Using the Health Care Physical Environment to Prevent and Control Infection

A Best Practice Guide to Help Health Care Organizations Create Safe, Healing Environments







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A PROJECT BY:

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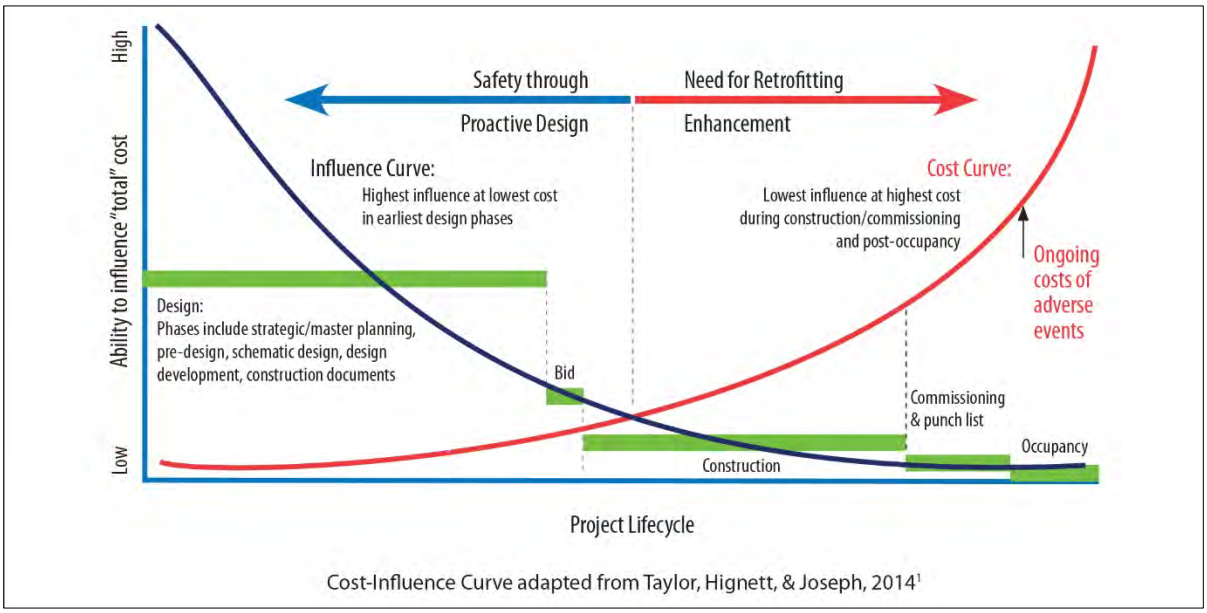
Executive Summary

Individuals enter various health care settings seeking safe, high-quality care. Patients, as well as the individuals who provide care, access health care environments in the hope that they will function as structured settings that promote positive health outcomes. Nonetheless, the transmission of infections within health care settings presents complications that can negatively affect patient and institutional well-being. Although numerous improvement efforts are ongoing, the prevalence of healthcare-associated infections (HAIs) remains a significant risk and cost within health care environments around the world. Since HAIs are identified as infections that arise specifically within health care settings, the continued prevalence of HAIs indicates a need for a better understanding of how aspects of the built environment relate to the transmission of infection, and what design, construction and operational changes can be made in the built environment to support HAI prevention.

Innovations are continually being made in the fields of health care and design, making the importance of communication and cooperation between designers and health care providers increasingly more apparent. A key theme throughout this document is the importance of bringing the right disciplines together to create safe, healing environments. By exchanging perspectives during all phases of planning, construction and renovation of health care facilities, designers and health care providers can create environments that directly contribute to reduction of HAIs. By encouraging facility managers, architects and designers, construction professionals and infection preventionists to work together, particularly in early planning phases, safer health care environments will be created. This publication was created to help illustrate strategies that health care organizations can employ to optimize their buildings for improved infection prevention and control.

Apart from fostering more positive health outcomes, building health care environments in a way that conscientiously addresses the issue of HAIs can also prove to be more financially sustainable. As illustrated in Figure 1, a proactive approach to safe facility design will lower costs incurred during design and construction and also influence long-term operational costs. The window to effect the most influence for lowest cost occurs in the earliest phases of design. As the design is completed and the project moves into construction, changes become increasingly expensive. Following occupancy, organizations are left with significant ongoing costs when spaces must be renovated due to missed design opportunities that may have come to light with early multidisciplinary collaboration. In addition, adverse events such as HAIs, which may not have been appropriately considered during design, may continue to occur, contributing to poor patient outcomes and unnecessary health care expenses.

Figure 1: Moving Safety Upstream in the Health Care Facility Design Process



Cost-Influence Curve adapted from Taylor, Hignett, & Joseph, 2014[1]

From placing hand sanitizers for optimal use to managing water systems to minimize pathogens, the physical environment plays an important role in infection prevention and control. This publication explores six important topics related to infection prevention and control through the physical environment:

- Infection control risk assessment
- Hand hygiene infrastructure
- Reprocessing
- Cleaning of environmental surfaces
- Water-related environmental infection control
- Flow of patients, personnel, equipment and waste

Based on peer-reviewed research, this document provides background information to help readers understand how the environment contributes to infection transmission in health care settings. Interviews and case studies are shared to illustrate actual infection prevention-related successes and challenges presented by the built environment. The document also provides additional key resources specific for each topic that readers may reference for regulations, guidelines and best practices. Those looking for a brief summary of the issues and an overview of best practices can use the Quick Guides in the beginning of this publication.

The remainder of this Executive Summary provides a brief overview of the six chapters included in this document.

Chapter 1 discusses the infection control risk assessment (ICRA), a process by which infection risks are taken into consideration during the design and construction of a health care space. This process results in specific design, construction and commissioning recommendations and risk mitigation measures. The spread of HAIs has been associated with both health care facility design and construction activity. Ongoing cycles of facility renovation and construction present continual risks for environmental contamination and subsequent infection transmission. The ICRAs are required by jurisdictions that acknowledge or adopt the Facility Guidelines Institute

(FGI) *Guidelines for the Design and Construction of Hospital, Outpatient and Residential Facilities* (three separate resources), which provide minimum standards for the design and construction of health care facilities.[1,2] The current *Guidelines* describe the ICRA as a proactive and integrated process for the planning, design, construction and commissioning activities to "identify and plan safe design elements, including consideration of long-range infection prevention; identify and plan for internal and external building areas and sites that will be affected during construction/renovation; identify potential risk of transmission of airborne and waterborne biological contaminants during construction and/or renovation and commissioning; and develop infection control risk mitigation recommendations (ICRMRs) to be considered."[3]

Chapter 2 illustrates how hand hygiene is essential to safe hospital care, and how the infrastructure supporting hand hygiene plays an important role in maintaining compliance. This infrastructure includes the design and placement of sinks, faucets, hand-drying facilities, and dispensers of alcohol-based hand rub. This chapter helps the reader understand how human factors play a role in hand hygiene compliance and explains how designers should consider human factors when planning hand hygiene facilities. These principles can be put into effect by:

- Minimizing the complexity of hand hygiene.
- Designing features that force appropriate behaviors.
- Minimizing the time spent on hand hygiene.
- Providing cues to prompt hand hygiene.
- Assessing the usability of new hand hygiene systems.
- Testing new systems in real-life conditions.

Chapter 3 shows why reusable instruments and equipment for medical care must be reprocessed utilizing low-level disinfection, high-level disinfection or sterilization prior to use with the next patient, and why locations where these functions are performed must meet specific requirements to assure appropriate reprocessing and worker safety. Additionally, best practices are identified that demonstrate the environments in which the process is most likely to be successful. Note that Chapter 3 addresses high-level disinfection (HLD) and sterilization, while Chapter 4 goes on to address general environmental cleaning and low-level disinfection that occurs in health care.

Chapter 4 discusses why cleaning and disinfecting environmental surfaces are a critical component in the prevention of HAIs and illustrates various design components that contribute to supporting or inhibiting effective environmental cleaning. For example, hard, nonporous surfaces, such as bed rails, call buttons and overbed tables form part of the environmental reservoir that are highly susceptible to microbial contamination.[4,5] Both routine and innovative new approaches may be utilized for disinfection of surfaces in patient rooms: chemical disinfection with manual cleaning; using "self-disinfecting" surfaces that are impregnated or coated with metals such as copper, silver or other germicides and no-touch technology such as ultraviolet light (UV-C) or fogging with hydrogen peroxide vapor or mist.[6] This chapter provides considerations for the built environment in view of these various methods. Health care leaders can better identify environmental process deficiencies, develop an action plan for correcting these deficiencies, implement the action plan and monitor the plan for positive outcomes. For both existing and new facilities, a multidisciplinary team including administration, nursing, environmental services, infection prevention, facility management, materials management and biomedical engineering should be formed for a successful environmental program.

Chapter 5 provides an overview of pathogenic risks inherent in premise plumbing, that is, plumbing between entry to the building and delivery to the user. The risks are largely attributable to the development of biofilm on protected inner surfaces of plumbing systems, such as joints, dead legs, encrustations and plumbing enhancements that prevent the inner surfaces from being smooth and contiguous.[7] This chapter proposes that the design of health care facility plumbing must intentionally avoid the features that foster growth and dissemination of waterborne pathogens such as *Legionella* spp., pseudomonads and other gram-negative bacteria, nontuberculous mycobacteria and fungi.[8] It also discusses how patients with invasive devices (for example, central venous lines, urinary catheters, ventilators), and patients with impaired immune systems (for example, malignant hematology, solid organ transplants, extremes of age) exposed to tap water are at increased risk for infection from waterborne pathogens, and how exposure occurs through bathing, showering, drinking water or ice, and contaminated medical equipment rinsed with tap water or that holds nonsterile water. Exposure may also occur through contamination of injectable medications, solutions or antiseptics or the possibility of aerosol or droplet transmission. Ultimately, absolute prevention of waterborne pathogens is unlikely, necessitating the development of a water safety or management program that includes monitoring and a plan for mitigation when controls are out of range. Recommended practices for mitigating waterborne pathogen growth in new construction and established facilities have been published.[9,10,11,12] This chapter will incorporate recommended practices for personnel tasked with water safety in the built health care facility environment.

Chapter 6 focuses on specific design strategies intended to minimize the risk of transmission of infection associated with space configuration within health care settings. These strategies include the arrangement of spaces based on intended use, the design of airflow relationships to contain contaminants or protect clean spaces, and design features intended to ensure the optimal flow of patients, personnel, materials and waste to minimize the risk of cross contamination. A portion of the chapter also specifically focuses on emergency department design to support effective triage and early isolation of potentially infectious patients, and to reduce the risk for transmission or acquisition of infection within the emergency department setting.

Developing design strategies intended to prevent the transmission of infection when building or renovating health care facilities requires a fundamental understanding of how infections are spread, a knowledge of regulatory requirements and an understanding of published and new and innovative best practices for infection prevention related to the built environment. Design and construction planning requires both multidisciplinary teamwork and a commitment by leadership to assure incorporation of best practices for new and renovated spaces that optimize prevention of infection.

Quick Guides

Quick Guide, Chapter 1: Infection Control Risk Assessments

Expanded information, case studies, references and other important items related to infection control risk assessments are available in Chapter 1 of this publication.

The design and construction of health care facilities influence infection outcomes. To help reduce infection risks, health care organizations should perform an infection control risk assessment (ICRA) when designing, renovating or constructing a health care facility. An ICRA is required by many jurisdictions through the adoption or use of the Facility Guidelines Institute (FGI) *Guidelines for the Design and Construction of Hospital, Outpatient and Residential Health Care Facilities* (three separate documents). Using the ICRA process can help hospitals identify infection risks and potential solutions.

