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Hospital-Associated Infections in Small Animal Practice



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KEYWORDS

• Nosocomial • Infection • Hospital • Veterinary • Control • Hospital-associated

KEY POINTS

- Hospital-associated infections (HAIs) occur in veterinary medicine, and their frequency is likely to increase.
- Urinary tract infections, pneumonia, bloodstream infections, surgical site infections, and infectious diarrhea are the HAIs most frequently identified in veterinary medicine.
- All staff members should be educated on the risks and signs associated with HAIs so that cases can be detected early and managed appropriately.
- A hospital infection-control program, consisting of an infectious disease control officer, a written protocol, and staff training, is critical to reducing HAIs and promoting patient, staff, and client health.

INTRODUCTION: NATURE OF THE PROBLEM

Hospital-associated infections (HAIs), sometimes referred to as nosocomial infections, are infections acquired by patients during hospitalization and are an inherent risk in human and veterinary medicine. In human hospitals, HAIs are a well-recognized contributor to illness and death, with an estimated 5% of patients developing an HAI and tens of thousands dying each year from HAIs.¹ It is estimated that, in the United States, human HAIs account for \$28 to \$45 billion in direct costs annually, not including the substantial indirect costs (eg, community care costs, lost wages, and productivity by the patient and caregivers).²

Veterinary data for this field are limited. In some aspects, risks may be lower because of the generally lower proportion of veterinary patients that have long hospital stays, are profoundly immunocompromised, and undergo highly invasive procedures

The authors have nothing to disclose.

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Vet Clin Small Anim 45 (2015) 217–233
<http://dx.doi.org/10.1016/j.cvsm.2014.11.009>

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compared with people. However, this may be countered with greater patient hygiene challenges, greater difficulty with patient compliance (eg, licking wounds), and a lesser “culture” of infection control. Although current data are limited for the veterinary field, similar (or even higher) HAI rates have been reported compared with human studies, such as HAIs in 16% of intensive care unit patients in one study.³ During a 5-year period, 82% of veterinary teaching hospitals in North America and Europe reported at least one HAI outbreak and 45% reported multiple outbreaks. Many of these outbreaks required restricted patient admissions (58%) or closure of the hospital or section (32%).⁴ Therefore, although HAIs are poorly quantified in veterinary medicine, they are undeniably a concern.

There are many potential adverse events from HAIs in veterinary patients. Animals suffering from HAIs may have an increased hospital stay (with accompanying increased cost to the client or clinic). These patients may also suffer permanent health consequences, or HAIs may result in death of the pet. Multidrug-resistant organisms (MDROs) are often involved in HAIs, complicating treatment and resulting in poor patient outcomes and extensive outbreaks. Furthermore, some veterinary hospital-associated (HA) pathogens (eg, methicillin-resistant *Staphylococcus aureus* [MRSA], *Salmonella*) can be transmitted to staff or pet owners, resulting in human illness. Additionally, as veterinary medicine advances, there may be parallel *increases* in HAI risk through the use of more invasive procedures, more use of invasive devices (eg, urinary catheters, intravenous catheters), more immunosuppressant therapies, and a greater intensity of critical care management. Patients that might not have survived their underlying disease in the past may now be alive, but highly susceptible to infection.

Perhaps most important to this topic is the assumption in human medicine that 10% to 70% of all HAIs are preventable through the use of practical infection-control measures.⁵ Large economic benefits are estimated to occur with the implementation of infection-control interventions (\$6-\$32 billion cost savings in the United States alone).² The proportion of HAIs that are preventable in veterinary medicine is unknown, but is likely to be similar, and even a 10% reduction in infections could constitute a major impact on patient health, owner cost, and owner and clinician satisfaction. The routine use of simple infection prevention practices can likely dramatically reduce HAIs.

APPROACH/GOALS

Infection control is the term best suited to the goal in small animal veterinary medicine of preventing (or, more practically speaking, limiting) the introduction and/or spread of pathogens with a group of patients and caregivers. Central to this goal is the establishment and refinement of an infection-control program at each animal hospital. Every hospital's infection-control program will be different, reflecting the unique pathogen risks, facility and personnel characteristics, animal populations served, and level of risk tolerance of the practice. However, at a minimum, each practice's program should include the following:

- An infectious disease control officer (otherwise known as an infection-control practitioner);
- A written infection-control protocol (plan);
- Regular training of staff about hospital infection-control protocols (and documentation of this training and assessment of comprehension);
- Monitoring of both disease rates and infection-control protocol compliance.

Together, the components of the program should address the HAI risks for patients and staff and recommended or required protocols to reduce these risks. The end

result will be a safer working environment for staff, optimal care for all patients, and protection of public health. Although good infection-control practices are not the only feature defining excellence in patient care, it is impossible to achieve excellent patient care without them. The standard of what is “acceptable” from an infection-control standpoint is changing in veterinary medicine, and it is clear that the “bar” is being raised in terms of the expected standard of care.

EPIDEMIOLOGY

In human medicine, urinary tract infections (UTIs), pneumonia, surgical site infections (SSIs), and bloodstream infections (BSIs) account for approximately 80% of all HAIs.⁶ In veterinary medicine, these sites along with gastrointestinal disease (infectious diarrhea) are likely to be the most common HAIs, although other conditions, such as upper respiratory tract infection, dermatophyte infection, iatrogenic blood-borne pathogen infection, and infections of a wide range of invasive devices can also occur. Each of these main areas is discussed later, highlighting (where available) incidence, risk factors for disease, and commonly identified pathogens. Because SSIs are being exclusively covered in a separate article in this issue, they are not discussed here.

