of MDR *E. coli* cultured from dog feces was the same strain of MDR *E. coli* cultured from hospital environment samples collected at the same time. Substantial risk of exposure to MDR *E. coli* has been established in the VTH environment so veterinary staff and students should take proper precautions especially when caring for sick animals with enteric clinical signs.

## **Environmental Sources of Zoonotic Pathogens in Veterinary Teaching Hospitals**

Although considerable research has been performed in human medicine concerning hospital-associated infections (HAIs), also known as nosocomial infections, comparable research in veterinary medicine is somewhat lacking.<sup>89</sup> However, by analyzing examples in human medical literature alongside studies in veterinary medicine, a better idea of the role that the veterinary hospital environment plays in HAIs and veterinarians' risk of zoonotic pathogens may begin to develop.

Studies of environmental contamination of zoonotic pathogens in VTHs have found MRSA,<sup>24, 26-28, 35, 90</sup> MRSP,<sup>24, 28</sup> *Salmonella enterica* subsp. *enterica*,<sup>59, 60, 63, 64, 66, 76, 91, 92</sup> MDR *E. coli*,<sup>28, 83, 88</sup> and many others. The exact sources of these pathogens in the hospital environment may be hard to pinpoint as many of these studies collected random sampling and reported samples based on location (ex. small animal ward, stalls, waiting room, etc.) rather than specific contact surfaces. However, one study in a VTH reported MRSA found in wedges used in radiology and a door handle<sup>90</sup> and another reported MRSA most commonly isolated from high frequency contact surfaces for veterinarians (door handles) and hospitalized patients (carts).<sup>27</sup> One study found computer keyboards in a VTH were a source for consistently culturing *S.*

*aureus* and *S. pseudintermedius* colonies throughout the 10-week study period;<sup>93</sup> testing of colonies for antimicrobial resistance was not performed in this study. Studies of environmental *Salmonella* contamination in the equine wing of VTHs have shown floor drains to be the most common area where *Salmonella* was cultured.<sup>60, 64, 92</sup> Further research into specific high-risk areas for bacterial contamination should be done, and may need to be individualized for each VTH, along with examination of which infection control practices are best at targeting certain areas.

Another component of HAIs is potential fomite carriage by veterinarians and other veterinary staff. A study of bacterial contamination on veterinary stethoscopes found 67% (20 of 30 samples) were culture positive for bacteria including commensals, opportunistic pathogens, and potential pathogens.<sup>29</sup> Studies at VTHs have isolated MRSA and MRSP from veterinarians' cell phones<sup>30</sup> and from clinical white coats and surgical scrubs of veterinary personnel, including veterinary students.<sup>31</sup> One study including 10 small animal veterinary hospitals found antimicrobial resistant enterococci contamination on cage doors (7/10), stethoscopes (7/10), thermometers (6/10), and mouth gags (1/10).<sup>94</sup> Recent studies among human medical professionals' stethoscopes have found stethoscopes to be a source for MRSA and other pathogenic bacteria.<sup>95-97</sup> Other studies in human healthcare have identified white coats,<sup>98, 99</sup> neckties,<sup>100</sup> cellphones,<sup>101</sup> and handbags<sup>102</sup> as fomites to carry pathogenic bacteria, including MRSA.

Research investigating whether there is a causal link between environmental MRSA contamination and number of MRSA cases among patients and staff in VTHs should be conducted to better understand the clinical relevance of this environmental contamination. Further research examining the causal link of other environmental pathogens with zoonotic

potential and incidence of nosocomial infections would also be beneficial in better understanding the full role of environmental contamination in pathogen spread at VTHs.

### **Preventing Zoonotic Infections at Veterinary Teaching Hospitals**

With an evaluation of the risk of zoonotic pathogen exposure in VTHs it is important to also discuss preventative measures that may be enacted to reduce such risk in these institutions. The final section of this review includes an analysis of how veterinarians perceive the zoonotic risk in their work, an overview of ways individual veterinarians may reduce their risk of zoonotic pathogen exposure, and a summary of ways to reduce zoonotic pathogen exposure in VTHs from an institutional perspective.

#### ***Zoonotic Infection Risk Perception among Veterinarians***

How do veterinarians perceive their risk of zoonotic pathogen exposure in their day-to-day work? How does this perception influence what actions they take to minimize this risk? One survey of over 300 veterinarians in Australia reported that about half of respondents perceived their risk of zoonotic exposure to be likely in a variety of situations; however, their reported use of personal protective equipment (PPE) was less than adequate (based on minimal PPE use recommendations from the National Association of State Public Health Veterinarians in the United States and the Australian Veterinary Association Guidelines for Veterinary Personal Biosecurity) for most scenarios of daily practice.<sup>103</sup> The authors of this study called for a change in work culture, emphasizing the need to better educate veterinarians about zoonotic disease risk and proper infection control.<sup>103</sup> A survey of 2,133 small animal, large animal, and equine veterinarians across the United States showed similar results – the majority of veterinarians in all 3 practice types were concerned with zoonotic disease risk; however, the majority of veterinarians also failed to use proper PPE in such situations where they had increased risk.<sup>104</sup>



The authors are not aware of such studies among veterinarians at VTHs. It may be that veterinarians with specialized training may be more aware of their risk of zoonotic pathogen exposure and proper use of PPE<sup>103</sup> but more research in this area is needed to confirm or disprove this.

The results of these surveys appear to demonstrate disconnect between veterinarians' concern for zoonotic pathogen exposure and their actions taken to prevent such exposure; it seems many veterinarians can improve in taking steps to prevent zoonotic pathogen exposure in daily practice. There may also be other perception issues that need to be evaluated. For example, there is a tendency in veterinary medicine to be less concerned about blood-borne pathogens as compared to our counterparts in human medicine;<sup>89, 105-108</sup> however, in the age of emerging zoonotic diseases, it would benefit our profession to adopt more rigorous preventative measures now rather than after a zoonotic blood-borne disease outbreak has occurred.<sup>89, 105</sup> Understanding veterinarians' perceptions about their risk for exposure to zoonotic pathogens and addressing the underlying reasons for these views is a key step to implementing practices to reduce that risk.