An interdisciplinary ICRA team should include experts in both medical and building sciences, such as front-line caregivers from clinical departments affected by the project, facility management, quality improvement representatives, environmental safety specialists, infection preventionists, epidemiologists, architects, interior designers, engineers, human factors specialists, environmental services staff, and contractors. Other disciplines, such as risk management or lab personnel, may be helpful on an ad hoc basis.

The ICRA team is responsible for conducting a health care risk assessment. A common approach to this process includes five steps:

1. Identify the hazards.
2. Decide who might be harmed and how.
3. Evaluate the risks and decide on the precautions.
4. Record findings, propose action and identify who will lead on what action.
5. Review the assessment and update if necessary.

Design solutions may be straightforward (such as choosing plumbing fixtures that can reduce the risk of contaminated water) or they may be more nuanced (such as locating a hand hygiene sink in a space within a patient room that promotes hand hygiene compliance).

Solutions to mitigate risks during construction may be more prescriptive and can be identified through tools such as an ICRA precautions matrix. An ICRA precautions matrix can help determine steps to take when conducting a construction or renovation project in a health care facility. Using the American Society for Heath Care Engineering (ASHE) ICRA precautions matrix as an example, an ICRA team would rate the type of construction (i.e., painting, sanding, duct work or new construction) and the risk of the patient groups affected (e.g., office areas, emergency rooms, operating rooms, burn unit). The precautions matrix would determine precautions needed (i.e., minimizing dust, cleaning the area after project completing, maintaining negative air pressure, using high efficiency particulate air (HEPA)-equipped air filtration units).

Best practices related to ICRA processes include:

- Ensure the ICRA team is interdisciplinary. Get infection prevention involved early in the design process.
- Involve the ICRA team to address minimum standards identified in several guidance

sources, including the Centers for Disease Control (CDC) and FGI *Guidelines.*

- Use the ICRA precautions matrix to determine precautions needed during construction activity.
- Include construction-related requirements of the ICRA into contract documents.
- Since safe design relies not only on the ICRA process but also on other aspects of a health system as well (organizational policies, staff, etc.), consider different perspectives and take a systems view of safety.

Quick Guide, Chapter 2: Hand Hygiene Infrastructure

Expanded information, case studies, references and other important items related to hand hygiene infrastructure are available in Chapter 2 of this publication.

Hand hygiene is essential to safe health care, and the infrastructure to support hand hygiene plays an important role in how well hand hygiene compliance is maintained. That infrastructure includes the design and placement of sinks, faucets, hand-drying facilities and dispensers of alcohol-based hand rub.

Studies show that the location of sinks is more influential than the number of sinks. One study found that each additional meter between the patient's immediate surroundings and the nearest sink decreased the likelihood of handwashing by 10 percent. However, pathogens can be spread by water splashed from sinks, so water pressure should be optimized and flow should be offset from the drain. Some studies have shown that sinks designated for handwashing, and not for patient use, improved hygiene.

Valves within faucets that automatically turn on and off by themselves have been shown to contribute to pathogen transmission, even though the design intention is to reduce transmission by negating the need for users to touch the handle. These faucets may have low flow, tepid temperature and internal components (valves) that may harbor biofilm, which can contribute to microbial amplification.

Paper towels are preferable to warm-air blowers for drying hands, because the towels can be used to turn off the faucet after use and the blowers may spread pathogens. However, pathogens can be spread by contaminated towel dispensers.

Availability of alcohol-based hand rub dispensers has been shown to improve hand hygiene compliance. The optimal location for dispensers appears to be just outside the doorways to patient rooms. In that location, the dispenser is typically highly visible, it is on the route of the caregiver, and the action of entering the room is a trigger for the caregiver to perform hand hygiene. Dispensers immediately near or on patient beds also help compliance. The design of the dispenser also is important – a bright color and a design that differentiates the hand rub dispenser from soap dispensers improve usage.

Designers should consider human factors when designing hand hygiene facilities. These principles can be put into effect in the following ways:

- Minimize the complexity of hand hygiene.
- Provide design features that force appropriate behaviors.
- Minimize the time spent on hand hygiene.
- Provide cues to prompt hand hygiene.
- Assess the usability of new hand hygiene systems.
- Test new systems in real-life conditions.

Best practices related to the design of hand hygiene facilities include:

- Ensure handwashing sinks are separate from patient-use sinks and are not used for waste disposal. Handwashing sink placement should be near the point of care.
- Ensure adequate space between areas used for medical preparation, and use splash guards where appropriate.
- Faucets should be operable without using hands, such as with foot controls or wrist

blades, and the water should angle away from the drain and flow at moderate pressure to minimize splashing.

- Choose paper towel dispensers that can be operated without touching, and avoid warm air dryers where noise or dispersion of bacteria would present patient risk.
- Install alcohol-based hand rub dispensers at patient room doors and at every bed.
- Evaluate the location of soap and glove dispensers at the hand hygiene sink during design.
- Ensure adequate space for waste containers is provided at the hand hygiene sink.
- During the design process, make hand hygiene processes an explicit point of concern.

Quick Guide, Chapter 3: Reprocessing

Expanded information, case studies, references and other important items related to reprocessing are available in Chapter 3 of this publication.

Areas in a hospital where sterilization and high-level disinfection are performed should be designed to permit effective workflow and maintain maximum cleanliness. Important issues to consider in the design of such spaces include the type of equipment used, the proximity to areas requiring the sterilized or disinfected equipment, the ability of surfaces to withstand copious amounts of water, and the flow of equipment and personnel.

The sterilization process involves five steps, the final four of which affect the design of the sterilization area. The first step is gross decontamination – the removal of visible debris – which happens frequently at the site of use and therefore doesn't affect the design of the sterilization area. The remaining four steps are decontamination, packaging for sterilization, sterilization, and storage, each of which affects space design.

The type of sterilizing equipment used affects design. For example, a table-top sterilizer does not require much infrastructure. Steam sterilizers require a certain quality of steam, separate access for maintenance and careful placement of air ducts. Hydrogen peroxide plasma sterilizers operate at lower temperatures than steam sterilizers, and thus demand less of the infrastructure. Ethylene oxide sterilizers demand more infrastructure because of safety issues and processing requirements unique to this modality.

The requirements for space used for high-level disinfection may differ from those of the space used for sterilization. Endoscopes and vaginal probes are examples of two items commonly reprocessed in high-level disinfection areas. Many hospitals use automated endoscope reprocessors, which have specific water pressure needs. The chemicals used in high-level disinfection must be disposed of properly, which may necessitate more infrastructure.

In both sterilization areas and high-level disinfection areas, the lighting in the sink areas must be bright to allow for effective removal of all visible debris. Staff in these areas must wear personal protective equipment, which can take up space and affect air temperature requirements. In addition, the spaces should be designed to minimize staff interruption and distraction.

The materials used in these areas must withstand copious amounts of water: wood or pressboard should not be used, and walls must not allow for fungal growth if saturated with water. Humidity and ventilation of these spaces also must be closely controlled.

Best practices in designing sterilization and high-level disinfection areas include:

- Flow through the space must be unidirectional from dirty to clean.
- Pipes, conduit or ductwork located above work areas should be enclosed to prevent dust accumulation, and ceilings should be made of materials that do not shed particulates.
- Sterilizers should be located in restricted areas to prevent accidental removal of unsterilized equipment.
- Hand-washing sinks should be readily available so staff can wash after handling items yet to be processed and before handling processed items.

Quick Guide, Chapter 4: Cleaning of Environmental Surfaces

Expanded information, case studies, references and other important items related to the cleaning of environmental surfaces are available in Chapter 4 of this publication.

Effectively cleaning and disinfecting surfaces in health care settings is essential to the prevention of infections. Pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA) and others (e.g., spores of *Clostridium difficile*, *Acinetobacter baumannii*, etc.) can survive for a long time on surfaces and infect patients, and studies have shown that traditional chemical cleaning methods do not always adequately remove the pathogens.

New technologies have entered the market and show promise in reducing these pathogens, including improved chemical disinfectants, antimicrobial surfaces that may reduce the numbers of organisms on a surface over time, and “no touch” automated disinfection systems.

It is a best practice to form a multi-disciplinary team that establishes policies and procedures regarding room cleanliness and disinfection. The team should include staff from administration, infection prevention and control, nursing, environmental services, and facility management. The team should develop a five-stage plan:

1. Determine which chemicals will be used to clean and disinfect surfaces, paying particular attention to the specific needs of the health care organization and various departments. Once the chemicals are chosen, establish usage guidelines.

2. Define policies and procedures, including what the cleaning tasks are, which department is responsible for each, how often the task should be completed, and which products will be used for each task. Pay particular attention to identification of “orphan items” that may not have been clearly designated to anyone for cleaning. Checklists and daily assignment sheets are useful tools for maintaining adherence to protocols.

3. Train environmental service staff and any other personnel designated to clean surfaces. New hires should be trained, and existing staff should have ongoing training. Staff should take part in yearly competency testing.

4. Effectiveness of cleaning and disinfecting should be regularly monitored, such as with direct observation, fluorescent marker systems or adenosine triphosphate (ATP) ATP bioluminescence assays. Timely feedback should be provided to staff, including the results of the cleaning and disinfecting monitoring results.

5. The multidisciplinary team should conduct an analysis and evaluate new technology for environmental cleaning and assess the need and application of these new technologies in their hospital setting.

Quick Guide, Chapter 5: Water-Related Environmental Infection Control

Expanded information, case studies, references and other important items related to water-related environmental infection control are available in Chapter 5 of this publication.

Plumbing in a health care facility can house pathogens. Taking steps to minimize pathogen growth is important. Pseudomonas grow in stagnant water found within the plumbing system, such as in joints, dead legs, encrustations and plumbing enhancements. The pathogens are closely associated with biofilms, which provide protection and food, and they are typically dispersed when biofilm reaches certain development phase or during sloughing events such as when the water system is disrupted, such as during construction or during high-demand periods.

Since completely eliminating these pathogens is unlikely even in new construction, it is important to develop a water safety or management program that iteratively monitors water at predetermined locations and addresses out of range control metrics when noted.

A multidisciplinary water management team should be developed in all health care facilities. This team, which should be given the authority to implement water decisions, has a number of important tasks. These include mapping the water system; analyzing hazards; developing mitigation strategies; establishing metrics; enacting policies that identify hazards; conducting surveillance for disease caused by waterborne pathogens; and developing a strategy for replacement of current higher-risk premise plumbing problem areas. Each team member has specific areas of responsibility.

A risk assessment is an important step in water system management. The risk assessment should identify potential problems with the domestic the water source, inlets, flow, stagnation, heat transference, faucets/showers/drains and other areas. Another important part of the risk assessment is to develop a plan to deal with water disruptions, both planned and unplanned, since such disruptions can lead to the dispersal of pathogens.

Regular monitoring of water disinfection strategies by the water source is key to understanding incoming water risks. Water quality reports should be routinely reviewed, and, if utilized, supplemental disinfection methods adjusted accordingly. Adjunct disinfection strategies for health care facilities to consider include hypochlorite, chlorine, chlorine dioxide, copper-silver ionization, hyper-chlorination filtration, ultraviolet light and thermal control. All have advantages and disadvantages.

Best practices regarding waterborne pathogen management include:

- Create and empower a multidisciplinary water management team. Among other purposes, this team socializes the concept of a water safety program.
- Perform a risk assessment for all water systems and water-containing equipment. Include water within equipment, stagnant water plumbing during construction, and rarely used locations, such as eye-wash stations and emergency showers.
- Be involved in renovation and construction to provide safe plumbing expertise.
- Avoid in-hospital decorative water features (water walls, reflecting pools, fountains).
- Be aware of waterborne pathogens and the diseases they may potentially cause, and maintain surveillance for trends. Some of these diseases include pneumonia, bloodstream infections, surgical site infections, meningitis, gastroenteritis and urinary tract infections.

