In the past 20 years, a number of large animal veterinary teaching hospitals have been forced to close for prolonged periods because of outbreaks of nosocomial disease. In the spring of 2004, for instance, the University of Pennsylvania equine hospital at New Bolton Center was forced to close because of a Salmonella outbreak. Most commonly, these teaching hospital outbreaks have involved salmonellosis in horses, although other pathogens such as Clostridium difficile, equine influenza, and equine herpesvirus-1 can also cause nosocomial disease, with diarrhea secondary to C difficile infection increasingly recognized as an important problem in horses. Because of the potential adverse effects of nosocomial disease, veterinary hospitals should develop and implement an infectious disease control (IDC) program to prevent the spread of infectious organisms to hospitalized patients.

In 1988, the large animal clinic at the University of California-Davis (UC-Davis) Veterinary Medical Teaching Hospital (VMTH) was closed to inpatient admissions for several months because of an outbreak of nosocomial disease associated with Salmonella serovar Typhimurium. Portions of the clinic were remodeled to make cleaning easier and more effective, and a more rigorous IDC program was adopted. Another outbreak of salmonellosis occurred in 1991, and the IDC protocols were again modified. Since then, the hospital has not experienced any additional large-scale outbreaks of nosocomial disease associated with gastrointestinal or respiratory tract pathogens.

The purpose of the present report is to describe the basic principles of the IDC program developed at the UC-Davis VMTH to prevent nosocomial gastrointestinal and respiratory tract disease among large animal patients of the hospital. Although not all aspects of the program will apply to all veterinary hospitals and each veterinary hospital should develop its own site-specific IDC program, taking local conditions into account, we believe that the general recommendations contained in the UC-Davis IDC program are broadly applicable to veterinary hospitals in the United States and can be used to help control and limit nosocomial gastrointestinal and respiratory tract infections in large animals. That said, the present report cannot provide details for prevention of every possible nosocomial or zoonotic disease, and important aspects of the program related to other aspects of IDC (eg, prevention of postoperative wound infection, catheter-site infections, and infections in small animals) are not contained in the present report.

Basic Principles of an IDC Program

Hospitalized patients typically have depressed immune function because of stress associated with transportation, management changes, and their underlying medical or surgical problem. In addition, they may have decreased resistance to gastrointestinal tract pathogens because of diminished gastrointestinal tract motility and alterations in the gastrointestinal tract flora secondary to anorexia, surgery, and antimicrobial administration. Thus, reducing nosocomial gastrointestinal and respiratory tract infections involves 2 basic strategies: reducing the number of pathogenic organisms to which patients are exposed and avoiding further increases in patient susceptibility to pathogens.

A vital component of any IDC program is monitoring the effectiveness of disease control efforts. Because salmonellosis is such an important nosocomial disease and Salmonella organisms survive well in the environment, are relatively difficult to kill, can spread
easily on fomites, and are easily cultured, the UC-Davis IDC program uses bacterial culture for *Salmonella* organisms as an indicator of the effectiveness of the program, with any increase in the prevalence of *Salmonella* organisms in the environment considered an early warning of problems with the IDC program.

**Reducing Exposure**

Major components of the IDC program at the UC-Davis VMTH revolve around controlling the number of pathogens to which patients are exposed by promoting appropriate personal hygiene habits among students, employees, and faculty; using effective methods for cleaning and disinfecting all areas of the hospital to which patients are exposed (including adopting appropriate methods for monitoring the effectiveness of cleaning and disinfecting and for disposal of infected materials, particularly bedding); controlling the flow of human and animal traffic; implementing protocols for prompt identification and isolation of patients with signs of a contagious disease; and controlling possible vectors of gastrointestinal and respiratory tract pathogens, such as birds, rodents, and flies.

Facility design has an important impact on the risk of infectious disease spread. Respiratory tract pathogens such as equine influenza virus, for instance, can be spread by aerosols. Therefore, barns in which large animal patients are housed should have ample airflow with a minimum of 4 air changes per hour during the winter, 15 air changes per hour during the spring, and 40 air changes per hour during the summer. These air exchange rates allow for the removal of excessive moisture and the dilution and removal of aerosolized pathogens. They also help to maintain a uniform temperature inside the barn during the winter and help prevent the barn temperature from rising >2.8°C (5°F) above the outside temperature during the summer. Ideally, barns should be designed so that animals that develop a cough and fever can be isolated from the general population in a separate airspace. In addition, building barns so that wards within the barn have separate airspaces is preferable to building barns that consist of a single large airspace, as this makes it easier to contain outbreaks of viral respiratory tract disease and allows cleaning of individual wards. Needless to say, control strategies will vary depending on the available facilities. At UC-Davis VMTH, for instance, a suitable isolation area for large animals with respiratory tract disease is not available. Therefore, to prevent outbreaks of respiratory tract disease, new patient admissions may be limited when equine influenza virus is identified (by means of a commercially available ELISA kit) in nasal swab specimens from hospitalized horses. In addition, whenever possible, an open stall is left between patients that are ill.

Thus, IDC protocols should be taken into consideration during the initial design of new animal barns and facilities, as retrofitting existing facilities is often costly and usually does not achieve the same degree of effectiveness. Ideally, handwashing sinks or alcohol-based hand disinfectant solutions should be readily available in areas where patients are handled.

