THE VETERINARY CLINICS
Food Animal Practice

Vet Clin Food Anim 18 (2002) 133–155

Biosecurity of veterinary practices

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Biosecurity refers to all hygienic practices designed to prevent occurrences of infectious diseases. This includes preventing introduction of infectious agents, controlling their spread within populations or facilities, and containment or disinfection of infectious materials. Biosecurity is affected tremendously by the ecology of animal and human populations, the biologic nature of infectious agents, and by management actions that affect interactions between host and agent. This aspect of husbandry has gained increasing attention in the past few years from producers and veterinarians. Globalization of the economy has increased pressures to control and regionally eradicate infectious diseases to preserve marketability of livestock and animal products. At the same time, trends in livestock production are toward larger, more intensive production units that have undoubtedly increased the risk of introduction and transmission of infectious agents. Veterinarians and hospital facilities likely play a role in this increased risk of disease transmission, conflicting with desires to make veterinarians an integral part of the production team. The litigious nature of modern business environments adds another stimulus for improved biosecurity, as do political and social pressures for increased food safety.

Nosocomial infections in veterinary hospitals are not solely a patient-care concern; the spread of infectious agents also can significantly affect normal hospital operations, revenue, client confidence, public image, and the morale of hospital personnel. In some cases nosocomial agents are also zoonotic. In 1996, Colorado State University's Veterinary Teaching Hospital (CSU-VTH) experienced an outbreak of *Salmonella infantis* in their large animal facility [21]. This outbreak involved a total of 59 animals, primarily horses, and the death of three animals was attributed to complications from *S.* Infantis infection. The large animal hospital was temporarily closed twice because of this epidemic, which resulted in an estimated $300,000 in lost revenues in addition to $250,000 required for facility renovation. These financial losses do not account for intangible losses such as diminished client

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PII: S0749-0720(02)00009-9

confidence, morale problems among hospital personnel, and lost learning opportunities for students. Fortunately this *Salmonella* outbreak at CSU did not result in identifiable human illness or infection, but exposure to a variety of zoonotic agents has been documented at other times in association with care of veterinary patients [5,11,14,19]

This type of outbreak is not unusual at large veterinary facilities. According to a 1997 survey of veterinary teaching hospitals in the United States, 12 of 18 veterinary schools that responded reported 18 outbreaks of nosocomial disease between 1985 and 1996 (Dr. A.W. Nelson, DVM, PhD, personal communication, Fort Collins, CO, 2000). Seventy-eight percent of outbreaks were attributed to *Salmonella*. High caseload was cited by eight respondents as being a significant contributor to the risk of nosocomial disease spread. Forty-three percent ($n = 6$) of *Salmonella*-associated outbreaks resulted in hospital closure, and estimated costs per outbreak ranged from approximately $10,000 to $550,000. At the time of this survey, only half of the respondents had active infection control committees, and only three employed a person responsible for infection control at the hospital.

Although most of the preceding information comes from events at large veterinary teaching hospitals, the same effects can and do occur in smaller, private veterinary practices. This article discusses the need for biosecurity programs in veterinary practices and describes a practical approach for developing biosecurity practices that are tailored to individual facilities.

Why is biosecurity important for veterinary practices?

Hospitalization of sick animals tremendously increases their risk of acquiring infections because it congregates animals that are most likely to be shedding infectious agents with animals that often have enhanced susceptibility. Removing livestock from their home environment, transporting them, and confining them in proximity to unfamiliar animals also likely affects inherent susceptibility to infection because of stress. Ambulatory practices are not immune to risks associated with infectious diseases. Clothing, equipment, and vehicles can easily become contaminated with infectious agents, and veterinarians can become vectors for disease transmission unwittingly as they move among animal populations.

To provide the best veterinary care possible, veterinarians have an underlying responsibility to minimize the risk of additional harm that might unintentionally befall an animal because of their interventions. This responsibility includes minimizing the risk of exposing patients to infectious agents. It is therefore incumbent on veterinarians to manage the risk of nosocomial infections actively.

In evaluating the benefits of formal biosecurity programs, it is perhaps useful to consider an example of such a program, the biosecurity program at CSU-VTH. The biosecurity program at CSU-VTH is a proactive prevention program designed to identify hazards before they become problematic to personnel, patients, or the normal operation of the hospital. In the wake of the 1996 *Salmonella* outbreak at CSU-VTH, this rigorous biosecurity program was formalized in an effort to minimize the risk of nosocomial and zoonotic infections. A faculty position was created to oversee this program, and ongoing funding was committed for a house officer to work and train in this area.

The four goals of the CSU-VTH biosecurity program are as follows: (1) to reduce the risk of zoonotic disease and promote public health among hospital personnel and clients, (2) to provide an environment in which patient care is optimized by minimizing the threat of nosocomial infections, (3) to promote the development of lifelong skills in public health and biosecurity among hospital personnel, and (4) to protect CSU-VTH from financial loss and litigation. This program works to minimize the risk of myriad nosocomial and zoonotic health problems. Some of these diseases are important to producers, although they might be considered more of a nuisance than medically important (e.g., contagious respiratory diseases such as influenza and kennel cough, infestations with fleas and lice). Some diseases targeted by this program are potentially life-threatening nosocomial infections such as salmonellosis, wound infections, and septicemias. Some have considerable regulatory importance such as vesicular stomatitis or foot-and-mouth disease. Other diseases are important to the biosecurity program because they are important zoonotic diseases such as cryptosporidiosis, rabies, and plague (*Yersinia pestis* infection). In the current international political climate, CSU-VTH also has increased its vigilance to prevent intentional introduction of infectious agents at the facility and to detect unusual illness among animals as they are presented by clients.

