Pertanika J. Trop. Agric. Sci. 46 (2): 485 - 501 (2023)

PERTANIKA JOURNALS

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Evaluation of Environmental Contamination with *Salmonella* spp. in a Large Animal Ward at a Veterinary Hospital in Malaysia

Alexandria de Lima[1], Nurul Hayah Khairuddin[1]*, Zunita Zakaria[1], Sarah Othman[2,3] and Siti Khairani-Bejo[1]

[1]Faculty of Veterinary Medicine, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[3]UPM-MAKNA Cancer Research Laboratory, Institute of Bioscience, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

ABSTRACT

Veterinary hospitals are important locations for various sick and immunocompromised animal patients. These centers may act as reservoirs for nosocomial diseases such as *Salmonella* infection, one of the most common causes of healthcare-associated infections in veterinary hospitals. The study was performed at the Large Animal Ward (LAW), University Veterinary Hospital, Universiti Putra Malaysia, to assess the environment's degree of *Salmonella* spp. contamination. Environmental samples were obtained from various floor and surface areas in the LAW using sterile, moistened gauze. *Salmonella* spp. was determined using conventional bacteriological culture on all samples. Positive *Salmonella* isolates were subject to antimicrobial sensitivity testing. A total of 6 out of 135 (4.4%) samples were found to be positive for *Salmonella* spp., with 5/116 (4.3%) samples obtained from the ward environment and 1/19 (5.3%) obtained from reusable equipment. Antimicrobial sensitivity testing revealed three resistance profiles: all isolates were resistant to penicillin and enrofloxacin, one isolate was resistant to streptomycin, and one was resistant to gentamicin. The results indicate that animal treatment areas within the LAW can become contaminated with *Salmonella* spp. This study highlights the importance of improving biosecurity programs to prevent nosocomial diseases in patients and the hospital environment.

Keywords: Environment, large animal, nosocomial, *Salmonella*, veterinary hospital

ARTICLE INFO

Article history:
Received: 26 September 2022
Accepted: 16 December 2022
Published: 12 April 2023

DOI: https://doi.org/10.47836/pjtas.46.2.07

E-mail addresses:
gs59131@student.upm.edu.my (Alexandria de Lima)
nurulhayah@upm.edu.my (Nurul Hayah Khairuddin)
zunita@upm.edu.my (Zunita Zakaria)
sarahothman@upm.edu.my (Sarah Othman)
skhairani@upm.edu.my (Siti Khairani Bejo)
* Corresponding author

ISSN: 1511-3701
e-ISSN: 2231-8542

INTRODUCTION

The most prevalent healthcare-associated infection in large animal veterinary clinics has been attributed to *Salmonella enterica,* and outbreaks of nosocomial salmonellosis have been documented (Hartmann et al., 1996; Schott et al., 2001; Steneroden et al., 2010). These outbreaks of salmonellosis have resulted in the closure of hospitals for extensive cleaning and disinfection, which has led to significant financial losses, including losses in client confidence, employee morale, and student educational opportunities (Aceto et al., 2007; Dallap Schaer et al., 2010; Ward et al., 2005). In addition to patients and resident animals being infected or acquiring the infection, they may also act as a reservoir for transmitting these microorganisms to other patients, hospital staff, students, and clients. *Salmonella* infection is a major concern for animal health; there is also a serious concern about its zoonotic potential, which significantly impacts public health (Bean & Griffin, 1990; Mead et al., 1999). Furthermore, there is a possibility that animals returning to their farms and stables after being discharged from the hospital may carry infectious agents to their herd mates, and therefore represent a further ethical obligation for veterinarians to prevent the spread of the disease outside of the hospital environment (Morley et al., 2013). The ethical and professional responsibility of veterinarians is to create a protective environment for hospitalized animals, students, staff, and clients to minimize infectious disease hazards in veterinary hospitals (Morley, 2013; Morley et al., 2013).

Stress is a factor that may instigate *Salmonella* fecal shedding by diseased animals (House et al., 1999; Wray et al., 1991). When animals infected with *Salmonella* are admitted to the hospital along with other immunocompromised animals, they may be subjected to environmental changes such as new locations, different feedings, and treatment regimens. These stressed animals pose a significant risk of nosocomial *Salmonella* infection to vulnerable animals (Pandya et al., 2009). Horses that have traveled an hour or more to the veterinary teaching hospital had antimicrobials before admission, abnormal nasogastric intubation findings, had an intravenous catheter placed, or rectal palpation performed, developed leukopenia, laminitis, or diarrhea during hospitalization, abdominal surgery performed (enterotomy or anastomosis) and were hospitalized for more than eight days had an increased likelihood of shedding *Salmonella* organisms in their feces (Burgess & Morley, 2019; Dallap Schaer et al., 2012; Ernst et al., 2004; Hird et al., 1984; Kim et al., 2001).

Hospitalized patients frequently have a compromised immune system because of the stress associated with transportation, management changes, and the underlying medical or surgical condition (Irwin, 1994; Radošević-Stasic et al., 1990; Sheridan et al., 1994; Tannock & Savage, 1974). Additionally, patients may have lowered resistance to gastrointestinal tract infections

because of decreased gastrointestinal tract motility and altered gastrointestinal tract flora because of anorexia, surgery, and antimicrobial therapy (Hird et al., 1984; Owen et al., 1983). Thus, eliminating nosocomial *Salmonella* infections requires two fundamental strategies: decreasing patient exposure to pathogenic organisms and limiting additional increases in patient vulnerability to pathogens.

In large animal facilities, the veterinary staff will likely perform duties in central services (e.g., pharmacy, storerooms, and laundry) and some specialties (e.g., radiology). Commonly, the individuals most likely to encounter patients are veterinary students, who is rotated throughout multiple sections and may be considered novices concerning patient management and infection control practices. The degree of integration and shared resources in the hospital can impact disease transmission even though infectious disease or environmental contamination in one area may likely affect patients managed in that region (Burgess & Morley, 2019; Steneroden et al., 2010). A study has demonstrated that the probability of *Salmonella* detection in the hospital environment increases as the caseload increases and the demand for personnel subsequently increases. Personnel may not comply with established infectious disease control protocols with increased demand of cleaning frequency and patient contacts, which creates more opportunities for infectious organisms' transmission between patients (Burgess & Morley, 2018; Dallap Schaer et al., 2010; Hartmann et al., 1996; Roberts & O'Boyle, 1981; Schott et al., 2001). These demonstrate that the ecological factors affecting the contamination of the hospital are complex and should be considered for the development of epidemics of nosocomial salmonellosis.