- Develop and execute an action plan to mitigate risks and address outbreaks when they occur.
- Monitor key metrics established by the water safety team to demonstrate that the water safety program is working. Key metrics may include 1) process control measures, such as chlorine levels or measurements of temperature control, 2) the burden of pathogens in humans (patients and health care professionals) and/or 3) the burden of pathogens in water as epidemiologically indicated.

Quick Guide, Chapter 6: Flow of Patients, Personnel, Equipment and Waste

Expanded information, case studies, references and other important items related to the flow of patients, personnel, equipment, and waste are available in Chapter 6 of this publication.

The risk of infection transmission in a hospital can be reduced by a number of strategies, including proper configuration of space, airflow design that minimizes the spread of pathogens, and design features that ensure the optimal flow of people and material to minimize cross contamination.

Separating patients who are actively ill with an infectious disease from other patients, either through isolation or barriers, is an important component of infection prevention. Consequently, designing spaces such airborne infection isolation rooms is important. Another way to limit the spread of infection is the development of "respiratory hygiene/cough etiquette," protocols which encourages patients and visitors with a cough or fever to cover their cough with tissues and to perform hand hygiene. This is especially important in emergency departments, where patients and their families often wait together for long periods of time and infectious patients may not be recognized immediately. Providing barriers (such as plexiglass dividers) for worker safety at triage entry points and provision of space for masks, tissues and hand sanitizer are examples of design considerations to support infection prevention.

Designing "flow" in in a health care setting also can reduce the spread of infection. For example, emergency departments may be designed with "pods" and zones and may include procedures that allow for triage "flex" to accommodate changes in patient volume. Creative use of barriers can help when crowding may present a challenge. Design should also consider the movement of environmental waste in the hospital, so that it can be removed and disposed of without the risk of pathogen spread.

Among the best practices in hospital design for reducing the spread of infection are:

- A multidisciplinary team should consider all aspects of infection prevention when the functional program of a new health care facility is being developed.
- Just as with new construction, infection prevention staff should be part of the planning team for updating and renovating existing facilities. Reflexively recreating existing work flows or spaces should be avoided.
- Incorporate infection prevention staff into plans for all areas of the hospital, including disaster and surge capacity planning.
- Consider designing an AII isolation room/area that enables unidirectional flow of health care professionals (HCP) entering/exiting for patients with highly infectious diseases.
- Use Human Factors Engineering (HFE) methods to analyze tasks as they are performed in existing spaces. Ask "what design features contribute to the lack of compliance". Work with HCP to design spaces/systems that support efficient workflows for HCP to access clean supplies while still protecting clean and sterile supplies from contamination.
- Remember that the separation of clean and dirty functions to limit cross contamination is fundamental to infection prevention.
- In areas designed to control airborne contaminants, ensure the ventilation system provides appropriate pressure relationships, air-exchange rates, filtration efficiencies, temperature and relative humidity.
- Provide space outside of clinical areas for removal of supplies from external shipping boxes.

- Ensure adequate storage on patient units for reusable patient care equipment and a location where these items may be cleaned.
- Explore new technology or simple containment approaches for the disposal of human waste.

CHAPTER 1: Infection Control Risk Assessments

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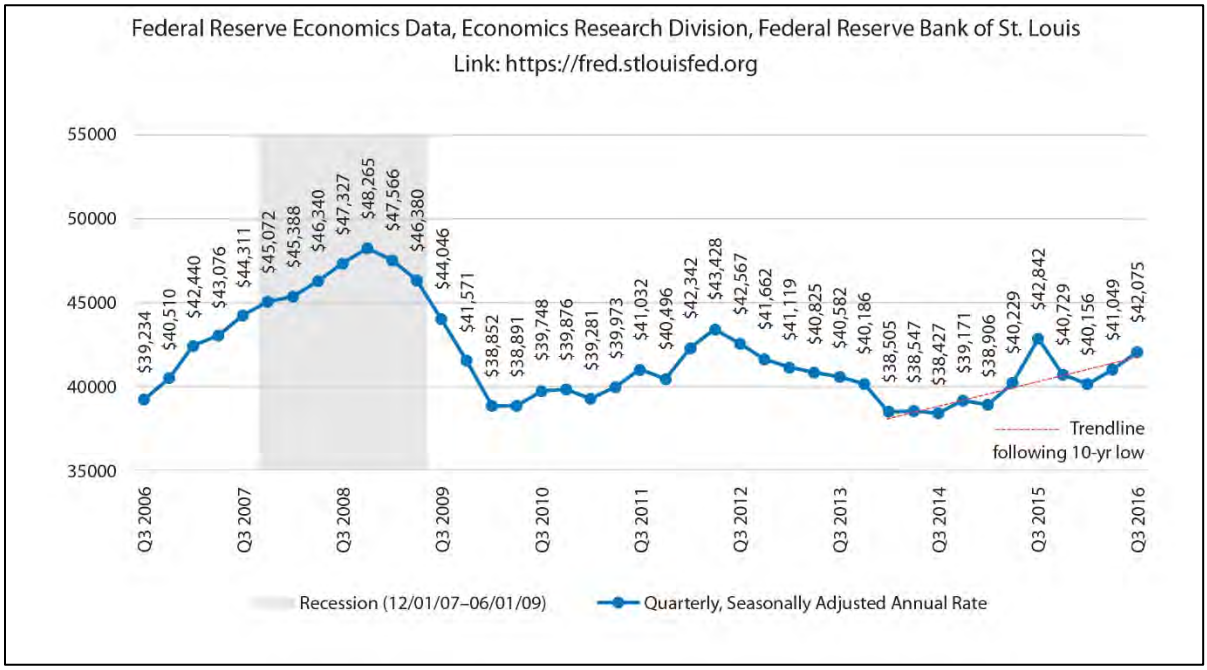
Introduction

Health Care Facility Construction

A continuous cycle of health care facility renovation and replacement is influenced by both infrastructure conditions and external factors (for example, economic conditions and the regulatory environment). The first building boom began in 1946 when the Hill-Burton program provided federal funding for the capital development of hospitals and health care facilities in the United States.[13] Wing reported that by 1974 when the legislation was replaced with the National Health Planning and Resources Development Act, $5 billion in grants and loans had fueled $14.5 billion in construction and modernization projects affecting more than 496,000 hospital and long-term care facility beds (about 40 percent of U.S. acute care hospital beds). Facilities age, and while a hospital physical plant lifespan is estimated to be 30 to 70 years,[14,15] many facilities become obsolete before the end of their effective physical lives.[16] The American Hospital Association (AHA) defines the useful life of a building as 40 years.[17]

A 2007 analysis found that health care sector construction spending grew faster than the rest of the economy and the value of hospital construction permits per capita was at the highest level since 1969.[18] These data are consistent with the AHA estimated 40-year lifespan of a health care facility. While the economic recession of 2008 resulted in a precipitous drop in spending, construction spending through the end of 2016 is trending upward again as shown in Figure 2.[19] A recent survey found that 25 percent of an organization's capital budget was allocated for new construction, 24 percent for renovation and 15 percent for infrastructure improvements, with renovation accounting for nearly 77 percent of the projects underway or planned in the next three years.[20]

Figure 2: Total Health Care Construction Spending



The aging and obsolescence of U.S. health care facilities generate a constant need for repair, remediation work (cabling, room additions) and replacement; in turn, ongoing risks of environmental contamination continue, affecting air and water quality.[21]

Evidence-Based Design in Health Care

The constructed health care facility is delivered following a design process, and the design of health care facilities has also evolved over the decades. For example, using varied information sources to aid in decision making has always been part of design, but the introduction of more rigorous research sources launched the growth of a process of evidence-based design. The Center for Health Design defined evidence-based design as "the process of basing decisions about the built environment on credible research to achieve the best possible outcomes."[22] Two comprehensive reviews of the literature provided an understanding of the body of research suggesting a relationship between facility design and outcomes, such as safety.[23,24] As one factor influencing safety, facility design may impact patient safety directly or indirectly as a latent condition leading to adverse events.[25,26,27,28] A healthcare-associated infection (HAI) is just one safety-related outcome related to the built environment with potential transmission through multiple routes: contact, air and water (See the literature review section later in this chapter).

Infection Control Risk Assessment for Health Care Facility Design

Owners are responsible for conducting the infection control risk assessment (ICRA) using an interdisciplinary expert panel. The use of risk assessments for infection control during design and construction have been evolving for the past several decades. A formal "Infection Control Risk Assessment" was introduced in the 1996-1997 edition of the *Guidelines for Design and Construction of Hospitals* although earlier editions required construction and renovation assessments related to specific risks. The goal of the assessment was to "describe how an organization determines the risk for transmission of various infectious pathogens."[29] A multidisciplinary committee was to coordinate the infection control needs of the individual

organization with the appropriate requirements for the isolation of infectious disease. Commonly, this early context resulted in the ICRA becoming a part of prevention planning solely for construction activity; however, infection prevention considerations during design of the project were not systematically integrated. The acronym "ICRA" appeared in the 2001 edition where the process was mandated as a continuous activity throughout programming, planning, design and construction of projects.[30] The ICRA in the *Guidelines* envisioned a long-range involvement of infection control/epidemiology leadership.[31]

The Business Case

The costs of infections have been estimated[32,33] and the cost-benefit of infection control programs evaluated.[34,35] However, business cases rarely recognize any contribution of the built environment. Part of the challenge in incorporating the built environment in the business case is that the complex causes of HAIs are multifactorial in nature.[36,37,38] The complexity makes it difficult to determine the exact role of a single specific facility design feature in infection prevention[39] in the context of a necessary "bundle."[40] The cost-benefit of the built environment has most often been represented through theoretical papers based on the literature and experiences of individual facilities. These can act as a narrative for discussion in health care settings,[41,42,43] but these types of narratives should be reviewed in the context of any stated assumptions (for example, cost avoidance, interpretation of research) that might warrant adjustment.[44]

