Guidelines for Reducing Veterinary Hospital Pathogens: Hospital Design and Special Considerations

Hospital-acquired infections pose a continual threat to veterinary patients. Current veterinary literature has generally focused on changes made at the patient level: the use of antibiotics to prevent the development of multi-drug-resistant bacteria, skin antisepsis, and technical instructions for invasive procedures. We are unaware of any veterinary articles on preventing colonization of the hospital (other than antibiotic usage strategies) and appropriate methods for reducing the pathogen load within the hospital.

A companion article presents a “nosocomial prevention triad” for pathogen load reduction as well as information on the appropriate use of disinfectants and hand hygiene practices in small animal veterinary hospitals. This article focuses on preventing the colonization and spread of pathogens through hospital design considerations and behavioral practices, specifically with regard to treating and handling surgical patients and patients that require isolation from the general hospital population. The routine cleaning and disinfection protocols provided in the companion article can also be used for surgical suites and isolation units.1

Hospital Design

Infection control must be considered during the planning of a veterinary hospital construction project, whether building a new facility or renovating an existing facility. Guidelines for the design of human hospitals are available to architects, as are recommendations from the Centers for Disease Control and Prevention (CDC) focusing on facility design, mechanical engineering aspects, and hospital finishes that can limit the risk of introduction or colonization of infectious agents on hospital surfaces.1,2 Many of these guidelines are not relevant to veterinary facilities, but some basic common strategies should be followed.

It should be determined early in the design process which areas of the hospital should receive special consideration for infection control. These areas include those used for housing or treating immunocompromised patients (e.g., patients receiving chemotherapy, geriatric patients, pediatric patients), such as operating rooms, isolation areas, intensive care units, postoperative recovery rooms, and oncology wards. Operating rooms require a higher degree of infection control than other areas. The design of the operating room should limit foot traffic in the adjacent areas.1 This mainly involves placing the operating room in a “dead end” to minimize the movement

Abstract: Prevention of nosocomial infection begins with the hospital layout and identification of special considerations for particular patients. The construction of a new hospital or renovation of an existing hospital requires careful planning and consideration of the needs of the expected patient population and hospital staff. This article discusses considerations for preventing cross-contamination of pathogens through hospital design, as well as special considerations for particular patients, specifically those in isolation areas and surgical suites.

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At a Glance

Hospital Design

Page E1

Recommended Practices for Sensitive Areas

Page E4

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of people outside the entrance. Windows in operating rooms should never be opened. Any windows in the hospital that are allowed to open should be well fitted with insect screens. Isolation rooms should be designed with an anteroom to provide a place for donning barrier clothing (e.g., gloves, gown, booties) as well as disinfectant footbaths and a hand washing station. The anteroom also limits the movement of air from the isolation room to the general population of patients and provides storage for contaminated linens. If space allows, the dedication of two separate areas for isolating patients enables the separation of animals with different infectious diseases. A separate bathing tub within the isolation unit is also useful if there is enough space.

Because hand washing is one of the main strategies for preventing nosocomial infections, special attention should be paid to providing convenient hand washing stations in all clinical areas of the hospital. Sinks should be as deep as possible to prevent splashing of water and scattering of organisms. Ideally, foot pedals or infrared sensors should be installed to allow hands-free operation of all faucets and limit the role of faucet handles as fomites. Antiseptic hand lotion dispensers can also be located in these stations to maximize staff compliance with hand hygiene policies. If cage blankets, surgical drapes, other clinical linens, or food bowls are to be washed in-house, the hot water system should be designed to provide temperatures in excess of 160°F to ensure disinfection through laundry and dishwasher cycles.