This study aims to ascertain the degree of *Salmonella* spp. contamination in the environment in a large animal veterinary hospital in Malaysia as one of the efforts to improve the biosecurity measures of the facility.

METHODOLOGY

Environmental samples were collected from 135 sites in the Large Animal Ward (LAW) at the University Veterinary Hospital (UVH), Faculty of Veterinary Medicine, Universiti Putra Malaysia. The selection of sample sites took into consideration the layout of the wards, the pattern of movement of the animals and staff in the ward, and the usage of space for treatment or procedures. A total of 17 pens/stable boxes were used to house resident animals and hospitalized patients in which the floors, walls, which are constructed from concrete and painted, feed, water buckets made of plastic, and the entrance gates were sampled. All wards are half-walled at the back, which faces outside or on the sides. Four stable boxes were used to ward horses, and four and nine pens were used to hospitalize large and small ruminant animals, respectively. Four walkways used to enter and exit the premises and five locations on treatment floor areas were also sampled. The other areas that were sampled were the cattle

crush and horse stock bars, and flooring, which is in the central area of the LAW and close to each other, and hand contact surfaces such as table surfaces and tap handles located at sinks for handwashing and near wards, the entrance gate handles, and table surfaces used for the treatment of patients and preparation of treatments kept in the central area, and cupboards handle at the drugs dispensary cabinet. Cleaning equipment (brooms, rakes, and scoops) and reusable equipment (nasogastric and orogastric tubes and stomach pumps) were also sampled. The frequency of specific sites sampled is demonstrated in Table 1.

Environmental samples such as taps, table surfaces, cupboard handles, equipment, and entrance handles were collected by swabbing the targeted surface for approximately 20 s with a sterile gauze saturated with sterile saline for 5 s. The gauze was then placed in a sealable and labeled plastic bag. All samples were collected aseptically using sterile gloves that were changed between sampling locations. One or three gauze swabs were swabbed along the entire surface for the sampling of table tops and restraint equipment. Three gauze swabs were swabbed to sample the floors and walls, covering an area of roughly 61 cm × 61 cm.

Standard aerobic bacterial culture of the environmental samples was performed. For enrichment, the gauze swab was placed in 90 ml of Buffered Peptone Water (BPW) (Thermo Scientific ™ Oxoid ™, USA), and the broth was incubated at 37°C for 24 hr in aerobic conditions. One ml of BPW mixture was transferred by micropipette into 9 ml of Rappaport-Vassiliadis (RV) broth (Thermo Scientific ™ Oxoid ™, USA) and incubated at 37°C for 24 hr in aerobic condition. A loopful of the RV broth was cultured onto brilliant green (BG) agar plates and xylose-lysine-deoxycholate (XLD) agar plates (Thermo Scientific ™ Oxoid ™, USA). The plates were incubated at 37°C for 24 hr in aerobic conditions. Three non-lactose fermenting, hydrogen sulfide-producing colonies would be selected and isolated. These colonies were then subjected to biochemical tests: urease agar, citrate utilization test, Sulfur Indole Motility (SIM) test, and triple sugars iron (TSI) agar slant (Thermo Scientific ™ Oxoid ™, USA), which were incubated at 37°C for 24 hr. TSI tubes were evaluated for changes that indicated alkaline (red) development in the slant and acid (yellow) and hydrogen sulfide (H_2S) precipitate in the butt, with or without gas presence. The absence of color in urease agar and color change from green to a blue indication of citrate utilization indicated positive *Salmonella* samples.

The antibiotic susceptibility of the positive isolates was tested using the standardized disc diffusion method (Bauer et al., 1966). Positive cultures were obtained from the nutrient agar collected using a wire loop, mixed into a test tube filled with 2–3 ml of sterile saline, and mixed using a vortex mixer until the density was visually equivalent to 0.5 MacFarland standard. The bacterial broth suspension was streaked evenly in 3 planes using sterile, non-toxic cotton swabs onto the surface of Mueller-

Hinton agar plates (Thermo Scientific ™ Oxoid ™, USA) and left to dry for 2 to 4 min. The antimicrobial sensitivity discs were then placed on the culture using a Disk Diffusion Dispenser (Oxoid™, USA). Antibiotic discs tested were penicillin 10 µg, streptomycin 300 µg, gentamicin 10 µg, and enrofloxacin 5 µg (Thermo Scientific ™ Oxoid ™ Antimicrobial Susceptibility Discs, USA). The plates were incubated at 37°C for 24 hr, and the size of the inhibition zone was interpreted as sensitive or resistant according to Clinical and Laboratory Standards Institute guidelines (Clinical and Laboratory Standards Institute [CLSI], 2020). According to Magiorakos' criteria, samples were classed as having Multiple Drug Resistance (MDR) when resistant to at least one drug in three or more antimicrobial classes (Magiorakos et al., 2012).

IBM SPSS Statistics for Windows (version 26.0) was utilized to generate descriptive statistics demonstrating *Salmonella* spp. contamination by different areas sampled and sampling locations.

RESULTS

Overall, 135 samples were collected from the walls (n = 49), floors (n = 10), hand-contact surfaces (n = 21), food and water buckets (n = 32), and equipment (cleaning, n = 10; reusable, n = 9; restraint, n = 4) at the large animal ward. Samples were evaluated by standard aerobic bacteriological culture and antimicrobial sensitivity testing. The results revealed that the large animal ward areas and equipment are contaminated with *Salmonella* spp. with an overall prevalence of 4.4% (6/135). *Salmonella* was successfully isolated from floors of walkways in the large animal section of the hospital ad flooring of a pen (3/26, 11.5%), walls of a stall box (1/16, 6.3%), and a water bucket (1/32, 3.1%). Additionally, only one (10%) sampled cleaning equipment recovered *Salmonella* spp., which was isolated from a rake used to scoop fecal materials from the wards. The overall prevalence of positive samples for *Salmonella* is demonstrated in Table 1. *Salmonella spp.* was not isolated from the treatment area, restraining equipment, or the commonly used veterinary equipment such

Table 1
The frequency of positively isolated Salmonella *spp. of environmental and equipment samples obtained from the LAW, UVH*

Type of sample	N	Positive	Negative
Walls	16	1 (6.3%)	15 (93.8%)
Floors	26	3 (11.5%)	23 (88.5%)
Hand-contact surfaces	38	0 (0%)	38 (100%)
Feed and water buckets	32	1 (3.1%)	31 (96.9%)
Equipment			
- Cleaning	10	1 (10%)	9 (90%)
- Reusable	9	0 (0%)	9 (90%)
- Restraint	4	0 (0%)	4 (100%)
Total	135	6 (4.4%)	129 (95.6%)

as nasogastric or orogastric tubes. There was no statistically significant difference between environment and equipment samples, χ (1) = 0.35, p = 0.852.