**Promoting appropriate personal hygiene habits**—A campaign to promote personal hygiene habits among students, faculty, and staff, including placement of appropriate permanent signs, can raise awareness of the importance of such behaviors in controlling nosocomial disease. These behaviors include washing hands or using alcohol-based hand wipes or lotions between patients, cleaning boots, avoiding walking on animals’ hay, wearing clean clothing, wearing gloves when handling contaminated wounds or soiled bandages, cleaning up manure promptly, and not bringing personal pets into barn areas.

One of the most important aspects of personal hygiene is washing one's hands before and after coming into contact with any patient. Hand hygiene prevents cross-infection, but adherence to guidelines is often poor among health care workers. Automatic or treadle-operated sinks and soap dispensers or alcohol-based hand disinfectant solutions should be available at key locations. Alcohol-based hand disinfectant solutions work quickly and have been found to be effective against all classes of pathogens including bacteria, fungi, and viruses. In addition, all personnel should be instructed to wear disposable gloves when handling contaminated wounds or soiled bandages.

Appropriate protective clothing should be worn and changed when soiled. Footwear should be appropriate, and care should be taken to not track pathogens on shoes or boots. In particular, personnel should be instructed to avoid walking on hay that might subsequently be eaten by an animal. Footbaths should be available so that personnel can clean their boots when they become soiled, and plastic shoe covers should be available for individuals who have only intermittent access to the barn. All manure should be cleaned up promptly.

To protect against zoonotic illnesses, consumption of food and drink in animal areas should be discouraged. In addition, all personnel should be instructed to not bring personal pets to the barn, even when making evening or weekend rounds.

Seminars describing teaching hospital closures can help impress upon people the seriousness of the IDC program. A program of responsible personal hygiene that has been developed with input from faculty and staff will be much more likely to have wide support and be successful. Faculty veterinarians should set an example of cleanliness for staff, students, and residents.

**Using effective methods for cleaning and disinfecting**—Enforcing basic rules for sanitation of equipment used on patients in the general hospital population is vital. At the UC-Davis VMTH, it is required that mouth gags, specula, endoscopes, and any other equipment that could be contaminated by body fluids be thoroughly cleaned between animals. Stomach tubes should be sterilized between animals, as they have been found to be a risk factor for development of salmonellosis. Storing frequently used equipment such as mouth gags and specula in a disinfectant such as chlorhexidine can prevent transmission of nosocomial agents, and chlorhexidine is relatively noncaustic to
skin and instruments, compared with many other disinfectants. It is effective against most viruses, most gram-negative bacteria and mycoplasma, and gram-positive cocci. For animals that are very susceptible to infection or are at high risk for enteric nosocomial disease (eg, animals in intensive care or that have undergone surgery because of colic) and animals that are housed in isolation because they have signs of or have tested positive for nosocomial infection, use of separate clean equipment (including rectal thermometers, buckets, and halters) for each individual animal is preferred. When these animals are discharged, all equipment must be completely sanitized before being used on a new patient.

Staff members involved in cleaning the large animal clinic and feeding hospitalized animals should be adequately trained and supervised. The goal when cleaning a barn is to physically remove all feces, bedding, and organic matter and to then disinfect the area without aerosolizing or pushing material into adjacent animal areas. The barn cleaning crew should receive instruction and feedback on how they are performing. Animal housing should be divided into zones, with separate cleaning implements (eg, forks, shovels, brooms, and hoses) used in each zone and stored in disinfectant between uses. If the same personnel are used to clean areas in > 1 zone, then areas in the zone that is used to house the most susceptible patients should be cleaned first. For instance, hospitalized horses might be divided into 4 zones, with zone 1 consisting of those horses considered most susceptible to infection (eg, neonatal horses and horses recovering from colic surgery), zone 2 consisting of the general equine population, zone 3 consisting of horses isolated in their stalls because of possible enteric disease, and zone 4 consisting of horses held in an isolation area because of enteric disease such as salmonellosis. In this instance, zone 1 should be cleaned first, followed by zone 2, then zone 3, and finally zone 4. Tractor-trailer tires should be hosed off between zones until visibly clean and then disinfected, or separate tractor-trailer equipment should be used for each zone. In either case, tractor-trailer equipment used in the isolation area should be separate from equipment used for cleaning the other zones. When moving between zones, workers should clean their boots and dip them in a 1:16 dilution of sodium hypochlorite. Third- or fourth-generation quaternary ammonium compounds are also effective in footbaths, whereas organic iodide solutions and chlorhexidine are not. For animals that are very susceptible to infection that nevertheless require intensive care (eg, horses recovering from colic surgery) can be isolated in a stall in zone 1, with each horse having its own separate cleaning implements and treatment equipment (eg, thermometer, bucket, and stomach tube). At the UC-Davis VMTH, each person entering such a stall must wash his or her hands or put on gloves, wear plastic shoe covers or disinfected rubber boots, and wear a disposable gown. Gowns, shoe covers, and gloves are kept outside each stall.

Cleaning requirements for any given hospital will be influenced by the type of facility, the physical space arrangements, the number and type of patients, and the local risk factors. Nevertheless, efforts should be made to minimize the chance that pathogens will be transmitted by people or instruments from animals most likely to be shedding those pathogens to animals most likely to be susceptible to infection.