### ***Individual Zoonotic Infection Risk Mitigation***

What are the best ways individual veterinarians can minimize their risk of exposure to zoonotic pathogens? What does proper protection really look like in the daily bustle working in VTHs? One simple answer is consistent, thorough hand hygiene. Proper hand hygiene has been declared by The Compendium of Veterinary Standard Precautions for Zoonotic Disease Prevention in Veterinary Personnel to be the most important thing veterinarians can do to lessen their risk of zoonotic disease transmission.<sup>109</sup> Although proper hand hygiene is recognized across all fields of medicine as key to preventing disease transmission between medical personnel and their patients, hand hygiene compliance rates are reportedly low in both human

medicine<sup>110-122</sup> and veterinary medicine.<sup>123-126</sup> Individual veterinarians can significantly reduce their risk of becoming infected with zoonotic pathogens simply by making a habit of cleaning their hands before and after contact with animal patients. This is shown in a model used to investigate effects of individual transmission of bacteria in a VTH<sup>127</sup> which used the movement of canine patients across ten areas (transmission points) within a VTH to simulate contamination of these transmission points, veterinary staff, and patients across the hospital. This model also included the effects of decontamination of hospital environment, disinfection practices of veterinary staff, and use of antimicrobials on bacterial transmission across the hospital. Results of the model suggested that better compliance with hand hygiene by veterinary staff was one factor that significantly reduced patients' risk of colonization with resistant pathogens.<sup>127</sup> A pilot study compared reduction factors of 3 different hand hygiene protocols used by veterinary students after performing standard physical exams on horses; this study found that hygiene protocols using alcohol-based gel or chlorhexidine-alcohol lotion were as or more effective than hand washing with antibacterial soap in reducing bacterial loads after performing a physical exam.<sup>128</sup> Both of these studies highlight the importance of thorough hand hygiene in preventing pathogen transmission.

Another important way for veterinarians to minimize zoonotic pathogen exposure risk is proper use of PPE such as gloves, face masks, laboratory coats, aprons, coveralls, proper footwear, and head covers. Proper use includes knowledge of when to use PPE. The Compendium of Veterinary Standard Precautions for Zoonotic Disease Prevention in Veterinary Personnel outlines veterinary standard procedures designed to reduce risk of zoonotic pathogen exposure in veterinary personnel, with particular emphasis on PPE use.<sup>109</sup> This document is available to all veterinarians through the *Journal of the Veterinary Medical Association*.<sup>109</sup> In

addition, several reviews in the literature examine infection control and proper use of PPE in veterinary practice.<sup>107, 129-131</sup>

Although these resources are available, the majority of veterinarians do not use PPE in clinical situations where they may be at increased risk for exposure to zoonotic pathogens.<sup>103, 104</sup> One survey in Australia documented 60-70% of veterinarians in Australia did not use PPE for treating respiratory and neurological cases and 50% did not use PPE when seeing gastrointestinal cases where they may have increased exposure to zoonotic pathogens.<sup>103</sup> Another survey in the United States showed less than 25% of small animal veterinarians used appropriate PPE when examining a variety of illnesses in animal patients, 95.6% of large animal veterinarians failed to use proper PPE in performing necropsies, and 50% of equine veterinarians failed to use proper PPE when evaluating horses with diarrhea.<sup>104</sup> Veterinarians surveyed about reasons for not using PPE cited safety concerns and concerns about animal and client reaction to veterinarian wearing PPE; participants cited perceived risk to self as their top reason for wearing PPE.<sup>103</sup>

These surveys were conducted among mostly private practice veterinarians and so results may be different for veterinarians who work at VTHs. However, as many sources in this review show, outbreaks of zoonotic disease do occur in VTHs, so veterinarians at these institutions should also be reminded of the importance of hand hygiene and proper PPE. It is also important to note that all private practice veterinarians who failed to use PPE graduated from veterinary schools, most with VTHs. It is essential that veterinarians at these institutions emphasize the value of proper hand hygiene and use PPE in daily practice to their students, the future of veterinary medicine.

### ***Institutional Zoonotic Infection Risk Mitigation***

How can VTHs be run to reduce the risk of zoonotic pathogen exposure to veterinary personnel as much as possible? How can zoonotic outbreaks be prevented in VTHs? These are two questions that directors of human hospitals have been struggling with for years.

Unfortunately, there are no 100% pathogen-proof answers. For AVMA-accredited schools, there are expectations of certain standards regarding biosecurity and infection control that these schools must follow in order to maintain accreditation.<sup>132</sup> However, a 2008 survey of 38 such schools' VTHs found that 31 (82%) had reported outbreaks of nosocomial infections within 5 years prior to the interview and 19 (50%) reported significant health problems among veterinary faculty and staff attributable to zoonotic infections had occurred within 2 years prior to the interview.<sup>133</sup>

This same study found a wide variance in how surveillance for infectious diseases was conducted at VTHs, with many institutions reportedly engaged in "active" surveillance programs not having predetermined intervals (e.g., monthly) of surveillance activities.<sup>133</sup> Hospital administrators of VTHs should consider what their biosecurity goals for their hospital are and whether their current surveillance programs are meeting these goals. Active surveillance, defined as collecting clinical and microbiological data specifically for biocontainment purposes, has been noted as a necessary part of biosecurity programs that include goals of higher risk aversion.<sup>134</sup> Among human hospitals, a surveillance program including over 300 hospitals across the United States involves active data collection from high-risk individuals, such as those in intensive care units and surgical wards, so that costs may be minimized in using such an aggressive surveillance approach.<sup>135</sup> VTHs may consider enacting a similar program among VTHs at AVMA-accredited schools. VTHs may also consider improving their passive surveillance programs as a more cost-effective way to improve their infection control programs. For example,

a VTH should designate a single infection control officer or a committee who reviews all bacterial cultures with certain characteristics (for example, all MRSA, MRSP, multi-drug resistant *Salmonella*, *E. coli*, and enterococci, or any other unusual isolates) and keeps track of any prevalence trends of bacteria within the hospital. If the infection control officer or committee notes any trends of concern they may enact targeted active surveillance measures as needed. Studies among human hospitals have shown the financial benefits of implementing stringent infection control programs<sup>136-138</sup> suggesting that research in this area among VTHs may be beneficial.