**Surfaces and Fittings**

**Floors**
The choice of flooring material depends on the area of the hospital. Floors in clinical areas should be easy to clean. This requires that the surface be relatively smooth, nonporous, water resistant, and not physically affected by germicidal cleaning solutions. Tile is a popular choice for reception areas, but it is important to select a nonporous tile that has minimal texture because small ridges or crevices can trap dirt and bacteria. Tile also requires the use of grout, and the grout selected should be smooth and waterproof. A tile floor should be well sealed; periodic professional cleaning and resealing is recommended (based on the installer’s recommendation). Tile is not a good choice for the clinical areas of the hospital because the grout-filled cracks between tiles can trap bacteria.

Ideally, the floors in clinical areas should be monolithic (seamless). Appropriate choices for clinical areas are poured epoxy or methyl methacrylate flooring or sheet vinyl products. All of these products are available in varying textures. It is important to avoid a completely smooth surface; although ideal for infection control, it can create a serious slip hazard for clients and personnel when wet, and some dogs may have difficulty walking on it. Vinyl composition tile is available with low-grade textures, but the joints between tiles can trap bacteria. The manufacturer or installer should be consulted on any type of flooring with seams to determine a method and frequency of sealing.

The wall base should also be selected with infection control in mind. The base should be coved, as right-angled corners between the wall and the floor are difficult to clean. If a rubberized base is selected, the joints between the floor and the base material must be tightly sealed. A better choice for clinical areas is an integral base. Poured epoxy flooring and sheet vinyl flooring both allow for continuation of the floor material up the wall, avoiding any joints that could harbor bacteria. A minimum of four inches of cove base above the floor is recommended to facilitate contact with mop heads.

**Drains**
The use of floor drains is controversial. Drains provide the opportunity to wash an area with large volumes of water and disinfectant or even high-pressure washers, which may be more effective than a mop. However, drains provide a potential site for bacterial colonization that can be difficult to eliminate. If floor drains are used, they must be disinfected routinely. Alternatively, wet vacuums allow the use of large volumes of water and disinfectant without relying on floor drains. We suggest placing floor drains either outside the patient holding area (e.g., in front of runs) or in a corner where patients are unlikely to spend time. Floors must be pitched to promote runoff of liquids into the drain and prevent pooling.

**QuickNotes**

Ventilation systems should allow for pressure differentials between rooms, keeping surgical suites and oncology wards above the general hospital pressure units below the general hospital pressure.
Walls
Wall finishes also depend on the area of the hospital. Textile or fabric wall covering should be avoided, except perhaps in administrative areas. In clinical areas where walls are likely to be soiled, the finish should be washable. There are several reasonable and inexpensive finishes. Drywall can be sealed and painted with washable paint. Vinyl wall covering is a good choice, as long as the texture is relatively smooth for cleaning. For areas where the walls require frequent cleaning, a nonporous, smooth surface is recommended. Good choices in these areas are painted, sealed concrete; laminates (e.g., melamine); or a fiberglass-reinforced plastic (FRP) covering on gypsum board or other wall panels. To limit the expense associated with this product, the FRP paneling can be used on the lower half of the wall, with painted drywall in higher areas that are less likely to be contaminated.

In sensitive areas of the hospital (e.g., isolation units, surgical suites, oncology wards), wall finishes should be free of fissures, open joints, or crevices that could harbor dirt particles. Wherever plumbing penetrates the wall, the joins should be well sealed.

Ceilings
Ceilings are less likely to be directly contaminated with infectious body fluids than walls or floors. In most areas of the hospital, acoustic ceiling tile is an affordable and reasonable selection. The greatest danger with acoustic ceiling tile occurs when the tile gets wet (e.g., from roof leaks or faulty plumbing), which allows mold and bacteria to thrive. Acoustic ceiling tiles should be replaced if they get wet.

Ceiling selection in operating rooms is of greater concern because particulate matter from the ceiling can drift into open body cavities. Acoustic ceiling tile has crevices that can trap dust and harbor bacteria or mold. It is also not washable, and it crumbles when handled. It is therefore advisable to install a hard ceiling that is smooth and washable (e.g., painted drywall) in operating rooms. Joins at any ceiling perforations (e.g., for surgical lighting, ventilation ducts) should be sealed.