Removal and disposal of soiled bedding presents a special challenge for large animal veterinary hospitals. Some hospitals have automated systems for removal of soiled bedding, but many, including the UC-Davis VMTH, rely on pitchforks and dumpsters. In our experience, trailers full of soiled bedding attract horses at our facility, with some horses reaching out and eating soiled bedding as the trailer moves by the stall. For this reason, efforts should be made to prevent horses from eating soiled bedding as it is removed from the hospital.

Soiled bedding can be used by mushroom growers if it contains the proper mixture of straw and horse manure, or it can be composted. Bedding from animals with salmonellosis can be composted or heat treated to destroy Salmonella organisms. At the UC-Davis VMTH, manure and soiled bedding are disposed of in a landfill. Steam heat is used to destroy microorganisms in soiled bedding from the isolation area. For this reason, trailers full of soiled bedding are placed in a dumpster fitted with a steam pipe coupling. A steam pipe used to heat the buildings is connected to the dumpster, and the manure and soiled bedding are steamed for at least 30 minutes. Tests indicate that this process destroys all Salmonella organisms.

Once all soiled bedding has been removed, clean bedding material can be distributed to the stalls of hospitalized patients. Bulk shavings used for bedding can become rodent nesting sites or cat litter boxes, and care must be used to avoid this type of contamination. For example, an outbreak of Salmonella serovar Krefeld infection among horses at the UC-Davis VMTH was traced to feces from feral cats that had used bulk shavings as a litter box. After clean bedding is distributed and before feed is distributed, the aisles of the barn should be swept or vacuumed and washed down to prevent recontamination of clean areas and contamination of feed. Aisles should be disinfected daily (eg, in intensive care and isolation areas) or weekly.

Stalls that are vacated should be stripped of soiled bedding and gently hosed down and scrubbed, taking care to avoid splashing into adjacent animal housing areas. High-pressure washers tend to cause splatter and can aerosolize pathogens. Thus, they may be appropriate for extensive cleaning of an empty facility or under certain conditions, but probably should not be used routinely. Once the stall appears clean of all feed, bedding, fecal material, and blood, it should be thoroughly scrubbed with a brush and detergent to remove...
organic matter and biofilms. The stall should then be rinsed, and a disinfectant should be applied. The detergent may be anionic, cationic, or nonionic, but must be compatible with the disinfectant. The disinfectant should have at least 10 minutes’ contact time. Once a stall is cleaned, disinfected, and dry, samples (eg, contact plates or other samples) should be submitted for bacterial culture to check on the effectiveness of cleaning and provide feedback to the barn crew. Stalls are allowed to dry before restocking.

Stalls that have been used to house an animal with clinical signs of gastrointestinal tract disease should be prominently marked for special handling. At the UC-Davis VMTH, a red sign is hung on the door of such stalls, and following removal of all feed, bedding, and manure, these stalls are washed with detergent, thoroughly rinsed, and then washed 3 times with disinfectant, allowing a 10-minute contact time for each disinfectant wash. Swab samples are then taken from cracks, corners, and drains and submitted for bacterial culture for Salmonella spp, and the stall is not used until results of bacterial culture are reported to be negative. If Salmonella organisms are isolated, the cleaning process is repeated. We adopted this protocol of 3 disinfectant washes after finding that swab specimens taken after a single disinfectant wash from stalls that had housed animals with salmonellosis were still sometimes positive for Salmonella spp.

Effective and practical disinfectants that can be used in large animal barns include sodium hypochlorite (bleach), phenolics, quaternary ammonium compounds, iodophors, alcohols, and chlorhexidine. Because of its low cost and broad spectrum of effectiveness on a variety of surfaces, sodium hypochlorite diluted 1:32 (ie, 4 oz/gal of water) is often the disinfectant of choice in barns that can first be cleaned of organic matter. In stables where there is more residual organic matter or where rotavirus is a problem, phenolics have been recommended because they are effective in the face of organic matter. Fifth-generation quaternary ammonium compounds are synergistic with nonionic detergents and often combined with them to enhance cleaning. They also remain active in high-protein environments and hard water and have excellent antimicrobial activity. Disinfectants tend to be less effective in colder temperatures, with phenolics being much less effective at temperatures < 15°C (60°F).

Each disinfectant has its advantages, disadvantages, and hazards, and cleaning staff should be aware of these. The individual in charge of the IDC program should ensure that workers receive training in the safe use of disinfectants and that proper apparel, face shields, and respirators are available if indicated.

It is equally important to ensure that surfaces remain in good repair so that they are cleanable. Chipped paint, loose flooring and floor mats, and damaged or rotted wood should be repaired. Moisture allows pathogens to survive, whereas drying reduces pathogen numbers. Drying and sunlight are excellent natural disinfectants.

Controlling the flow of human and animal traffic—A key to minimizing exposure of patients to nosocomial diseases is control of traffic patterns. Traffic should always flow from cleaner to less clean areas. Barn cleaning crews should have separate cleaning implements and tractors and carts for each zone and separate cleaning implements for each stall in the intensive care unit (ICU) and isolation. Animals should not be moved from one stall to another without due consideration for IDC protocols. For large animal veterinary hospitals, some consideration should be given to separating food animals from horses, as intensively raised animals such as dairy cattle may be a source of pathogenic Salmonella organisms that could put equine patients at risk.

