FINDINGS

INFECTIONS: Mitigating Risk in Healthcare Facility Design
A Module on a Safety Risk Assessment Component

THIS SAFETY MODULE INCLUDES:

Backgrounder

Design Strategies

Issue Brief

This module was created as a supplement to the Safety Risk Assessment (SRA) toolkit and other SRA-related Issue Briefs, Backgrounders, and Top Design Strategies. This toolkit is not intended to be a guarantee of a safe environment; the environment is one part of a safety solution that includes operational policies, procedures and behavior of people. It is intended for use with collaborative input of project- and facility-based expertise.

The Safety toolbox is made available through a partnership with Grainger.

This document will be updated in 2018 to be a stand-alone reference under the Grainger sponsorship.
Understanding Healthcare-Associated Infections (HAIs)

Healthcare-associated infections (HAIs) are defined as infections that patients acquire during the process of receiving care in healthcare facilities (Office of Disease Prevention and Health Promotion, n.d.). HAIs are among the most common complications found in healthcare systems, directly contributing to morbidity and mortality as well as billions of dollars of preventable healthcare costs each year. Recent outbreaks of HAIs, such as Ebola, severe acute respiratory syndrome (SARS), and methicillin-resistant Staphylococcus aureus (MRSA), further highlight the importance of prevention efforts. Prevention practices may lead to a 70% reduction in HAIs and annual financial benefits of $25–31.5 billion (Scott, 2009).

In the U.S., financial measures have been in place to incentivize healthcare organizations to reduce HAIs. Since 2008, legislation has been enacted to connect a hospital’s performance in infection prevention to the payment it receives from the government. Poor performance leads to significant payment reduction (Centers for Medicare & Medicaid Services, n.d.; West & Eng, 2014).

Many factors impact the likelihood of pathogen transmissions in healthcare settings, including the sources of infectious pathogens, susceptible patients (e.g., patient characteristics), and transmission routes (i.e., modes). Infection prevention efforts aim to cut off the major routes of transmission (Siegel, Rhinehart, Jackson, Chiarello, & Health Care Infection Control Practices Advisory Committee, 2007):

- Contact transmission (the most common transmission mode), including:
  - Direct contact: Pathogens transmitted directly from person to person
  - Indirect contact: Pathogens transmitted through an intermediate object (e.g., hands of nursing staff, inanimate environmental surfaces);
- Droplet transmission by respiratory droplets (>5 μm) carrying infectious pathogens over a short distance; and
- Airborne transmission by droplet nuclei or small particles which remain airborne and are dispersed for a long distance by air flow.

HAI TRACKING SYSTEMS

Most countries lack tracking systems for HAIs, and even those that do have them often lack standardized diagnosis criteria.

In the U.S., the National Healthcare Safety Network (NHSN) is the most widely used national tracking database for HAIs.

Currently, more than 14,500 healthcare facilities ranging from acute care hospitals to nursing homes are tracking HAIs and reporting data to NHSN.

Standard metrics and analytics tools enable individual facilities and government agencies to identify problems and engage in improvement efforts.

See the associated Issue Brief for additional detail.
Different pathogens (including bacteria, viruses, fungi, parasites, and prions) may be transmitted through one or more routes (Siegel et al., 2007).

References


OVERVIEW

To mitigate the risk of HAI, efforts should be made to cut off the main routes of pathogen transmission: airborne, droplet, contact, and water transmission.

Safety Risk Assessment: Healthcare-Associated Infections (HAIs) Design Strategies

The following design solutions are a brief summary of the content found in the SRA Issue Brief "Infections: Mitigating Risk in Healthcare Facility Design." They are organized by building design category.

Site Optimization and Building Layout

- There may be sources of contamination in or near healthcare facilities. These potential sources should be identified and addressed through disinfection methods (e.g., isolation, filtration).

Unit Layout

- Physical separation and isolation represent a key method of infection control through unit layout design. Considerations include:
  - Separation of supplies/equipment; and
  - Separation of patients through the provision of negative-/positive-pressured isolation rooms.
- A sufficient number of hand hygiene devices should be provided throughout the unit to increase hand hygiene compliance.

Room Layout

- Considerations should include the occupancy of both the patient room and bathroom, as well as the placement of sinks and other hand hygiene devices.
- Single occupancy rooms are ideal in terms of infection prevention. Room layout should allow easy visual and physical access to hand hygiene devices but prevent water splashes from sinks from reaching patient care areas.