The results of the antimicrobial sensitivity testing revealed three antimicrobial-resistant profiles. Four isolates had an antimicrobial-resistance profile of penicillin-enrofloxacin, one isolate was penicillin-enrofloxacin-streptomycin, and one isolate was penicillin-enrofloxacin-gentamicin. None of the six *Salmonella* isolates were pan-susceptible: all isolates were resistant to penicillin and enrofloxacin. Five isolates were sensitive to streptomycin, while one was resistant. All isolates except one were sensitive to gentamicin (Table 2). Four of these isolates (the floor and water bucket of wards and floors of the two walkways) had similar antimicrobial patterns where isolates were sensitive to streptomycin and gentamicin and resistant to penicillin and enrofloxacin. Of these isolates, 2/6 (33.3%) were classified as having multiple drug resistance, as these were resistant to one agent in three or more antimicrobial classes.

DISCUSSION

Prevalence

The environmental contamination reported in this study is less prevalent than that reported at Ohio State University Veterinary Teaching Hospital (VTH) (5.9%) (Pandya et al., 2009), Colorado State University VTH (11.9%) (Burgess et al., 2004), and Equine Veterinary Hospital Santiago Chile (4.5%) (Soza-Ossandón et al., 2020), but higher than the prevalence reported by Michigan State University VTH (0.1%) (Ewart et al., 2001), and Purdue University VTH (2.1%) (Alinovi et al., 2003). However, it is challenging to directly compare the prevalence of *Salmonella* contamination in different hospital environments due to differences in microbiological culture techniques between institutions and their laboratories and various sampling techniques.

Various techniques and methods are used to recover or isolate *Salmonella* from environmental samples. The use of direct plating without enrichment, enrichment in a variety of broth media (including buffered peptone water, selenite, thioglycolate,

Table 2
The antimicrobial resistance profiles of the isolates of positively isolated Salmonella *spp. from environmental samples acquired from the LAW, UVH*

Salmonella spp. frequency	Antimicrobial resistance profiles	
4	Penicillin-enrofloxacin	
1	Penicillin-enrofloxacin-streptomycin	
1	Penicillin-enrofloxacin-gentamicin	
Antimicrobials	Sensitive	Resistance
Penicillin	0 (0%)	6 (100%)
Streptomycin	5 (83.3%)	1 (16.6%)
Gentamicin	5 (83.3%)	1 (16.6%)
Enrofloxacin	0 (0%)	6 (100%)

tetrathionate, and Rappaport-Vassiliadis broths), and culture on a variety of agar medium (including MacConkey, brilliant green, XLD, and xylose-lysine-tergitol-4 [XLT-4] agar) (Adzitey et al., 2012; Cummings et al., 2014; Rostagno et al., 2005; Ruple-Czerniak et al., 2014) are among the reported. Despite the numerous methods available to culture and isolate *Salmonella* spp., not all are equally effective at isolating the bacteria. A study compared two culture techniques during a *Salmonella* epidemic at a large animal hospital, one was the current method used in the diagnostic laboratory associated with the hospital, where samples were cultured in selenite broth (SEL) and plated on XLD (SEL-XLD), and the other method was reported for environmental surveillance in a veterinary teaching hospital where samples were incubated in tetrathionate broth with brilliant green (TBG), followed by Rappaport-Vassiliadis (RV) broth and plated on XLT-4 (TBG-RV-XLT) (Burgess et al., 2004). According to a study, the TBG-RV-XLT culture approach was significantly more sensitive than the SEL-XLD culture method for detecting *Salmonella* in environmental samples (Lyle et al., 2015).

A similar finding was also noted in another study which demonstrated that enrichment with tetrathionate and RV broth was three times more sensitive than a culture method that incubated in thioglycolate enrichment broth (Ruple-Czerniak et al., 2014). Failing to correctly detect *Salmonella* bacteria resulting from the use of poorly sensitive culture techniques that yield false negatives delays the application of strategies to curb nosocomial outbreaks and thereby facilitating the spread of *Salmonella* in hospital environments and between patients (Dallap Schaer et al., 2010; Hyatt & Weese, 2004). The more sensitive method could be attributed to increased testing that uses selective enrichment that encourages the growth of *Salmonella* spp.; however, more steps in the cultivation can cause a delay in the reporting of results. A rapid diagnosis is also vital to initiate proper treatment and infection control measures (Hyatt & Weese, 2004).

There is a general lack of sensitivity in all detection methods for *Salmonella* spp., which is why enrichment methods are typically recommended for use to aid in detection with culture (Hyatt & Weese, 2004). Recognizing that using enrichment broths in the culture process produces qualitative rather than quantitative results (positive vs. negative) is critical. It would preclude it from determining the degree of environmental contamination adequate to induce infection in animals or people (Burgess et al., 2004; Ruple-Czerniak et al., 2014). It is noted that there is a distinction between sampling strategies, such as the use of premoistened sponged, gauze sponges, gauze swabs, and electrostatic wipes. To date, there are no superior sampling or culture methods that have been determined; nonetheless, there have been two studies that have evaluated two distinct samplings and culture approaches. Both studies (Goeman et al., 2018; Ruple-Czerniak et al., 2014) agree that electrostatic wipes are more effective

at collecting bacteria and debris and using enrichment broths to aid in the detection of *Salmonella* bacteria. The sampling and recovery techniques applied in this study were deemed reliable and effective at isolating the bacteria, as the study used the lowest effective number of steps to isolate *Salmonella* spp. successfully. Bacterial growth may be inhibited by environmental factors such as disinfectants. Therefore, polymerase chain reaction (PCR) can be used to detect *Salmonella* bacteria in the environmental samples obtained. Studies have demonstrated that PCR was more sensitive in detecting positive *Salmonella* spp. in environmental samples than bacterial culture (Cohen et al., 1996; Ewart et al., 2001).