Cattle feces can splatter the surrounding environment and contaminate boots, and cattle entering a clinic often have watery feces, which compounds this problem. Thus, having separate barns for food animals and horses facilitates IDC. At the UC-Davis VMTH, individuals who work in the ruminant areas must wear cleanable rubber boots and use footbaths; visitors are required to wear disposable plastic shoe covers. When cattle are brought to areas of the hospital also used for horses (eg, for a diagnostic procedure or surgery), all feces are immediately cleaned up, and the area is disinfected.

Ostriches and other raptors should not be housed with cattle and horses, as such animals frequently shed Salmonella organisms. Salmonella organisms were recovered at necropsy from 96 of 407 (23%) ratites.

People and equipment that are leaving the necropsy area are also likely to be contaminated with pathogenic microorganisms should be required to undergo decontamination.

Implementing protocols for prompt identification of patients with signs of contagious disease—There must be defined criteria, agreed upon ahead of time by clinicians, for instituting IDC protocols for patients. In particular, protocols should be developed to identify patients with specific signs indicative of gastrointestinal or respiratory tract disease. At the UC-Davis VMTH, horses from which any nosocomial pathogen is isolated and horses with any 2 of the following 3 signs are routinely moved to isolation: rectal temperature > 38°C (101.5°F), diarrhea, and leukopenia (neutrophil count < 2,000 cells/mL). The importance of recognizing neutropenia as an early sign of salmonellosis is well documented.

Horses that have undergone celiotomy and large colon surgery are particularly susceptible to developing diarrhea and nosocomial infection. Ruminants with salmonellosis do not as reliably develop leukopenia; therefore, any ruminants from which a nosocomial pathogen is isolated and ruminants with a fever and diarrhea are routinely moved to isolation. Any animal developing these signs or from which a pathogen is isolated is moved to the isolation facility under authority of the IDC officer or hospital director, and no clinician has the power to alter this rule to suit his or her personal expectations or the expectations of his or her client.

In our experience, when isolation staff is trained as well as large animal ICU staff and the isolation facility is of high quality, resistance among clinicians to moving animals to the isolation barn dramatically diminishes. The UC-Davis VMTH microbiology laboratory notifies the cli-
cian of record, the IDC officer, and the hospital director whenever Salmonella organisms are isolated, and notifies the attending clinician and IDC officer when any nosocomial pathogen is identified.

At the UC-Davis VMTH, a horse that has watery feces or diarrhea but does not have fever or leukopenia is not moved to isolation but is put under enteric precautions. Similarly, horses with unexplained fever or leukopenia are handled with caution. A large plastic or metal sign with the words “enteric precautions” or some other appropriate notice is hung prominently at the stall entrance, and disposable gloves, plastic shoe covers, and lab coat are hung on the stall. A thermometer is also assigned to that patient and is kept in disinfectant outside the stall. The halter and other equipment are not used on another patient or moved to another area without first being disinfected. The horse is confined to the stall unless it is essential that it be moved for diagnostic or therapeutic procedures. Fecal samples are collected daily from horses under enteric precautions and submitted for bacterial culture for Salmonella spp and C difficile and for testing for C difficile toxin.

For isolation of C difficile, fecal specimens are plated onto cycloserine cefoxitin fructose agar (CCFA) plates and inoculated into cycloserine cefoxitin fructose broth; plates and broth samples are then incubated in an anaerobic chamber for 48 hours at 37°C. Colonies appearing on CCFA plates as large yellow colonies with irregular edges are presumptively identified as C difficile and subcultured to a brucella plate. The following day, colonies consisting of large, gram-positive rods that test positive for t-proline-aminopeptidase are identified as C difficile. Chartreuse fluorescence of the colonies is used as another identifying characteristic. If the primary CCFA plate is negative for C difficile, then the broth culture is plated on another CCFA plate; the plate is incubated for 48 hours and examined for typical colonies.

The C difficile toxin assay is an enzyme immunoassay designed to detect both C difficile common antigen and toxinant A. Any antigen or toxinant A in the fecal specimens is isolated and immobilized on a membrane by specific antibodies. The immobilized antigens are incubated with an antibody-enzyme conjugate that binds to specific sites on the antigens, and the presence of antigen or toxinant A is detected visually by a purple-black bar on the test device.

Any horse that develops a high fever (> 38.8°C [102°F]) that cannot be explained by another disorder should be suspected of having developed equine influenza, equine herpesvirus-1 (EHV-1) infection, equine herpesvirus-4 (EHV-4) infection, equine viral arteritis (EVA), or some other viral respiratory tract disease, and isolation to a separate airspace should be considered. A commercial ELISA can be used to test for equine influenza, and polymerase chain reaction (PCR) testing is available to identify EHV-1 and EHV-4. Paired blood samples should be examined for antibodies to EHV-1, EHV-4, and the causative organisms of equine influenza and EVA. When cough, nasal discharge, and lymphopenia, or any 2 of these 3 signs, accompany fever, isolation is indicated. Horses with neurologic signs should also be isolated until EHV-1 is ruled out as the cause, because explosive outbreaks of EHV-1 neurologic disease have occurred in a veterinary hospital.

Equine viral arteritis occurred in 10 of 57 horses in a teaching hospital, with fever; anorexia; and edema of the limbs, ventral aspect of the abdomen, and prepulse as the major signs.