The author's experiences with biosecurity concerns since the inception of the program suggest that more rigorous biosecurity precautions are becoming a necessary part of standard-of-care expectations. The author and his colleagues at CSU-VTH have received numerous inquiries from veterinarians and animal owners regarding control and prevention of nosocomial infections. We have found that our biosecurity program is an important aid to patient and facility management at CSU-VTH. Personal communications with colleagues throughout the United States and Canada indicate that biosecurity programs are being developed at referral centers that are similar to or modeled after the CSU-VTH biosecurity program. Many of these programs have been developed at private and public facilities in response to experiences that are similar to the 1996 *Salmonella* epidemic at CSU as described previously. We also have been contacted by veterinarians in private practice and animal owners because of pending legal action related to nosocomial disease.

The importance of surveillance

When discussing the use of biosecurity programs in veterinary practices, the author is told by some veterinarians that they do not need additional precautions because they do not have a problem; however, further discussion often reveals that they do not actually know if nosocomial transmission is occurring because they do not look for it. There is considerable wisdom in the adage, "You cannot manage what is not measured."

Surveillance is an important tool for management of any operation, including veterinary practices. Managers must have feedback regarding the status of the system so that corrective action can be taken when necessary. In fact, monitoring programs provide the foundation for any planned veterinary service in food animal production [18], and there are multiple benefits to using such programs. Monitoring programs provide information regarding the current status of the operation. They can help pinpoint problem areas that should be targeted for additional investigation or corrective action, which assists in making disease prevention efforts efficient and economical by identifying where resources are needed most. Regular review of data gathered from monitoring programs stimulates re-evaluation of disease prevention strategies. Monitoring programs can provide early warning for veterinarians and producers regarding problems that threaten productivity before these problems become large and unmanageable.

Should your practice use a formal biosecurity program?

Beyond realizing the importance of infection control and biosecurity, there is a critical need to evaluate whether a specific veterinary practice needs to enact a *formal* biosecurity program, and how much rigor is appropriate. Practicing veterinarians routinely perform actions that decrease the risk of disease transmission (e.g., sterilizing surgical instruments, washing hands and boots); however, the sum of these individual actions does not necessarily equate with enacting a systematized biosecurity program. The latter implies that a thoughtful, logical approach is being used to systematically reduce the risk of transmitting infectious agents in the process of delivering veterinary care. These actions may target specific agents and diseases, or they may be more generally intended to improve hygiene and thereby reduce contamination for a number of agents.

Determining if a formal biosecurity program should be enacted or if existing actions need to be enhanced requires careful consideration of disease risks and an equally thoughtful consideration of the level of risk aversion that is appropriate for a practice. No "one-size-fits-all" program can be transferred from one practice to another. What is practical and reasonable for some veterinarians in their practice situation may be untenable and unreasonable for others. A useful exercise is to make a comprehensive list of all infectious agents that can be transmitted among patients in the practice. Zoonotic diseases also should be considered in this list. Once this list is complete, each disease should be categorized according to the overall risk that it poses for the practice. Many factors influence the relative importance of diseases to a specific practice. These factors include biologic characteristics of the agents (i.e., contagiousness, pathogenicity, and the ability of an agent to persist in the environment), the characteristics of the patient population (i.e., immune versus susceptible), the value of patients in one's care, the health concerns of veterinary personnel and clients regarding zoonotic agents, and the risk of damage to one's practice if nosocomial infections were to occur (e.g., lost revenue, costs for cleaning a contaminated facility, damaged professional reputation, and the potential for legal action). Another aspect to consider is that there is considerable variability in the pathogenicity and medical importance among different strains of various agents. An interesting common feature of many documented and undocumented outbreaks of nosocomial bacterial infections is that the organisms are often resistant to a large number of important antimicrobial drugs [1,13,15,20,21] . It is not clear if multidrug-resistant bacteria are more likely to become resident in a hospital environment, or if they are more likely to be noticed than are nosocomial infections that can be treated with standard antibiotic regimens. Regardless, it can be difficult to effectively treat multiple animals infected with resistant bacteria, just as it is tremendously difficult to explain to several clients that these infections were unforeseen and not preventable.

After ordering hazards identified in this process according to their relative importance, precautions that are currently being taken to prevent introduction or the spread of each agent should be cataloged. An assessment of current operating procedures that might increase the risk of disease transmission also should be made.

It should be recognized that failure to take necessary precautions and breakdowns in performance are not the only causes of biosecurity problems. Experience at CSU-VTH suggests that a heightened desire to provide optimal care for individual patients and the needs of clients can also sometimes impair the ability of veterinarians and support personnel to appropriately gauge the immediate importance of their actions relative to biosecurity for the larger population or the practice. In fact, actions taken to provide every possible benefit for the individual can sometimes be directly contrary to the greater good of other patients and the practice. For example, given the stresses produced by hospitalizing some large animal patients in unfamiliar enclosed environments, it might be beneficial to house livestock outdoors in dirt- or grass-based enclosures for recuperation. A single animal shedding an environmentally persistent agent such as *Salmonella*, however, can extensively contaminate these environments, which are impossible to disinfect completely. The risk of nosocomial disease also can be inadvertently increased for individual patients when rigorous management practices are used, as is the case regarding frequent physical contact with patients. More frequent evaluation and treatment may be thought to ensure an animal's well-being but also increase the potential for inadvertent transmission of infectious agents, particularly if there are animals in a facility with a high risk of shedding infectious agents.

This risk-assessment process should then lead to an appraisal of whether current operating procedures are sufficient to protect one's patients and practice, considering the relative importance of each agent or whether there is a mismatch between risk assessment and the level of risk aversion. It is critical in this process to consider realistically whether current biosecurity precautions are followed routinely. In this regard, it should be realized that a manager's impression of what *should* be done does not always coincide with the procedures *actually* used by personnel. If actions do not appear to match the potential risks and the level of risk aversion, a more rigorous formalized program seems appropriate. At minimum, this should provide a basis for evaluation of procedural options to determine whether they can reasonably be incorporated to assist management of the veterinary practice.