Impact

The study's findings imply that students and veterinarians working in the large animal hospital should be mindful of the dangers of nosocomial infections spreading to other patients and potential zoonotic infections spreading to themselves, clients, and visitors. Potential health problems that could be attributed to *Salmonella* infections in students, staff, and clients could not be identified as this was beyond the scope of the study. The two floors used as walkways are the most used entrances to the hospital by students and staff. Floor samples are the most frequently contaminated in veterinary hospital environments after floor drains (Alinovi et al., 2003; Pandya et al., 2009). It is a commendable finding that the treatment floor area, stock, crush, treatment tables, and the entrance floors and gates used by animals are not contaminated with *Salmonella* spp. A water bucket in one of the small ruminant wards was contaminated with *Salmonella* spp. It could be a potential source of nosocomial infection to the resident animals or patients, as *Salmonella* is transmitted by ingesting the bacteria. Nasogastric intubation, a routine procedure to treat colic in horses, has been established as a risk factor for *Salmonella* detection (Hird et al., 1984, 1986; Traub-Dargatz et al., 1990). In this study, it was found that these gastric tubes were not contaminated with *Salmonella* spp. However, one of the cleaning equipment, the rake, was found to be harboring *Salmonella* organisms. It could be a potential method to disseminate the bacteria throughout the rest of the hospital environment. *Salmonella* spp. in the hospital environment could be detrimental to hospitalized patients, resident animals, and personnel working due to increased nosocomial and zoonotic risks. It is essential to comprehend and manage the microbial contamination of components interacting with patients to prevent nosocomial infections.

Current Cleaning Protocols

There have been no outbreaks of nosocomial infections due to *Salmonella* in this veterinary hospital. The current cleaning and disinfection protocols used at the hospital where areas are cleaned using a high-pressure water hose while scrubbing with a brush broom and disinfected with a diluted bleach solution (1:32). There is a foot bath

that is cleaned and filled daily with a diluted bleach solution, along with a separate area to wash boots at one entrance to the hospital, with sinks and soap available for hand washing near the treatment area. The entrances and treatment areas are cleaned at least twice daily and immediately following each animal examination. When there was suspicion or confirmed cases of infectious disease, animals were hospitalized at the ward, and infection control programs and other biosecurity measures such as the use of disposable gloves and gowns and frequent hand washing, and sanitizing were enforced. Unfortunately, a large animal isolation facility for infectious diseases is not available at the current time. Based on the output of this study, an environmental surveillance report for *Salmonella* spp. has been issued, and a suggestion for routine disinfection, guidelines for best-practice prevention efforts, and environmental surveillance protocol have been brought forward to the management of the large animal ward. The suggestions have been accepted positively. Other measures to further help reduce the population of pathogenic organisms in the wards by adding disinfectant footbaths at all entrances into the large animal ward, and not just at the main entrance to the facility. Before entering the hospital premises, boots should be vigorously scrubbed and cleaned after each farm/stable visit. The boots should be immersed in a regularly changed footbath containing disinfectant such as 1:16 dilution of sodium hypochlorite (bleach) for the appropriate contact time, which has been shown to decrease microbial loads on the surface of the boots significantly (Hornig et al., 2016; Kirk et al., 2003; Morley et al., 2005; Stockton et al., 2006). Bleach is a very potent and inexpensive disinfectant used in veterinary settings that thoroughly inactivates numerous pathogens of concern. However, it is considerably deactivated by organic matter and has no detergent action (Steneroden, 2012). Disposable boot covers have significantly reduced nosocomial infections in hospital settings (Schott et al., 2001).

Infectious Disease Control Program

Infection prevention and control recommendations include wearing gloves when cleaning wards and treating animals, removing gloves, and washing hands immediately after work is complete. In places where patients are handled, hand-washing sinks or alcohol-based hand-sanitizing solutions should be readily available (Smith et al., 2004; Wright et al., 2005). All disinfectants require a clean and debris-free surface, and the disinfectant must be utilized at the manufacturer's recommended dilution and contact time. Stalls that housed discharged animals should be cleaned by removing all soiled bedding, followed by gently hosing down and scrubbing. Once the stall looks completely free of feed, bedding, feces, and blood, it should be cleaned extensively with a brush and detergents such as an iodophor detergent (Lindores*-30, Sunzen Biotech Berhad, Malaysia) to remove organic matter and biofilms. Follow up with rinsing

and application of the disinfectant, such as sodium hypochlorite, diluted at 1:32, allowing at least 10 min of contact time. In a study comparing the effectiveness of different types of disinfectants, bleach was the most effective in eliminating *Salmonella* organisms from all surfaces when detected using bacterial culture or PCR testing (Ewart et al., 2001). It is because of the mechanism of action of bleach, which causes the breakdown of the cellular lining but also destroys the DNA of the bacteria (Merritt et al., 2000).

It has been suggested that periodic environmental surveillance by dried environmental sampling should be collected and cultured for *Salmonella* spp. to determine the cleaning protocol's efficiency (Smith et al., 2004). While continuous monitoring is not required, it is preferable to undertake it on a set schedule, such as monthly or biannually (Burgess & Morley, 2015). It is also essential to ensure that any defect, chipped paint, loose flooring, floor mats, and damaged or rotted wood on surfaces of the ward and treatment areas are in good repair so that they can be easily cleaned and not become a nidus for pathogens to survive (Kramer & Ames, 1987). A study has shown that environmental sampling is indicated following the cleaning and disinfection protocol as a small proportion of stalls may remain contaminated with *Salmonella* spp.; therefore, a second round of cleaning and disinfection can be performed before the stall can be used for admissions (Alinovi et al., 2003). However, it has been noted that certain strains of *Salmonella* have been shown to survive in the environment despite rigorous cleaning and disinfection methods, functioning as a reservoir for hospital-acquired diseases and zoonoses. It was speculated that complete eradication might be difficult or unattainable in a large animal hospital environment (Pandya et al., 2009; Ruple-Czerniak et al., 2014; Steneroden et al., 2010).

Veterinary health care providers have an ethical and legal responsibility to minimize risks for infectious disease transmission in health care settings. To date, there have been few published discussions on the responsibilities of nosocomial infections in veterinary settings, and this aspect has to be emphasized and highlighted to the many veterinary care providers throughout the country. Several veterinary associations from various countries such as Australia, Britain, Canada, and the United States have released guidelines for infection control procedures (Australian Veterinary Association [AVA], 2017; Canadian Committee on Antibiotic Resistance [CCAR], 2008; Gerrad, 2021; Newbury et al., 2010; Stull et al., 2018). While Veterinary Associations set protocols, the employment and implementation of the procedures may vary from facility to facility. It was surmised from multiple studies that a significant number of veterinarians are either unaware of the risks of zoonoses or nosocomial infections or are complacent about the risks (Anderson & Weese, 2022; Lipton et al., 2008; McMillian et al., 2007; Tambuwal et al., 2009; Wright et al., 2008). An international group of experts recently developed a consensus on

opinions about infection control in equine populations (Morley et al., 2013). Therefore, at the current time, the best practice of infection control should be acknowledged and promoted in veterinary settings.