With the design of the UC-Davis VMTH facilities, it has often not been possible to move horses suspected of having respiratory tract disease to a separate barn or airspace. Despite this, the hospital has been able to contain several outbreaks of equine influenza by regulating the flow of horses through the barn. The strategy used has included postponing all elective inpatient cases to reduce the number of horses in the barn and discharging noninfected horses that can be managed at home. We advise owners to try to isolate such horses at home for at least 21 days (3 times the incubation period) in case they are incubating EHV-4. Reducing the number of horses in the barn is important in providing flexibility in relocating horses for isolation and cleaning. Reducing the density of horses in the barn also reduces the risk of transmission, although sending horses home could increase the risk of transmission if some of these horses are incubating a disease and susceptible horses at home happen to be exposed. Foot traffic in the barn is restricted. Infected horses are relocated to one end of the barn, and infectious disease containment protocols are implemented with each horse. The aisle on the opposite side of the barn is vacated and cleaned as a block, and an empty aisle is maintained between remaining noninfected and infected horses. Any new admissions are placed in the recently cleaned block of stalls as far as possible from known infected horses. Admission of horses into the barn is regulated to sequentially fill and empty the barn, avoiding random placement of horses in stalls. The result of the rearrangement is the creation of 3 separate populations within the barn, including infected, potentially exposed, and nonexposed groups. If there is sufficient space, empty stalls are maintained between horses in the noninfected potentially exposed and noninfected nonexposed groups. All patients in the facility are carefully monitored, and nasal swab specimens are collected from febrile horses to facilitate rapid detection of new infections. Once staff became familiar with this system, it worked well for the hospital and appeared to prevent disease transmission to newly admitted horses.

Animals suspected of having rabies are handled according to widely established procedures. Animals suspected of having other contagious diseases or a zoonotic disease are treated according to protocols specifically designed for that condition. It is not within the scope of this report to address each specific condition.
to keep birds out of the barn rafters. Pigeons are particularly troublesome because their numbers tend to increase rapidly; they are messy; and they may shed Salmonella organisms, although pigeon-specific strains of Salmonella spp are rarely isolated from other animals.1 At certain times of the year, ducks or geese may frequent barn or corral areas, leaving large amounts of fecal material in locations containing new shoots of grass or grain used to feed livestock. One of the authors (BPS) has found that ducks can shed Salmonella organisms and can act as fomites, transmitting diseases from isolation areas to the main hospital population. Netting can be used to keep birds out of barn rafters, and doors or other barriers can be used to keep birds out of animal feed and feed storage areas.

Mice are coprophagic, so once a population of mice is infected with salmonellae, it may remain so indefinitely.40 Rodent feces that contaminate feeds can be a continuing source of Salmonella organisms. If the moisture level and the ambient temperature are sufficiently high, Salmonella organisms can rapidly multiply in feeds. Feeds must be kept dry and in rodent-proof containers. Effective rodent control is essential. At the UC-Davis, poison bait is used for rodent control.

Fly control is important because flies move from feces, nasal discharges, and contaminated wounds to other areas, acting as mechanical vectors for microorganisms. One fly can carry 6,000 Salmonella organisms.3 Flies hatched in Salmonella-positive feces remain culture positive for life (about 4 weeks on average),11 so manure must not be kept on site if it can serve as a fly breeding site. In addition, flies worry animals when they bite and contribute to stress and lowered immune resistance. At the UC-Davis VMTH, barns are fogged each night during fly season with an insecticide.3

Cats and dogs may also shed Salmonella organisms40 and should not be allowed in areas housing large animals. If cats are used as part of a rodent control program, fecal samples should periodically be submitted for Salmonella culture, or the cats should be trained to use a litter box so that they do not use animal feed or bedding for this purpose.

Avoiding Increasing Susceptibility to Pathogens

The second set of major components of the IDC program at the UC-Davis VMTH involves strategies to avoid increasing the susceptibility of patients to nosocomial disease. The key points of this strategy are minimizing high ambient temperatures and other stresses on ill animals; using antimicrobials appropriately, including administering them for only as long as needed and monitoring for antimicrobial resistance; making feed available and attractive to aid in reestablishing normal gut or rumen flora; controlling endotoxemia; and increasing passive immunity.

Controlling ambient temperature—A high ambient temperature increases the likelihood that horses will shed Salmonella organisms in their feces, and high ambient temperature is a risk factor for development of nosocomial Salmonella infections in horses.44,45 Therefore, environmental cooling during periods of high ambient temperature is indicated. The effects of endotoxins in animals are also greatly exaggerated by high ambient temperatures.46 For instance, Salmonella infection may not have severe consequences at ambient temperatures of 21.1°C (70°F) but may be fatal at temperatures of 37.8°C (100°F).46 Not surprisingly, the percentage of horses shedding Salmonella organisms in their feces is highest during the hot months of the year.44