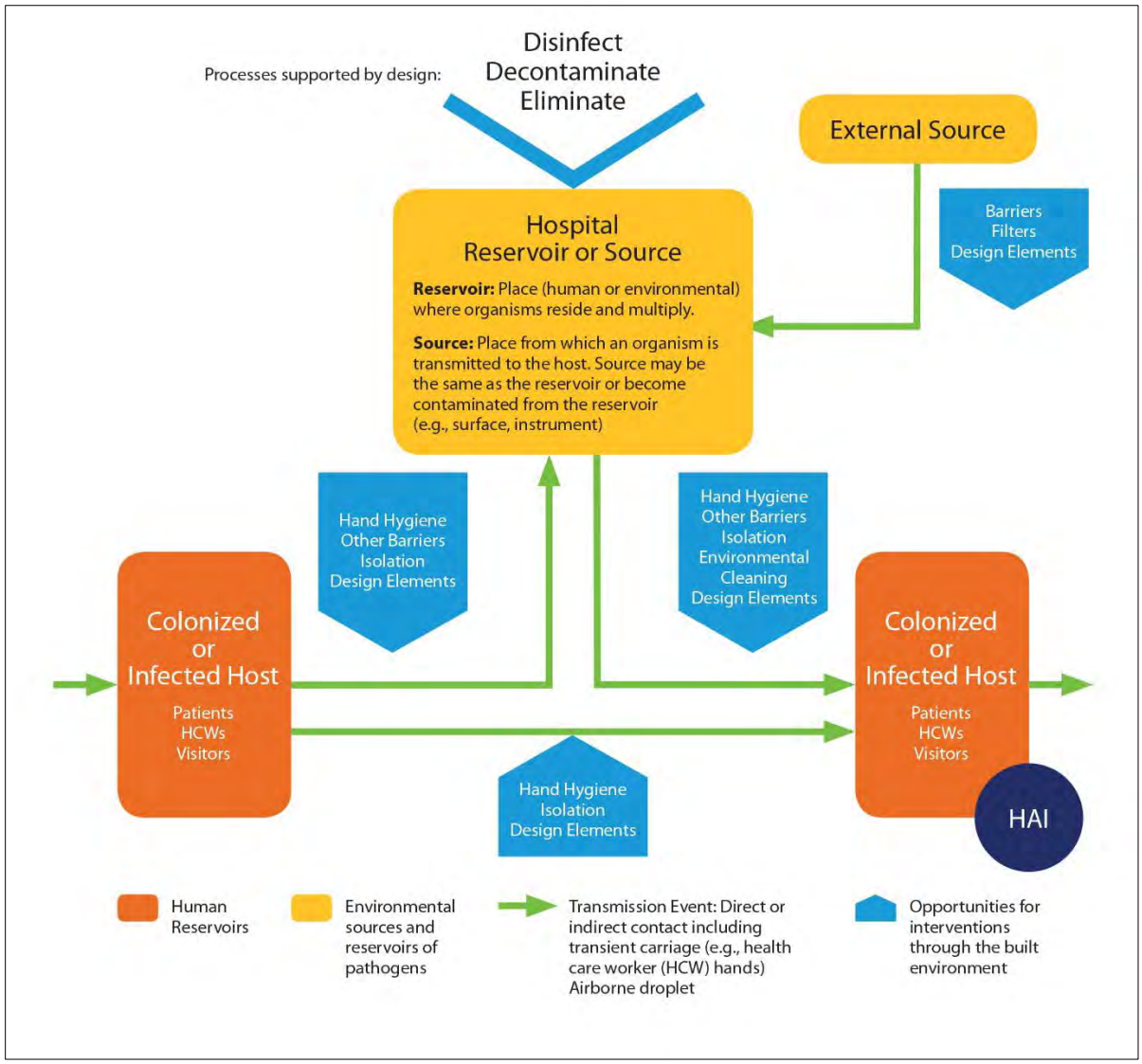
Brief Literature Review

Transmission of pathogens in a hospital is complex, with multiple transmission pathways, hosts, reservoirs and sources. Pathogens can enter the hospital through infected or colonized humans, including patients, or come from external sources.[45] An early narrative review describing the role of the environment in infection control provides an overview of the health care design pertinent to the control of puerperal fever, aspergillosis, tuberculosis and Legionellosis through considerations such as ventilation (for example, heating, ventilation, and air conditioning systems), isolation (for example, patient room occupancy), water disinfection (for example, metal ionization), fixture and surface selection and availability of hand hygiene locations.[46] A more recent systematic literature review contracted through the Agency for Healthcare Research and Quality resulted in a special supplement addressing the role of facility design in the acquisition and prevention of healthcare-associated infections.[47]

A Conceptual Framework of the Role of the Built Environment and Healthcare-Associated Infections

Zimring et al.[48] established a conceptual framework for the environment's role in infection control using a "chain of transmission" model that can be viewed as a map of the predicted route of pathogens including a distinction between direct and indirect transmission (Figure 3).

Figure 3: The chain of transmission adapted from Zimring et al., 2013[49]



Zimring's article was published in a special issue with other papers focused on opportunities in the environment for the prevention of HAIs transmitted by contact, air and water with survival time on inanimate surfaces ranging from hours to minutes[50,51,52]

The following sections (contact, airborne, waterborne) provide a high-level summary of the study findings.

Contact

Many organisms can survive on surfaces for days, weeks or months. However, the presence of a pathogen may lead to colonization but not infection, and an infection may develop long after acquisition.[53] According to Steinberg et al., most HAIs are caused by organisms that are carried by the patient or transmitted from one person to another, making the exact role of environmental surfaces in causing healthcare-associated infections unclear. However, the authors cite a number of studies that suggest the chain of transmission between environmental contamination and HAIs through direct or indirect contact. To summarize the authors' findings,[54] strategies to prevent the transmission of pathogens include:

- Adherence to and monitoring of cleaning protocols.
- Room disinfection technologies to supplement manual cleaning such as ultraviolet germicidal irradiation or hydrogen peroxide/hydrogen peroxide vapor.
- Surfaces that resist contamination and are easily cleaned such as hard floor surfaces in patient care areas.
- Materials that have antimicrobial properties such as copper alloys used for high touch surfaces (for example, door handles, bed rails).
- Physical barriers such as single patient rooms.
- Hand hygiene infrastructure that promotes hand hygiene compliance through clearly visible sinks and gels in convenient and standardized locations.

Additionally, appropriate use of personal protective equipment (PPE) is an essential strategy to prevent contact spread of infection. PPE convenience/accessibility and visibility within the workflow are important considerations during design.[55]

Airborne

Infection from airborne pathogens is a result of a complex interaction of the pathogen, the individual and the inanimate environment. Airborne transmission occurs when infectious particles, small and light enough to float for distances on air currents, are inhaled. Mitigating risk is important in protecting health care personnel, patients and visitors from being exposed to patients with infectious diseases transmitted via air.[56] Primary interventions to interrupt transmission of small airborne particles include ventilation, filtration and isolation/pressurization.[57]

- Ventilation: Design considerations include the airflow of heating, ventilation and air conditioning systems (that is, turbulent airflow for upward displacement, vertical down-flow systems, horizontal cross-flow distribution systems and unidirectional laminar air flow systems).
- Filtration: Filtration of ventilated air can reduce the number of airborne pathogens, and this is often achieved through HEPA (high efficiency particulate air) filtration in specific areas of the hospital or through filters treated with antimicrobial agents. Filtration is used as a result of air quality associated with the use of both outside (fresh) and recirculated air.
- Isolation/pressurization: The use of airborne infection isolation rooms controls airflow from unclean to clean through the use of positive or negative pressurization and/or anterooms. Negative pressure isolation rooms (higher pressure to lower pressure airflow gradient for airborne infection isolation rooms) are used for airborne infection isolation rooms (e.g., patients with highly transmittable airborne pathogens such as tuberculosis). In contrast, positive pressure rooms (lower pressure to higher pressure airflow gradient) keep contaminated air away in protective environment isolation rooms (e.g., immunocompromised patients).

Waterborne

According to Denham and colleagues,[58] pathogens from water sources account for only a small fraction of HAIs. However, these may be under-recognized and under-reported. Denham et al.[59] report that other waterborne pathogens are opportunistic (for example, *Pseudomonas aeruginosa, nontuberculous mycobacteria,* etc), often living harmlessly in or on humans but causing infection under certain conditions. They cite that other bacteria types that persist in the environment (for example, *Acinetobacter* spp.) may be low virulence organisms but are frequently a cause of intensive care unit-related infections. Similar to other transmission modes,

evidence clearly identifying the environment's role in the chain of infection is limited.[60] The authors point out that while public water in the United States is treated, even low concentrations of waterborne pathogens can be dangerous for immunocompromised patients. In summary, Denham et al.[61] conclude that interrupting the chain of transmission of waterborne pathogens includes three primary approaches (proactive or reactive) that include:

- Disinfection of water through chlorination, hyper-chlorination, superheat-and-flush, copper-silver ionization or ultraviolet germicidal irradiation.
- Selection of appropriate design elements to minimize the potential for contamination such as faucets (including no-touch electronic faucets), sinks, and aerators; point-of-use filters (where costs should be balanced with the estimated risk); carefully considered decorative fountains (the most recent Facility Guidelines Institute (FGI) *Guidelines* precludes the use of open fountain systems inside health care facilities, although sealed systems can be used).
- Safe plumbing practices to eliminate dead legs and maintain optimal water temperature/ pressure.

Adding to the complexity of the relationship between infection and the health care facility design is the fact that specific patients may be at more risk: patients such as neonates[62]; pediatric patients[63]; burn patients[64]; hematology patients.[65,66] those who are immunocompromised and others.[67] As a result, specific spaces have different considerations requiring a comprehensive understanding of the epidemiology of infections and the potential role of facility design to contribute to solutions.[68,69,70,71,72,73,74]

Best Practices and Recommendations

An ICRA is necessary in both design and construction, but the approaches to identifying risks and solutions are different. Design solutions may be straightforward, for example, to mitigate a direct risk (fixture and equipment selections to prevent contaminated air and water) or they may be more nuanced (for example, the location of a hand hygiene sink to promote compliance). Solutions to mitigate the risks during construction are more prescriptive and can be identified through tools such as an ICRA precautions matrix. Several guidelines provide requirements and best practice recommendations for the ICRA process; these are outlined below. However, the ICRA practice can also be advanced through explicit thinking about safety science and complexity in health care and how these concepts can be supported by health care facility design.

Hazards and Risks

A hazard can be defined as a source of danger,[75] for example, non-circulating hot water improperly maintained or water temperature maintained in ranges that allow bacterial growth.[76] Risk is associated with the probability (chance) of an outcome,[77,78] for example, the chance that a pathogen in the water results in a patient becoming infected. Risk is subjective and is relative to an individual's or organization's perspective, therefore certain risks may be both acceptable and necessary.[79,80] The purpose of risk assessment is to inform decisions that involve risk, costs and benefits.[81] Risk is often discussed either numerically or descriptively with respect to the severity of harm (consequence) and the likelihood of the occurrence of that harm.[82,83] In one case study, a facility design team modified a more traditional and complicated numeric approach into a simpler descriptive system of low, medium or high.[84] A common challenge is that many risk management processes identify and assess problems without systematically identifying risk control solutions.[85]

ICRA Development and Use

Standard approaches in safety science mitigate risk through properties of prevention, protection and facilitation.[86] Mitigating risk is often addressed through elimination, design controls or administrative procedures.[87] Relatively few studies report about tools that support proactively designing for safety and mitigating design-related risk.[88,89,90] These studies do not focus on infection control in detail but describe the development tools for safe health care facility design. A limited number of studies cover the development and use of an ICRA process or specific ICRA tools. Most reports are part of conference presentations and proceedings[91,92,93,94,95] and most focus on construction.

Kennedy and colleagues' 1996 study[96] is one of the first appearing references to present the use of a risk matrix for barriers during constructions. This led to what is now commonly used as an ICRA precautions matrix (see the tools section at the end of this chapter). Moore and Huber[97] describe improved ICRA compliance following the assignment of a construction trained infection preventionist to construction activities, and Kidd et al.[98] outline compliance following the implementation of a contractor training program. Johnson and Lenz[99] retrospectively identify the underlying conditions leading to errors during construction using a human factors framework to understand the complex interactions of the system. Dickey and Taylor[100] presented the most recent requirements for a proactive multidisciplinary safety risk assessment in the 2014 FGI *Guidelines*.[101,102] The safety risk assessment requirements are largely based on the framework established by the ICRA, and infection control is one of multiple safety components to be considered during design and construction.