Designing a tailored biosecurity program

An effective biosecurity program must be tailored to the needs and limitations of each individual operation. As discussed previously, it is not possible to take a biosecurity program designed for one practice and simply apply it in another operation without modification. There are systematic approaches that can be used to assist in the design of disease management programs, however. Applying the Hazard Analysis and Critical Control Point (HACCP) concepts is one such systematic approach that the author has found quite useful in a variety of situations. The HACCP concepts were originally developed to manage potential hazards to food production industries, and more recently were incorporated into regulations used by the US Department of Agriculture, Food Safety Inspection Service to minimize introduction of pathogens into the US food supply [23]. This systematic approach for identifying and managing operation hazards is ideally suited for guiding infectious disease control efforts in operations such as that of CSU-VTH or other veterinary practices.

The HACCP approach has seven integrated steps for systematic monitoring and control of operations [23]:

1. Conduct a hazard analysis. Prepare a list of steps in the operational system at which significant problems or hazards can occur and identify preventive measures.
2. Identify the critical control points in the system. A critical control point is one at which control can be applied and a hazard can be prevented, eliminated, or reduced to acceptable levels.
3. Establish critical limits associated with each critical control point that would trigger enactment of preventive or corrective measures.

4. Establish critical control point monitoring requirements. Establish procedures for using monitoring results to adjust the process and maintain control of the production system.
5. Establish corrective actions to be taken when a critical limit is exceeded.
6. Establish procedures for verifying that the HACCP system is working correctly.
7. Establish effective record-keeping procedures that document the HACCP system.

Step 1: conduct a hazard analysis

Considerations for conducting a risk or hazard analysis relative to biosecurity efforts have been described in detail previously in this report. One approach to identifying points in veterinary operations at which hazards can occur is to think of the general routes of transmission for the various agents and then think more specifically about how this happens in one's own practice. For example, a problem management point relative to biosecurity controls for veterinary hospitals is the continual introduction of animals to the environment. Depending on standard procedures, this may be more problematic for chutes or outpatient facilities that are less likely to be cleaned as often as stalls. Another management problem is the shared air space for patients in enclosed hospitals. Larger hospitals such as CSU-VTH have a high potential for frequent indirect contact between patients given the large number of patients and the large number of caregivers involved in patient management.

At CSU-VTH, gastrointestinal and respiratory pathogens are probably one of the greatest nosocomial risks because animals are commonly infected with these agents, they tend to be extremely contagious, and there are numerous vectors for indirect transmission in a busy hospital environment. Another important concern is contamination and infection of surgical wounds, particularly with multidrug-resistant bacteria. In addition, specific zoonotic agents are given special consideration because of their potential for morbidity and mortality in people (e.g., rabies virus, and *Yersinia pestis* is a particular concern in the Rocky Mountains). Agents of regulatory concern also are given special priority because of the risk to normal hospital operations (e.g., vesicular stomatitis virus). Considering different agents in these categories provides a list of several important agents. As an example, a few of the agents that have been recognized as common or important threats to the patients at CSU-VTH include *Salmonella*, rabies virus, *Cryptosporidium parvum*, bovine viral diarrhea virus, bovine leukosis virus, bovine herpesvirus, equine influenza virus, equine herpesvirus, *Streptococcus equi*, canine parvovirus, *Bordatella bronchisepticum*, feline calicivirus, feline leukemia virus, feline immunodeficiency virus, *Yersinia pestis*, several ectoparasites, and foreign animal disease agents (especially vesicular stomatitis virus and foot-and-mouth disease virus).

Step 2: identify critical control points and corrective actions

Many of the critical control points for different agents are similar because of their routes of transmission. Oral-fecal transmission is a common feature of several agents of concern, such as *Salmonella*, *Cryptosporidium*, and bovine viral diarrhea virus. Similarly, aerosol transmission is a common feature among several respiratory pathogens. These transmission features need to be considered when targeting prevention efforts. In addition, hospital environments can become contaminated easily by many different agents, facilitating indirect transmission by hospital personnel. This is particularly true for agents that can persist in the environment.

General actions for breaking transmission cycles for contagious diseases should be emphasized throughout the hospital. These actions include quarantine or segregation of animals known (or suspected) to be infected with contagious pathogens, quarantine or segregation of animals with a high risk of acquiring infections, limiting intentional and circumstantial human contact with high-risk patients, and optimizing hygiene for personnel and the environment.

The large animal hospital in CSU-VTH is segregated into six distinct areas with increasing rigor for biosecurity precautions. These areas (in increasing order of precautions) are the outpatient examination and treatment areas, equine inpatient housing area, equine colic patient housing area, bovine inpatient housing and treatment areas, equine anesthesia and surgery areas, and isolation units. A specific action taken to prevent direct and indirect contact between patients includes housing animals with contagious diseases in isolation units. Animals considered to have a high risk of acquiring infections (e.g., critically ill animals and those with failure of passive transfer) also are housed separately. Personnel movement between the biosecurity areas described is limited and sometimes prohibited. Barrier nursing precautions (e.g., gloves and water- impervious gowns) are used whenever working with high-risk patients to prevent strike-through and to minimize the potential for cross-contamination between animals. Barrier gowns are assigned for use with specific patients so that clothing most likely to be contaminated essentially stays with the patient. Clinicians managing high-risk animals sometimes limit the number of people contacting patients and assign specific students to care for a specific patient and no others. Hand washing is required before handling each patient, and alcohol-based hand-sanitizing gels are available for use at other times when hand washing is not possible. Rubber boots and disinfectant footbaths are used throughout the large animal hospital. All hospital personnel that contact patients are required to wear clean, appropriate attire at all times. Protocols have been established for appropriate cleaning and disinfection of all contact surfaces, including instruments, waterers, and feeders, and also for changing all bedding, including sand, between every patient. The importance of maintaining a clean hospital environment is continually emphasized with all hospital personnel. Stalls are cleaned and thoroughly disinfected between all animals, paying particular attention to feeders, waterers, and surfaces frequently contacted by hands. Dumpsters and cleaning tools are marked for identification, and different sets are assigned for use only within specific assigned areas of the hospital. Personnel are required to store and consume food in specific areas that are separated from animal housing and handling areas to reduce the risk of zoonotic infections.