Using antimicrobials appropriately—The microbial flora of the gut plays a role in increasing host resistance to enteric pathogens.13,45,46 Oxytetracycline,16,37,46 lincomycin,46 erythromycin,46 and potentiated sulfonamides combined with penicillin13 have been associated with diarrhea in horses. Although antimicrobials have therapeutic application in the treatment of salmonellosis, the use of antimicrobials alters intestinal flora, attenuating the patient’s innate resistance to Salmonella infection. Antimicrobials that undergo enterohepatic circulation tend to cause the greatest alterations in gut flora.13,46,49 Antimicrobial use in hospitalized patients increases the risk for nosocomial salmonellosis and C difficile infection.13,14,18,36,48,50-54 Even mares whose foals were treated with erythromycin and rifampin have developed C difficile-associated acute colitis.30 High concentrations of erythromycin were found in foal feces, leading to the theory that the mares ingested the foal feces, which contained erythromycin- and rifampin-resistant C difficile.30 Foals treated with antimicrobials frequently do not develop any gastrointestinal tract abnormalities but may serve as a reservoir of C difficile. Antimicrobial administration may induce diarrhea, and antimicrobial-associated diarrhea may have a worse prognosis than other types of acute diarrhea.37,31 Antimicrobials that decrease the number of colonic and cecal anaerobic bacteria also increase bacterial translocation through the intestinal wall.33

Horses that have undergone surgery for large colon impaction are at an increased risk for developing nosocomial Salmonella infections.139 Antimicrobials administered prophylactically after colic surgery in horses should be given for only 24 to 48 hours, unless there is a specific infection identified that requires more prolonged treatment.5

Emerging resistance among pathogens in the hospital is monitored through the use of antimicrobial susceptibility testing.31 All enteric isolates, including salmonellae, undergo susceptibility testing. Staphylococcus isolates are also routinely tested. To minimize selection pressure and the potential for development of resistance, the use of certain antimicrobials is restricted and allowed only under approval of the IDC officer, hospital director, or hospital pharmacist. Restricted antimicrobials include several third-generation cephalosporins and the carbapenems. Systemic use of vancomycin is also limited. Oral use of vancomycin is allowed in horses in the isolation unit with enteric C difficile infections that are unresponsive to metronidazole or that are caused by organisms resistant to metronidazole and in horses that had been treated with metronidazole prior to the development of diarrhea.16,37
Aiding in reestablishing normal gut or rumen flora—Encouraging postoperative and ill animals to eat by offering green feed or other highly palatable forage is helpful in reestablishing normal flora and gastrointestinal tract motility. The normal gut or rumen flora is a major barrier to nosocomial enteric agents, and fed cattle have rumen fluid that inhibits growth of *Salmonella Typhimurium*. 

Enteroctytes with removal of colon contents and rumenotomy with removal of rumen contents are often accompanied by transport, general anesthesia (for horses), anorexia, and ileus. Attempts have been made to repopulate the intestinal flora of horses through the use of fecal cocktails and the rumen flora of ruminants through the use of transfaunation. There is little information on the effectiveness of these measures in adult animals, and most information that is available is from newborn chicks or pigs, in which competitive exclusion has been shown to be valuable when the inoculum contains multiple bacterial species found in the cecum and hind gut of that species. On the other hand, a study found no reduction in *Salmonella* shedding when 2 commercial probiotic products were administered to horses following colic surgery. Many clinicians believe that walking can stimulate gut motility and appetite but should be used only if the animal no longer has diarrhea and is known to be free from *Salmonella* spp and *C difficile* in its feces.

Controlling endotoxemia and increasing passive immunity—Several studies have examined the role of hyperimmune serum in increasing passive immunity to *Salmonella* organisms in horses. Endotoxemia plays an important role in morbidity and mortality rates, so any steps to ameliorate its effects can improve survival rate. Nonsteroidal anti-inflammatory drugs are frequently used to mitigate the effects of endotoxemia. Researchers were also able to demonstrate that serum from horses hyperimmunized against *Escherichia coli* J5 significantly increased survival rate when administered to horses in an ICU. However, 1 study did not find any benefit to administering *E coli* J5 antisera prior to IV administration of endotoxins. Because there is insufficient time to protect hospitalized animals by vaccination to stimulate active immunity, most efforts have been directed at enhancing passive immunity. At the UC-Davis VMTH, plasma from horses hyperimmunized with *E coli* J5 is given to most horses with acute colitis and horses with colic that have hypoproteinemia or clinical signs of endotoxemia. Plasma is also used to supply albumin, antithrombin, clotting factors, and other humoral factors. It is important that all efforts be directed toward avoiding environmental conditions (eg, excessive heat or cold) and treatments (eg, corticosteroids) that might depress the patient’s immune response, unless corticosteroids are specifically indicated for that patient.

**Monitoring Effectiveness of the UC-Davis IDC Program**

From 1990 through 2001, fecal samples from randomly selected bovine, ovine, caprine, and equine patients of the UC-Davis VMTH and from all animals with clinical signs of gastrointestinal tract disease were submitted for bacterial culture for *Salmonella* spp. The goal was to submit a single fecal sample collected within 24 hours of admission from as many cattle, sheep, goats, and horses admitted to the hospital during regular working hours Monday through Friday as possible. Thus, samples were not collected from many animals that arrived after hours and on weekends, unless they had clinical signs of gastrointestinal tract disease. At least 5 fecal samples were collected from animals with clinical signs of gastrointestinal tract disease and animals in the ICU or isolation barn. During this period, 1 or more fecal samples from 41% (3,183/7,705) of hospitalized cattle, 28% (7,200/25,303) of hospitalized horses, 22% (266/1,204) of hospitalized goats, and 22% (197/898) of hospitalized sheep were submitted for bacterial culture for *Salmonella* spp.