Minimum Considerations During Design

This interdisciplinary team should address minimum standards identified in several guidance sources.[103,104,105] These include the number, location and type of airborne infection isolation and protective environment rooms; special heating, ventilation, and air-conditioning needs (for example, in surgical areas, airborne infection isolation (negative pressure) and protective environment (positive pressure) rooms, labs, pharmacies and areas with hazardous agents using local exhaust systems); water and plumbing systems; and the selection of materials for surfaces and furnishings. The team should also consider the design implications for potential natural and man-made disasters.[106]

Methods to Assess Safety During Design

Numerous methods can be used to assess safety as part of the design process. A report on designing for patient safety cites the potential for several methods already in use in other areas of health care based on usability, relevance, feasibility and generalizability.[107,108] These methods include link analysis, root cause analysis, failure mode and effects analysis, simulation, work sampling, balanced scorecard and process analysis. These processes evaluate design options in the context of other aspects of the system and are not a prescriptive list of design solutions. Several methods (failure mode and effects analysis, simulations and link analysis) were most highly rated to be of use across design phases and support decision making at varying levels of design detail. Morrill[109] used a failure mode and effects analysis where participants identified key areas of risk, bringing clarity to the desired conditions and necessary next steps and engaging in prompt decision making about facility design solutions.

A risk assessment in health care facility design can be conducted as a proactive approach to safety. A common approach to conducting a health care risk assessment includes five steps[110]:

1. Identify the hazards.
2. Decide who might be harmed and how.
3. Evaluate the risks and decide on the precautions and risk mitigation strategies.
4. Record findings, propose action and identify who will lead on what action or strategy.
5. Review the assessment and update periodically if necessary.

The same steps are used in health care facility design and construction.

Minimum Considerations During Construction

Risks associated with construction include dust and debris compromising the environment, airborne microbes journeying via air currents to infect other susceptible hosts, an unbalanced ventilation system affecting air quality, water stagnation and contamination, accumulated and multiple waste reservoirs and ineffective dustproof barriers, and managing the transportation of waste and contaminated workers, among others.[111] Two reviews of the literature[112,113] outlined the characteristics of outbreaks and infections associated with construction, renovation and demolition.

Given the extent of known conditions, construction-related requirements of the ICRA must be included into the contract documents and implemented during construction.[114] According to the FGI and The Association for Professionals in Infection Control and Epidemiology (APIC),[115,116,145] the minimum considerations for construction include the disruption of essential services and the impact on those occupying the building; identification of specific hazards and protection levels for each designated area; plans for locating patients according to their infection vulnerability; the impact of movement of debris, traffic flow, spill cleanup, and testing and certification of installed systems; assessment of both internal and external construction activities and identification of known hazard locations.

An ICRA precautions matrix is often used to guide this process.[117,118,119] The matrix is recommended during the design process to assist the multidisciplinary team to identify the patient population at risk and the preventive measures to be initiated. The matrix describes the levels of construction activity and four risk groups (lowest to highest risk), and provides identification of the risk groups that may be affected by their proximity or exposure to the construction zone.

As part of the infection control risk mitigation recommendations, specific methods to reduce the potential for the transmission of airborne and waterborne biological contaminants are documented in writing. The FGI *Guidelines*[120,121] include the following considerations as a minimum standard:

1. Patient placement and relocation plans.
2. Protection from airborne contaminants (barriers and other protective measures to protect adjacent areas and patients), demolition and emergencies—planned and unplanned utility outages and evacuation.
3. Phasing (or temporary provisions) for construction or modification of heating, ventilation and air conditioning and water supply systems.
4. Training for staff, visitors and construction personnel.
5. Construction worker flows including construction worker routes (for example, elevator use for personnel and materials); movement of debris, traffic flow, cleanup; and

provisions for bathroom and food facility use.
6. Installation of clean materials that have not been damaged by water.

Opportunities for a Systems Approach

Safety requires a systems approach that takes into account the interactions of the complex system of health care that includes the organization, the people and the environment in which care takes place. According to Storr et al.,[122] a systems approach using human factors and ergonomics can be used to move infection prevention into thinking for everyday work flow in health care as compared to viewing infection prevention activities as additional workload. A recent study on hand hygiene used a human factors framework to understand the interactions of the systems, including how the built environment might influence outcomes.[123] Design for hand hygiene has also used a human factors ergonomics framework to ensure usability[124] and help capture understanding of mental models.[125] (See also Chapter 2.) Others suggest the complexity of health care requires embedding a macro-ergonomic approach at an organizational level to effectively use human factors in an infection prevention approach.[126]

While conducting an ICRA during design and construction is often required as part of a health care facility project, a safe environment should not be designed in a silo. A traditional approach to safety (Safety-I) assumes that adverse events occur because of identifiable failures or malfunctions of technology, procedure, personnel and the organizations in which they work in a stable environment of known, stable controllable conditions.[127] Organizations reactively identify contributing factors to an adverse event and establish procedures to prevent a reoccurrence. Newer views of safety (Safety-II) supplement a Safety-I approach and attempt to develop proactive ways to support things the many things that "go right," helping people adapt to variation, disruption and degradation of expected conditions.[128,129,130] In creating built environment solutions that are part of the ICRA, this means incorporating other aspects of the system (for example, organizational policies and procedures, staff and patients, different perspectives and expertise) as part of the solution to optimize both the health and well-being of the facility occupants and overall system performance.

Communication

The Role of the Infection Preventionist

In the past, infection control considerations were minimized during design and construction, if not forgotten, which led to the possibility of costly (preventable) mistakes[131] and an increase in ongoing life-cycle costs.[132] As infection control and prevention (IPC) has been evolving and today, infection preventionists (IPs) play an important role in the development and ongoing maintenance of infection prevention and control programs.[133,134,135,136] Still, many may consider the role of an infection preventionist as operational, so leadership and communication must promote the proactive involvement of infection preventionists during design. An infection preventionist should be part of the interdisciplinary team during facility design, and the infection preventionist must routinely address infection control factors throughout the project and assist administration in understanding the rationale for the floor plan, equipment and furnishings required to support sound infection control practices.[137]

The ICRA Team

To adequately understand the issues and potential solutions in both design and construction, an interdisciplinary ICRA team is necessary. This team can identify key design features to enhance safety of patients, personnel and visitors through diverse perspectives to ensure the

environment supports complex interactions of human factors and behavior.[138] Several documents offer suggestions for participants of an ICRA team that include experts in both medical and building sciences such as front-line caregivers from clinical departments affected by the project, facilities management, performance and/or quality improvement representatives, safety specialists, infection preventionists, epidemiologists, architects, interior designers, and/or engineers, human factors specialists, environmental services staff, laboratory personnel, contractors and risk management personnel.[139,140,141]

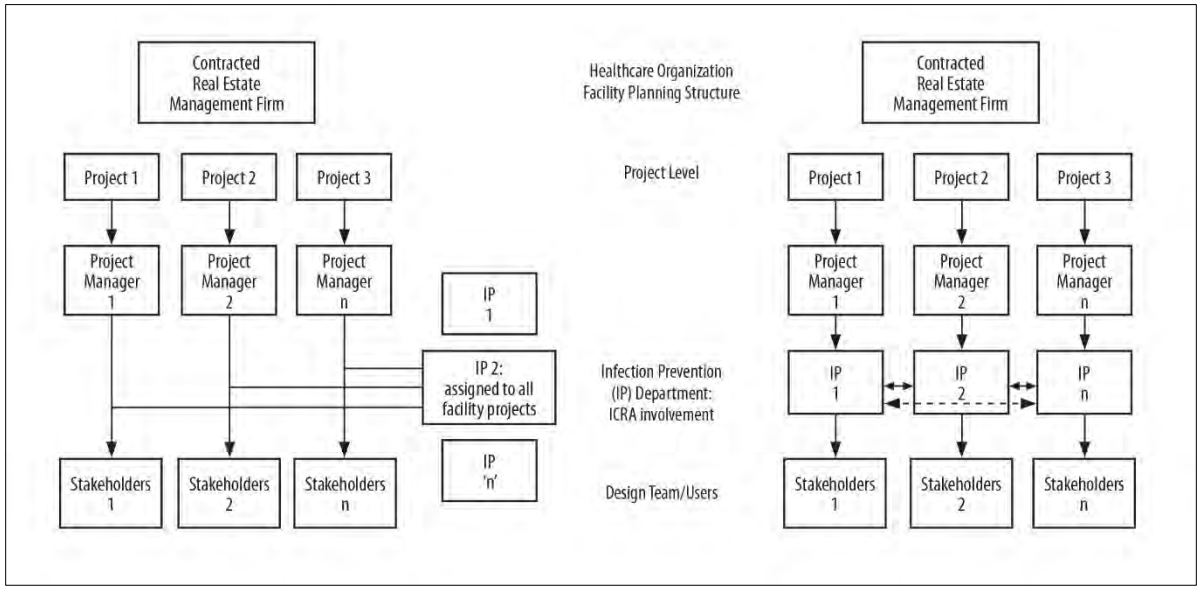
Leadership

The leadership team should establish a vision to measure and target outcome improvements and use building design and construction to advance cultural transformation; redesign care processes; and mitigate the risk of patient and staff harm, reduce stress and improve the bottom line.[142] Leadership of health care organizations should have an awareness of the role of the built environment to promote safety and insist on interdisciplinary teams of experts (internal and external) that can combine their knowledge and experience to optimize facility design solutions. However, while health care personnel often generate risk control plans, with the assumption that a good understanding of risk will lead to good risk control, the same personnel are generally not trained in the principles of safety science.[143] This warrants additional guidance and structure to aid in the process for infection preventionists and the rest of the team. A systematic process of risk assessment for health care facility design can advance participation and collaboration and foster an evidence-based process for decision making.

Case Studies

Infection preventionists are increasingly included in the design and construction of health care facilities as part of the infection control risk assessment process. Interviews were conducted with two experienced IPs to understand process, barriers and opportunities in well-established programs. Common to both organizations is a less organized process for considering infection control during design, a higher level of structure and standardization for the construction mitigation phase, and years of participation in the process to create organizational awareness and “buy-in.” The standardization for construction helps set expectations and accountability (and would benefit design, as well). Each organization enters construction-related information into an online system for both new construction and renovations and the timing of the process is dependent on the scope—larger projects being entered well in advance of construction. As shown in Figure 4, System A uses a hierarchical process of alert and sign-off, whereas in System B, the online construction mitigation is a collaborative effort. (An important perception in System A that may exist in other organizations is related to the term “ICRA,” which is perceived to apply solely to construction mitigation as compared to the broader definition that encompasses the full design cycle.) Each organization has multiple IPs, but each structures the role of the IP in a different way.

Figure 4: Dual approaches to including IPs during the design ICRA



Health System A: A medium-sized regional system that includes academic medical centers

The ICRA process is managed by the facility project management team. Three project managers working for a contracted real estate management firm are responsible for facility project management associated with new construction and/or renovation. In large scale projects, the IP is brought in by the system's contracted project managers once a project is initiated. The project manager is also responsible for including the IP at appropriate intervals within the project.

Design questions related to infection control are not standardized or structured by any kind of tool but are discussed in face-to-face meetings and are not explicitly considered relative to risk levels. In some cases, it may feel like the design ideas come from thin air. If the type of space is familiar to the IP, the project review may be done remotely. For project types that are less familiar, it is more important to be present, either on-site looking at the conditions or at a meeting where drawings are being discussed. As referenced above, the ICRA for construction mitigation is addressed through a structured online format that is also used for construction permitting.

While there are five IPs in the system, a single IP is assigned to all design and construction projects, allowing for consistency and continuity, especially in lessons learned from project to project and in the relationships that are developed. As a result, the IP is fully embedded in the process. The IP has the opportunity to engage at different levels depending on the project, keeping end users aware of infection prevention-related decisions and issues that may arise during the project and chooses whether to attend all or selective meetings, determines how much IP-related education might be needed for an unfamiliar team on smaller projects and provides feedback during room mockups.