Ventilation
It is important to involve a mechanical engineer in designing the ventilation system to address issues such as odor and humidity control and heating and cooling system efficiency. Infection control must also be a factor in the design; air contamination is likely the most significant risk in the development of surgical site infections. Sensitive areas such as operating rooms and chemotherapy treatment areas should be ventilated so that the room air pressure is higher than the corridor air pressure. This “positive-pressure ventilation” ensures that air moves from clean to less-clean areas (i.e., from inside the room to the corridor), thereby keeping airborne infectious particles from entering the sensitive area. Operating rooms should be kept at a pressure that is 2.5 Pa greater than adjacent areas. Supply air should enter the room at the ceiling, and exhaust vents should be placed near the floor.

The use of laminar airflow ventilation systems has been advocated in human medicine. Laminar airflow ventilation systems provide vertical or horizontal layers of air movement in the operating room such that the flow is highest directly over the surgical site, limiting the introduction of particles from the environment and personnel. Several studies in the mid-1980s demonstrated a significant reduction in the rate of surgical site infections in human hospitals after the introduction of laminar airflow systems. However, these studies were not able to separate laminar systems as a single factor. The use of perioperative antibiotic prophylaxis was becoming more common at the same time, and the reduction in surgical infections could be at least partially attributed to this measure. Several multicenter studies have failed to demonstrate a significant effect of laminar airflow ventilation systems on infection control, and therefore the additional costs associated with these systems may not be justified.

In addition to positive-pressure ventilation, the operating room should be provided with at least 15 air changes per hour, at least three of which should consist of fresh outside air. If fresh air cycles cannot be provided, high-efficiency particulate air (HEPA) filters should be added to the supply system. It is important to have a maintenance agreement with the providers of the hospital heating, ventilation, and air conditioning (HVAC) system, as routine replacement of all filters—particularly HEPA filters—is necessary. HEPA filters are changed,
Isolation rooms and soiled areas of the hospital (e.g., areas where dirty laundry collects) should be under negative pressure (<2.5 Pa) in relation to adjacent areas. This prevents infectious particles from being transmitted to clean areas of the hospital by air currents. Isolation areas should receive six to 12 air changes per hour, and all air should be exhausted directly outdoors with no recirculation. If this is not possible, the air should pass through HEPA filters before being added to general circulation.

Ventilation professionals (usually the provider of the HVAC system) should routinely check the balance of airflow in the various areas of the hospital, ideally when the building’s climate control changes from predominantly heating to predominantly air conditioning or vice versa, or at least once a year. In the interim periods, an easy way to confirm the presence of positive or negative ventilation is to hold a smoldering match or cigarette lighter near a door that is open approximately 0.25 inch to assess the direction of air movement. If no air movement is detectable, there is probably no significant pressure differential. No oxygen or gas anesthetics should be in use before or while this test is conducted.

Another design consideration for the ventilation system is the location of air intake equipment and exhaust vents. Fresh-air intake sources should not be located near exhaust vents because this will reintroduce odors and organisms into the hospital.

**Recommended Practices for Sensitive Areas**

**Barrier Precautions and Isolation**

Patients at risk of spreading or contracting highly transmissible diseases often must be admitted to the hospital for further care and must be separated from the rest of the hospital population through the use of barrier precautions and/or isolation protocols. Barrier precautions essentially isolate the patient from the veterinary staff, thus limiting contamination of hands and clothing and the potential spread of pathogens to other patients or hospital areas. The goal of an isolation unit is to contain pathogens in a environment separate from the rest of the hospital. Isolation protocols have been shown to significantly reduce the incidence of hospital-acquired infections.