Plumbing

- Plumbing system design considerations include:
  - Ease of cleaning and maintenance;
• Design elements to prevent contamination of fixture-related water splashing; and

• Proper water disinfection methods if needed.

**Technology Integration**

• Implement technology to monitor and enhance hand hygiene performance (e.g., audible or visual reminders).

**Interior Design/Finishes**

• To minimize surface contamination, it is important to select surface materials that are easy to clean, disinfect, and maintain; contain antibacterial/antimicrobial characteristics; and/or minimize dust collection (e.g., sloped instead of horizontal surfaces).

**Furnishings**

• Avoid environmental furnishings and fixtures that are likely to serve as reservoirs of pathogens, and include environmental measures (e.g., disinfection methods) to control infection risks. In addition, design should consider features (e.g., movable furniture) to make it easy to clean environmental surfaces and equipment.

**Heating, Ventilation, and Air Conditioning (HVAC)**

• Considerations include:

  o Location and accessibility of filters (e.g., point-of-use for critical areas);

  o Adequate monitoring for pressurization, filter life, temperature, and humidity;

  o Appropriate quantity and configuration of HVAC zones to allow environmental control flexibility;

  o Appropriate number of AII or PE rooms needed for intended use of space;

  o Use of specialty HVAC features/systems to support unique environmental conditions (e.g., entryways, ICU, or neonatal areas);

  o Antibacterial characteristics that reduce the risk of contamination; and

  o Easy access to properly maintain or replace contaminated HVAC and other building components.
Additional Resources

CDC 2003 Guidelines for Environmental Infection Control in Health-Care Facilities
http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_HCF_03.pdf

Infection Control Risk Assessment Matrix of Precautions for Construction & Renovation
www.ashe.org/advocacy/organizations/CDC/pdfs/assessment_icra.pdf

Understanding the Role of Facility Design in the Acquisition and Prevention of Healthcare-Associated Infections: A Special Supplement to the Health Environments Research & Design Journal

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FINDINGS

INFECTIONS:
Mitigating Risk in Healthcare Facility Design
An Issue Brief on a Safety Risk Assessment Component

INSIDE YOU WILL LEARN ABOUT:
The importance of infection prevention in healthcare environments.
Key physical environmental elements for infection prevention.
A systems approach that integrates the physical environment, operations, and people.

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Healthcare-associated infections (HAIs) are defined as infections that patients acquire during the process of receiving care in healthcare facilities. Among the most common complications in U.S. healthcare, HAIs directly contribute to the deaths of tens of thousands of patients and cost billions of dollars every year, despite being largely preventable. Mounting research evidence indicates that the physical environment of healthcare facilities plays a significant role in infection prevention. Key recommendations include:

- Single-bed patient rooms, as compared with multi-bed rooms, may provide physical separation between patients and thereby reduce the risk of cross-contamination through air and contact transmission;
- Isolation rooms with proper air flow design may help reduce airborne transmission of pathogens;
- Hand hygiene device design (including quantity, location, and features that reduce the possibility of re-contamination) and reminders may impact hand hygiene performance, which is considered the single most important measure of infection prevention;
- Heating, ventilation, and air conditioning (HVAC) design can provide air dilution, filtration, and disinfection for the purpose of reducing air contamination;
- Easy-to-clean/maintain finishes and furnishings can contribute to environmental cleanliness; and
- Potential sources of contamination, such as construction sites, should be monitored and controlled.

There is no silver bullet for solving the problem of HAIs. When healthcare organizations endeavor to prevent HAIs, they often find a systems approach to be most effective. In this approach, physical environment measures are...
coordinated with many other factors, including organizational and clinical policies and procedures, as well as the workflow and behavior of caregivers, staff, and patients who use the facility, to achieve the best possible outcomes.

Mitigating the Risk of Infections With Environmental Design

Site Optimization and Building Layout

Construction sites, as well as other building activities or components, may become a source of contaminants and cause infection outbreaks. Research has found that certain disinfection methods, including HEPA filtration, are effective in controlling major sources of contaminants, such as construction sites (Barnes & Rogers, 1989).