The rigor of the procedures used at CSU-VTH may not seem reasonable or feasible for smaller practices. It is possible, however, to design other protocols for limiting high-risk contact with particular patients, establishing appropriate traffic patterns in the hospital, and maintaining high levels of personal and environmental hygiene. For example, in hospitals that do not have separate isolation facilities, an animal known or suspected of having a contagious disease might be separated by leaving an empty stall between it and other patients. A standard protocol could be established to treat and examine these contagious animals after handling other lower-risk patients. Inexpensive web-based cameras could be used to monitor the general safety of patients and thereby reduce traffic through high-risk areas. Disposable gloves and separate coveralls or inexpensive disposable plastic barrier gowns (PolyWear gowns; PolyConversions, Rantoul, IL) could be assigned for use with specific patients. These barrier precautions minimize the likelihood of contaminating clothing worn around other patients. Disinfectant footbaths could be maintained outside those stalls and at other important traffic intersections.

Biosecurity in veterinary practices is fundamentally about optimizing patient care, and personal cleanliness is undisputably an important cornerstone of infection control. Contaminated hands are perhaps the most frequent route of indirect nosocomial transmission in all species [16]. The author often illustrates the common sense of this control feature with students by asking them to look closely at their hands and to consider whether they would appreciate a physician with similar cleanliness performing an examination or an invasive procedure on them.

Environmental cleanliness and waste disposal are other features that should not be overlooked in the practical application of biosecurity. Effective cleaning and disinfection are critical for breaking transmission cycles. Several reviews are available regarding disinfection recommendations for livestock facilities [4,6–8,17] . Applying copious amounts of disinfectant to dirty surfaces is not effective for decontamination. Disinfectants are quickly inactivated in the presence of even small amounts of dirt and organic debris and can be truly relied on only when applied to clean surfaces. Some disinfectants such as phenolics are more effective in the face of organic material, but they are also more likely to cause irritation with skin contact in patients or personnel. Bleach, chlorhexidine, and quaternary ammonium–based products are less irritating, but they are easily inactivated. Bedding and feces should be removed from stalls between all patients to facilitate more thorough cleaning. Physical disruption is generally required to remove gross contamination and surface films to ensure adequate disinfection. High-pressure washing can be an efficient method for cleaning large areas, but it is also possible to disseminate surface contaminants further because they may be aerosolized in the cleaning process. Cleanable surfaces should be maintained throughout practice environments wherever possible. Concrete floors are preferable to dirt, particularly for housing animals shedding contagious pathogens, because it is impossible to completely disinfect the latter. Rubber stall mats are usually quite porous, and it is difficult to maintain effective seals at edges. This was thought to be a major factor in maintenance and dissemination of *Salmonella infantis* during the 1996 outbreak at CSU-VTH [21]. Sealing or painting exposed wood and other porous surfaces greatly improves cleanability. It is important to consider quality of products and maintenance of painted surfaces when selecting sealants, however, because chipped and peeling paint provides a niche for bacterial contamination that is difficult clean. Attention also must be paid to controlling wildlife (e.g., mice and birds) and insect vectors.

Step 3: establish critical limits associated with each critical control point

Critical limits might be considered in two groups: procedural tolerances and tolerances associated with clinical and microbiologic surveillance. Procedurally, there effectively should be zero tolerance for failure of personnel to comply with established biosecurity procedures. This factor is important to consider when designing protocols. Biosecurity procedures should be rigorous enough to achieve infection control goals for the practice, but they should not be so onerous as to interfere with performance or inhibit compliance. A common barrier to compliance with more rigorous protocols are lack of appropriate resources or facilities and lack of appropriate motivation among personnel. Effective communication is essential to achieve good compliance so that personnel know *what* is expected as well as *why* these procedures are important. Formalizing protocols in written documents assists in this effort. Preparing such a document necessitates consideration of details that might be overlooked otherwise. Written documents also provide a reference for personnel to consult when there are questions, and they facilitate consistency in the event of personnel turnover. The need for some flexibility in adherence also must be considered. Despite the comprehensive and clear-cut nature of biosecurity protocols for CSU-VTH [3], the author and colleagues are continually faced with clinical situations that require special consideration and accommodation. Who will be allowed to "bend" the rules, who will authorize these deviations, and under what circumstances? An obvious situation requiring flexibility is when patient care emergencies require unusual action. We maintain a general policy that biosecurity rules should never interfere with the animal's need for immediate attention.

At CSU-VTH, there is zero tolerance for nosocomial infections in the hospital. This policy does not mean that we believe nosocomial infections will never occur, only that we are committed to all reasonable efforts necessary for prevention. For this reason, identification of all potential nosocomial infections is important. Less rigorous tolerance limits might call for identification of outbreaks rather than of every occurrence. What specifically constitutes an adverse event worthy of concern (i.e., an individual case versus a series of cases) is a matter of debate that hinges on the balance between rigor and efficiency that is appropriate for individual practices. In both instances, however, monitoring is necessary to trigger corrective action. It also should be noted that nosocomial infections resulting in clinical disease are quite often less common than subclinical infections.