Sites of Infections

Urinary tract infections

Catheter-associated UTIs are one of the more common HAIs in small animal veterinary medicine, although veterinary data are often limited by the failure to differentiate bacteriuria (a potentially benign condition) from UTI (disease). Studies have reported catheter-associated bacteriuria occurring in 10% to 32% of hospitalized dogs, with a subset of these exhibiting clinical signs or other evidence of infection.^{7–10} The interference of normal defense mechanisms by urinary catheters, such as mucosal-secreted adhesion inhibitors, along with patient comorbid factors and some catheter handling factors, facilitate bacterial colonization of the catheter and ascension of the organism or organisms into the bladder. These pathogens may be endogenous to the patient, arising from the rectum or perineum, or directly from the hospital environment or people through contamination of the drainage system or bag. If the collection system has been contaminated, bacteria can ascend into the bladder through the catheter if there is retrograde flow of urine. Retrograde urine flow can occur if the collection system is elevated above the level of the patient; if collection lines are flushed, or if there is obstruction to flow in the collection system. In addition, biofilms (a complex structure of microorganisms and extracellular matrix) can be produced by bacteria on surfaces of urinary catheters. Biofilm formation can be associated with poor antimicrobial penetration, antimicrobial resistance, and treatment failure.¹¹

Pneumonia

In human medicine, several factors, such as recumbent position, mechanical ventilation, and use of endotracheal or nasogastric tubes, are likely to increase the risk for HA pneumonia.^{12,13} This topic has been minimally investigated in the veterinary field, in large part because of the limited use of mechanical ventilation. In one study, *Escherichia coli* and *Acinetobacter* spp were commonly identified in feline HA ventilator-associated pneumonia cases.¹⁴ Although not included in the human surveillance definition, aspiration pneumonia is not uncommon in small animal medicine and can occur in patients hospitalized for a wide range of disorders as well as otherwise healthy patients undergoing sedation or anesthesia. In addition to those factors listed for human HA pneumonia, factors that increase aspiration pneumonia, such as

laryngeal or esophageal disorders and decreased mentation or recumbency, likely increase HAI risk.^{15–17} If these patients have been hospitalized for multiple days before aspiration, it is more likely that the oropharynx is colonized with organisms from the hospital environment or hands of staff, and the pneumonia may be more likely to involve MDROs, particularly if patients have been treated with antimicrobials.

Bloodstream infections

In the human literature, most HA BSIs are associated with intravascular devices. Duration of catheterization has been recognized as the most important risk factor for the development of catheter-related (CR) BSIs (most developing 4–5 days after placement).¹⁸ Despite this increased risk, studies have not documented a benefit with prophylactic catheter changes (eg, every 3 days). In human medicine, the current recommendation is for catheters to be removed as soon as medically indicated, but for routine changes to be avoided. A similar approach is appropriate in veterinary medicine.

Veterinary studies have revealed that jugular and intravenous catheters are frequently contaminated with enteric or environmental pathogens.^{9,19} Several factors have been positively associated with intravenous catheter contamination/colonization in dogs and cats, including receipt of dextrose infusion, longer duration of catheter placement, and patient immunosuppression (presence of immunosuppressive diseases or receipt of immunosuppressive drugs).²⁰ Commonly isolated organisms include staphylococci, *E coli*, *Enterobacter* spp, *Proteus* spp, and *Klebsiella* spp.^{19–21} Contamination may occur from the hands of people placing or handling the catheter, the patient's own flora, or the hospital environment. However, there is little evidence indicating that contaminated but not infected catheters (ie, catheters from which bacteria can be isolated but where the catheter insertion site and vein are clinically normal) pose a risk for subsequent BSI. As a result, routine culture of catheters at time of removal or culture of catheter insertion sites is not recommended because skin bacteria are expected to be present. Veterinary outbreaks involving CR BSIs have been associated with inadequate skin preparation or contaminated materials used in skin preparation,^{21,22} something that is of most concern when antiseptic solutions or wipes are prepared by refilling bottles or containers, which can become contaminated with biocide-resistant bacteria over time.

Infectious diarrhea

HA gastrointestinal infections are usually recognized when there is a noted increase (outbreak) of infectious diarrhea in hospital patients. Although identification of diarrhea is simple, determination of the cause is often difficult, even for known pathogens. In small animal veterinary facilities, salmonellosis is the most frequently reported gastrointestinal HAI^{4,23}; however, it is unclear whether that is because it poses the greatest risk or (more likely) it is more readily identified and reported compared with other potential causes. In nonhospitalized small animal populations, several risk factors for *Salmonella* colonization or infection have been identified, including animal species (eg, reptiles, amphibians, young poultry, exotics), consuming a raw animal-based diet or treats (eg, raw meat/eggs, rawhides), exposure to livestock, and recently receiving a probiotic.^{24,25} These factors may substantially increase the risk of shedding *Salmonella*, 14% to 69% shedding in dogs with one or more of these risk factors as compared with less than 5% typically noted in dogs without these risk factors.^{25,26} However, the true scope of this issue is unclear because most outbreaks go unnoticed or testing is not performed, but, conversely, clusters of diarrhea seem to be uncommon in most facilities.

Pathogens of Concern

Pathogens involved in small animal HAIs often have one or more of the following characteristics: opportunistic pathogen in companion animals and/or humans, environmentally stable, or multidrug-resistant. Many pathogens involved in HAIs are opportunistic pathogens that can be found in healthy animals, highlighting the inability to prevent entrance of all potential pathogens into a veterinary facility. The frequency of each pathogen varies for each veterinary practice (in part influenced by antimicrobial use/pressure, geography, animal species, vaccine coverage of animals in “catchment” area, level of care provided). In addition, environmentally stable pathogens (eg, parvovirus, clostridial spores, dermatophytes) have a demonstrated clear “advantage,” increasing the chance of transmission. Given the close interaction between veterinary staff and patients as well as the often poor hand hygiene practices documented in veterinary practices, human commensals with zoonotic potential are represented by HAIs in veterinary medicine. Finally, increased resistance to antimicrobials is a common feature of most nosocomial bacteria.

Several pathogens are a concern from a small animal infection-control standpoint (**Box 1**). Although a wide range of pathogens may be involved in HAIs, currently there is a strong focus on the emerging epidemic of multidrug-resistant bacteria because of dramatic increases in infections, limited antimicrobial options, and potential public health consequences. These MDROs are not inherently more virulent than antimicrobial susceptible organisms, but treatment options are limited, something that ultimately can worsen the prognosis. The US Centers for Disease Control and Prevention has recently assessed domestic antibiotic resistance threats for people based on

Box 1

Pathogens of concern in a small animal clinic

- Adenovirus (canine)
- *Bordetella bronchiseptica*
- Calicivirus (feline)
- *Chlamydophila* (feline)
- Distemper virus (canine)
- Herpes virus (feline)
- Influenza viruses (canine, novel)
- *Microsporium canis*
- Parainfluenza virus (canine)
- Parvoviruses (canine, feline)
- Respiratory coronavirus (canine)
- Multidrug-resistant organisms
 - *Acinetobacter* spp
 - *Escherichia coli*
 - *Enterococcus* spp
 - *Salmonella* spp
 - *Staphylococcus* spp
 - *Pseudomonas* spp

clinical and economic impact, incidence, transmissibility, availability of effective antimicrobials, and barriers to prevention. Several pathogens of importance relative to veterinary HAIs were included as “serious antibiotic resistance threats,” namely, *Acinetobacter* spp, extended spectrum β -lactamase-producing Enterobacteriaceae (ESBLs), *Pseudomonas aeruginosa*, *Salmonella* spp, and MRSA.²⁷ As animals and people may share common infection sources or transmit these pathogens to each other, this concern is equally important in the veterinary field, and all of the above-named pathogens can be found in veterinary patients. Given these relatively novel threats and the often limited knowledge by veterinary personnel on this group of pathogens, the attention here is focused on MDROs as HAIs.