**Bacterial culture technique**—Bacterial culture of fecal samples was performed by the VMTH Microbiology Laboratory. Briefly, approximately 1 g of feces was inoculated directly onto a xylose-lysine-tergitol 4 agar plate and into 8 mL of selenite broth for overnight enrichment. The following morning, the selenite broth was subcultured on a xylose-lysine-tergitol 4 agar plate. For samples from cattle, enteric agar plates were also inoculated. All media were incubated at 37°C in air.

Agar plates were examined after 24 hours of incubation for characteristic colonies. Suspect colonies were subjected to agglutination testing with *Salmonella* O polyvalent A-I antiserum. Four typical colonies were subcultured to a sheep blood agar plate that was incubated at 37°C for 24 hours in air. The following morning, each subculture was subjected to both *Salmonella* O polyvalent A-I and monovalent antiserum testing. Each serovar that was isolated was inoculated on differential biochemical test media for confirmation as a *Salmonella* isolate. For each new *Salmonella* isolate, antimicrobial susceptibility testing was performed according to NCCLS guidelines. A microbroth dilution assay was performed, and the minimal inhibitory concentration was defined as the lowest concentration of the antimicrobial that prevented growth of the isolate. Isolates were sent to the National Veterinary Services Laboratories in Ames, Iowa, for serotyping.

Although the sensitivity of detecting *Salmonella* organisms can be increased by use of PCR assays, PCR testing is likely to detect both viable DNA (ie, DNA from live organisms) and nonviable DNA (ie, DNA from dead organisms). Therefore, PCR testing of fecal samples was not incorporated in the IDC program. Similarly, although sensitivity of detecting *Salmonella* organisms can be increased if rectal mucosal biopsy specimens are used, rather than fecal samples, this practice was not routinely followed.

**Results of bacterial culture of fecal samples for *Salmonella* spp**—*Salmonella* organisms were recovered from at least 1 fecal sample collected from 225 of the 3,183 (7%) bovine patients treated at the UC-Davis VMTH between 1990 and 2001. A total of 231 *Salmonella* isolates were recovered because > 1 isolate was obtained from some patients. During all but 1 of
these years, the percentage of cattle from which Salmonella organisms were recovered ranged from 5% to 11%. The remaining year, the rate was 17% because during this year a number of cattle from dairies experiencing problems with Salmonella infection were admitted to the hospital. Twenty-eight serovars were identified, including serovars from serogroups B, C1, C2, C3, D1, E1, E2, E3, E4, and K. Salmonella Typhimurium was isolated from 84 of the 225 (37%) bovine patients with Salmonella organisms in their feces.

Salmonella organisms were isolated from only 1 of the 197 (0.5%) sheep from which fecal samples were collected; the isolate was identified as Salmonella Typhimurium. Similarly, Salmonella organisms were isolated from only 5 of the 266 (2%) goats from which fecal samples were collected. Salmonella Typhimurium was isolated from 4 of these 5 goats.

Finally, Salmonella organisms were recovered from at least 1 fecal sample collected from 527 of the 7,200 (7%) equine patients treated at the UC-Davis VMTH between 1990 and 2001. A total of 553 Salmonella isolates were recovered because >1 isolate was obtained from some patients. During 1990, Salmonella organisms were recovered from 26% of horses from which samples were collected, mainly because of endemic Salmonella serovar Agona infection. During 1991, Salmonella organisms were recovered from 27% of horses from which samples were collected, mainly because of an outbreak of Salmonella Typhimurium infection and endemic Salmonella Krefeld infection. From 1992 through 2001, the percentage of horses from which Salmonella organisms were recovered ranged from 3% to 9%. Fifty serovars were identified, including serovars from serogroups B, C1, C2, C3, D1, E1, E2, E3, E4, G1, G2, H, I, K, and M. Salmonella Typhimurium was isolated from 169 of the 527 (32%) horses with Salmonella organisms in their feces.

Discussion

An effective IDC program is essential for all veterinary hospitals, but especially so for those that treat large animals. Failure to control nosocomial diseases can result in a loss of client confidence in the facility, with resultant loss of caseload and income. Staff morale may also suffer when nosocomial disease persists without an effective control program. Thus, steps should be taken to develop and maintain an effective IDC program (Appendix). The key is to develop grassroots support for the program among clinicians and then to manage it attentively. Veterinarians must set an example by adhering to protocols even when inconvenient.

The effort and costs associated with developing and maintaining an IDC program pay off by increasing the confidence of referring veterinarians, clients, and hospital staff. The time and effort of the IDC officer or veterinarian charged with overseeing the program must be recognized when merit pay raises and promotions are considered. The costs of the program must be built into the hospital fee structure for the program to be sustainable. During 2001, costs associated with bacterial culture of samples in conjunction with the IDC program in the large animal clinic at the UC-Davis VMTH were approximately $4 per inpatient hospital day, not including microbiology laboratory staff time and the extra labor required for disinfecting stalls. One staff member spends 20% of her time taking samples for bacterial culture, and many other staff members spend some of their time disinfecting stalls and stock- ing booties and gloves. In contrast, the cost for bacterial culture of samples in conjunction with the IDC program in the small animal clinic was only about $0.10/inpatient hospital day because a lower level of monitoring has proven effective and disinfection is less time consuming.