Health System B: A large statewide system that includes academic medical centers

Most projects are managed by an internal capital project management office, but some smaller projects (e.g., maintenance of plumbing) may be led by facility management. Increasingly, everyone is aware to contact the IP for ICRA-related input. The IP department relies on project management to notify the department about projects that involve infection prevention.

During design, the IP is invited to provide input at different stages and to look at design issues specific to infection prevention in an iterative manner. There is not a structure or tool that is used in a systematic way so the process is somewhat "free flowing." The architects are generally responsible for completing meeting minutes and providing the subsequent design direction to their team. The level of involvement is related to the project scope, but the IP department would like to be included on projects from the earliest phases, even programming, to ensure items are not overlooked.

Managed by the project management office of capital planning, the ICRA for construction risk mitigation is hard-wired and completed in a stepwise manner online during a preconstruction risk assessment meeting. Participants include the contractor and subject matter experts, as needed, and an algorithm is used to review conditions such as adjacencies, risks associated with the scope of the project, and control of air and water. This is viewed together on screen and becomes part of the construction documents.

The department head has sent everyone to the American Society for Health Care Engineering (ASHE) training for a basic understanding for IP role in design and construction. The infection prevention department is divided by unit (e.g., med-surg, ICU). Each IP on the team is familiar with the stakeholders for their assigned area (nurse managers, physicians and others who should have been involved in planning and design). That same IP follows the project through to the discussion for construction mitigation. The IP team meets on a weekly basis about all projects (performance improvement and construction) and can ask questions of each other or their peers within the system or colleagues in other organizations throughout the country.

The ICRA is needed throughout the project lifecycle to address safety in general through an interdisciplinary team that can break down silos with input that supports all stakeholders. A significant benefit of early use of the ICRA for programming and design is to ensure that requirements are appropriately established such that change orders do not incur additional costs. Following construction, commissioning needs to occur to ensure proper functioning of systems, for example, ensuring airflow and pressure are correct, standing water is not present, and so forth.

Aids for an ICRA

The audience for the ICRA is really the C-suite. The CFO and CEO need to understand the financial and safety implications that result when an IP is not brought in early. Even though you have to slow down to move fast, it's time and effort well-spent. Many are completely unware of the requirement for the safety risk assessment. There is a lot vying for the attention of those on the C-Suite—often threats and opportunities at a national level—and if ICRA/safety risk assessment (SRA) examples or case studies could reach into reputable journals read by the C-suite, or in meetings they are likely to attend, this would aid in strengthening the ICRA process from a quality, safety and financial perspective. Influential papers could also be shared with professional organizations such as APIC or The Society for Healthcare Epidemiology of

America (SHEA) for member dissemination. A secondary route is to approach ICRA and safety from a regulatory standpoint, through the Centers for Medicare & Medicaid Services (CMS) or the Joint Commission.

Tools

APIC offers ICRA resources through their continually updated APIC text, a subscription-based service (http://text.apic.org/). The organization also supports infection preventionists with resources such as the 2015 release of the Infection Prevention Manual for Construction & Renovation.[144] APIC offers training for ICRA activities as part of their consulting services and the ECRI Institute offers an online training program (www.ecri.org/components/Pages/Infection_Control_Risk_Assessment.aspx).

Several tools and resources are available to guide the development of solutions to facilitate safety. To proactively consider infection control during design, the Center for Health Design has developed a Safety Risk Assessment toolkit for the design of health care facilities. This toolkit supports the requirements in the FGI *Guidelines* and is available at no charge in an online format (www.healthdesign.org/sra). In the Safety Risk Assessment toolkit, infection control is one of six components of safety to be considered during design. The Safety Risk Assessment content was developed with grant funding through a research-based consensus process[145] and tested through both hypothetical scenarios and real-world conditions.[146] The Center for Health Design offers training and workshops in the use of the tool as a participatory process during design and an online webinar provides an overview of the tool's development and use (https://www.healthdesign.org/insights-solutions/safety-risk-assessment-20). Free short tutorial videos are also included in the online version of the Safety Risk Assessment toolkit.

The Center for Health Design also developed a framework that outlines the safety issues to be considered in the design of various residential and long-term care settings.[147] The resulting matrix serves as a broad evaluation framework for key design areas (for example, noise, light levels, design of outdoor spaces) contributing to resident safety. Healthcare-associated infections are one of the referenced outcomes.

Another tool that might be used during health care facility design is a process tool developed to optimize the development of risk control solutions.[148,149] The Generating Options for Active Risk Control (GO-ARC) tool is not specific to infection control but outlines a structured brainstorming technique with prompts used to elicit risk control options (http://activeriskcontrol.com/tools-and-templates/). Additional design resources can be found at Premier Safety Institute's building design links page (www.premiersafetyinstitute.org/safety-topics-az/building-design/building-design-links/).

With respect to construction, numerous organizations post similar versions of the ICRA precautions matrix originally conceived by Kennedy et al.[150] One version can be found at the Premier safety Institute (www.premiersafetyinstitute.org/safety-topics-az/building-design/infection-control-risk-assessment-icra/) as well as at ASHE's website (www.ashe.org/resources/tools/pdfs/assessment_icra.pdf). An easy-to-read description of the process was written by Streifel and Hendrickson[151] and is posted by Industrial Air Solutions (www.industrialairsolutions.com/contamination-control/hospital-air-purifiers-pdf/HPAC-Construction-maintenance-health%20care-facilities.pdf).

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CHAPTER 2: Hand Hygiene Infrastructure

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Introduction

Infrastructure that supports good hand hygiene is critical to patient safety. The design and placement of sinks, faucets and dispensers for alcohol-based hand rub influences patients' risk for HAIs directly and indirectly. Directly, the built environment itself can be a vector for infections. The design of handwashing sinks and their placement relative to patients and patient care materials warrant careful consideration so that waterborne pathogens are not transferred from the environment to patients.[152,153,154,155] Aerosols and splashes from contaminated handwashing sinks have been implicated as the source of outbreaks that resulted in patient infections and deaths.[156,157,158]
Indirectly, the built environment can facilitate or impede proper hand hygiene behavior by health care personnel, thereby affecting transmission of microbes and infection. Improvements in hand hygiene have been associated with reduced rates of infections in hospitalized and long-term care patients.[159160161] Thus, a poor physical design that impedes hand hygiene will increase patients' risk of infection. Deficiencies in the structural layout of hand hygiene resources include poor visibility, poor access, placement at an undesirable height, lack of redundancy, lack of standardization, and wide spatial separation of supplies that are used sequentially.[162] Any of these ergonomic flaws can act as a barrier to hand hygiene.

Expert hand hygiene guidelines affirm the importance of the built environment for promoting hand hygiene.[163,164,165]

Alcohol-based hand rub is generally preferred for most hand hygiene opportunities, because it requires less time to use, causes less skin irritation and is more effective in reducing the bacterial count on hands than soap and water.[166] However, washing hands is recommended in some circumstances such as when hands are visibly soiled and during outbreaks of norovirus or *Clostridium difficile* infection.[167,168,169] Thus, infrastructure for both hand sanitizing and hand washing will be considered in this chapter.

The purpose of this chapter is to help health care facilities prevent and control infections by providing excellent hand hygiene infrastructure in new construction and existing facilities. A review of current literature addressing hand hygiene infrastructure is provided, followed by recommendations for the design and placement of sinks, faucets, hand towels and dryers and alcohol-based hand rub dispensers. Four case studies are provided to illustrate the practical application of recommendations. Also provided are tools that can be used to assess existing hand hygiene infrastructure, prioritize areas for improvement and select the most appropriate equipment and products.

Brief Literature Review

Most studies of hand hygiene infrastructure are observational or quasi-experimental in design. Thus, the evidence for action is of moderate or low quality. Here, we summarize the evidence from primary research, as well recommendations from the Centers for Disease Control and Prevention (CDC), World Health Organization (WHO), Society for Healthcare Epidemiology of America (SHEA), the Facility Guidelines Institute (FGI) and others where appropriate.[170,171,172,173,174] With a few exceptions, we focus on studies published after the 2002 CDC guidelines.

Sinks

Number of Sinks

Evidence suggests that increasing the number of handwashing sinks does not of itself increase hand hygiene compliance. In one study, hand hygiene compliance by nurses in an intensive care unit with a sink-to-bed ratio of 1:1 was 25 percent higher than in another intensive care unit with a sink-to-bed ratio of 1:4.[175] However, the study sampled only 160 hand hygiene opportunities, and did not control for possible confounders such as sink location or staffing levels. Three other studies, also conducted prior to the widespread use of alcohol-based hand rub, did not show any improvement in hand hygiene rates when the number of handwashing sinks was increased.[176,177,178] The negative results were similar across settings and unit types.

Location of Sinks

The proximity of sinks to the patient may influence hand hygiene performance more than the absolute number. A study of hand hygiene during care of patients with *C. difficile* infection in one hospital found that hand washing compliance was independently associated with the distance of the sink from the patient. In their setting of one sink per eleven beds, and distances of 1.2 to 37.8 meters (4 to 124 feet) between the patient's immediate surroundings and the sink, each additional meter decreased the likelihood of hand washing by 10 percent.[179] However, the benefits of having sinks in close proximity to patients must be balanced with the risk of aerosols and splashes reaching the patients directly. During an outbreak of multi-drug resistant *Pseudomonas aeruginosa* in an adult intensive care unit, investigators found that water that flowed forcefully from the faucets and directly into the drains of handwashing sinks splashed onto adjacent surfaces and onto patients at a distance of more than 1 meter away.[180] The outbreak ended after sinks were redesigned so that water flow was offset from the drain and water pressure was reduced. Another study in a neonatal intensive care unit found that air samples taken half a meter from sinks with water running showed that a majority were positive for *P. aeruginosa*.[181] The impact of sink contamination and aerosolization of pathogens was demonstrated in a study in which removal of sinks from patient rooms in the ICU was associated with reduced colonization of patients with Gram negative bacilli.[182]

Designated Handwashing Sinks

Some literature suggests that designating certain sinks for hand washing may reduce contamination of the hands of health care personnel. A study published in 1996 established that health care personnel's hands can become contaminated when washing at a patient sink.[183] In a pediatric unit that housed patients with cystic fibrosis, 21 of 24 sinks were contaminated with *P. aeruginosa* or *Burkholderia cepacia*. The researchers instructed 17 staff members to disinfect their hands with alcohol-based hand rub and then wash their hands at one of the contaminated sinks for 30 seconds and dry with paper towels. By glove juice method, five of the 17 health care personnel were positive for the same strain as the sink.[22] These results led to a

recommendation by the Public Health Agency of Canada to avoid using patient sinks for hand washing whenever possible.[184]

However, dedicated handwashing sinks may be similarly contaminated, especially if the sinks have been inappropriately used for other purposes. During an outbreak of *Elizabethkingia meningoseptica,* investigators discovered that nurses were using handwashing sinks for disposal of patient waste and for rinsing used patient care items.[185] Isolates recovered from the handwashing sinks were indistinguishable from patient isolates. Similarly, during an outbreak of *Shigella sonnei* in a microbiology lab, investigators discovered that concentrated *Shigella* suspension had been disposed of in a handwashing sink rather than a processing sink.[186] This break in protocol, combined with the fact that use of paper towels for turning off faucet handles had a protective effect for the technologists, led the researchers to conclude that the contaminated sink had been the source of the outbreak. Further study is needed to determine whether use of dedicated handwashing sinks results in less contamination of health care personnel's hands than use of patient sinks.