In human medicine, HAIs are often captured through voluntary or mandatory hospital reporting. As such, the occurrence (and trends) of HAIs are fairly well-established. In the United States, recent data indicate bacteria are responsible for 90% of HAIs, with commonly identified groups including *Staphylococcus aureus*, *Enterococcus* spp, *E coli*, coagulase-negative staphylococci (CoNS), *Klebsiella* spp, *P aeruginosa*, *Enterobacter* spp, and *Acinetobacter baumannii*.²⁸

Despite the importance of this field, current knowledge of many aspects of the epidemiology of important MDROs and pathogens responsible for HAIs in veterinary medicine is unclear (eg, prevalence, risk factors, and transmission dynamics). Unfortunately, companion animal veterinary medicine has been slow to implement surveillance systems; however, this is changing. Currently, most data come from limited retrospective studies of clinical isolates, likely resulting in geographic and culture-based bias, potentially misrepresenting the frequency of these pathogens and potentially overestimating the prevalence of antimicrobial resistance if culture submissions are biased toward infections that failed to respond to empirical therapy. Regardless, based on the reported veterinary HA outbreaks or supposition from the human literature, several important MDROs responsible for HAIs are identifiable: *S aureus*, *Staphylococcus pseudintermedius*, Enterococci, *Salmonella* spp, *Acinetobacter* spp, *E coli*, and other Enterobacteriaceae, and *Pseudomonas* spp. The specific resistance profiles and treatment options for common multidrug-resistant (MDR) pathogens have recently been summarized.²⁹ The reader is directed to the article elsewhere in this issue of *Veterinary Clinics of North America: Small Animal Practice* by Guardabassi and Prescott entitled, “Antimicrobial stewardship in small animal veterinary practice: from theory to practice,” which expands on the topic of MDROs in HAIs and antimicrobial stewardship.

Current Examples of Multidrug-Resistant Organisms Involved in Hospital-Associated Infections

Staphylococcus

S pseudintermedius and to a lesser extent *S aureus* are common causes of veterinary HAIs.³⁰ Both are frequently carried on the skin and mucosal surfaces of dogs and people (respectively), creating the potential for both endogenous infection (infection caused by bacteria the animal was harboring at the time of hospital admission) and acquisition of the pathogen during hospitalization directly or indirectly from other patients, the environment, or human caregivers. The emergence of methicillin resistance in these species (methicillin-resistant *S pseudintermedius* [MRSP] and MRSA) has had important implications for HAI prevention and control. Methicillin resistance is mediated by the *mecA* gene, which results in resistance to β -lactam antimicrobials (penicillins, cephalosporins, and carbapenems). In addition, resistance to other classes of antimicrobials is frequently observed: lincosamides (clindamycin), fluoroquinolones, macrolides (erythromycin), tetracyclines, trimethoprim-sulfonamides.^{29,31,32}

MRSA is an important pathogen in human HAIs, being a common cause of SSIs and various other types of infections.³³ To a lesser extent, MRSA has also been noted in veterinary HAIs.³⁴ Risk factors for veterinary MRSA HAIs have not been well studied, but prior antimicrobial use, prior hospitalization, ownership by veterinary or human health care workers/students, and longer hospitalization (>3 days) have been associated with MRSA colonization or infection in dogs.^{35–38} Furthermore, the use of fluoroquinolones and cephalosporins has been linked to the emergence of MRSA in people and may play a role in veterinary species.³⁹ It is important to note that an abnormally high proportion of veterinarians are colonized with MRSA as compared with the general public.⁴⁰ As such, they may serve as a source for HAIs in their patients if infection-control practices (notably hand hygiene) are substandard. This also likely indicates deficiencies in standard infection control and hygiene practices that allow for transmission of MRSA between veterinary personnel and animals.

MRSP has rapidly spread in canine populations, often with high levels of antimicrobial resistance,⁴¹ something that is of tremendous concern because *S pseudintermedius* is the leading opportunistic pathogen in dogs (and, to a lesser degree, cats). It is the most common cause of SSIs in some regions,⁴² and treatment may be complicated because of the high level of resistance. In one study, more than 90% of MRSP isolates were also resistant to 4 additional antimicrobial classes.⁴³ Recent prior hospitalization and β -lactam antimicrobial administration have been associated with MRSP infections,⁴⁴ suggesting hospital-associated transmission may be a factor in MRSP disease.

The topic of CoNS deserves mention. Veterinary diagnostic laboratories often consider these species as a group and speciation is rarely performed. CoNS are frequently identified as commensals in small animal species, with high methicillin resistance in healthy animals. With the exception of highly compromised individuals, it has been generally assumed that CoNS, even those that are multidrug resistant, are of limited clinical concern. That assumption has been challenged to some degree and some CoNS species may be more clinically relevant than others; however, this group remains a less common cause for concern compared with *S pseudintermedius* and *S aureus*. However, their commonness as skin or mucous membrane commensals can complicate interpretation of culture results because differentiating infection from contamination may be challenging.

Escherichia coli

E coli is a frequent component of the commensal gastrointestinal microbiota and is an important pathogen, particularly in UTIs. MDRE *coli* is frequently shed in the feces of both community and hospitalized small animals.^{45–47} Multiple factors have been associated with dogs shedding or acquiring MDR *E coli* during hospitalization, including duration of hospitalization (>3 days) and treatment with antimicrobials shortly before or while hospitalized (cephalosporins, metronidazole).^{38,48}

Antimicrobial resistance is an important problem with *E coli* and other Enterobacteriaceae (eg, *Enterobacter*). Although β -lactamase-producing isolates have been common for some time, there has been a recent emergence of ESBLs producers, which provide resistance to a broad range of β -lactam antimicrobials, including third-generation cephalosporins. In addition, ESBLs are conferred resistance to other antimicrobial classes through genetic linkage with resistance mechanisms.⁴⁹ Extended spectrum β -lactamase-producing *E coli* has been identified as the source of veterinary HAIs, occurring as SSIs and catheter-associated UTIs, with observed hospital contamination.^{50,51} Other genera in the Enterobacteriaceae family (ie, *Klebsiella*,

Enterobacter) are considered to be important in human HAIs; however, less is known of their involvement in veterinary infections.