Antimicrobial Resistance

In this study, antimicrobial sensitivity testing tested the common antimicrobial drugs currently used in large animal practices in Malaysia. In this study, all the *Salmonella* isolates were resistant to penicillin (100%) and enrofloxacin (100%). Only two isolates had different antibiograms; one demonstrated resistance to gentamicin in addition to penicillin and enrofloxacin, and the other demonstrated resistance to streptomycin. It could be interpreted as three different species of *Salmonella* bacteria; however, further investigation with serotyping is warranted to assess this accurately. The emergence of resistance to antimicrobial drugs in salmonellae is a worldwide problem (Chaslus-Dancla et al., 2000; Dargatz & Traub-Dargatz, 2004). An amount of 28.6% of isolates in this study was resistant to one agent in three antimicrobial classes, which agrees with earlier reports in humans, horses, and other domestic animals (Mammina et al., 2002; van Duijkeren et al., 2002). Many of the documented nosocomial outbreaks associated with *Salmonella* in veterinary hospitals have been associated with MDR strains, even in isolates obtained from the environment (Amavisit et al., 2001; Castor et al., 1989; Dallap Schaer et al., 2010; Hartmann et al., 1996; Hartmann & West, 1995; Schott et al., 2001; Steneroden et al., 2010; Tillotson et al., 1997). Even routine environmental surveillance of veterinary hospitals has demonstrated isolates that possess MDR, where 6.25–40.1% of isolates demonstrated MDR (Pandya et al., 2009; Soza-Ossandón et al., 2020). These studies showed that isolates were resistant to streptomycin (Pandya et al., 2009) and gentamicin (Soza-Ossandón et al., 2020), similar to what was seen in this study; however, neither study reported resistance to enrofloxacin as seen in all isolates obtained from this study.

CONCLUSION

This study has established the presence and degree of *Salmonella* spp. contamination in the environment in this large animal veterinary hospital for the duration of sampling highlighted the importance of periodic environmental surveillance and monitoring. Implementing infectious disease control and biosecurity protocols is vital to controlling nosocomial infections, especially with *Salmonella* spp., and is considered an ethical and professional responsibility of any veterinary practice. It can be recommended that other veterinary facilities in this country consider evaluating the environmental contamination in their healthcare premises.

ACKNOWLEDGEMENTS

The authors thank the veterinary and assistant veterinary officers at the Department of Farm and Exotic Animal Medicine and Surgery, University Veterinary Hospital

(UVH) of Universiti Putra Malaysia, for their assistance and cooperation throughout the study period.

FUNDING

This research is supported by Universiti Putra Malaysia, Putra Grant- Putra Graduate Initiative (GP-IPS/2022/9724200).

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Aceto, H., Rankin, S. C., Dallap, B. L., Dolente, B., Munro, D. S., Benson Charles, C. E., & Smith G. (2006). Salmonella *infection at a veterinary teaching hospital: The University of Pennsylvania experience*. https://www.usaha.org/upload/Proceedings/2006_USAHA_Proceedings.pdf

Adzitey, F., Rusul, G., & Huda, N. (2012). Prevalence and antibiotic resistance of *Salmonella* serovars in ducks, duck rearing and processing environments in Penang, Malaysia. *Food Research International*, *45*(2), 947–952. https://doi.org/10.1016/j.foodres.2011.02.051

Alinovi, C. A., Ward, M. P., Couëtil, L. L., & Wu, C. C. (2003). Detection of *Salmonella* organisms and assessment of a protocol for removal of contamination in horse stalls at a veterinary teaching hospital. *Journal of the American Veterinary Medical Association*, *223*(11), 1640–1644. https://doi.org/10.2460/JAVMA.2003.223.1640

Amavisit, P., Markham, P. F., Lightfoot, D., Whithear, K. G., & Browning, G. F. (2001). Molecular epidemiology of *Salmonella* Heidelberg in an equine hospital. *Veterinary Microbiology*, *80*(1), 85–98. https://doi.org/10.1016/s0378-1135(00)00373-4

Anderson, M. E. C., & Weese, J. S. (2022). Video observation of hand hygiene practices at a petting zoo and the impact of hand hygiene interventions. *Epidemiology and Infection*, *140*(1), 182–190. https://doi.org/10.1017/S095026881100029X

Australian Veterinary Association. (2017). *Guidelines for veterinary personal biosecurity*. AVA. https://www.ava.com.au/siteassets/resources/veterinary-personal-biosecurity/guidelines-for-veterinary-personal-biosecurity-2017-final.pdf

Bauer, A. W., Kirby, W. M. M., Sherris, J. C., & Turck, M. (1966). Antibiotic susceptibility testing by a standardized single disk method. *American Journal of Clinical Pathology*, *45*(3), 493–496.

Bean, N. H., & Griffin, P. M. (1990). Foodborne disease outbreaks in the United States, 1973-1987: Pathogens, vehicles, and trends. *Journal of Food Protection*, *53*(9), 804–817. https://doi.org/10.4315/0362-028x-53.9.804

Burgess, B. A., & Morley, P. S. (2015). Veterinary hospital surveillance systems. *Veterinary Clinics of North America: Small Animal Practice*, *45*(2), 235–242. https://doi.org/10.1016/j.cvsm.2014.11.002

Burgess, B. A., & Morley, P. S. (2018). Risk factors for veterinary hospital environmental contamination with *Salmonella enterica*. *Epidemiology and Infection*, *146*(10), 1282–1292. https://doi.org/10.1017/S0950268818001164

Burgess, B. A., & Morley, P. S. (2019). Risk factors for shedding of *Salmonella enterica* among hospitalized large animals over a 10-year period in a veterinary teaching hospital. *Journal of Veterinary Internal Medicine*, *33*(5), 2239–2248. https://doi.org/10.1111/jvim.15579

Burgess, B. A., Morley, P. S., & Hyatt, D. R. (2004). Environmental surveillance for *Salmonella*

enterica in a veterinary teaching hospital. *Journal of the American Veterinary Medical Association*, *225*(9), 1344–1348. https://doi.org/10.2460/javma.2004.225.1344

Canadian Committee on Antibiotic Resistance. (2008). *Infection prevention and control best practices for small animal veterinary clinics*. https://www.oahn.ca/wp-content/uploads/2021/04/OAHN-IPC-Guide-SB-Final-Jan0820_All_tagged.pdf

Castor, M. L., Wooley, R. E., Shotts, E. B., Brown, J., & Payeur, J. B. (1989). Characteristics of *Salmonella* isolated from an outbreak of equine salmonellosis in a veterinary teaching hospital. *Journal of Equine Veterinary Science*, *9*(5), 236–241. https://doi.org/10.1016/S0737-0806(89)80078-4

Chaslus-Dancla, E., Lafont, J. P., & Martel, J. L. (2000). Spread of resistance from food animals to man: The French experience. *Acta Veterinaria Scandinavica*, *93*, 53–60.