Unit Layout

Contaminated air flow from rooms where airborne infectious patients stayed was reported to increase the risk of infections among patients and staff in nearby spaces (Gustafson et al., 1982; Hutton, Stead, Cauthen, Bloch, & Ewing, 1990). Research strongly suggests that airborne infectious patients should be isolated in negative-pressured rooms to minimize the risk of cross-contamination by preventing contaminated air from flowing from isolation rooms to nearby spaces (Sehulster & Chinn, 2003). Immunocompromised patients are particularly vulnerable to infections. Research strongly suggests that immunocompromised patients should be isolated in positive-pressured rooms to minimize the risk of contracting airborne pathogens by preventing potentially contaminated air from flowing from nearby spaces into the isolation rooms (Sehulster & Chinn, 2003).

Hand hygiene is considered the single most important method of infection prevention, as pathogens are often transferred via the unwashed hands of staff, patients, and families. The number of hand hygiene devices is an important factor, significantly impacting hand hygiene performance. More sinks, gel dispensers, and other hand hygiene devices likely make it easier for staff, patients, and families to gain access to the devices and clean their hands when needed (Kaplan & McGuckin, 1986).

The contamination of linen and other supplies increases the risk of infections. Physical separation (e.g., a separate soiled utility room) is an important method of preventing the transfer of pathogens from soiled to clean linen, equipment, and other supplies.

With respect to specific space types, research has found that frequent door openings during surgical procedures may generate disturbances to air flow and

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SITE & BUILDING
Construction sites could potentially become sources of contamination and should therefore be monitored and controlled using methods such as high-efficiency particulate air (HEPA) filtration.

UNIT LAYOUT
Conditions associated with unit layout include:

1. Provision of isolation rooms to prevent cross-contamination.
2. High number of hygiene devices to improve cleanliness of hands.
3. Physical separation to reduce contamination of linen and other supplies.
increase the air contamination level in operating rooms (ORs) (Andersson, Bergh, Karlsson, Eriksson, & Nilsson, 2012). The need for OR door openings during surgical procedures may be reduced through building design (e.g., locating certain supplies within the OR; wireless consultation). This, in turn, may help reduce the risk of infections for OR patients.

Room Layout
Direct and indirect contact constitute major routes of pathogen transmission between patients (Chang & Nelson, 2000). Reducing the chances of direct/indirect contact between patients by physically separating and isolating them, especially with single-bed patient rooms, has been associated with significantly lower risks of HAIs and better health outcomes (MacKenzie et al., 2007; McManus, Mason, McManus, & Pruitt, 1992).

Water splashes from sinks have been found to increase the risk of contamination and infection transmission of water-borne pathogens. Research has found that the location and orientation of hand hygiene devices are important factors that impact the possibility of water splashes from sinks reaching nearby patient care areas (Hota et al., 2009). Carefully located hand hygiene devices may make it easy for staff and other individuals to see and use the devices to clean their hands.

Shared bathrooms may serve as reservoirs of infectious pathogens that can spread from patient to patient in a short period. Single-patient bathrooms may help reduce cross-contamination and improve environmental cleanliness. Even in bathrooms less frequently used by patients, pathogens could be brought in on staff members’ hands or used equipment and supplies.

Plumbing
There are reports about infections associated with fixtures and equipment (e.g., certain types of water faucets) (Sydnor et al., 2012). Fixtures and equipment that are easy to clean and maintain may be associated with a lower chance of becoming pathogen reservoirs and a lower risk of contributing to infection transmission.

Hand hygiene devices themselves may become contaminated and play a role in pathogen transmission by contaminating the hands of staff, patients, and families (Harrison, Griffith, Ayers, & Michaels, 2003). Certain features of hand hygiene devices, such as foot-operated sinks and hands-free faucets, may help reduce the likelihood of re-contamination of hands after cleaning. In addition to the location of sinks, the design of sinks should be considered in order to prevent splashing into nearby patient care areas. Several sink design features
were recommended by research studies: faucet spouts that do not flow directly into the drain, decreased water pressure, and physical barriers between sinks and adjacent preparatory spaces (Hota et al., 2009).

Research has found different levels of effectiveness of various water disinfection methods in preventing or controlling various types of water contamination and outbreaks of water-borne infections (Modol et al., 2007). Proper water disinfection methods should be considered when designing plumbing systems.

**Technology Integration**

Design solutions that provide reminders (electronic or visual) and/or offer automated compliance reporting have been found in multiple studies to improve hand hygiene compliance (Armellino et al., 2012; Fakhry, Hanna, Anderson, Holmes, & Nathwani, 2012).