One of the most important drug classes for treatment of ESBL-producing bacteria is carbapenems (eg, meropenem). Unfortunately, carbapenemase-producing Enterobacteriaceae (or carbapenem-resistant Enterobacteriaceae; CRE) (including *E coli*) have emerged as a significant problem in human health care. Additional resistance mechanisms are often present, rendering isolates virtually pan-resistant, and ability for CREs to spread rapidly in health care settings with extension into the community.⁵² High mortality (>40%) has been documented for invasive human CRE infections.⁵³ Carbapenemase-producing *E coli* have recently been identified in small animals, with suggested nosocomial transmission.⁵⁴ Nosocomial transmission currently seems to be a rare, albeit concerning, occurrence, and one that is likely to increase as CREs increase in prevalence in the human population, with subsequent exposure of pets.

Enterococci

Enterococci are often found in the gastrointestinal tract of animals and humans. Two species, *Enterococcus faecium* and *Enterococcus faecalis*, are most often involved in disease, including HAIs, although enterococci tend to be of limited virulence and typically cause infections in compromised hosts. Enterococci are inherently resistant to several antimicrobial classes, including cephalosporins, some penicillins, fluoroquinolones, clindamycin, and trimethoprim.⁵⁵ They may also acquire resistance to various other antimicrobial classes and, although they are typically of limited virulence, they may be difficult to eliminate in cases when disease develops.

Vancomycin-resistant enterococci (VRE) are an increasing concern in human medicine, with vancomycin resistance noted in up to 83% of *E faecium* involved in HAIs.²⁸ To date, VRE appears to be rare in companion animals.⁵⁶ However, other MDR enterococci are regularly recognized in small animals and have been identified in HAIs.^{30,57,58} Enterococci are often identified as UTIs (including catheter-associated); however, infections at other anatomic sites occur (eg, SSIs, BSIs, pneumonia). The high degree of antimicrobial resistance, ability to propagate for extended periods in small animal hosts as a commensal, and environmental persistence make enterococci particularly challenging when involved in HAIs.

It is important to note that isolation of *Enterococcus* species (regardless of antimicrobial resistance) does not always indicate treatment is indicated. Without clinical signs in an otherwise immune-competent animal, it may be warranted to withhold treatment and monitor the patient. When isolated in a patient with clinical signs (notably infections of the urinary tract, wound, or body cavity), treatment should often be directed at the organism or organisms also isolated that are thought to be primarily responsible for clinical disease.²⁹ Often, that involves ignoring the *Enterococcus* and targeting therapy toward another, more convincing, pathogen, such as *E coli*.

Salmonella spp

Salmonella is most frequently a concern in equine facilities, but has been identified as a source of sporadic illness and hospital-associated outbreaks in small animal hospitals.^{23,59} An important concern with *Salmonella* HAIs is the occurrence of zoonotic transmission with accompanying human infections.^{23,59} Because most infections in dogs and cats are subclinical, there is a high risk for inadvertent hospital-wide environmental contamination and nosocomial transmission. Reported factors leading to an increased risk of *Salmonella* shedding in small animals include consumption of raw meat diets, exposure to livestock, and receiving a probiotic in the previous 30 days.^{25,60} As with *E coli*, ESBL-producing strains are a concern for antimicrobial

resistance and have been identified in small animals.⁶¹ Given its environmental stability, potential shedding by healthy animals, and significant zoonotic health hazard to clinic staff and clients, *Salmonella* needs to be considered an important companion animal nosocomial pathogen.

Acinetobacter spp

Acinetobacter is well-recognized as an important HA pathogen in human medicine, in part because of recently recognized high levels of antimicrobial resistance in *A baumannii*. More than 60% of *A baumannii* human isolates involved in HAIs were MDR in one study.²⁸ Given its role as an opportunistic pathogen in small animals, ability to persist in the environment for extended periods, and documented outbreaks in veterinary facilities, it is also a concern for veterinary medicine.^{30,62,63} Documented HAIs involving *A baumannii* include intravenous and urinary catheters, surgical drain infections, SSIs, pneumonia, and BSIs.⁶²

Pseudomonas spp

Multidrug resistance is frequently encountered with *Pseudomonas spp*. This along with their noted persistence in the hospital environment makes *Pseudomonas spp* a concern for HAIs. In humans, most infections are HA and occur in immunocompromised hosts.⁶⁴ In companion animal species, *Pseudomonas spp* infections often involve the skin, urinary system, and ears,^{65–67} along with SSIs and invasive device infections.^{68,69} Biofilm formation by *Pseudomonas spp* can further complicate treatment. Identification of within hospital clusters of *Pseudomonas* infections should prompt investigation of potentially contaminated environmental, equipment (eg, endoscope), or consumable (eg, catheter preparation supplies) sources.

CHALLENGES/RISKS

The admission of sick animals occurs daily in most if not all small animal veterinary facilities. Furthermore, every animal admitted to the veterinary clinic, healthy or not, can reasonably be assumed to be shedding multiple microorganisms that could cause infection in humans or animals, given the opportunity. As such, there is always a risk for the introduction and spread of HAIs and for exposure to zoonotic pathogens. The level of risk will be determined, in part, by the population of animals served (eg, young, elderly, immunocompromised), pathogens circulating in the community animals, proportion of patients for which protective or increased-risk practices are taken by their owners (eg, vaccination, husbandry practices to reduce pathogen acquisition), intensity of care typically provided for patients, and clinic infection-control practices and adherence to these practices by staff and clients. Veterinary clinic staff will not be able to alter many of these risks; however, infection-control practices is an area that with some planning and dedicated time, can be relatively easy to address.