Airborne and droplet-borne pathogens (e.g., Bordetella spp, canine distemper virus, upper respiratory complex viruses), and fecal pathogens (e.g., canine parvovirus, coronaviruses, enteric bacteria, intestinal parasites) are common in veterinary hospitals. Often, several patients with different infections require isolation at the same time—most commonly puppies and cats with respiratory infections and puppies with parvovirus—necessitating patient cohorting in separate isolation units. For example, a puppy with a severe upper respiratory infection should not be housed in the same unit as a puppy infected with parvovirus, although both should be separated from the general hospital population. When separate isolation for patients with different highly transmissible pathogens cannot be achieved, transfer to another facility may be necessary. If transfer is not possible, isolation decisions must be based on the transmissibility of each pathogen. Because many respiratory pathogens are airborne, patients with these infections should take priority in being admitted to an isolation unit. In the above example, if transfer is not possible, the puppy infected with parvovirus should be managed in the general population with strict barrier precautions and be separated from other susceptible patients (e.g., incompletely vaccinated puppies), allowing the puppy with the upper respiratory infection to be admitted to the isolation unit.

Once a patient has been identified as potentially infectious, movement of that patient through the hospital must be limited and well planned. Patients should be admitted to the isolation unit efficiently; once a patient is admitted, it should remain in the isolation unit until discharge. If the patient must be moved through the hospital (e.g., for diagnostic imaging), barrier protection should be used and the path through the hospital should be as direct as possible, avoiding sensitive areas such as oncology wards, intensive care units, and surgical areas.

Veterinary staff should wear isolation gowns to minimize contamination of their clothing and skin, even though available information regarding the efficacy of gowns...
in isolation settings tends to suggest that gowns are not a necessary part of barrier protection strategies in nosocomial prevention.\textsuperscript{13–15} Despite the apparent lack of evidence supporting the use of gowns, the CDC and World Health Organization still recommend the use of gowns if infectious particles may be spread.\textsuperscript{11,16} We also believe that barrier gowns and masks are probably of greater benefit in veterinary medicine because of higher exposure to droplet particles and risk of clothing contamination from patients in isolation wards. These patients often cough and sneeze from respiratory infections or have profuse vomiting and diarrhea from enteric infections, increasing the dispersion of contaminated droplet particles. Masks may be more important when handling immunocompromised patients because pathogens can colonize human nasal passages and serve as a source of infection (the nose is a frequently reported site for colonization by methicillin-resistant \textit{Staphylococcus aureus} in human nurses).

Foot covers and footbaths are commonly used in veterinary isolation protocols. Veterinary studies have found significant reductions in bacterial colonization on the soles of boots treated in a footbath with a peroxygen compound; quaternary ammonium compounds were ineffective for this purpose.\textsuperscript{17,18} We have not identified any references in the human medical literature that address the use of footbaths or footmats. We recommend the use of disinfectant footbaths or footmats with an intermediate-level agent (preferably a hypochlorite solution or peroxygen compound), as well as shoe covers, in isolation areas. Disinfectant solutions should be changed at least once daily or when visibly contaminated.

Clean gloves are indicated for handling every patient. This practice serves to reduce transmission of microorganisms from the hands of the staff member to the patient and vice versa, especially during invasive procedures and contact with mucous membranes. Gloves must be changed between patients to prevent cross-contamination. Because of the risks of unnoticed defects, tears during patient care, or contamination during glove removal, appropriate hand disinfection must always be performed after glove removal.\textsuperscript{11,16,19} Hand disinfection must also be performed before obtaining gloves from a multiunit box to minimize colonization of the glove box.\textsuperscript{e}

Reusable items are often needed in the isolation unit, particularly linens and food/water bowls. Care should be taken to prevent contamination of personnel or the local environment, but the risk of disease transmission is minimal with appropriate handling and disinfection.\textsuperscript{d} Dishes should be appropriately disinfected with hot water (>160°F) and detergents in a standard dishwasher. Linens and food bowls should be transported to appropriate cleaning areas in bags. All medical equipment should be thoroughly cleaned and disinfected before use on another patient within the isolation unit or before removal from the isolation unit.\textsuperscript{11} Disposable items may be of benefit in limiting the movement of pathogens through the hospital.