**Interior Design/Finishes**

Research shows that the contamination of environmental surfaces may serve as a link in the chain of infection transmission. Certain surface materials have been reported to be easier to clean, disinfect, and maintain and are associated with a lower risk of contamination (Anderson, Mackel, Stoler, & Mallison, 1982; Harris, Pacheco, & Lindner, 2010; Lankford et al., 2006; Noskin, Bednarz, Suriano, Reiner, & Peterson, 2000). Recent research reports indicated that antibacterial and antimicrobial characteristics of certain surface materials may be associated with a lower risk of surface contamination and may therefore help to prevent infection transmission (Karpanen et al., 2012; Takai et al., 2002).

Dust particles may also carry pathogens. Without proper cleaning, environmental surfaces (especially high-touch objects) may catch dust and become reservoirs of pathogens. Design that reduces the amount of dust caught on environmental surfaces may help reduce the risk of environmental surfaces becoming pathogen reservoirs, thereby reducing the risk of infection transmission (Williams, Singh, & Romberg, 2003).

Antibacterial and antimicrobial characteristics of certain surface materials may be associated with a lower risk of surface contamination.
Furnishings

Environmental design may facilitate the cleaning of high-touch objects (e.g., door handles, toilet handles, hand rails), thus reducing environmental contamination and reducing the risk of infection transmission (Williams et al., 2003). According to multiple recent epidemiological reports, without proper maintenance and cleaning, certain environmental features (e.g., open water fountains, curtains) could become reservoirs of pathogens and cause outbreaks of infections (e.g., Palmore et al., 2009). Precautions should be taken to reduce the risks involved with environmental features known to be potential reservoirs of pathogens.

Heating, Ventilation, and Air Conditioning (HVAC)

Research indicates that HVAC system design elements (including the location of ventilation grilles, air pressure difference between nearby spaces to prevent leakage of contaminated air, type and location of air filters, air disinfection, and ventilation rates) significantly impact an HVAC system’s effectiveness in reducing air contamination and improving air hygiene in healthcare settings (Beggs, Kerr, Noakes, Hathway, & Sleigh, 2008; Menzies, Fanning, Yuan, & FitzGerald, 2000).

Data shows that the filtered air is often re-contaminated after being filtered with central filters (located inside the main air ducts) and before flowing into healthcare spaces. Peripheral filters (located at the openings of ducts) were found to make the air flowing into healthcare spaces cleaner (Crimi et al., 2006). HVAC equipment can be contaminated and subsequently contaminate the air entering into other healthcare spaces (Lutz, Jin, Rinaldi, Wickes, & Huycke, 2003). Studies found that certain HVAC components with antibacterial characteristics were associated with a lower risk of HVAC system contamination and air contamination (Schmidt et al., 2012). Research has identified cases in which the ventilation systems may not work as designed (e.g., air flowing from negative pressure rooms to other spaces) and the deficiency in ventilation may cause infection outbreaks (Fraser et al., 1993). Proper monitoring, commissioning, and maintenance should be done in order to optimize the performance of ventilation systems.

Research indicates that environmental hazards such as dampness in the HVAC system may result in contamination during the lifecycle of a building (Lutz et al., 2003). It’s essential to proactively monitor potential environmental hazards and identify methods of controlling contamination. After the identification of potential problems, easy access to system components is very important to facilitate necessary maintenance or replacement to mitigate the environmental hazards.

HVAC SYSTEM

HVAC system design elements significantly impact the effectiveness of reducing air contamination and improving air hygiene in healthcare settings. Factors include:

- Location of ventilation grilles
- Air pressure difference between nearby spaces to prevent leakage of contaminated air
- Type and location of air filters
- Air disinfection (e.g., ultraviolet germicidal irradiation)
- Ventilation rates
- Air flow design (e.g., laminar flow)
With respect to specific space types, the effectiveness of different OR ventilation methods (e.g., conventional, laminar, non-aspirating, displacement) varies significantly depending on different surgical procedures and OR layout (Memarzadeh & Manning, 2002). To minimize the risk of infections contracted in the OR, the most effective OR ventilation method should be selected.

### Conclusion

The physical environment of healthcare facilities constitutes an essential component in infection prevention. A multifactorial systems approach should be taken to coordinate environmental design efforts around layout (building, unit, and room), finishes, furnishings, HVAC systems, and plumbing fixtures, with efforts coordinated around organizational policies and procedures, as well as the individual users of healthcare spaces (e.g., caregivers, maintenance staff, and patients).

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### References