PREVENTION

Although complete prevention of HAIs is the goal, given the nature of patient care, bacterial adaptation, and complexity of many pathogens (subclinical shedding, insensitive diagnostic tests), it is inevitable they will continue to occur. Methods to reduce the risk of HAIs are paramount. In general, methods to reduce HAIs can be divided into the following main categories:

- Hand hygiene and use of personal protective equipment (PPE; ie, clothing and/or gloves to reduce contamination of staff, patients, and the environment);
- Cleaning and disinfection (environmental surfaces and patient equipment);

- Patient management (eg, cohorting patients based on risk, isolating high-risk patients, discontinuing the use of higher risk devices when indicated);
- Surveillance (identification of infected or colonized patients, HAIs, and source/risk factors);
- Antimicrobial stewardship (prudent antimicrobial use);
- Education and training (clients, staff).

These methods will not only reduce overt problems such as hospital-associated outbreaks but also reduce the likelihood of patient colonization with a HA pathogen, which can become part of the patient's resident microbiota, potentially increasing disease risk at a later date and posing a risk to other animals and humans. Each of these areas should be addressed in a hospital's infection-control manual. Several "model" plans are widely available to use as a starting point for developing an individualized hospital plan; infection-control officers are encouraged to review these resources.^{70,71} Individual articles in this issue of *Veterinary Clinics of North America: Small Animal Practice* are devoted to each of these areas, so they are only briefly discussed here. Unfortunately, studies on the area indicate only a minority of small animal veterinary hospitals have written infection-control plans (0%–31%).^{72,73} Given the relative ease of putting together an infection-control plan and potential health, legal, and financial benefits of doing so, every clinic should invest the time and effort to make this a priority.

Hand Hygiene and Personal Protective Equipment

Hand hygiene (washing hands with soap and water or using an alcohol-based hand rub) and use of PPE, such as nonsterile gloves and gowns, are simple techniques that can reduce the risk of HAIs. Effective use of hand hygiene and appropriate PPE use reduces the risk of contamination of personal clothing, reduces exposure of skin and mucous membranes of veterinary staff to pathogens, and reduces transmission of pathogens between patients by veterinary personnel. Unfortunately, several studies indicate that veterinarians and staff do a poor job at performing hand hygiene between patients (~20%) or using PPE when indicated (6%–37% depending on the situation).^{72,74}

Cleaning and Disinfection

Recent evidence suggests environmental contamination in human hospitals increases the risk for HAIs,⁷⁵ whereas interventions that reduce environmental contamination have assisted with cessation of HA outbreaks or reduction of HAIs.^{76,77} The same connection is assumed to occur in veterinary medicine. Effective cleaning and disinfection of hospital equipment and environmental surfaces play an important role in reducing HAIs. In order for a disinfectant to work properly, the surface or item must first be clean (free of visible organic material) and the product must be applied at the manufacturer's suggested dilution and contact time (amount of time the disinfectant is in contact with the item before being removed). Disinfectants should be selected based on several criteria, including the product's spectrum of activity, susceptibility to inactivation by organic matter, and potential pathogens in the environment.

Patient Management

Given the close contact between veterinary patients and their hospital housing, environmental contamination is inevitable. Furthermore, staff caring for these patients is at increased risk for spreading the pathogen through contact with the patient or its

environment. To protect other patients and clinic staff, special attention to patient housing is important in managing infectious patients. Isolation procedures, use of dedicated medical equipment, and patient cohorting are important stopgaps in the transmission of HAIs for animals suspected to be infectious. In addition, specific patient care procedures may be helpful in reducing HAIs associated with catheters, aspiration pneumonia, BSIs, infectious diarrhea, and SSIs.

Resident small animals are sometimes kept at veterinary facilities as blood donors, companionship for staff, or other reasons. Because these animals may harbor MDR pathogens and be sources or propagation of hospital contamination or outbreaks, special attention should be devoted to hospital policies for these animals regarding staff-animal contact and restricted movement (not permitting direct contact with patients or patient areas, including areas for exercise and elimination).^{78,79}

Surveillance

The early identification of HAIs is critical for effective infection control. Identification of “abnormal” (increases in disease incidence or patterns) depends on a reasonable understanding of “normal.” Understanding of endemic rates can be useful to allow for comparison with other facilities, to establish benchmarks for ongoing surveillance, to serve as a baseline for interventions, to allow for more accurate counseling of clients about risks (eg, SSI rates), and to provide a greater overall awareness of the importance of HAIs and corresponding control measures. It is not unusual for HAI outbreaks to “smolder” below the radar of veterinary staff for extended periods because of the lack of centralized data reporting or communication, resulting in substantial environmental contamination, patient morbidity (and potentially mortality), and even increased zoonotic disease risk for staff and clients. Key elements of early HAI identification include (1) a surveillance program tailored to the risks and needs of the veterinary practice and (2) routine use of diagnostic culture and susceptibility data to establish practice-specific baseline levels of pathogen prevalence and antimicrobial resistance and detect changes from this baseline.

Antimicrobial Stewardship

Careful selection and appropriate use of antimicrobials are important steps in combating patient MDRO development and subsequent contamination and transmission in the hospital environment. Antimicrobials should be avoided when a bacterial infection has not been confirmed. Antimicrobials used in the initial treatment of an infection should be selected based on the effectiveness against the most likely organisms causing the infection (something that can be facilitated by having good passive surveillance data) as well as patient (eg, renal function, comorbidities) or drug (eg, penetration, route of administration, frequency of administration) factors. Whenever possible, a culture should be submitted to determine the true susceptibility pattern of the bacteria involved. Local therapy can be an important option that is often overlooked.

Education and Training

During their careers, approximately two-thirds of veterinarians report a major animal-related injury resulting in lost work or hospitalization.^{71,80} Animal bite injuries and infections are a large contributor to this hazard, but zoonotic infections (eg, MRSA, dermatophytosis [ringworm], salmonellosis) are also frequently reported.^{23,81} Educating staff and clients on zoonotic disease risks and enforcing in-hospital infection-control protocols to reduce these risks will be beneficial to the health of people and patients.

All veterinary personnel and visitors should be familiar with the hospital's infection-control plan and policies.