Clinical and Laboratory Standards Institute. (2020). *Performance standards for antimicrobial susceptibility testing* (32nd ed.). CLSI. https://clsi.org/standards/products/microbiology/documents/m100/

Cohen, N. D., Martin, L. J., Simpson, R. B., Wallis, D. E., & Neibergs, H. L. (1996). Comparison of polymerase chain reaction and microbiological culture for detection of salmonellae in equine feces and environmental samples. *American Journal of Veterinary Research*, *57*(6), 780–786.

Cummings, K. J., Rodriguez-Rivera, L. D., Mitchell, K. J., Hoelzer, K., Wiedmann, M., McDonough, P. L., Altier, C., Warnick, L. D., & Perkins, G. A. (2014). *Salmonella enterica* serovar Oranienburg outbreak in a veterinary medical teaching hospital with evidence of nosocomial and on-farm transmission. *Vector-Borne and Zoonotic Diseases*, *14*(7), 496–502. https://doi.org/10.1089/vbz.2013.1467

Dallap Schaer, B. L., Aceto, H., Caruso, M. A., & Brace, M. A. (2012). Identification of predictors of *Salmonella* shedding in adult horses presented for acute colic. *Journal of Veterinary Internal Medicine*, *26*(5), 1177–1185. https://doi.org/10.1111/j.1939-1676.2012.00984.x

Dallap Schaer, B. L., Aceto, H., & Rankin, S. C. (2010). Outbreak of salmonellosis caused by *Salmonella enterica* serovar Newport MDR-AmpC in a large animal veterinary teaching hospital. *Journal of Veterinary Internal Medicine*, *24*(5), 1138–1146. https://doi.org/10.1111/j.1939-1676.2010.0546.x

Dargatz, D. A., & Traub-Dargatz, J. L. (2004). Multidrug-resistant *Salmonella* and nosocomial infections. *Veterinary Clinics of North America: Equine Practice*, *20*(3), 587–600. https://doi.org/10.1016/j.cveq.2004.07.008

Ernst, N. S., Hernandez, J. A., Mackay, R. J., Brown, M. P., Gaskin, J. M., Nguyen, A. D., Giguere, S., Colahan, P. T., Troedsson, M. R., Haines, G. R., Addison, I. R., & Miller, B. J. (2004). Risk factors associated with fecal *Salmonella* shedding among hospitalized horses with signs of gastrointestinal tract disease. *Journal of the American Veterinary Medical Association*, *225*(2), 275–281. https://doi.org/10.2460/javma.2004.225.275

Ewart, S. L., Schott, H. C., Robison, R. L., Dwyer, R. M., Eberhart, S. W., & Walker, R. D. (2001). Identification of sources of *Salmonella* organisms in a veterinary teaching hospital and evaluation of the effects of disinfectants on detection of Salmonella organisms on surface materials. *Journal of the American Veterinary Medical Association*, *218*(7), 1145–1151. https://doi.org/10.2460/javma.2001.218.1145

Gerrad, E. (2021). *Infection control and hygiene: A guide to best practice*. British Veterinary Nursing Association. https://bvna.org.uk/blog/infection-control-and-hygiene-a-guide-to-best-practice/

Goeman, V. R., Tinkler, S. H., Hammac, G. K., & Ruple, A. (2018). Evaluation of environmental sampling methods for detection of *Salmonella enterica* in a large animal veterinary hospital. *Canadian Veterinary Journal*, *59*(4), 408–412.

Hartmann, F. A., Callan, R. J., McGuirk, S. M., & West, S. E. (1996). Control of an outbreak of salmonellosis caused by drug-resistant *Salmonella anatum* in horses at a veterinary hospital and measures to prevent future infections. *Journal of the American Veterinary Medical Association*, *209*(3), 629–631.

Hartmann, F. A., & West, S. E. H. (1995). Antimicrobial susceptibility profiles of multidrug-resistant *Salmonella anatum* isolated from horses. *Journal of Veterinary Diagnostic Investigation*, *7*(1), 159–161. https://doi.org/10.1177/104063879500700128

Hird, D. W., Casebolt, D. B., Carter, J. D., Pappaioanou, M., & Hjerpe, C. A. (1986). Risk factors for salmonellosis in hospitalised horses. *Journal of the American Veterinary Medical Association*, *188*(2), 173–177.

Hird, D. W., Pappaioanou, M., & Smith, B. (1984). Case-control study of risk factors associated with isolation of *Salmonella* Saintpaul in hospitalized horses. *American Journal of Epidemiology*, *120*(6), 852–862. https://doi.org/10.1093/oxfordjournals.aje.a113957

Hornig, K. J., Burgess, B. A., Saklou, N. T., Johnson, V., Malmlov, A., van Metre, D. C., Morley, P. S., & Byers, S. R. (2016). Evaluation of the efficacy of disinfectant footmats for the reduction of bacterial contamination on footwear in a large animal veterinary hospital. *Journal of Veterinary Internal Medicine*, *30*(6), 1882–1886. https://doi.org/10.1111/jvim.14576

House, J. K., Mainar-jaime, R. C., & Smith, B. P. (1999). Risk factors for nosocomial *Salmonella* infection among hospitalized horses. *Journal of the American Veterinary Medical Association*, *214*(10), 1511–1516.