Personnel issues are also important in the management of the isolation unit. The number of staff working within the unit should be minimized. If possible, a single technician and a single attending clinician should treat infectious patients. These staff members must limit contact with at-risk patients, such as surgical, geriatric, pediatric, and other immunocompromised patients. The isolation patients should be treated last when possible, and at any shift change, the staff at the end of the shift should complete necessary treatments just before leaving the building.

After every patient discharge, the isolation unit must be disinfected before admission of the next patient. All hard surfaces—including the floors, walls, table, and cage and its latch—should be disinfected. If cages are stacked, the cage immediately under the vacated cage should also be disinfected. Cabinets, sinks, door and cabinet handles, and other items that may have been contaminated (e.g., gauze containers) should also be disinfected. We recommend using a 1:50 solution of commercial bleach solution for these noncritical surfaces.\textsuperscript{e}

**Surgical Suites**

The use of critical items and invasion of sterile sites increase the risk of hospital-acquired infections for surgical patients. Surgical site

\textsuperscript{e}Hand hygiene is discussed in the companion article.

\textsuperscript{d}Linen care is discussed in the companion article.

\textsuperscript{f}Tables of appropriate disinfectants and contact times for various surfaces are presented in the companion article.
infections in human patients account for nearly $3 billion in hospital costs and extend hospital stays an average of at least 6 days. Surgical site infections are the most common hospital-acquired infections in small animal patients.

Foot traffic has been identified as a significant source of contamination in the surgical suite, although recommendations to reduce transmission are unclear and often contradictory. Data regarding the use of shoe covers versus dedicated operating shoes conflict, although both methods reduce bacterial colonization of floors. Footwear should be changed or covered before entering the induction area, and this site should be as far from the operating room as possible, based on evidence that bacterial contamination of corridors leading to operating rooms decreases significantly as the distance from the site of footwear change increases. A dedicated gurney should be used in the induction area if possible, with the patient transferred to another gurney for transport through the rest of the hospital. If this is not possible, the wheels of the gurney should be disinfected daily.

The operating table and surfaces around it must be thoroughly disinfected at least daily. This includes monitoring equipment, warming equipment (e.g., heating blankets, hot water bottles, wraps, blankets, surgical lamps), instrument tables, and the operating room floor. Intermediate-level disinfection after removal of all visible debris is recommended for this task. Anesthesia tubing and reservoir bags are considered semicritical items and should be disinfected at least daily or when used for patients with contagious diseases (e.g., pneumonia). We recommend using fresh disinfectant solution and submerging the equipment for the corresponding appropriate contact time, then turning the equipment over and resubmerging for the same time period to ensure that air bubbles do not restrict disinfectant contact. All equipment must be dried thoroughly before reuse.

Mops used in the surgical suite should be dedicated to the operating rooms and induction area. At the end of the day, the floors of the operating rooms and induction area should be cleaned of all visible debris before being disinfected with a fresh mop head and disinfectant solution. The end-of-day cleaning should disinfect operating rooms first, then the induction areas, and finally the entry corridor. Walls should be inspected daily and cleaned as needed. Once-weekly disinfection of walls should be considered.

The table and floor should be disinfected between patients. The Swiffer Wet Jet (Proctor & Gamble) is an economical means for single-use mopping between patients. The antimicrobial solution used for this product contains a chlorhexidine base. If a reusable mop is used, the disinfectant solution should be changed when it is visibly soiled or when contamination is suspected. The mop used to disinfect floors between surgical patients should be used only in the operating room to reduce the possible spread of pathogens from the induction area into the operating room.

Numerous reports have been published regarding the efficacy of products and protocols associated with presurgical hand hygiene. Many reports suggest that standard hand washing followed by a 30-second rub with a solution containing alcohol and a secondary antiseptic (e.g., povidone-iodine, chlorhexidine) is more effective than a full scrub procedure at reducing bacteria on hands. Alcohol rubs also seem to be tolerated by surgical staff better than scrubbing procedures in many of these reports. If scrubbing is used without an alcohol hand rub solution, a 5-minute scrub with chlorhexidine or povidone-iodine using a single brush is sufficient. We recommend a standard 5-minute hand scrubbing procedure with attention to areas under the fingernails. Subsequent scrubs can be performed using a 2-minute scrub with disinfectant (e.g., 4% chlorhexidine, povidone-iodine), followed by a 30-second hand rub with a preparation containing 60% to 70% ethanol and 1% chlorhexidine.