Faucets

Numerous studies have examined electronic sensor-regulated faucets, which conserve water and should reduce hand contamination by negating the need to touch faucet handles. The studies suggest, however, that rather than reducing pathogen transmission, sensor-regulated faucets may contribute to it. Most studies report that counts of *Pseudomonas* and *Legionella* species are significantly higher in water from sensor-regulated faucets than from conventional faucets.[187,188,189,190,191] Contamination can persist despite remediation with chlorine dioxide.[3,25,27] Design features typical of sensor-regulated faucets that have been implicated include low flow, tepid temperature, fittings made of polyvinylchloride rather than copper and contaminated aerators.[192,193,194]

Investigation of an outbreak of *P. aeruginosa* infections in neonatal units in Northern Ireland found the mean count of *P. aeruginosa* in aerators of conventional faucets was two percent of the mean count in aerators of sensor-regulated faucets.[195] No difference was observed in *P. aeruginosa* counts for any other faucet components. Complex plastic aerators had significantly higher counts of *P. aeruginosa* than simple designs. However, complex aerators were only found on sensor-regulated faucets, making it impossible to determine whether it was the design of the aerator or another attribute of the sensor-regulated faucet that resulted in higher contamination with *P. aeruginosa*.[196] The Canadian Standards Association mandates against aerators on faucets for hand hygiene sinks in health care facilities.[197]

Hand Dryers and Paper Towels

Some evidence suggests that for drying hands, paper towels may be preferable to air dryers.[198] The CDC recommends that after washing, hands should be dried thoroughly with a disposable paper towel. Drying removes residual moisture that facilitates transfer of microbes to and from hands, and friction helps remove microbes. The paper towel should be used to turn off the faucet. A recommendation is made against multi-use cloth towels from a rotary dispenser. There is no comment on air driers.[199]

Since that publication, warm air hand driers have been investigated further, in regards to their ability to remove microbes from hands and tendency to disperse microbes into the environment. In general, no difference in the removal of bacteria has been found after drying by paper towels compared to air dryers.[200,201,202] However, bacterial counts are higher if hands are rubbed under a warm air dryer than if they are held still.[203,204]

More than one study has identified heavier contamination of the immediate environment when hands are dried using a warm air dryer (blade-type) compared to paper towels.[205,206] In a laboratory experiment, when jet air dryers were used, bacterial counts were 27 times higher than when paper towels were used, and 4.5 times higher than when air dryers were used.[207] The significance of these environmental bacterial counts to infection control is not known. A systematic review of the relative efficacy of paper towels and air dryers concluded that paper towels are superior to electric air dryers from a hygienic viewpoint, and thus should be used in hospitals and clinics.[208]

Studies have shown that pathogens can be transferred from contaminated paper towel dispensers to clean hands. In a laboratory setting, researchers loaded standard folded paper towels into generic stainless-steel front-loading paper towel dispensers, then used *Serratia marcescens* and *Micrococcus luteus* to contaminate the exit slots. Subjects were instructed to pull out paper towels by reaching into the dispenser exits. Results showed that between four and 16 percent of organisms contaminating the dispenser exits were transferred to the volunteers' hands.[209] Contamination of the exit slots of paper towel dispensers has been confirmed in the clinical setting.[210] In eight wards in four hospitals in the United Kingdom, researchers found that 19 percent of dispensers were in excess of the clean benchmark value of 2.5 cfu/cm^2 for aerobic colony counts and staphylococci, and more than 80 percent exceeded desirable adenosine triphosphate (ATP) levels (>500 relative light units).[211] Although faucet handles and soap dispensers were more heavily contaminated than paper towel holders, the paper towels may present a more important risk for transmission since they are accessed after hands are washed.

Studies have also documented that lever-type dispensers can be cumbersome to use. In one long-term care facility, researchers found that each pump of the lever delivered a scant 5.4 inches of paper towel. Paper dispensed prior to hand washing was splashed with water from the faucet.[212]

General Recommendations from the Facility Guidelines Institute

The FGI makes specific recommendations for the design and installation of sinks, faucets, hand dryers and alcohol-based hand rub dispensers in hospitals, long-term care facilities and outpatient facilities.[213,214] Readers are referred to the source documents for information about specialty facilities, support areas and surgical scrub stations. The following is a brief summary of the essential recommendations for general patient areas in hospitals:

Number and Location of Hand Hygiene Stations

1. Provide a handwashing station in the patient room in addition to the one in the toilet.
    a. A handwashing station includes a faucet that can be operated without using hands (e.g. wrist blades or sensor activated), soap and a means of drying hands.
2. The station should be located near the room entrance, outside cubicle curtains and with visible, unobstructed access.
    a. In open-plan multi-patient areas, provide at least one handwashing station for every four beds, spaced so that the two farthest beds are about equidistant from the hand wash station.
    b. In intensive care units provide one handwashing station for every three beds.
3. Provide alcohol-based hand rub dispensers in addition to hand wash stations.
4. Use the infection control risk assessment to determine the number and placement of handwashing stations and alcohol-based hand rub dispensers.

Design of Sinks and Faucets

1. Sinks should be designed to minimize splashing onto adjacent areas.
    a. Basins should be of adequate size and depth to minimize splashing (nominal size not less than 144 square inches; minimum dimension of 9 inches in width or length).
    b. Faucets should discharge water so that it is angled away from the drain.
    c. Water pressure should not be forceful enough to cause splashing.
2. Sinks should be made of porcelain, stainless steel or solid-surface materials.
3. Countertops should be made of porcelain, stainless steel, solid-surface materials or sealed plastic laminate over marine-grade plywood.
    a. Under-mounted sinks are discouraged.
    b. Casework should prevent storage beneath the sink.
4. Sinks should fit tightly against the wall or countertop and be sealed to prevent water leaks.
5. Mirrors should not be mounted above handwashing stations in areas where hair combing should be discouraged.
6. Faucets should discharge water at least 10 inches from the bottom of the basin.
7. Faucets should be operable without using hands.
    a. Wrist blade handles should be at least four inches long.
    b. Sensor-regulated faucets should meet user need for temperature and length of time the water flows.
    c. Sensor-regulated faucets should be operable during loss of normal power.

Hand Dryers

1. Hand drying devices should not require hands to contact the dispenser.
2. Paper towels should be enclosed and dispensed in single units.
3. While hot air dryers are permitted, paper towels are preferable.

Alcohol-Based Hand Rub

Although at least one study of the introduction of alcohol-based hand rub recorded no change in hand hygiene compliance,[215] many subsequent studies have documented an improvement in hand hygiene compliance. In one large hospital that had one to three sinks in every patient room, hand hygiene compliance increased from 48 percent to 66 percent over three years after alcohol-based hand rub dispensers were mounted on beds and individual pocket dispensers were distributed.[216] However, it is impossible to assess the influence of other interventions introduced at the same time.[217] Similar increases in hand hygiene frequency have been documented after alcohol-based hand rub dispensers were installed in long-term care facilities,[218] academic medical centers,[219] and children's hospitals.[220] The effects were consistent across different professional groups. Based on this evidence, the CDC, WHO and SHEA strongly recommend providing health care personnel with a readily accessible alcohol-based hand rub product.[221,222,223]

A recent systematic review examined the efficacy of providing alcohol-based hand rub to patients for facilitating patient hand hygiene and/or reducing infections.[224] All ten included studies showed improvements in hand hygiene and/or lower infection rates, but all were at moderate to high risk of bias. Most of the interventions were multi-modal and included assistance from staff to use the alcohol-based hand rub, diminishing the relative importance of simple provision of alcohol-based hand rub. As the authors note, bedside dispensers would be inappropriate for many patient populations, including those who are confused or at risk for self-harm.[225]

Number of Alcohol-Based Hand Rub Dispensers

Some evidence points to a positive correlation between the number of alcohol-based hand rub dispensers and hand hygiene compliance. In a medical intensive care unit, hand hygiene compliance after patient care increased from 22 percent to 41 percent when alcohol-based hand rub dispensers were introduced in a ratio of one dispenser per four beds, and further increased to 48 percent when dispensers were added at every bed.[226] A survey of 309 hospitals in Europe found that in intensive care units and medical and surgical wards where alcohol-based hand rub was available at more than 75 percent of points of care, alcohol-based hand rub consumption was higher than in areas with less availability.[227]

Because alcohol-based hand rub is flammable, fire regulations restrict the number alcohol-based hand rub dispensers that may be installed within a given area. To meet the Centers for Medicare & Medicaid Services Conditions of Participation, hospitals, long-term and intermediate care facilities, ambulatory surgery centers, inpatient hospices and other types of health care facilities are required to adhere to the 2012 editions of the Nation Fire Protection Association's NFPA 101: *Life Safety Code*®, and NFPA 99: *Health Care Facilities Code*.[228] The *Life Safety Code* dictates the upper limits for the size of dispensers, number of dispensers allowed within a single smoke compartment, distance between dispensers and separation between dispensers and sources of electricity.[229] The Joint Commission also endorses NFPA 101 in their document *Acceptable Practices of Using Alcohol-Based Hand Rub*.[230]

The regulations reflect an abundance of caution; fires involving alcohol-based hand rub are rare. A 2003 survey of hospitals in all 50 United States found there had been no fires involving alcohol-based hand rub in 1,430 hospital years of use.[231] Similar findings were reported in a survey of 788 German hospitals.[232] A majority of the hospitals had wall dispensers mounted in patient rooms (70 percent), corridors (80 percent), and operating rooms (69 percent). Seven incidents had occurred in a combined 25,038 hospital years using alcohol-based hand rub. The incidents were precipitated by personnel lighting cigarettes or candles with hands still moist with alcohol-based hand rub (n=4), or by vandalism (n=2) or suicide attempt (n=1).[233]

Location of Alcohol-Based Hand Rub Dispensers

The location of alcohol-based hand rub dispensers may influence hand hygiene compliance more than the absolute number of dispensers. The CDC strongly recommends that alcohol-based hand rub be available at the entrance to the patient's room or at the bedside, in other convenient locations, and in individual pocket-sized containers for health care personnel.[234] They comment that alcohol-based hand rub dispensers should not be placed adjacent to sinks, lest they be confused with soap dispensers.[235]Researchers have compared the effect of relocating alcohol-based hand rub dispensers with the effect of increasing their number, and found location was more influential.[236,237]

The optimal location for dispensers is just outside the doorways to patient rooms.[238,239,240,241] The ideal in-room location is less certain, but attaching a dispenser to every patient bed may be optimal if the dispensers are not obstructed by curtains or equipment.[242,243,244] Researchers conducted work flow observations, interviews, focus groups, surveys, automated counts of dispenser usage and field tests to identify processes and environments that were supportive of hand hygiene.[245] Study settings included a family medicine clinic, an inpatient rehabilitation unit, an intensive care unit and an emergency department. Results showed that across health care settings, the optimal location for alcohol-based hand rub was just outside of a patient's room within arm's reach of the door. Although no consistent optimal location was observed inside patient rooms, the foot of each patient bed was one location identified by health care

personnel.[246] Similarly, a review of hand hygiene literature concluded that the two most important locations for alcohol-based hand rub dispensers were by the entrance of patient rooms and within arm's reach of where care takes place.[247] In one adult general care unit, locating alcohol-based hand rub dispensers at the foot of patient beds and strategically throughout the hallways offered optimal usability, provided standardization and met regulatory requirements.[248]