The survey of biosecurity practices among VTHs also found that although only 16 (42%) of VTHs had required infection control training, presence of training was not significantly associated with whether nosocomial or zoonotic health problems had occurred at a VTH.<sup>133</sup> Although it was not the aim of this study to evaluate the effectiveness of biosecurity programs at VTHs, the authors did note that infection control training is generally perceived as an inconvenience to veterinary personnel so the value of these programs must be made apparent to participants.<sup>133</sup> This reflects the previously mentioned survey finding that veterinarians are more likely to use PPE if they perceive increased risk to themselves.<sup>103</sup> Hospital administrators of VTHs should critically evaluate their training programs to see if they not only educate personnel on infection control but also convey the importance of such protocols in a believable way. Further research should be done in this area to determine its effect on zoonotic and nosocomial disease rates.

To best answer the questions presented above, studies of pathogen movement in VTHs should be reviewed. One study created a model of transmission of antimicrobial resistant bacteria throughout a VTH by following the movements of canine patients across 10 different locations

(transmission points) in the hospital.<sup>127</sup> This model suggested that contact with veterinarians and veterinary staff, and canine movement to housing wards, diagnostic rooms, and ICUs were associated with highest risk of transmission.<sup>127</sup> This model may not be the same in other VTHs; however, it is a good example for other hospitals to follow. Combining further research in similar areas with current knowledge on zoonotic pathogens and their spread in VTHs is important in further minimizing zoonotic pathogen exposure risk at VTHs. Overall these findings show opportunities for hospital administrators to further improve their ability to prevent nosocomial infections and minimize risk of zoonotic pathogen exposure at their VTHs.

## **Conclusion**

Current literature provides evidence that veterinarians, veterinary staff, and veterinary students at VTHs are at risk for zoonotic pathogen exposure at these institutions. However, in review of the literature, it is apparent that more work needs to be done in this area. With relatively few studies in zoonotic disease transmission at VTHs and lack of consistent surveillance programs of zoonotic pathogens at VTHs it is likely that our current ideas of zoonotic disease risk at VTHs are underestimated. There is a critical need for more targeted research to assess true incidence and risk of zoonotic disease at VTHs. In our world of increasing antimicrobial resistance and emerging and re-emerging zoonotic pathogens, it is logical for the veterinary profession to make zoonotic exposure risk and prevention top priorities. Veterinary teaching hospitals are centers of knowledge gathering, innovation, and education of the future leaders of our profession. VTHs must raise the standard in zoonotic pathogen risk assessment and zoonotic disease prevention so that veterinarians may be better prepared to face the threat of zoonoses now and in the years to come.

## **Chapter 2 - Public Health Campaign to Promote Hand Hygiene before Meals in a College of Veterinary Medicine**

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### **Introduction**

Proper hand hygiene is a key element in reducing the risk of disease transmission, including the spread of zoonotic infections to veterinary professionals.<sup>109</sup> The concept of hand hygiene is not new in the field of medicine. The first clear documentation of a hand-hygiene campaign occurred in the 1840s when a physician, Ignaz Semmelweis, required his students to use a disinfectant after performing autopsies, which subsequently reduced mortality rates.<sup>139</sup> Although hand hygiene is recognized as an important element in all health care settings, hand-hygiene compliance remains poor among health care providers when attending to patients, as documented by studies in human<sup>121, 140, 141</sup> and veterinary<sup>125</sup> medicine. Reasons for poor hand hygiene among health care professionals include many environmental, behavioral, and cultural factors observed on individual, group, and institutional levels.<sup>142</sup> These factors include lack of appropriate hygiene supplies, lack of education, high work load, lack of encouragement or role models, lack of specific hand-hygiene guidelines, and lack of a culture or tradition of hand-hygiene compliance.<sup>142</sup>

Recent reports highlight the need for an enhanced emphasis regarding hand-hygiene education among human medical students,<sup>119, 139</sup> and recent studies have demonstrated evidence to support the effectiveness of educational campaigns among medical<sup>119, 139, 143</sup> and nursing<sup>140</sup> students. Veterinarians are at high risk for acquiring zoonotic diseases,<sup>144-146</sup> and veterinary students may encounter infectious zoonotic agents at veterinary teaching hospitals, such as

*Salmonella*, *Clostridium*, *Campylobacter*, methicillin-resistant *Staphylococcus aureus*, and *Cryptosporidium*.<sup>147</sup> As the veterinary curriculum involves hands-on learning through laboratories and encouragement to visit the clinical teaching hospital, even in pre-clinical years students have the potential to be exposed to zoonotic pathogens. Outbreaks of zoonotic disease have been reported among veterinary students,<sup>7, 8, 11, 148-150</sup> further emphasizing the importance of hand-hygiene education among veterinary students.

Research in human health care settings suggests that multiple, continuous interventions are better than single interventions in having a profound and long-term effect on hand-hygiene compliance.<sup>151</sup> Multifaceted educational campaigns that include educational seminars and written materials are considered most effective.<sup>141, 152, 153</sup> Success of a low-cost, multimodal educational campaign on hand hygiene has been reported in a veterinary teaching hospital;<sup>125</sup> however, to the authors' knowledge, no hand-hygiene campaigns have been studied among pre-clinical veterinary students.

At Kansas State University College of Veterinary Medicine (KSU-CVM), as at most colleges of veterinary medicine, there are numerous extracurricular organizations that host lunch or dinner meetings on a monthly basis where they invite guest lecturers or hold wet labs to practice hands-on procedures. It is very common for these organizations to provide buffet-style meals at these meetings. Alcohol-based hand sanitizer is sometimes provided by the meeting organizers, but rates of actual sanitizer usage are unknown, and most meeting rooms are held in lecture halls that do not have sinks for washing hands with soap and water.