Hyatt, D. R., & Weese, J. S. (2004). *Salmonella* culture: Sampling procedures and laboratory techniques. *Veterinary Clinics of North America: Equine Practice*, *20*(3), 577–585. https://doi.org/10.1016/j.cveq.2004.07.007

Irwin, M. (1994). Stress-induced immune suppression: Role of brain corticotropin releasing hormone and autonomic nervous system mechanisms. *Advances in Neuroimmunology*, *4*(1), 29–47. https://doi.org/10.1016/S0960-5428(06)80188-9

Kim, L. M., Morley, P. S., Traub-Dargatz, J. L., Salman, M. D., & Gentry-Weeks, C. (2001). Factors associated with *Salmonella* shedding among equine colic patients at a veterinary teaching hospital. *Journal of the American Veterinary Medical Association*, *218*(5), 740–748. https://doi.org/10.2460/javma.2001.218.740

Kirk, J., Boggs, C., Jeffery, J., & Cardona, C. (2003). Efficacy of disinfectants for sanitizing boots under dairy farm conditions. *The Bovine Practitioner*, *37*(1), 50–53.

Kramer, G. F., & Ames, B. N. (1987). Oxidative mechanisms of toxicity of low-intensity near-UV light in *Salmonella typhimurium*. *Journal of Bacteriology*, *169*(5), 2259–2266. https://journals.asm.org/journal/jb

Lipton, B. A., Hopkins, S. G., Koehler, J. E., & DiGiacomo, R. F. (2008). A survey of veterinarian involvement in zoonotic disease prevention practices. *Journal of the American Veterinary Medical Association*, *233*(8), 1242–1249. https://doi.org/10.2460/javma.233.8.1242

Lyle, C. H., Annandale, C. H., Gouws, J., & Morley, P. S. (2015). Comparison of two culture techniques used to detect environmental contamination with *Salmonella enterica* in a large-animal hospital. *Journal of the South African Veterinary Association*, *86*(1), 1292–1295. https://doi.org/10.4102/jsava.v86i1.1292

Magiorakos, A. P., Srinivasan, A., Carey, R. B., Carmeli, Y., Falagas, M. E., Giske, C. G., Harbarth, S., Hindler, J. F., Kahlmeter, G., Olsson-Liljequist, B., Paterson, D. L., Rice, L. B., Stelling, J., Struelens, M. J., Vatopoulos, A., Weber, J. T., & Monnet, D. L. (2012). Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: An international expert proposal for interim standard definitions for acquired resistance. *Clinical Microbiology and Infection*, *18*(3), 268–281. https://doi.org/10.1111/j.1469-0691.2011.03570.x

Mammina, C., Cannova, L., Massa, S., Goffredo, E., & Nastasi, A. (2002). Drug resistances in *Salmonella* isolates from animal foods, Italy 1998–2000. *Epidemiology and Infection*, *129*(1), 155–161. https://doi.org/10.1017/S0950268802007239

McMillian, M., Dunn, J. R., Keen, J. E., Brady, K. L., & Jones, T. F. (2007). Risk behaviors for disease transmission among petting zoo attendees. *Journal of the American Veterinary Medical Association*, *231*(7), 1036–1038. https://doi.org/10.2460/javma.231.7.1036

Mead, P. S., Slutsker, L., Dietz, V., McCaig, L. F., Bresee, J. S., Shapiro, C., Griffin, P. M., & Tauxe, R. V. (1999). Food-related illness and death in the United States. *Emerging Infectious Diseases*, *5*(5), 607–625. https://doi.org/10.3201/eid0505.990502

Merritt, K., Hitchins, V. M., & Brown, S. A. (2000). Safety and cleaning of medical materials and devices. *Journal of Biomedical Materials Research*, *53*(2), 131–136. https://doi.org/10.1002/(SICI)1097-4636(2000)53:2<131::AID-JBM1>3.0.CO;2-I

Morley, P. S. (2013). Evidence-based infection control in clinical practice: If you buy clothes for the Emperor, will he wear them?. *Journal of Veterinary Internal Medicine*, *27*(3), 430–438. https://doi.org/10.1111/jvim.12060

Morley, P. S., Anderson, M. E. C., Burgess, B. A., Aceto, H., Bender, J. B., Clark, C., Daniels, J. B., Davis, M. A., Hinchcliff, K. W., Johnson, J. R., McClure, J., Perkins, G. A., Pusterla, N., Traub-Dargatz, J. L., Weese, J. S., & Whittem, T. L. (2013). Report of the third Havemeyer workshop on infection control in equine populations. *Equine Veterinary Journal*, *45*(2), 131–136. https://doi.org/10.1111/evj.12000

Morley, P. S., Morris, S. N., Hyatt, D. R., & van Metre, D. C. (2005). Evaluation of the efficacy of disinfectant footbaths as used in veterinary hospitals. *Journal of the American Veterinary Medical Association*, *226*(12), 2053–2058. https://doi.org/10.2460/javma.2005.226.2053

Newbury, S., Blinn, M. K., Bushby, P. A., Cox, C. B., Dinnage, J. D., Griffin, B., Hurley, K. F., Isaza, N., Jones, W., Miller, L., O'Quin, J., Patronek, G. J., Smith-Blackmore, M., & Spindel, M. (2010). *Guidelines for standard of care in animal shelters*. The Association of Shelter Veterinarians. https://oacu.oir.nih.gov/system/files/media/file/2021-02/shelterguide.pdf

Owen, R. A., Fullerton, J., & Barnum, D. A. (1983). Effects of transportation, surgery, and antibiotic therapy in ponies infected with *Salmonella*. *American Journal of Veterinary Research*, *44*(1), 46–50.

Pandya, M., Wittum, T., Tadesse, D. A., Gebreyes, W., & Hoet, A. (2009). Environmental *Salmonella* surveillance in the Ohio State University Veterinary Teaching Hospital. *Vector-Borne and Zoonotic Diseases*, *9*(6), 649–654. https://doi.org/10.1089/vbz.2008.0120

Radošević-Stasic, B., Cuk, M., Mrakovčić-Šutić, I., Barac-Latas, V., Muhvić, D., Lučin, P., Petković, M., & Rukavina, D. (1990). Immunosuppressive properties of halothane anesthesia and/or surgical stress in experimental conditions. *International Journal of Neuroscience*, *51*(3–4), 235–236. https://doi.org/10.3109/00207459008999706

Roberts, M. C., & O'Boyle, D. A. (1981). The prevalence and epizootiology of salmonellosis among groups of horses in south east Queensland. *Australian Veterinary Journal*, *57*(1), 27–35. https://doi.org/10.1111/j.1751-0813.1981.tb07081.x

Rostagno, M. H., Gailey, J. K., Hurd, H. S., Mckean, J. D., & Leite, R. C. (2005). Culture methods differ on the isolation of *Salmonella enterica* serotypes from naturally contaminated swine fecal samples. *Journal of Veterinary Diagnostic Investigation*, *17*(1), 80–83. https://doi.org/10.1177/104063870501700118