Active microbiologic surveillance is not likely to be conducted in many practice settings. Passive surveillance that relies on summarization of results from clinical specimens can be used as an alternative. Depending on the virulence of the organism involved, however, a nosocomial organism can become widely disseminated in the hospital environment before a pattern in clinical disease is identified. Unfortunately, this was the case for *Salmonella* Infantis infections during the 1996 epidemic at CSU-VTH [21]

Before that outbreak, there had been no purposeful monitoring of *Salmonella* isolates obtained from hospitalized patients. Laboratory results were forwarded promptly to individual clinicians, but there was no active surveillance in other patients and no single person was responsible for compiling or summarizing results from all submissions. When it was suspected that *Salmonella* was being recovered with an unusually high frequency, a retrospective analysis of data showed that *Salmonella* Infantis was isolated from 13 equid patients during the first 5 months of 1996, and no isolates of this serotype had been obtained from CSU-VTH during all of 1995 [21]. All of these samples were submitted from animals with suspected salmonellosis, however. Active surveillance of all hospitalized patients during 7 subsequent weeks identified a much higher rate of infection; the same organism was isolated from 34 large animal patients, all of which had negative culture results at the time of admission [21]. In addition to monitoring shedding in patients, evaluating contamination of the hospital environment was critical to breaking the cycle of transmission during this outbreak, and ongoing surveillance has proven to be important in subsequent ongoing infection control efforts.

Step 4: establish critical control point monitoring requirements

As illustrated in the preceding paragraphs, it is necessary to monitor occurrences of infection or disease adequately to know when established critical limits are being exceeded. For this type of surveillance it is necessary to track both the frequency of different types of disease or infection (numerator information) and the number of patients at risk of developing these events (denominator information). Many veterinary practices do not currently use computerized records systems, other than for billing, which makes it extremely difficult to monitor and summarize diagnoses adequately for the purposes of a surveillance system. Although this system is optimal, it may not be feasible. It is possible to set up a tally system to track important numerator information over time, however. Specific categories for tallies would coincide with priorities set during the hazard analysis. Denominator information might be tracked in the same manner, or it also might be obtainable from billing records or census sheets. In larger, more complex practices, it is important to establish specifically who will track this information and how these data will be summarized and interpreted. Monitoring efforts are not efficient in these complex practices unless thorough reporting is performed by all personnel.

Meeting more stringent biosecurity goals that accompany higher levels of risk aversion often necessitate some form of active surveillance in which clinical and microbiologic data are specifically collected for biosecurity purposes, rather than for management of individual patients. It is essential to consider the specifics of what will be sampled and how it will be cultured. For example, it is one thing to decide that the stabling environment of a hospital should be monitored for contamination. It requires an entirely different level of thought to determine specifically what areas to sample, how samples will be taken, and what they will be cultured for (e.g., *Salmonella*, *Escherichia coli*, *Staphylococcus*, *Enterococcus*, and so forth). Different culture methods are required to ensure optimal sensitivity, which therefore increases the expense and difficulty of rigorously monitoring for multiple bacterial species. The interpretation of this information also must be considered. Environmental monitoring at CSU-VTH shows that it is the rule rather than the exception to isolate enteric organisms from the hospital environment and even from hands. The author and colleagues have had long-standing discussions of what this information means and when it represents a problem. We do not believe that we will be able to sterilize the entire hospital, nor do we believe that we should try. We do consider specific identification of *Salmonella* in the environment an important event, however. In this sense, *Salmonella* is important as a specific pathogen but also as a marker of general hygiene in the hospital. There should be no residual environmental source of *Salmonella*, because we expect our cleaning and disinfection procedures to eliminate these sources. In addition, environmental samples are regularly obtained from "clean" areas such as surgical suites and cultured aerobically to identify many different bacterial species, including enteric organisms. We do not expect these cultures to be sterile, but we do expect this environment to be cleaner than the stabling facility and not heavily contaminated with fecal organisms. Biosecurity personnel occasionally show up in clinical service areas unannounced and obtain swabs of hands for culture. This activity increases hygiene awareness among all personnel, and results clearly demonstrate that fecal organisms nearly always contaminate hands of personnel in the hospital except when they have been washed recently. Another aspect to consider is whether isolates are resistant to antimicrobial drugs. We routinely characterize antimicrobial resistance in isolates collected for surveillance purposes because this provides us a relatively easy method of distinguishing between isolate phenotype and looking for distribution of bacterial clones. Environmental distribution of multidrug-resistant bacteria of the same species and resistance pattern can be an indicator of a nosocomial threat. These bacteria do not have to be typical pathogens to be important, as has been discovered on numerous occasions regarding septicemias and wound infections with "resident" nosocomial organisms such as *Pseudomonas*, *Klebsiella*, *E. coli*, *Acinetobacter*, *Enterococcus*, *Staphylococcus*, *Serratia*, and so forth [1,2,9,10,15].

Monitoring for compliance with biosecurity procedures is equally important. The general tendency in all operations is for compliance with less convenient procedures to degrade over time, particularly when personnel are not fully aware or appreciative of goals and consequences. At CSU-VTH, personnel supervisors are expected to monitor and police their respective areas for compliance with biosecurity protocols, and biosecurity personnel are responsible for monitoring overall compliance with the biosecurity program. This provides a stimulus for reminding and reinforcing protocols with personnel who may have honestly forgotten to do something (or not do something). There are consequences for failing to comply with procedures, however, because biosecurity protocols are considered official hospital policy and purposeful disregard is grounds for disciplinary action.

Step 5: establish corrective actions to be taken when a critical limit is exceeded

Unless there is a will to establish corrective action when problems are recognized, there is really no need to establish a formal biosecurity program. Although this may seem obvious, good intentions for action do not necessarily predict how an operation will actually respond when a specific situation arises. Invariably, exceeding established limits for biosecurity tolerance occurs at the worst possible time logistically. It occurs when the practice is busiest, when staffing is shortest, and budgets are smallest. The long-term goal of protecting patients, personnel, and the practice should not be overshadowed by the immediacy of short-term needs, however. Allowing a formal biosecurity program to protect one's interests effectively requires that this long-range perspective be given appropriate priority.