The goals of this study were (1) to determine the baseline percentage of hand hygiene for attendees of extracurricular meetings where buffet-style food was served at KSU-CVM and hand sanitizer was provided by the researchers; (2) to implement a multifaceted educational campaign,



including an educational and motivational video presented to all pre-clinical students and a novel motivational poster displayed at extracurricular meetings; (3) to statistically compare the probability of engaging in hand-hygiene practices during the three study periods (baseline, post-intervention, and 3-month follow-up); and (4) to determine if zoonotic pathogens, including *Clostridium* and *Salmonella*, could be cultured from environmental samples collected at areas where extracurricular meetings were held.

## **Method**

### ***Sample***

This was an observational study of hand hygiene among veterinary students attending extracurricular meetings at KSU-CVM. A convenience sample of nine of the 25 recognized extracurricular student organizations at KSU-CVM were enrolled in this study. Membership of these organizations included students in all years of the veterinary curriculum, with the majority being in their pre-clinical years (first, second, and third years of veterinary training). Organizations were selected based on attendance at meetings, with organizations with larger attendance preferred, but no organizations were selected or excluded based on the organization's interests or meeting topics. It was recognized that some students were members of multiple organizations. Faculty advisors for each organization were informed of the study's objectives and consented for enrollment; however, students in each organization were not informed, so as to avoid bias of their hand-hygiene habits at baseline. This study was reviewed and approved by the KSU Institutional Review Board (IRB) for investigation with human subjects; the IRB waived the need for informed consent by the human subjects observed in this study due to observation of public behavior and anonymous data collection.

## *Procedure*

### *Data Collection Methods*

There were three periods of data collection: baseline, post-intervention, and follow-up. Data were collected from October of 2012 through May of 2013. Baseline observations of hand-hygiene opportunities were performed over 3 months from October through December 2012. Following an informative and motivational hand-hygiene video shown to all first-year through third-year veterinary students during one class period in January, post-intervention observations were performed over 3 months from January through March 2013. Post-intervention observations occurred when motivational hand-hygiene posters (see Figures 1 and 2) were presented at all meetings of enrolled organizations. Follow-up observations began in April 2013, approximately three months after the video was shown and one week after the final post-intervention observations. The follow-up period lasted from April until late May 2013. No motivational posters were available for viewing during the follow-up period.

All enrolled organizations held two meetings each that were observed during baseline data collection, except for one organization that held one observed meeting. During post-intervention, all enrolled organizations held two meetings each that were observed, and two organizations held one additional observed meeting each. During the follow-up period, most (five) organizations held one observed meeting each, three organizations held two observed meetings each, while one organization did not hold a meeting during the follow-up period. All scheduling of meetings was determined by student organization members and was outside of the control or influence of individuals involved in this study. Observers attended meetings where food was served that were held over the lunch hour (noon) or dinner hours (5:30 or 6:30 p.m.) Monday through Thursday during the regular school year. Two bottles of hand sanitizer were

provided by the research team for each observed meeting during all time periods. Prior to the arrival of meeting attendees, hand sanitizer was placed at the beginning of the food buffet table. A hand-hygiene opportunity was defined as any instance in which a student approached the buffet line and had the opportunity to use the hand sanitizer. Observations of each opportunity included use of hand sanitizer (yes/no) and gender (male/female). Observation logs also included the date of the meeting and the organization name. Observations for the study were performed by one of two trained individuals at each meeting to lessen potential bias and to address issues of time overlap of observed meetings.

### ***Educational Campaign and Intervention***

Following collection of baseline data, a low-cost, multimodal, cinematographic educational campaign was conducted from January to the end of March 2013. The campaign included a short video shown once before the post-intervention period (January 2013) and a novel motivational poster (see Figures 1 and 2) displayed at all meetings of organizations involved in the study throughout the 3-month post-intervention period.

The 3.5-minute video<sup>a</sup> was created by the authors and aimed at motivating veterinary students to clean their hands before eating meals held at student organization meetings. The video was shown to first-year, second-year, and third-year veterinary students at KSU during a regular class period. The video showed students from each pre-clinical year performing well-known activities associated with each year of the curriculum that could allow for exposure to zoonotic pathogens. The opening scene featured a clinician speaking about various zoonotic pathogens and emphasizing the risk to veterinary students and then showed a student in the crowd considering the relevance of these risks to her fellow veterinary students. In the next scene, first-year students are seen eating potato chips while they study bones in the anatomy lab

and pet a student's dog. Next, second-year students practice performing fecal flotations, and then one student is shown exiting the necropsy lab without using the provided hand sanitizer. After this, third-year students are shown with a dog as if they were performing a physical exam before junior surgery lab. Then the video shows the same third-year student, who had petted the dog and taken notes with gloved hands, remove the gloves to eat a snack and then pick up the same pen to make a note on her records. The final scene shows a student in line for food at a student organization meeting who tells the students, "Clean your hands. It's easy to do, so why not?"

Following the video presentation, a novel motivational poster was propped up next to the hand sanitizer at the beginning of buffet food lines in meetings (see Figure 2.1) and displayed on doors leading to all meetings for all enrolled organizations (see Figure 2.2). The poster included text asking "Where have your hands been today?" with pictures of veterinary students similar to those shown in the video and pictures of hand washing and using hand sanitizer with the caption "Clean your hands. It's easy to do, so why not?" After each meeting, the posters were removed. For the production of the educational intervention part of this study, IRB approval was obtained along with informed written consent from all individuals shown in the video and posters to use their images in the video, posters, and all publications related to this study.