Ruple-Czerniak, A., Bolte, D. S., Burgess, B. A., & Morley, P. S. (2014). Comparison of two sampling and culture systems for detection of *Salmonella enterica* in the environment of a large animal hospital. *Equine Veterinary Journal*, *46*(4), 499–502. https://doi.org/10.1111/evj.12193

Schott, H. C., Ewart, S. L., Walker, R. D., Dwyer, R. M., Dietrich, S., Eberhart, S. W., Kusey, J., Stick, J. A., & Derksen, F. J. (2001). An outbreak of salmonellosis among horses at a veterinary teaching hospital. *Journal of the American Veterinary Medical Association*, *218*(7), 1152–1159. https://doi.org/10.2460/javma.2001.218.1152

Sheridan, J. F., Dobbs, C., Brown, D., & Zwilling, B. (1994). Psychoneuroimmunology: Stress effects on pathogenesis and immunity during infection. *Clinical Microbiology Reviews*, *7*(2), 200–212. https://doi.org/10.1128/cmr.7.2.200

Smith, B. P., House, J. K., Magdesian, K. G., Jang, S. S., Cabral, R. L., Madigan, J. E., & Herthel, W. F. (2004). Principles of an infectious disease control program for preventing nosocomial gastrointestinal and respiratory tract diseases in large animal veterinary hospitals. *Journal of the American Veterinary Medical Association*, *225*(8), 1186–1195. https://doi.org/10.2460/javma.2004.225.1186

Soza-Ossandón, P., Rivera, D., Tardone, R., Riquelme-Neira, R., García, P., Hamilton-West, C., Adell, A. D., González-Rocha, G., & Moreno-Switt, A. I. (2020). Widespread environmental presence of multidrug-resistant *Salmonella* in an equine veterinary hospital that received local and international horses. *Frontiers in Veterinary Science*, *7*, 346. https://doi.org/10.3389/fvets.2020.00346

Steneroden, K. (2012). Sanitation. In L. Miller & S. Zawistowski (Eds.), *Shelter medicine for veterinarians and staff* (2nd ed., pp. 37–47). Wiley. https://doi.org/10.1002/9781119421511.ch4

Steneroden, K. K., van Metre, D. C., Jackson, C., & Morley, P. S. (2010). Detection and control of a nosocomial outbreak caused by *Salmonella* Newport at a large animal hospital. *Journal of Veterinary Internal Medicine*, *24*(3), 606–616. https://doi.org/10.1111/j.1939-1676.2010.0484.x

Stockton, K. A., Morley, P. S., Hyatt, D. R., Burgess, B. A., Patterson, G., Dunowska, M., & Lee, D. E. (2006). Evaluation of the effects of footwear hygiene protocols on nonspecific bacterial contamination of floor surfaces in an equine hospital. *Journal of the American Veterinary Medical Association*, *228*(7), 1068–1073. https://doi.org/10.2460/javma.228.7.1068

Stull, J. W., Bjorvik, E., Bub, J., Dvorak, G., Petersen, C., & Troyer, H. L. (2018). 2018 AAHA infection control, prevention, and biosecurity guidelines. *Journal of the American Animal Hospital Association*, *54*(6), 297–326. https://doi.org/10.5326/JAAHA-MS-6903

Tambuwal, F. M., Shittu, A., Abubakar, M. B., Salihu, M. D., Junaidu, A. U., Magaji, A. A., Lawal, M., & Danyaro, M. (2009). A survey of veterinary hospitals in Nigeria for the presence of some bacterial organisms of nosocomial and zoonotic potential. *Veterinaria Italiana*, *45*(2), 235–241.

Tannock, G. W., & Savage, D. C. (1974). Influences of dietary and environmental stress on microbial populations in the murine gastrointestinal tract. *Infection and Immunity*, *9*(3), 591–598. https://doi.org/10.1128/iai.9.3.591-598.1974

Tillotson, K., Savage, C. J., Salman, M. D., Gentry-Weeks, C. R., Rice, D., Fedorka-Cray, P. J., Hendrickson, D. A., Jones, R. L., Nelson, W., & Traub-Dargatz, J. L. (1997). Outbreak of *Salmonella infantis* infection in a large animal veterinary teaching hospital. *Journal of the American Veterinary Medical Association*, *211*(12), 1554–1557.

Traub-Dargatz, J. L., Salman, M. D., & Jones, R. L. (1990). Epidemiologic study of salmonellae shedding in the feces of horses and potential risk factors for development of the infection in hospitalized horses. *Journal of the American Veterinary Medical Association*, *196*(10), 1617–1622.

van Duijkeren, E., Wannet, W. J. B., Heck, M. E. O. C., van Pelt, W., Sloet van Oldruitenborgh-Oosterbaan, M. M., Smit, J. A. H., & Houwers, D. J. (2002). Sero types, phage types and antibiotic susceptibilities of *Salmonella* strains isolated from horses in The Netherlands from 1993 to 2000. *Veterinary Microbiology*, *86*(3), 203–212. https://doi.org/10.1016/S0378-1135(02)00007-X

Ward, M. P., Brady, T. H., Couetil, L. L., Liljebjelke, K., Maurer, J. J., & Wu, C. C. (2005). Investigation and control an outbreak of *Salmonella typhimurium* in a population of hospitalized horses. *Veterinary Microbiology*, *107*(3-4), 233–240. https://doi.org/10.1016/j.vetmic.2005.01.019

Wray, C., Todd, N., McLaren, I. M., & Beedell, Y. E. (1991). The epidemiology of *Salmonella* in calves: The role of markets and vehicles. *Epidemiology and Infection*, *107*(3), 521–525. https://doi.org/10.1017/S0950268800049219

Wright, J. G., Jung, S., Holman, R. C., Marano, N. N., & McQuiston, J. H. (2008). Infection control practices and zoonotic disease risks among veterinarians in the United States. *Journal of the American Veterinary Medical Association*, *232*(12), 1863–1872. https://doi.org/10.2460/javma.232.12.1863

Wright, J. G., Tengelsen, L. A., Smith, K. E., Bender, J. B., Frank, R. K., Grendon, J. H., Rice, D. H., Thiessen, A. M. B., Gilbertson, C. J., Sivapalasingam, S., Barrett, T. J., Besser, T. E., Hancock, D. D., & Angulo, F. J. (2005). Multidrug-resistant *Salmonella* Typhimurium in four animal facilities. *Emerging Infectious Diseases*, *11*(8), 1235–1241. https://doi.org/10.3201/eid1108.050111