Planning for hypothetical scenarios can help ease the burden of crisis management when triggering events are identified. For example, if one specific goal of the biosecurity program is to minimize nosocomial *Salmonella* infections, appropriate planning can help predetermine some actions that will likely be taken whenever this infection is detected. Animals known or suspected to be infected with *Salmonella* might be segregated or moved to an isolation unit. Stalls would be identified for special cleaning to minimize environmental reservoirs and may not be released for further use until negative environmental culture results were obtained. Fecal samples could be obtained daily from all animals housed near affected patients and any others considered at risk of exposure. Special diagnostic procedures such as DNA "fingerprinting" could be used to look more precisely for similarities among pertinent isolates. Increased biosecurity precautions might be initiated, such as additional footbaths, further restrictions in personnel movement, and more extensive use of barrier precautions. Appropriateness of each specific action will need to be evaluated, but usually this type of planning is helpful.

It should be noted that the most efficient method for controlling outbreaks of nosocomial disease can sometimes include drastic management procedures such as temporarily restricting or stopping new admissions. Although these drastic measures are obviously not desirable, they may be necessary to remove the fuel from the fire to stop the occurrences of new infections because the risk to new patients may be too great. It may be tempting to limp along, making all possible management changes except for temporary closure of a facility, but in the end this may not be the most efficient method of correcting the problem. Even in the absence of identifying transmissions, CSU-VTH regularly suspends or restricts admissions in various areas of CSU-VTH to facilitate depopulation and thorough top-to-bottom cleaning. We have encountered outbreak situations in both the large animal and small animal facilities, in which it was deemed most expedient and efficient to suspend activities until the problem could be corrected [21]. This action protected patients that would have been admitted from potential injury and allowed our practice to concentrate on clean-up efforts rather than carrying out separate missions for patient care and clean-up. A certain negative stigma is associated with the occurrence of outbreaks of nosocomial disease, however, which may provoke practice managers into taking a defensive posture. Unfortunately, this perception may lead practices to continue activities when it is most efficient for control to suspend admissions. This defensive position may also influence veterinarians not to be completely open about disclosure of potential risks with clients. It is almost as if veterinarians are sometimes in denial about the known risk of nosocomial infection in every hospitalized patient. Failure to disclose to clients the increased risk to patients when they are admitted during recognized outbreaks of nosocomial infection creates considerable liability for both the veterinarian and the practice, even if the incidence of new infections is low.

We maintain an open information policy at all times regarding risks for nosocomial infections at CSU-VTH. Using an informed consent form, clients are told at the time patients are admitted that nosocomial infections are one of the known risks associated with hospitalization. They also are told that fecal samples and other biologic specimens may be obtained from their horses for the purposes of surveillance. The results of these tests are fully disclosed to clients when they become available. In situations in which nosocomial infections have been identified but were believed to be under control, our standard policy is to disclose this information to clients and give them the option to seek other veterinary care if they choose. We also have encountered situations in which the stalls in our isolation facility were occupied, and the animal being admitted would normally be managed in isolation. In these situations, we believe it is better to direct clients to seek care at other referral facilities in the area or treat animals in the field rather than take unacceptable risks by not managing patients in compliance with our Biosecurity Standard Operating Procedures [3].

Step 6: establish procedures for verifying that the hazard analysis and critical control point system is working correctly

Establishing procedures for verifying that HACCP is working correctly is important for the sustained success of a biosecurity program. Procedures should be established for routine summarization and interpretation of surveillance data. There is a biosecurity committee at CSU-VTH composed of faculty and staff representatives from all hospital sections that is responsible for reviewing biosecurity activities and recommending policy actions to the hospital director. The oversight of biosecurity personnel and this committee helps to ensure that goals of the program are being met. Biosecurity committee meetings are held quarterly in which results from microbiologic surveillance, clinical incidents affecting biosecurity, and personnel compliance with biosecurity procedures are reviewed. Corrective actions are discussed and recommended, if necessary.

Step 7: establish effective record-keeping procedures

For biosecurity purposes at CSU-VTH, we are fortunate that effective operation of a large, complex referral center requires detailed record keeping of patient information and diagnostic data. It is likely that information that is useful for tracking events related to biosecurity is already being captured and archived somewhere in the hospital (e.g., medical records, financial records, pharmacy records, diagnostic laboratory data, and so forth). This may not be the case for all veterinary hospitals, and procedures must be established that allow proper recording of events affecting biosecurity, and optimally so that data can be quickly searched, retrieved, and summarized. Incident reports pertaining to biosecurity at CSU-VTH are filed routinely to archive action on specific events. Summaries of microbiologic surveillance provided to the Biosecurity Committee are maintained and updated regularly. It is also necessary to document procedures thoroughly. At CSU-VTH, biosecurity procedures are maintained in a formal standard operating procedures manual [3]. Printed copies of this manual are made available throughout the hospital and on-line [3]. Formal recording of procedures is particularly important because of the large number of people involved in the program and the annual turnover of students and other personnel.