### ***Environmental Sampling***

On the day of certain organization meetings selected by convenience, samples were obtained for aerobic and anaerobic bacterial culture and *Salmonella* enrichment from potential fomites in and near the rooms where observed meetings took place. A total of 42 environmental samples were collected. Samples were chosen from high-traffic sites, including doors leading into meeting areas, table surfaces where food was served, and bathrooms just outside of where meetings took place. Each sample was taken from a 10 cm x 10 cm area using a sterile swab

soaked in sterile water. An individual trained in environmental sampling performed all sampling for this study. Samples were immediately submitted and processed using standard microbiological technique<sup>154</sup> in the KSU Veterinary Diagnostic Laboratory. For aerobic growth, samples were plated onto 5% sheep blood in Tryptic Soy Agar Base, MacConkey agar, and Hektoen Enteric agar and incubated at 37 °C for 15–18 hours. For anaerobic growth, specifically *Clostridium*, samples were plated on Brucella blood agar with hemin and vitamin K, placed in an anaerobic jar, incubated at 37 °C for 3 days, and checked daily for growth. *Clostridium* isolates were further analyzed for specific toxins (alpha, beta, epsilon, iota, and enterotoxin) using multiplex PCR. After streaking the above plates, all swabs were placed into Rappaport-Vassiliadis broth and incubated overnight at 42 °C, then plated onto Hektoen Enteric agar and incubated at 37 °C to identify *Salmonella* growth. Identification was performed with standard biochemical testing and use of MALDI-TOF mass spectrometry.

### ***Analytical Strategy***

Recorded observation data were entered into a spreadsheet (Excel) and imported into statistical software<sup>b</sup> for analysis. Potential associations between the probability of hand sanitizing and gender, specific organization (nine organizations), and time relative to campaign intervention (baseline, post-intervention, and follow-up) were evaluated. Potential interactions among main factors of interest relative to the probability of hand sanitizing were also evaluated. Multiple individual meeting events were recorded, and the individual event (organization and date) was included as a random effect to account for repeated measures within that event. The final model was created and included effects and interactions that were significantly ( $p < .05$ ) associated with the probability of observing hand sanitization. The final model was a

multivariable mixed logistic regression model, including the three predictors of hand sanitizing (gender, organization, and time) as well as organization and meeting date.

## Results

Baseline data, post-intervention data, and follow-up data were collected from nine student organizations at KSU-CVM for a total of 678, 780, and 486 observations, respectively. Seventeen meetings were observed during baseline data collection, 20 meetings were observed during post-intervention, and 11 meetings were observed during follow-up. Table 2.1 includes additional demographic data, such as total observations per organization, number of meetings per organization, and gender distribution of observed participants for each organization.

No significant ( $p < .05$ ) interactions among primary covariates (time, gender, organization) were identified; therefore, only results from main effects are described. Gender was a significant ( $p < .01$ ) factor influencing the probability of hand sanitization, and females had a higher ( $\pm$  SE) probability of hand sanitization ( $35.9\% \pm 2.2$ ) compared to males ( $21.4\% \pm 2.4$ ). The timing between intervention and observation was associated ( $p < .01$ ) with the probability of observing hand sanitization (see Figure 2.3), with sanitizer use peaking immediately after the intervention and remaining above baseline during the follow-up period. The probability of observing hand sanitizing differed ( $p < .01$ ) by individual organizations (see Figure 2.4) with a wide range of values.

Environmental sampling identified bacterial growth in areas in and around rooms where meetings took place, with growth identified in 14/42 samples overall (see Table 2.2). *Clostridium perfringens* was cultured from 2/42 samples, both collected from tables where food was served; these samplings were collected during two different organization meetings and were not from the same meeting room. The alpha toxin gene was detected in both *Clostridium perfringens* isolates.

*Salmonella* spp. were cultured (from enrichment only) from 4/42 samples overall, originating from a door handle, stairwell handle, light switch, and pizza box; these samples were taken from various meeting locations during the study. Various *Staphylococcus* species were also isolated on five separate occasions from numerous surfaces, including a table where food was served that also grew *Clostridium*, a door handle leading into a meeting room, and a stairway handle leading to a meeting room. An alpha-hemolytic *Streptococcus* spp. was isolated from a handle used to lower a seat in a meeting room on one occasion. *Bacillus* spp. were isolated from three samples; speciation for further identification of these isolates and testing for presence of toxins was not performed.

## Discussion

This study documented that a short-term, multimodal campaign aimed at veterinary students in their pre-clinical years was effective in significantly improving hand hygiene before meals at extracurricular meetings. These findings are similar to other studies of hand-hygiene campaigns that also show short-term improvement in hand hygiene in human health care settings<sup>121, 125, 141, 151-153, 155, 156</sup> and in a hospital cafeteria.<sup>155</sup>

Females had a significantly higher probability of sanitizing their hands before eating when compared to males throughout the present study. Being male has been documented in other studies as a factor contributing to poor hand hygiene.<sup>156-158</sup> This might be because men have a stronger need to be convinced that their hands are dirty enough to need cleaning and that not cleaning poses a risk to them, while women are more likely to clean their hands out of habit. Little research has been done seeking why this gender difference exists, and further investigation is warranted. Based on the fact that there was no statistical interaction between time period and gender, it appears that the hand-hygiene campaign did not differentially influence the probability

of hand hygiene among males and females in this study. This is noteworthy because studies have shown that males and females respond differently to health messages—females are more motivated by knowledge-based messages while males respond better to messages that provoke emotions such as disgust.<sup>159</sup> Although females currently outnumber males in veterinary classes, there is no reason to believe that zoonotic disease transmission risk varies by gender, thus hand hygiene is equally important for both genders.

Due to lack of interaction seen between organization type and time period, it can be concluded that although overall hand hygiene improved throughout the study (baseline vs. post-intervention vs. follow-up), the relationship between evaluation timing and probability of hand sanitation was not influenced by specific organizations. In this particular study, there was likely crossover of attendees between organizations; that is, many students were likely members of multiple organizations. This means there may be a lack of independence among observations because the same student could have been observed at more than one meeting, something that should be taken into account when interpreting the results. This lack of independence of observations was unavoidable in this study because the people observed were not identified and therefore could not be tracked across organizations.