The Infection-Control Officer/Infection-Control Practitioner

The infection-control officer is integral to the successful development, maintenance, and enforcement of an infection-control plan. In the human health care field, infection-control practitioners are formally trained and certified, with the infection-control program typically overseen by a physician with specialized training in infectious diseases, infection control, and/or microbiology. In veterinary medicine, this type of approach is only practiced in large facilities (mainly teaching hospitals), yet the basic concepts remain the same for veterinary facilities of any type and size. A functional infection-control program can be directed by a single infection-control practitioner in a veterinary hospital, with minimal time requirements. This individual can be a technician or veterinarian who has an interest in infection control. The skills required (eg, general understanding of infection-control concepts) can be obtained on the job and need not be a prerequisite for the position, and the limited time requirement under normal circumstances means that a new position does not need to be added. Rather, direction of the infection control can usually be undertaken by an existing staff member. Of greatest importance for the individual filling this position is an interest in the topic, motivation to make improvements in the clinic's infection-control policies, and the support of clinic leaders (eg, practice owners, veterinarians). Without full support by clinic leaders (eg, time to perform the required duties, financial investments, serving as a role model by following clinic infection-control policies), the infection-control officer, and resulting program, is unlikely to be successful.

SUMMARY

HAIs have been reported in veterinary medicine and their frequency is likely to increase with the increase in intensive care practices in many veterinary hospitals. Prolonged hospitalization and the use of invasive devices and procedures increase the risk of HAIs. All staff members should be educated on the risks and signs associated with HAIs so that cases can be detected early and managed appropriately. Ultimately, a multifaceted approach is necessary to address HAIs in small animal veterinary medicine, including prudent antimicrobial use, strengthening surveillance of HAIs in companion animals, improving infection-control practices (eg, hand hygiene, PPE, cleaning and disinfection, patient management), instilling an infection-control culture among veterinary staff, and improving health care and public education of antimicrobials. A hospital infection-control program, consisting of an infectious disease control officer, a written protocol, and staff training, is a key component to unifying these elements and successful reduction of HAIs in small animal veterinary practice.

REFERENCES

1. Klevens RM, Edwards JR, Richards CL Jr, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. *Public Health Rep* 2007;122(2): 160–6.
2. Scott RD. *The direct medical costs of healthcare-associated infections in U.S. hospitals and the benefits of prevention*. Atlanta (GA): Centers for Disease Control and Prevention; Division of Healthcare Quality Promotion; 2009.

3. Ruple-Czerniak A, Aceto HW, Bender JB, et al. Using syndromic surveillance to estimate baseline rates for healthcare-associated infections in critical care units of small animal referral hospitals. *J Vet Intern Med* 2013;27(6):1392–9.
4. Benedict KM, Morley PS, Van Metre DC. Characteristics of biosecurity and infection control programs at veterinary teaching hospitals. *J Am Vet Med Assoc* 2008; 233(5):767–73.
5. Harbarth S, Sax H, Gastmeier P. The preventable proportion of nosocomial infections: an overview of published reports. *J Hosp Infect* 2003;54(4): 258–66.
6. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. *Am J Infect Control* 2008;36(5):309–32.
7. Ogeer-Gyles J, Mathews K, Weese JS, et al. Evaluation of catheter-associated urinary tract infections and multi-drug-resistant *Escherichia coli* isolates from the urine of dogs with indwelling urinary catheters. *J Am Vet Med Assoc* 2006; 229(10):1584–90.
8. Smarick SD, Haskins SC, Aldrich J, et al. Incidence of catheter-associated urinary tract infection among dogs in a small animal intensive care unit. *J Am Vet Med Assoc* 2004;224(12):1936–40.
9. Lippert A, Fulton R Jr, Parr A. Nosocomial infection surveillance in a small animal intensive care unit. *J Am Anim Hosp Assoc* 1988;24(6):627–36.
10. Biertuempfel PH, Ling GV, Ling GA. Urinary tract infection resulting from catheterization in healthy adult dogs. *J Am Vet Med Assoc* 1981;178(9):989–91.
11. Saint S, Chenoweth CE. Biofilms and catheter-associated urinary tract infections. *Infect Dis Clin North Am* 2003;17(2):411–32.
12. von Dossow V, Rotard K, Redlich U, et al. Circulating immune parameters predicting the progression from hospital-acquired pneumonia to septic shock in surgical patients. *Crit Care* 2005;9(6):R662–9.
13. Drakulovic MB, Torres A, Bauer TT, et al. Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: a randomised trial. *Lancet* 1999;354(9193):1851–8.
14. Lee JA, Drobatz KJ, Koch MW, et al. Indications for and outcome of positive-pressure ventilation in cats: 53 cases (1993-2002). *J Am Vet Med Assoc* 2005; 226(6):924–31.
15. MacPhail CM, Monnet E. Outcome of and postoperative complications in dogs undergoing surgical treatment of laryngeal paralysis: 140 cases (1985-1998). *J Am Vet Med Assoc* 2001;218(12):1949–56.
16. Brainard BM, Alwood AJ, Kushner LI, et al. Postoperative pulmonary complications in dogs undergoing laparotomy: anesthetic and perioperative factors. *J Vet Emerg Crit Care* 2006;16(3):184–91.
17. Java MA, Drobatz KJ, Gilley RS, et al. Incidence of and risk factors for postoperative pneumonia in dogs anesthetized for diagnosis or treatment of intervertebral disk disease. *J Am Vet Med Assoc* 2009;235(3):281–7.
18. Collins RN, Braun PA, Zinner SH, et al. Risk of local and systemic infection with polyethylene intravenous catheters. A prospective study of 213 catheterizations. *N Engl J Med* 1968;279(7):340–3.
19. Marsh-Ng ML, Burney DP, Garcia J. Surveillance of infections associated with intravenous catheters in dogs and cats in an intensive care unit. *J Am Anim Hosp Assoc* 2007;43(1):13–20.
20. Seguela J, Pages JP. Bacterial and fungal colonisation of peripheral intravenous catheters in dogs and cats. *J Small Anim Pract* 2011;52(10):531–5.