Conclusion

The prevention of hospital-acquired infections begins with the design and construction of the hospital. The design should make disinfection equipment and hand hygiene stations easily accessible and reduce the number of sites where bacteria and dirt can collect. Surfaces should be easy to clean and durable. Attention should be given to air and water systems and the placement and movement of patients through the hospital, especially in isolation or surgical settings.
If the potential for nosocomial infection is considered during hospital construction and patient treatment, especially treatment of patients at high risk for transmitting or contracting infectious organisms, the incidence of such infections can be significantly reduced. Many of the behavioral changes recommended here are relatively simple and inexpensive and, combined with staff education, can dramatically reduce the hospital's pathogen load.

References

### CE TEST

This article qualifies for 3 contact hours of continuing education credit from the Auburn University College of Veterinary Medicine. To take individual CE tests online and get real-time scores, visit Vetlearn.com. Those who wish to apply this credit to fulfill state relicensure requirements should consult their respective state authorities regarding the applicability of this program.

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1. To minimize bacterial colonization, hospital flooring should be
   a. seamless.
   b. relatively smooth and nonporous.
   c. water resistant.
   d. all of the above

2. Floor drains should be placed
   a. in animal containment areas.
   b. outside of the patient holding area.
   c. in a low-traffic area.
   d. at elevated points in the flooring.

3. What areas of the hospital should receive special consideration for infection control during the hospital design phase?
   a. surgical suites
   b. isolation units
   c. intensive care units
   d. all of the above

4. Windows in surgical suites should
   a. open outward.
   b. open inward.
   c. never be opened.
   d. be well screened.

5. A cocker spaniel puppy with suspected pneumonia and possible distemper presents to a hospital with a single isolation unit already containing a Labrador retriever puppy infected with parvovirus. There are no other hospitals in the area with an isolation unit to accept one of the puppies. The best option is to
   a. admit the spaniel to the general hospital for supportive care and treatment and leave the Labrador in the isolation unit.
   b. admit the spaniel to the isolation unit with the Labrador for supportive care and treatment.
   c. euthanize the spaniel.
   d. move the Labrador to the general hospital ward away from other dogs and using strict barrier precautions, and admit the spaniel to the isolation unit.

6. Which type of flooring is ideal in patient care areas of a hospital?
   a. monolithic poured epoxy or methylmethacrylate
   b. carpeted
   c. tile
   d. wood

7. The solution used in footbaths should contain
   a. a quaternary ammonium compound.
   b. a peroxygen compound.
   c. povidone-iodine.
   d. ethanol.

8. Which statement regarding precautions in isolation units is false?
   a. Gowns reduce contamination of the clothing of the person treating the patient.
   b. Gloves prevent contamination of the hands of the person treating the patient, and hand washing is not necessary after removal.
   c. Dedicated footwear or shoe covers, combined with footbaths, help to contain pathogens in the unit.
   d. Food bowls can be reused but should be transported directly to the designated cleaning area (e.g., the dishwasher) after each use.

9. The floor of the surgical suite should be disinfected
   a. between patients and at the end of the day.
   b. daily.
   c. weekly.
   d. monthly.

10. Which of the following is/are reported as effective for presurgical hand antisepsis?
    a. hand washing with plain soap containing triclosan for 1 minute
    b. hand washing with plain soap for 1 minute, followed by a 30-second rub with a product containing 60% to 70% ethanol combined with chlorhexidine or povidone-iodine
    c. a 5-minute scrub with chlorhexidine or povidone-iodine
    d. b and c