However, this study also brings to light the effect of group situations on hand-hygiene behavior. Although there may be students observed for more than one organization, as Figure 2.4 shows there is a significant difference in hand sanitizer use across the organizations in the study. A recent systematic review of hand-hygiene improvement strategies found that, although it has been less frequently studied, social influence is an important factor to address in hand-hygiene campaigns. This systematic review of 41 hand-hygiene studies found that when hand-hygiene interventions target determinants such as social influence and attitude, the effect is larger than



interventions targeting a combination of determinants that include knowledge (informing people that not cleaning their hands allows the spread of pathogens), awareness (making people more aware of the need to clean their hands), action control (using cues or reminders, like posters, to prompt people to clean their hands), and facilities (providing materials, like sanitizer, to make it easier for people to clean their hands).<sup>160</sup> Another recent review of the literature had similar findings, concluding that the most effective intervention strategy should target both social and cultural influences to hand-hygiene behavior.<sup>161</sup> In this particular study, it appears that social influence may have both positive and negative effects on hand hygiene. At one organization's meeting, a person may be more likely to use hand sanitizer, possibly because more people in that organization do, whereas at another organization the same person may be less likely to use hand sanitizer. This hypothesis is extrapolated from the wide variance of hand hygiene among different organizations that likely include many of the same members.

Environmental sampling identified bacterial growth with the potential to cause zoonotic disease. Organisms of particular zoonotic concern included *Clostridium* and *Salmonella*, which were identified from tables where food was served and a pizza box, respectively. *Staphylococcus* spp. were also isolated from various areas near where food was served; however, further speciation and antimicrobial susceptibility testing were not performed, so the significance of these organisms remains unknown.

Isolation of *Bacillus* spp. from three surfaces in this study is of unknown significance. Because *Bacillus* can be a benign component of normal skin flora and a common contaminant of bacterial cultures, its isolation may have little clinical relevance for the current study.<sup>162</sup> Ideally, these isolates would have been further identified to the species level and screened for toxins, as certain toxin-producing species of *Bacillus* can cause food-borne illness (such as *B. cereus*) and

others carry zoonotic potential (such as *B. anthracis*). A separate study found that *Bacillus* was the most common bacterial species contaminating unused disposable paper towels in commercial dispensers, suggesting that transmission could occur from clean paper towels to recently-washed hands<sup>163</sup>; this is an interesting finding since one *Bacillus* isolate from this study was from a surface in a bathroom in which paper towels were available.

Isolation of bacteria from sites in and around meeting locations emphasize the risk of coming in contact with zoonotic pathogens in public places and the importance of proper hand hygiene, especially before hand-to-mouth contact that can occur with eating. However, more studies examining specifically the number and types of bacteria present at veterinary student extracurricular meetings where food is served are needed to better quantify the disease risk to veterinary students in this environment.

This study involved observing the use of hand sanitizer by veterinary students immediately before eating food at extracurricular meetings. It is possible that true hand-hygiene rates may be higher than this study documents because some students may have washed their hands in the bathroom before entering the meeting room and eating. However, as documented in this study (see Table 2.2), the isolation of bacterial pathogens, including *Clostridium* and *Salmonella* spp. from areas within meeting rooms, including places where food was served, shows that it is possible for attendees' hands to become contaminated between washing their hands in the bathroom and before eating food in the meeting room. Furthermore, a recent study in a college-town environment found that only 5.3% of 3,749 people were observed to wash their hands with proper technique for 15 seconds or longer, as recommended by the CDC; if similar behavior is expected at our university, washing hands in the bathroom before meetings may not effectively clean hands.<sup>164</sup> It is for these reasons that hand sanitizer use directly before obtaining

food from the buffet table was encouraged and observed to determine hand-hygiene rates for this study.

There are several limitations to the present study. It was conducted using a sample of organizations at a single veterinary school. Hand-hygiene patterns may differ among other organizations within the school or across different veterinary schools. In this study there is high likelihood of the same individuals being recorded at several meetings for different organizations; however, the extent of this overlap is unknown because the identities of persons being observed were not recorded. There was also an uneven distribution of meetings per organization, which could allow one organization to be slightly overrepresented in the post-intervention results. Due to time limitations at the end of the school year, the follow-up data collection began just 1 week after data collection during the post-intervention period. This may cause follow-up hygiene rates to be higher than if there were a longer time gap between post-intervention and follow-up data collection. Because of the relatively short time frame of the study, long-term effects of this campaign remain unknown and are unable to be extrapolated from the given results. The video was only shown to first-year, second-year, and third-year classes; however, fourth-year students are invited to extracurricular meetings and, even though their attendance is thought to be low, their presence could influence the effectiveness of the intervention. Specifically, if fourth-year students have poor hygiene habits, their presence may dilute the observed effect of the campaign; alternatively, the fourth-year students could have improved hygiene habits because they are attending meetings right after direct contact with clinical patients, thus amplifying the observed effect of the campaign. Despite these limitations, the findings of this study are consistent with other studies among human medical students and nursing students that emphasize the need for

and effectiveness of hand-hygiene campaigns among these student populations, and they reflect the results of previous hand-hygiene studies in human and veterinary medicine.

The Compendium of Veterinary Standard Precautions for Zoonotic Disease Prevention in Veterinary Personnel states that “consistent, thorough hand hygiene is the single most important measure veterinary personnel can take to reduce the risk of disease transmission.”<sup>109</sup> Despite this statement, risk of zoonotic disease transmission appears to be an overlooked issue for many veterinarians, as documented in several studies.<sup>103, 104, 133, 145, 146</sup> A recent study<sup>103</sup> found that almost half of surveyed Australian veterinarians had contracted a zoonotic disease sometime during their careers and that although they perceived their risk of zoonotic disease to be high, the majority of veterinarians failed to properly protect themselves in situations with increased risk. Another study including veterinarians in the United States showed similar results.<sup>104</sup> It is clear from these studies that veterinarians should be more cognizant of zoonotic disease risk and be better trained in ways to mitigate their risk, including having proper hand hygiene, recognizing potential zoonotic disease in animals, properly handling infectious biological materials, and taking other biosecurity measures. This awareness and training should begin with veterinary students in their pre-clinical years and emphasize the importance of proper hand hygiene.

The effect of hand-hygiene campaigns in the veterinary community, especially among veterinary students, is an area of research that is still in its early stages. Results of this study emphasize the need to educate veterinary students about the importance of proper hand hygiene as a key component in addressing this issue and the need for further research in this area. This includes researching the most effective hand-hygiene campaign strategies for veterinary students, the long-term effects of hand-hygiene campaigns, and the factors that influence veterinary student hand-hygiene behavior at individual, group, and institutional levels.