21. Burrows CF. Inadequate skin preparation as a cause of intravenous catheter-related infection in the dog. *J Am Vet Med Assoc* 1982;180(7):747–9.
22. Mathews KA, Brooks MJ, Valliant AE. A prospective study of intravenous catheter contamination. *J Vet Emerg Crit Care* 1996;6(1):33–43.
23. Cherry B, Burns A, Johnson GS, et al. *Salmonella* Typhimurium outbreak associated with veterinary clinic. *Emerg Infect Dis* 2004;10(12):2249–51.
24. Leonard EK, Pearl DL, Finley RL, et al. Evaluation of pet-related management factors and the risk of *Salmonella* spp. carriage in pet dogs from volunteer households in Ontario (2005–2006). *Zoonoses Public Health* 2011;58(2):140–9.
25. Lenz J, Joffe D, Kauffman M, et al. Perceptions, practices, and consequences associated with foodborne pathogens and the feeding of raw meat to dogs. *Can Vet J* 2009;50(6):637–43.
26. Cantor GH, Nelson S Jr, Vanek JA, et al. *Salmonella* shedding in racing sled dogs. *J Vet Diagn Invest* 1997;9(4):447–8.
27. Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States, 2013. Atlanta (GA): Centers for Disease Control and Prevention; 2013.
28. Sievert DM, Ricks P, Edwards JR, et al. Antimicrobial-resistant pathogens associated with healthcare-associated infections: summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2009–2010. *Infect Control Hosp Epidemiol* 2013;34(1):1–14.
29. Papich MG. Antibiotic treatment of resistant infections in small animals. *Vet Clin North Am Small Anim Pract* 2013;43(5):1091–107.
30. Boerlin P, Eugster S, Gaschen F, et al. Transmission of opportunistic pathogens in a veterinary teaching hospital. *Vet Microbiol* 2001;82(4):347–59.
31. Faires MC, Gard S, Aucoin D, et al. Inducible clindamycin-resistance in methicillin-resistant *Staphylococcus aureus* and methicillin-resistant *Staphylococcus pseudintermedius* isolates from dogs and cats. *Vet Microbiol* 2009;139(3–4):419–20.
32. Sasaki T, Kikuchi K, Tanaka Y, et al. Methicillin-resistant *Staphylococcus pseudintermedius* in a veterinary teaching hospital. *J Clin Microbiol* 2007;45(4):1118–25.
33. Anderson DJ, Sexton DJ, Kanafani ZA, et al. Severe surgical site infection in community hospitals: epidemiology, key procedures, and the changing prevalence of methicillin-resistant *Staphylococcus aureus*. *Infect Control Hosp Epidemiol* 2007;28(9):1047–53.
34. Weese JS, Dick H, Willey BM, et al. Suspected transmission of methicillin-resistant *Staphylococcus aureus* between domestic pets and humans in veterinary clinics and in the household. *Vet Microbiol* 2006;115(1–3):148–55.
35. Hoet AE, van Balen J, Nava-Hoet RC, et al. Epidemiological profiling of methicillin-resistant *Staphylococcus aureus*-positive dogs arriving at a veterinary teaching hospital. *Vector Borne Zoonotic Dis* 2013;13(6):385–93.
36. Faires MC, Traverse M, Tater KC, et al. Methicillin-resistant and -susceptible *Staphylococcus aureus* infections in dogs. *Emerg Infect Dis* 2010;16(1):69–75.
37. Soares Magalhaes RJ, Loeffler A, Lindsay J, et al. Risk factors for methicillin-resistant *Staphylococcus aureus* (MRSA) infection in dogs and cats: a case-control study. *Vet Res* 2010;41(5):55.
38. Hamilton E, Kruger JM, Schall W, et al. Acquisition and persistence of antimicrobial-resistant bacteria isolated from dogs and cats admitted to a veterinary teaching hospital. *J Am Vet Med Assoc* 2013;243(7):990–1000.
39. Dancer SJ. The effect of antibiotics on methicillin-resistant *Staphylococcus aureus*. *J Antimicrob Chemother* 2008;61(2):246–53.

40. Hanselman BA, Kruth SA, Rousseau J, et al. Methicillin-resistant *Staphylococcus aureus* colonization in veterinary personnel. *Emerg Infect Dis* 2006;12(12):1933–8.
41. Perreten V, Kadlec K, Schwarz S, et al. Clonal spread of methicillin-resistant *Staphylococcus pseudintermedius* in Europe and North America: an international multicentre study. *J Antimicrob Chemother* 2010;65(6):1145–54.
42. Nicol C, Singh A, Weese JS. Economic impact of tibial plateau leveling osteotomy surgical site infection in dogs. *Vet Surg* 2014;43:899–902.
43. Bemis DA, Jones RD, Frank LA, et al. Evaluation of susceptibility test breakpoints used to predict *mecA*-mediated resistance in *Staphylococcus pseudintermedius* isolated from dogs. *J Vet Diagn Invest* 2009;21(1):53–8.
44. Weese JS, Faires MC, Frank LA, et al. Factors associated with methicillin-resistant versus methicillin-susceptible *Staphylococcus pseudintermedius* infection in dogs. *J Am Vet Med Assoc* 2012;240(12):1450–5.
45. Wedley AL, Maddox TW, Westgarth C, et al. Prevalence of antimicrobial-resistant *Escherichia coli* in dogs in a cross-sectional, community-based study. *Vet Rec* 2011;168(13):354.
46. Murphy C, Reid-Smith RJ, Prescott JF, et al. Occurrence of antimicrobial resistant bacteria in healthy dogs and cats presented to private veterinary hospitals in southern Ontario: a preliminary study. *Can Vet J* 2009;50(10):1047–53.
47. Gibson JS, Morton JM, Cobbold RN, et al. Risk factors for multidrug-resistant *Escherichia coli* rectal colonization of dogs on admission to a veterinary hospital. *Epidemiol Infect* 2011;139(2):197–205.
48. Gibson JS, Morton JM, Cobbold RN, et al. Risk factors for dogs becoming rectal carriers of multidrug-resistant *Escherichia coli* during hospitalization. *Epidemiol Infect* 2011;139(10):1511–21.
49. Pitout JD. Infections with extended-spectrum beta-lactamase-producing *enterobacteriaceae*: changing epidemiology and drug treatment choices. *Drugs* 2010;70(3):313–33.
50. Sanchez S, McCrackin Stevenson MA, Hudson CR, et al. Characterization of multidrug-resistant *Escherichia coli* isolates associated with nosocomial infections in dogs. *J Clin Microbiol* 2002;40(10):3586–95.
51. Sidjabat HE, Townsend KM, Lorentzen M, et al. Emergence and spread of two distinct clonal groups of multidrug-resistant *Escherichia coli* in a veterinary teaching hospital in Australia. *J Med Microbiol* 2006;55(Pt 8):1125–34.
52. Centers for Disease Control and Prevention (CDC). Vital signs: carbapenem-resistant Enterobacteriaceae. *Morb Mortal Wkly Rep* 2013;62(9):165–70.
53. Patel G, Huprikar S, Factor SH, et al. Outcomes of carbapenem-resistant *Klebsiella pneumoniae* infection and the impact of antimicrobial and adjunctive therapies. *Infect Control Hosp Epidemiol* 2008;29(12):1099–106.
54. Stolle I, Prenger-Berninghoff E, Stamm I, et al. Emergence of OXA-48 carbapenemase-producing *Escherichia coli* and *Klebsiella pneumoniae* in dogs. *J Antimicrob Chemother* 2013;68:2802–8.
55. Mascini EM, Bonten MJ. Vancomycin-resistant enterococci: consequences for therapy and infection control. *Clin Microbiol Infect* 2005;11(Suppl 4):43–56.
56. Damborg P, Sorensen AH, Guardabassi L. Monitoring of antimicrobial resistance in healthy dogs: first report of canine ampicillin-resistant *Enterococcus faecium* clonal complex 17. *Vet Microbiol* 2008;132(1–2):190–6.
57. Ossiprandi MC, Bottarelli E, Cattabiani F, et al. Susceptibility to vancomycin and other antibiotics of 165 *Enterococcus* strains isolated from dogs in Italy. *Comp Immunol Microbiol Infect Dis* 2008;31(1):1–9.