Experience with surveillance and biosecurity at Colorado State University Veterinary Teaching Hospital

The value of surveillance and biosecurity in veterinary hospitals can be seen by reviewing experiences at CSU-VTH regarding *Salmonella* surveillance. As part of an overall biosecurity program, CSU-VTH instituted an active surveillance program in 1997 to monitor *Salmonella* shedding in large animal patients. Fecal samples are obtained at arrival from all bovine inpatients for *Salmonella* culture, as well as from all equine colic patients at arrival and every other day after that. Using this sampling scheme for 4 years, we have found that an average of approximately 18% of bovine inpatients have positive culture results at admission, and approximately 8% of colic patients have positive culture results for *Salmonella* at least once during hospitalization (average number of fecal cultures per horse = 3.1). It should be noted that the prevalence of shedding in bovine inpatients would likely be greater if a more rigorous sampling scheme were used. These data do not include culture results passively collected from animals suspected of having-salmonellosis, but data from active and passive surveillance of *Salmonella* shedding are combined for monitoring of nosocomial infections. *Salmonella* isolates are characterized further regarding serogroup, serotype, and susceptibility to antimicrobial drugs. Patient information is collated regarding hospitalization dates, stabling location in the hospital, herd of origin, and other management information such as clinician of record. On about five or six occasions during these 4 years, an apparent link between *Salmonella* isolates from different patients has been identified. Longitudinal analysis of these data clearly shows that most *Salmonella* isolates are not apparently linked to temporal or geographical patterns of shedding in other hospitalized patients, however. The major exception to this statement is shedding patterns of dairy cattle from the same herd. Most cattle hospitalized at CSU-VTH are dairy animals. Isolation of *Salmonella* from beef cattle at our facility is uncommon, whereas the likelihood of shedding in dairy cattle clusters by dairy, and shedding prevalences using the sampling strategy described previously vary among different dairies from approximately 10% to 50%. In comparison, limited information gathered from other equine inpatients (not colic patients) suggests that their prevalence of *Salmonella* shedding is approximately 3% using every-other-day sampling and even lower among small animal patients (≤1%) [16]. Understanding typical shedding rates in our patients has allowed us to identify on some operations where subclinical *Salmonella* infections were endemic. This has allowed us to take special precautions with animals from these farms when they are admitted to the hospital and to assist these operations with efforts to control infections and prevent disease.

Data from the 1996 *Salmonella* outbreak suggest that nosocomial infections occurred for several months before detection. Our experience with the current surveillance program suggests that it would not be possible for similar events to occur without being detected, illustrating the tremendous power that a well-designed surveillance program can provide to biosecurity programs. Active or passive data gathering in a surveillance program is not without cost, however. Considerable effort is needed to sustain these data-gathering efforts, not to mention the costs associated with fecal cultures and subsequent susceptibility testing of *Salmonella* isolates.

It would be foolish to engage in the surveillance effort described if there were not a willingness to act on the available information. Although this may seem obvious, it is possible that monitoring activities might be enacted when a deeper consideration would show that there is an inability or unwillingness to act when these data indicate that a problem exists. The importance of surveillance findings also varies depending on the goals and risk aversion of the veterinary practice or producer. For example, although the incidence of *Salmonella* shedding among equine patients at CSU-VTH is substantially lower than the incidence in bovine patients, we find that owners of horses are generally far more risk averse regarding the consequences of *Salmonella* shedding than are owners of cattle. This may be partially attributable to differences in the consequences of *Salmonella* infections in animals, it may be somewhat related to differences in the monetary and personal value of individual animals, but it may also be attributable to differences in acceptance and familiarity with this problem. A national study of *Salmonella* shedding in dairies suggests that an average of approximately 5% of all lactating dairy cattle sampled once were found to shed *Salmonella*, and an average of approximately 18% of dairy cattle that were to be culled within a week of sampling had positive culture results [24]. Shedding prevalence varied greatly depending on season. In comparison, less than 1% of horses sampled in a similar nationwide study had positive culture results for *Salmonella* [12]. Regardless of differences in national trends among species, our obligation to all patients and clients is the same at CSU-VTH: we must strive to provide an optimal environment for animal care. We believe this means that appropriate efforts must be taken to minimize the risk of nosocomial infection in all patients.

The success of the biosecurity program is greatly dependent on participation and compliance of all personnel working at CSU-VTH, from the maintenance and cleaning crew, to the students, staff, clinicians, and administration. As such, there must be acceptance and buy-in for achieving goals for the program. Education of all personnel regarding the importance of biosecurity measures is critical to the success of biosecurity efforts so that they will know what actions are generally used to protect patients, when standard operations should change, how they change in these situations, and who to talk to if they have problems or questions. Efforts should be made to educate all personnel about the biology of important diseases whenever possible, including information about modes of transmission, the relative contagious nature of disease, shedding, persistence of agents in the environment, effective methods of disinfection, and the zoonotic potential. This knowledge allows them to better understand the importance of the program and to act wisely when specific situations require some improvisation regarding biosecurity measures.

Although participation from all personnel is critical for the success of the biosecurity program, it has been useful to have a single person with oversight responsibilities for the entire program. The author believes that this allows consistent application of biosecurity precautions for all patients, regardless of which veterinarian is responsible for patient care. If only the clinicians are responsible for ensuring application of biosecurity precautions as is true in most other hospitals, this can place veterinarians in the difficult position of attempting to provide every possible benefit to patients while protecting the best interests of the clients, in addition to protecting the practice and hospital. As discussed previously, this can create situations in which the long-term goals of the biosecurity of the program and safety of future patients can be overshadowed by the immediacy of decisions regarding the patient standing before us today. In comparison, the Director of Biosecurity at CSU-VTH is responsible for representing the interests of the hospital, which frees the veterinarian for less conflicted representation of client and patient interests. In his own role in this capacity, the author can therefore serve as an in-house consultant for biosecurity concerns regarding management of individual patients. This can actually improve the relationship between clients and the primary care veterinarian, because responsibility or "blame" for difficult management decisions pertaining to biosecurity (i.e., placing patients in isolation units, in which daily care charges to the client are greater) can be abdicated ("I feel badly about the extra charges, but our Director of Biosecurity is responsible for preventing infections in other patients, and he has decided that this move is best for all of the patients in our hospital").

We are sometimes asked by colleagues working at other veterinary practices whether our rigorous protocols and open information policy could potentially be harming the reputation of the practice. Although some might think that these actions inappropriately advertise weakness and fallibility, the author believes that our actions demonstrate an effort to achieve a higher level of patient care. In other words, our program demonstrates that our concern for patient care and personnel safety is so great that we take extra safety precautions. Who could possibly disagree with the idea that biosecurity precautions can help to reduce the risk of nosocomial infections, which in turn provides an environment where patient care is optimized? Above all, do no harm.