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## Notes

- a The video can be accessed at <http://www.vet.kstate.edu/jwplayer/handhygienevideo.html>.
- b SAS. Version 9.2. Cary, NC: SAS Institute Inc.

## Figures

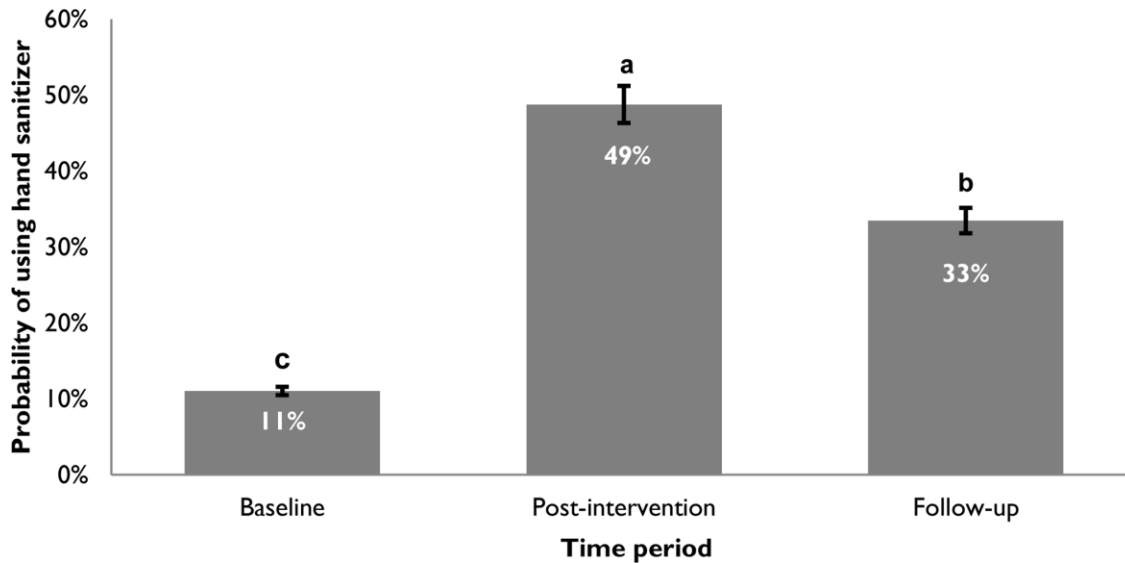
**Figure 2.1** Poster next to hand sanitizer displayed at veterinary student organization meetings during post-intervention observations.



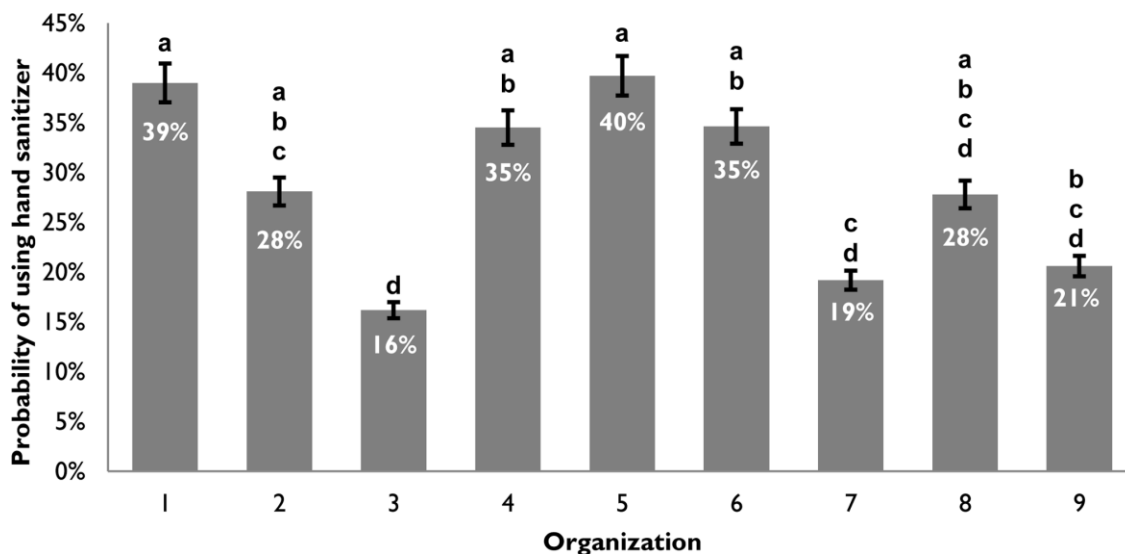
**Figure 2.2** Poster displayed on doors outside meetings of enrolled veterinary student organizations.



**Figure 2.3** The model-adjusted probability (+/- standard error) of using hand sanitizer differed statistically ( $p < .01$ ) during the three study periods of the educational hand-hygiene campaign. The statistical model included effects for gender, organization type, observation timing, and a unique number for each event identification. Columns with different letters (a, b, c) were statistically ( $p < .01$ ) different.



**Figure 2.4** The model-adjusted probability (+/- standard error) of using hand sanitizer differed statistically ( $p < .01$ ) by organization (labeled 1–9) across all three periods (baseline, post-intervention, and follow-up). The statistical model included effects for gender, organization type, observation timing, and a unique number for each event identification. Columns with different letters (a, b, c, d) were statistically ( $p < .05$ ) different.