58. Ghosh A, Dowd SE, Zurek L. Dogs leaving the ICU carry a very large multi-drug resistant enterococcal population with capacity for biofilm formation and horizontal gene transfer. *PLoS One* 2011;6(7):e22451.
59. Wright JG, Tengelsen LA, Smith KE, et al. Multidrug-resistant *Salmonella* Typhimurium in four animal facilities. *Emerg Infect Dis* 2005;11(8):1235–41.
60. Leonard EK, Pearl DL, Finley RL, et al. Comparison of antimicrobial resistance patterns of *Salmonella* spp. and *Escherichia coli* recovered from pet dogs from volunteer households in Ontario (2005–06). *J Antimicrob Chemother* 2012;67:174–81.
61. Frye JG, Fedorka-Cray PJ. Prevalence, distribution and characterisation of ceftiofur resistance in *Salmonella enterica* isolated from animals in the USA from 1999 to 2003. *Int J Antimicrob Agents* 2007;30(2):134–42.
62. Francey T, Gaschen F, Nicolet J, et al. The role of *Acinetobacter baumannii* as a nosocomial pathogen for dogs and cats in an intensive care unit. *J Vet Intern Med* 2000;14(2):177–83.
63. Zordan S, Prenger-Berninghoff E, Weiss R, et al. Multidrug-resistant *Acinetobacter baumannii* in veterinary clinics, Germany. *Emerg Infect Dis* 2011;17(9):1751–4.
64. Agodi A, Barchitta M, Cipresso R, et al. *Pseudomonas aeruginosa* carriage, colonization, and infection in ICU patients. *Intensive Care Med* 2007;33(7):1155–61.
65. Lin D, Foley SL, Qi Y, et al. Characterization of antimicrobial resistance of *Pseudomonas aeruginosa* isolated from canine infections. *J Appl Microbiol* 2012;113(1):16–23.
66. Nuttall T, Cole LK. Evidence-based veterinary dermatology: a systematic review of interventions for treatment of *Pseudomonas* otitis in dogs. *Vet Dermatol* 2007;18(2):69–77.
67. Gatoria IS, Saini NS, Rai TS, et al. Comparison of three techniques for the diagnosis of urinary tract infections in dogs with urolithiasis. *J Small Anim Pract* 2006;47(12):727–32.
68. Fine DM, Tobias AH. Cardiovascular device infections in dogs: report of 8 cases and review of the literature. *J Vet Intern Med* 2007;21(6):1265–71.
69. Peremans K, De Winter F, Janssens L, et al. An infected hip prosthesis in a dog diagnosed with a 99mTc-ciprofloxacin (infecton) scan. *Vet Radiol Ultrasound* 2002;43(2):178–82.
70. Canadian Committee on Antibiotic Resistance. Infection prevention and control best practices for small animal veterinary clinics. 2008. Available at: [http://www.wormsandgermsblog.com/uploads/file/CCAR%20Guidelines%20Final\(2\).pdf](http://www.wormsandgermsblog.com/uploads/file/CCAR%20Guidelines%20Final(2).pdf). Accessed December 6, 2014.
71. Scheffel JM, Elchos BL, Cherry B, et al. Compendium of veterinary standard precautions for zoonotic disease prevention in veterinary personnel: National Association of State Public Health Veterinarians Veterinary Infection Control Committee 2010. *J Am Vet Med Assoc* 2010;237(12):1403–22. Available at: <http://www.nasphv.org/Documents/VeterinaryPrecautions.pdf>.
72. Wright JG, Jung S, Holman RC, et al. Infection control practices and zoonotic disease risks among veterinarians in the United States. *J Am Vet Med Assoc* 2008;232(12):1863–72.
73. Murphy CP, Reid-Smith RJ, Weese JS, et al. Evaluation of specific infection control practices used by companion animal veterinarians in community veterinary practices in southern Ontario. *Zoonoses Public Health* 2010;57(6):429–38.
74. Shea A, Shaw S. Evaluation of an educational campaign to increase hand hygiene at a small animal veterinary teaching hospital. *J Am Vet Med Assoc* 2012;240(1):61–4.

75. Donskey CJ. Does improving surface cleaning and disinfection reduce health care-associated infections? *Am J Infect Control* 2013;41(Suppl 5):S12–9.
76. Orenstein R, Aronhalt KC, McManus JE Jr, et al. A targeted strategy to wipe out *Clostridium difficile*. *Infect Control Hosp Epidemiol* 2011;32(11):1137–9.
77. Denton M, Wilcox MH, Parnell P, et al. Role of environmental cleaning in controlling an outbreak of *Acinetobacter baumannii* on a neurosurgical intensive care unit. *J Hosp Infect* 2004;56(2):106–10.
78. Weese JS, Armstrong J. Outbreak of *Clostridium difficile*-associated disease in a small animal veterinary teaching hospital. *J Vet Intern Med* 2003;17(6):813–6.
79. Ghosh A, Kukanich K, Brown CE, et al. Resident cats in small animal veterinary hospitals carry multi-drug resistant enterococci and are likely involved in cross-contamination of the hospital environment. *Front Microbiol* 2012;3:62.
80. Baker WS, Gray GC. A review of published reports regarding zoonotic pathogen infection in veterinarians. *J Am Vet Med Assoc* 2009;234(10):1271–8.
81. Lipton BA, Hopkins SG, Koehler JE, et al. A survey of veterinarian involvement in zoonotic disease prevention practices. *J Am Vet Med Assoc* 2008;233(8):1242–9.