Acknowledgment

The author thanks all of the personnel at the Colorado State University Veterinary Teaching Hospital who have assisted in our efforts to refine and develop the biosecurity program for the hospital.

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Appendix
Common disinfectants used in veterinary medicine

Class	Disinfectant	Application in veterinary medicine	Activity in organic material	Comments
Acids	Acetic acid, citric acid	Disinfectant for Foot and Mouth Disease Virus	Poor	Non-toxic and non-irritating at typical dilutions.
	Lactic acid	Carcass decontamination	Poor	Non-toxic and non-irritating at typical dilutions. Immediate bactericidal effect and delayed bacteriostatic effect results in extended shelf-life of meat and decreased risk of food-borne pathogen transmission.
Alcohols	Ethanol, methanol, isopropanol	Surface disinfectant, topical antiseptic, hand sanitizing lotions.	Very poor	High concentrations for effective use in most situations as a germicide. Commercially available hand sanitizing lotions have been shown to greatly reduce bacterial counts on skin. Also effective against many viruses. Highly flammable. Irritating to injured skin, but low toxicity.
Aldehydes	Formaldehyde	Surface disinfectant, fumigant	High	Highly irritating and toxic, both through contact and fumes. Exposure to formaldehyde vapor has associated carcinogen risk. Contact sensitization can develop rapidly. Active against nonenveloped viruses, and gluteraldehyde is an effective sporocide with sufficient contact. Non-corrosive on metals, rubber, plastics, lenses, and cements. Gluteraldehyde is most active at alkaline pH.
	Gluteraldehyde	Surface disinfection and sterilization	High	
Alkalis	Sodium hydroxide (lye, soda lye)	Environmental disinfection, surface disinfectant	High	Highly caustic. Strong concentrations can be used for prion disinfection.

	Calcium hydroxide (slaked lime)	Environmental disinfection	Moderate	Sometimes used as a whitewash that kills or inhibits growth of non-spore-forming bacteria.
	Sodium carbonate	Cleansing agent	Moderate	Used extensively in Foot and Mouth Disease outbreaks.
Biguanides	Chlorhexidine	Surface disinfectant, topical antiseptic	Very poor	Very low toxicity potential. Typical dilutions are non-irritating even when contacting mucosa. Inactivated by anionic detergents. Bacteriocidal activity on skin is more rapid than many other compounds, including iodophors. Residual effect on skin diminishes regrowth.
Chlorine releasing agents	Sodium hypochlorite (Bleach)	Surface disinfectant	Very poor	Bacteriocidal activity is reduced with increasing pH, lower temperatures, and in the presence of ammonia and nitrogen compounds which can be important when urine is present. Not affected by water hardness. Considered to have relatively low toxic potential with standard dilutions. Chlorine gas can be produced when mixed with other chemicals. Strong oxidizing (bleaching) activity that can damage fabric and is corrosive on metals, silver, and aluminum (not stainless steel). Strong solutions can deactivate prion material. Chlorine dioxide is irritating and toxic.
	Calcium hypochlorite	Surface disinfectant	Very poor	
	Chlorine dioxide	Fumigant, gas sterilization	Moderate	

(*continued on next page*)

Appendix (*continued*)

Class	Disinfectant	Application in veterinary medicine	Activity in organic material	Comments
Iodine releasing agents	Iodine solutions	Surface disinfectant, topical antiseptic	Very poor	Absorption of iodine and associated toxicity is greatest with tinctures and solutions, and reduced with iodophores. People can become sensitized to skin contact. Generally less active than chlorine releasing agents. Bacteriocidal activity is slowed at lower temperatures and alkaline pH, but affected less by organic material than chlorine releasing agents. Dilution of iodophors increases free iodine concentration and antimicrobial activity. Metal surfaces can be oxidized. Staining of tissues and plastics also occurs.
	Iodophors	Surface disinfectant, topical antiseptic	Very poor	
Peroxygens	Peroxymonosulfate	Surface disinfectant, fumigant	High	Low toxic potential and non-irritating. No harmful decomposition products. Peroxymonosulfate is labled for use against Foot and Mouth Disease Virus, and can be used in the presence of animals. Peracetic acid (PAA) may be a weak carcinogen. Hydrogen peroxide (HP) has brief germicidal activity when applied to tissues. Poor lipid solubility. Less active at low temperatures. Excellent against spores. PAA is germicidal at much lower concentrations than HP. Corrosive to plain steel, iron, copper, brass, bronze, and vinyl, and rubber.
	Hydrogen peroxide	Surface disinfectant, topical antiseptic, gas sterilization	Low	
	Peracetic acid	Surface disinfectant fumigant	High	

Phenols	Various phenols (2-phenylphenol, benzylphenol, 4-chloro-3,5-dimethylphenol, etc.)	Surface disinfectant	High	Irritation is variable among compounds, but these compounds are in general highly irritating and should not be used on surfaces that contact skin or mucosa. Environmental safety is also variable. Not affected by hardness of water. Extended residual activity after drying. Active against non-enveloped viruses. Some residual activity after drying.
Quaternary ammonium compounds	Various ammonium salts (mono-alkyltrimethyl ammonium salts, etc.)	Surface disinfectant	Moderate	Irritation and toxicity is variable among products, but these compounds are generally non-irritating and have low toxicity at typical dilutions. Inactivated by anionic detergents. Some residual activity after drying. Good hard water tolerance, more effective at alkaline pH.

Data from Block SS, editor. Disinfection, sterilization, and preservation, 5th edition. Philidelphia: Lippincott Williams and Wilkins; 2001; and Linton AH, Hugo WB, Russell AD, editors. Disinfection in veterinary and farm animal practice. Oxford: Blackwell Scientific Publications; 1987.