It is important to recognize that many clinically important nosocomial diseases can also be zoonoses. Thus, steps taken as part of the IDC program also help to protect students, staff, and clinicians from salmonellosis and cryptosporidiosis. In particular, cryptosporidiosis is likely to be an important zoonotic disease among individuals handling calves, lambs, kids, or foals in the clinic or at necropsy. However, protocols should also exist for handling animals suspected of having rickets, coccidiodomycosis, leptospirosis, anthrax, brucellosis, avian psittacosis, and other serious zoonotic diseases. Protocols should also exist for handling animals infected with other nosocomial pathogens, such as oxacillin-resistant strains of Staphylococcus aureus, Streptococcus equi, Rhodococcus equi, rotavirus, cryptosporidia, contagious mycoplasmas, contagious ecthyma virus, bovine viral diarrhea virus, and infectious bovine rhinotracheitis virus.

The IDC program did not eliminate all problems at the UC-Davis VMTH, but it helped to more readily identify problems and helped limit the number of patients affected. In 1993, an outbreak of C difficile diarrhea involving 10 horses was identified and rapidly controlled, and IDC protocols were modified in an attempt to prevent further outbreaks. Similarly, an outbreak of salmonellosis in 2002 was confined to only 6 horses, only 4 of which developed clinical signs. In both instances, the IDC protocols resulted in rapid identification of the problem and isolation of affected animals and facilitated control of the outbreak.

Recently, the UC-Davis VMTH made the decision to stop routinely collecting fecal samples from randomly selected horses for bacterial culture for Salmonella spp. Rather, fecal samples are now collected only from those animals with clinical signs, although additional samples are collected if Salmonella organisms are recovered. At the same time, the number of environmental samples collected for bacterial culture was increased to monitor the effectiveness of the hospital’s IDC protocols.

Between 1990 and 2001, >50 Salmonella serovars were isolated from large animal patients at the UC-Davis VMTH. Not all Salmonella serovars are equally pathogenic; therefore, the IDC program should emphasize control of the most pathogenic serovars, such as Salmonella Typhimurium DT 104. However, serovars that are resistant to multiple drugs and serovars obtained from multiple animals must also be considered important. Salmonella serogroups B, C, D, and E are the most important in terms of causing illness in farm animals.

Because not all Salmonella strains are equally viru-
lent and Salmonella organisms can be isolated from apparently healthy animals, \(^{1,6}\) fecal shedding of Salmonella organisms during hospitalization is not associated with alterations in mortality rate. \(^{6,7}\) Nevertheless, infected patients can serve as a source of nosocomial pathogens.

An aggressive IDC program can be effective at controlling nosocomial disease in large animal veterinary hospitals. In particular, establishing IDC protocols can help limit the spread of pathogens and minimize the number of affected patients.

\(^{1}\)Directigen FlaA ELISA Kit, Becton-Dickinson, Franklin Lakes, NJ.


\(^{3}\)Replicate organism direct agar contact (RODAC) plates, Remel Labs, Lenexa, Kan.

\(^{4}\)Triage Clostridium difficile panel, Biosoite Diagnostics, San Diego, Calif.

\(^{5}\)Cycloserine cefoxitin fructose agar (CCFA) plates, Biological Media Laboratory, School of Veterinary Medicine, University of California, Davis, Calif.

\(^{6}\)Pro Disk, Remel Labs, Lenexa, Kan.

\(^{7}\)Taq Man PCR testing, The Lucy Whittier Core Molecular Laboratory, Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California, Davis, Calif.

\(^{8}\)Kohn CW, Department of Clinical Sciences, College of Veterinary Medicine, The Ohio State University, Columbus, Ohio: Personal communication, 2003.

\(^{9}\)Withe HH, Withe S. Pigeon specific strains of S typhimurium in man, domestic animals and sewage (abstr), in Proceedings. World Cong Food-Borne Infect Intoxications 1980;169.

\(^{10}\)One Bite rat poison bars, Farnam Inc, Phoenix, Ariz.

\(^{11}\)Fly Die, Haco Inc, Madison, Wis.

\(^{12}\)Equine IgG polymune normal equine plasma, Veterinary Dynamics Inc, Templeton, Calif.

\(^{13}\)Xylose-lysine-tergitol 4 agar, Hardy Diagnostics, Santa Maria, Calif.

\(^{14}\)Hektoen enteric agar, Hardy Diagnostics, Santa Maria, Calif.

\(^{15}\)Trek Diagnostic Systems Inc, Westlake, Ohio.

Appendix

Recommended steps in developing an effective infectious disease control (IDC) program for a large animal hospital.

* Have all clinicians work together to develop and approve the IDC program, as grassroots buy-in is vital.

* Develop a specific, written IDC program and disseminate it widely among staff members.

* Identify a veterinarian who is active in the large animal hospital to serve as the IDC officer; this individual will oversee the IDC program and should report to the hospital director and practice partners.

* Provide the resources, both human and monetary, needed for the IDC officer to effectively carry out the approved IDC program; prevention costs less than the alternatives.

* Make students, residents, and staff aware of the key points of the IDC program and the importance that clinicians place on compliance.

* Teach the barn crew, particularly those actually responsible for cleaning, disinfecting, and feeding, about the goals of the IDC program and the methods to be used.

* Monitor the effectiveness of cleaning and sanitation by means of bacterial culture of environmental samples and give regular feedback to the barn crew, staff, students, and clinicians.

* Hold a seminar at least yearly to distribute written information about the IDC program and results of monitoring.

References