## Tables

**Table 2.1 Total number of students observed over the study period per organization; total number of observed meetings; and mean number of female, male, and total attendees for each organization's meetings.**

<b>Organization</b>	<b>Total observations</b>	<b>Total number of observed meetings</b>	<b>Mean number of females observed per meeting</b>	<b>Mean number of males observed per meeting</b>	<b>Mean number of total students observed per meeting</b>
<b>1</b>	200	6	25.0	8.3	33.3
<b>2</b>	201	6	23.2	10.3	33.5
<b>3</b>	271	5	32.2	22.0	54.2
<b>4</b>	206	6	24.7	9.7	34.4
<b>5</b>	74	4	15.5	3.0	18.5
<b>6</b>	133	5	21.2	5.4	26.6
<b>7</b>	571	6	72.2	23.0	95.2
<b>8</b>	88	5	14.0	3.6	17.6
<b>9</b>	200	5	33.6	6.4	40.0



**Table 2.2 Results of environmental sampling for bacterial growth.**

<b>Location of samples</b>	<b>Number of samples positive for aerobic bacterial growth/total samples tested (organism/s)</b>	<b>Number of samples positive for anaerobic bacterial growth/total samples tested (organism/s)</b>	<b>Number of samples with growth on <i>Salmonella</i> enrichment/total samples tested</b>
<b>Inside meeting room</b>			
Door handle*	1/9 ( <i>Staphylococcus</i> sp.)	0/9	1/9
Chair handle*	1/2 ( <i>Streptococcus</i> sp.)	0/2	0/2
Pen for signing attendance sheet	0/1	0/1	0/1
Cabinet at front of room	0/1	0/1	0/1
Light switch*	1/3 ( <i>Bacillus</i> sp.)	0/3	1/3
Various computer surfaces*	1/6 ( <i>Bacillus</i> sp.)	0/6	0/6
<b>Food service</b>			
Table where food was served	1/2 ( <i>Staphylococcus</i> sp. non-hemolytic)	2/2 ( <i>Clostridium perfringens</i> , alpha toxin positive)	0/2
Food-cart handle	0/1	0/1	0/1
Microwave*	0/2	0/2	0/2
Pizza box	0/1	0/1	1/1
<b>Outside meeting room</b>			
Water fountain	0/1	0/1	0/1
Stairwell handle*	1/3 ( <i>Staphylococcus</i> sp. non-hemolytic)	0/3	1/3
Wall of student mailboxes near entrance to meeting	0/1	0/1	0/1
Elevator	0/1	0/1	0/1
Bathrooms near meeting room*	3/8 (2 <i>Staphylococcus</i> sp. non-hemolytic, 1 <i>Bacillus</i> sp.)	0/8	0/8
<b>Total pathogens grown</b>	<b>9/42</b>	<b>2/42</b>	<b>4/42</b>

## **Chapter 3 - Future Directions of Research in Risk of Zoonotic Pathogen Exposure and Preventative Measures at Colleges of Veterinary Medicine**

In concluding this discussion about risk of zoonotic pathogen exposure among veterinary personnel and students at VTHs and preventative measures that may be taken to reduce such risk throughout the CVM environment there are 3 future research areas that need to be explored.

The first area is research of environmental contamination of zoonotic pathogens in CVMs, including VTHs, and how their presence correlates to illness from zoonotic pathogens among veterinary staff and students in the CVM environment. Several studies examining environmental contamination in VTHs have been discussed; however, relatively few studies causally link environmental contamination of zoonotic pathogens with infection of humans or animals in CVMs. One example of how to further explore this topic is research of environmental MRSA and MRSP in VTHs that can be expanded to determine whether there is a link between the presence of such bacteria and cases of MRSA and MRSP among patients, staff, and students at VTHs. Another example would be examining whether *Salmonella* environmental contamination of VTHs and nosocomial spread among patients can be causally linked to salmonellosis among veterinary staff and students. A more firm establishment of the impact of environmental contamination with zoonotic pathogens in CVMs is a key step in better understanding risk and prevention of zoonotic pathogens at CVMs.

The second area is research in the area of prevention of zoonotic pathogen exposure by veterinary staff and veterinary students at CVMs. This includes investigations of why there seems to be discrepancy between veterinarians' concerns for zoonotic pathogen exposure and their actions taken to prevent such exposure. Research questions to be considered include what

factors influence whether veterinarians clean their hands properly between seeing patients and factors that influence when they use PPE. Research should also be done on the behavior aspect of hand hygiene, including why gender differences exist in hand hygiene habits and the effect of group situations on hand hygiene behavior. Another component in this area is researching better ways to educate veterinary students about their risk of zoonotic pathogen exposure, both in pre-clinical and clinical years of school, and best preventative measures, including good hand hygiene and proper PPE use, for mitigating such risk while in school and out in practice. Research is needed to define what factors most influence a veterinary student's decision to clean their hands and how these influences can be used to create hand hygiene campaigns with long-term benefits in improving hand hygiene habits. Drawing from the many studies described here, it seems that veterinary students are an ideal target group for better understanding how to educate the veterinary community in the areas of hand hygiene, PPE use, and other preventative measures for minimizing zoonotic pathogen exposure.

The third area is research in the area of infection and surveillance programs at CVMs, particularly at VTHs. It can be concluded from studies described here that zoonotic transmission of pathogens does occur in VTHs so there are opportunities for improvement in infection control at these institutions. A more detailed assessment of current infection control and surveillance measures taken at CVMs and the unique biosecurity challenges that must be addressed at such institutions is a good starting point to better understanding this issue. Research targeting incidence and risk of zoonotic disease at VTHs and the movement of zoonotic pathogens in the VTH environment is important in better addressing zoonotic risk at an institutional level. Specific research questions may include: what surveillance programs are most effective at detecting zoonotic pathogens in a cost-effective manner, what training programs are best in

making infection prevention and control a priority among faculty and staff at VTHs, and what infection control measures are most effective at preventing zoonotic disease outbreaks at VTHs. These questions are complex undertakings and may have individual answers for CVMs across the United States and globally. However, this area of research is important because it has the potential to benefit CVMs financially by better preventing zoonotic and nosocomial infections and to benefit the health of all who work in CVMs and the patients they treat in VTHs.

In conclusion, this thesis on risk and prevention of zoonotic pathogen exposure at CVMs has, like any good research, been followed by more questions than answers. CVMs are locations where veterinarians, veterinary students, and staff may be exposed to zoonotic pathogens. Current preventative measures may not be fully addressing this risk. This impacts a major facet of the veterinary community and so these 3 research areas should be explored to better address the overall topics of zoonotic pathogen exposure risk and prevention.

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