Locating dispensers in the hallway at the entrance to patient rooms has strong underlying rationale. An ethnographic study of medical ward design found that entering and exiting private rooms served as a reminder to perform hand hygiene.[249] In addition, the room entry location meets other requirements for usability; namely, it is on the clinicians' work route, unobstructed by equipment or other clinicians, in the line of sight, and similar from room to room.[250] Mounting literature supports the notion that visibility of alcohol-based hand rub dispensers is a key factor in improving hand hygiene. In a community hospital, researchers found that locating dispensers close to the room entrance and easily visible on entry significantly and independently influenced hand hygiene compliance.[251] Another study, which assigned 150 doctors and nurses to examine standardized patients, reported that average hand hygiene compliance before patient contact was 37 percent when dispensers were located just inside the doorway but were not visible upon entering the room.[252]Hand hygiene compliance improved to 53 percent when flickering lights were added to the dispenser, and to 60 percent when the dispenser was relocated so that it was in the clinician's line of sight on room entry. When both visual cues were combined, compliance improved to 67 percent.[253] Two studies suggest that locating alcohol-based hand rub dispensers in direct line of site of visitors may increase visitor hand hygiene frequency in hospital lobbies.[254,255]

Brightly colored dispensers may also improve hand hygiene compliance, either by drawing attention, or by indicating the contents of the dispenser. In a medical intensive care unit where hand hygiene compliance was already high, replacing alcohol-based hand rub dispensers with dispensers colored signal red resulted in a further six percent increase in compliance.[256] Dispensers for soap, lotion and alcohol-based hand rub that are similar in size, shape and color and use the same actuation method can be a barrier to hand hygiene.[257] Discipline-specific focus groups conducted with physicians, nurses, allied health personnel and housekeepers suggested that colored labels on dispensers would improve hand hygiene practice.[258] Colors thought to be most intuitive were pink for soap, yellow for lotion and blue for alcohol-based hand rub. SHEA comments that it is important for health care personnel to be able to distinguish between alcohol-based hand rub for surgical hand preparation and alcohol-based hand rub for routine use.[259]
Inconsistent dispenser height (as high as 57 inches) was reported to be problematic in three studies.[260,261,262] The optimal height for dispensers is thought to be between 33 and 44 inches (85 to 110 cm) above the finished floor.[263]

Dispensers at the Point of Care

The optimal dispenser location for supporting hand hygiene at room entry and exit has been studied more thoroughly than at the point of care. This may be attributable to the Joint Commission's focus on hand hygiene compliance at room entry and exit, rather than at all five moments proposed by the WHO, and on the difficulties associated with monitoring hand hygiene compliance inside patient rooms at the point of care.[264]Providing hand hygiene infrastructure at the immediate point of care (that is, within arm's reach of the patient) is especially important because contacts during aseptic procedures and after body fluid exposure may present the highest risks for transmission of microbes between health care personnel and

patients. Although hand hygiene opportunities at the point of care occur less frequently than on room entry or exit, compliance is especially poor at the point of care.[265] Options for positioning alcohol-based hand rub dispensers at the point of care include wall-mounting dispensers, hanging dispensers in brackets (for example, on wheelchairs or IV poles), putting dispensers on horizontal surfaces (for example, overbed tables, window sills or procedure carts) and providing small bottles that health care personnel can carry in their pockets.[266]

A systematic review of the impact of point of care alcohol-based hand rub dispensers on hand hygiene compliance identified three studies, all of which showed increases in hand hygiene when dispensers were located near the patient's bed.[267] An industry-funded survey completed by 350 doctors and nurses in the United States and Canada found that alcohol-based hand rub was readily available at less than 90 percent of hospitals.[268] However, a majority of respondents agreed that their hand hygiene performance would improve if alcohol-based hand rub was located closer to the patient. When asked where alcohol-based hand rub should be positioned, the first choice of participants was a wall-mounted dispenser within three feet of the patient (77 percent) and the second choice was attached to the foot of the bed (42 percent). Locations infrequently chosen by respondents included inside the room entrance, on the IV pole, on the nightstand and in the pockets of health care personnel.[269] Among anesthesia providers, after accounting for gender, level of training, glove use and distance between the anesthesia machine and wall-mounted alcohol-based hand rub dispenser, researchers found that hand hygiene was performed more frequently when an alcohol-based hand rub dispenser was available on the anesthesia machine compared to when it was only available in a wall-mounted dispenser, which was located on average 7.2 feet away.[270]

When considering locating alcohol-based hand rub dispensers at the point of care, some populations warrant special consideration. SHEA notes that "cognitively impaired, behavioral health, or substance abuse patients may be injured by ingestion of alcohol-based hand rub. A point-of-care risk assessment can help guide placement of dispensers or decision to use nontoxic hand hygiene products."[271]

Dispenser Design

Hands-free alcohol-based hand rub dispensers may be preferred by health care personnel over manual dispensers.[272] A drip tray can be integrated into the design of alcohol-based hand rub dispensers. An automated door handle dispenser, which releases alcohol-based hand rub from a cartridge directly into the user's hand was pilot tested in a radiology department.[273] Directly observed hand hygiene compliance increased from 25 percent to 77 percent in the room with the dispenser handle, but did not change in two control rooms. The results may have been affected by novelty effects.[274]

Poorly functioning or empty alcohol-based hand rub dispensers can be a barrier to compliance. The CDC recommends that before purchasing decisions are made, dispenser systems should be evaluated to ensure they function well.[275] Also, hand hygiene behavior should be monitored carefully when a new system is introduced, to exclude any negative effects of the new devices or products. When alcohol-based hand rub dispenser systems were novel technology, Kohan and colleagues installed wall-mounted dispensers throughout their hospital. Sixteen months later, inspection revealed that only 77 percent of the dispensers were functioning (2 percent were broken, nine percent were obstructed, and the reservoir was empty or absent in 12 percent).[276] Of the working dispensers, 35 percent required more than one pump to deliver any product. Reports also tell of malfunctioning dispensers spraying health care personnel or creating a fall risk due to slippery floors.[277]

In a survey of 350 doctors and nurses in active clinical practice, empty dispensers were among the top three reasons for not performing hand hygiene.[278] Four strategies have been suggested for keeping dispensers filled: (1) purchase dispensers that have flags to cue environmental services staff that they are empty, (2) purchase dispensers that have transparent windows to clearly show product levels, (3) affix a label to each dispenser displaying the phone number to call for refill, and (4) establish an "adopt-a-dispenser" program to encourage individual environmental services staff (EVS) to keep their dispenser full.[279] In a field test of the flag strategy, one team of researchers found that the flags were poorly visible and rarely used.[280] The CDC strongly states that partially empty product dispensers should not be "topped up" with more soap.[281]

Electronic Hand Hygiene Monitoring Systems

Monitoring and feedback of hand hygiene performance is widely recommended, and is required by The Joint Commission.[282,283,284] However, direct observation of hand hygiene is labor-intensive and only a small fraction of total hand hygiene opportunities are sampled. Also, health care personnel who know they are being observed may change their behavior during the observation and revert to usual behavior when the observer leaves. For this reason SHEA recommends using more than one method to measure hand hygiene compliance.[285] Electronic hand hygiene monitoring systems are available in a range of configurations, from simple electronic counters embedded in dispensers to complex systems that issue real-time feedback to health care personnel.[286] Table-top and personal dispensers can be monitored in addition to wall-mounted dispensers. Electronic hand hygiene monitoring systems measure large numbers of hand hygiene opportunities and are unobtrusive. Some systems are capable of providing real-time feedback.

The evidence that electronic monitoring systems improve health care personnel hand hygiene performance is not yet convincing. A systematic review of the literature identified seven studies that evaluated the efficacy of electronic hand hygiene monitoring systems for improving hand hygiene.[287] Although four studies showed increases in raw compliance scores of 34 to 75 percent with the introduction of electronic monitoring, three other studies demonstrated minimal to no difference. Overall study quality was poor and none of the studies used an objective measure of hand hygiene compliance that was independent of the system being tested.[288] Facilities that are considering installing an electronic hand hygiene monitoring system may encounter several challenges, including disruption of physical infrastructure and clinician work flow, problems delivering the data directly to health care personnel and the concerns of personnel about the accuracy of the system and the potential for punitive use of the data.[289]

Gloves

SHEA recommends that glove use should be considered in any discussion of hand hygiene.[290] Glove use is especially important when caring for patients with norovirus or *C. difficile* infection. Although more research is needed to determine whether hand hygiene is necessary before donning non-sterile gloves, it makes sense to provide gloves close to other hand hygiene supplies. The society suggests that glove boxes be designed so that the act of dispensing gloves from the box does not contaminate the remaining gloves in the box.[291]

Hand Lotion

CDC strongly recommends that heath care personnel be provided with hand lotions or creams to minimize the occurrence of dermatitis associated with hand hygiene.[292] SHEA notes that irritant contact dermatitis is the most frequently occurring adverse reaction to hand hygiene

products. They recommend providing lotion in non-refillable containers, and encouraging its use.[293]

Construction Design Process

Some literature is available that suggests how to approach major changes to hand hygiene infrastructure. A full-scale model can be used to optimize hand hygiene infrastructure prior to construction. During the design phase of one new hospital build, a mock-up of a patient room was built and different dispenser configurations were trialed.[294] There were significant differences in observed hand hygiene compliance when alcohol-based hand rub dispensers were installed in different locations. The investigators noted that the cost of the mock-up was a small fraction of the potential cost of remediating a design flaw that might have reduced patient safety and necessitated work-arounds.[295]

Anderson and colleagues suggest that principles of human factors engineering should be applied during the design phase of construction and renovation.[296] They provide the following examples of how the principles can be put into action during changes to hand hygiene infrastructure:

- Minimize the complexity of cleaning hands (for example, make hand hygiene product dispensers highly visible and install them at a convenient height, in accessible locations, close to other hand hygiene accessories)
- Use design features that force health care personnel to perform desirable hand hygiene behaviors (for example, install foot faucet controls and automated paper towel dispensers that compel health care personnel to avoid touching contaminated faucets and dispenser surfaces after washing their hands)
- Minimize the time spent on hand hygiene (for example, conduct work flow analyses to identify when and where hand hygiene is required, so that product dispensers can be installed where they are needed)
- Provide cues to prompt health care personnel to perform hand hygiene (for example, locate product dispensers consistently by the door of every patient room, or add brightly colored stickers to the dispensers)
- Assess the usability of any new hand hygiene system, including a simulated interaction of typical users with the item (for example, ask the vendor of an automated hand hygiene monitoring system to report their usability tests, or to supply material and equipment to the hospital for testing)
- Test new equipment under real-life conditions (for example, install a few new sinks and faucets in an environment typical of where they will be widely used, and solicit feedback from all disciplines through observation and interviews)

During the design phase, architects need specific information from infection preventionists. Farrow and Black note that when infection preventionists work with architects to design new spaces, the discussion is often superficial.[297] As a result, infection prevention concerns take a back seat to other design drivers. To ensure that infection prevention concerns are addressed, they recommend that infection preventionists provide explicit details of the processes that will take place in the space, and the pathogens that are of concern. For example, if patients with *C. difficile* diarrhea are routinely placed in private rooms rather than ward rooms, that fact will inform decisions about how to prioritize additional handwashing sinks during a renovation.[298] A team is needed to successfully modify hand hygiene infrastructure, because members of different disciplines will identify different issues. Anderson notes, “Engineers, for example, will see issues from a reliability and maintenance perspective, whereas educators will see

opportunities from an implementation and training perspective, and nurses will see 'flaws' from daily operational perspective."[299] A report of the installation of more than 20,000 new hand hygiene product dispensers in more than 100 facilities in one health care system emphasized the importance of a team approach.[300] The authors recommended collaborating with stakeholders from the following departments:

- Infection prevention and control
- Facilities management
- Purchasing
- Fire safety
- Environmental services
- Occupational health and safety
- Patient care providers
- Product vendors

Best Practices and Recommendations

Sinks

- The number, type and location of handwashing sinks should be informed by the infection control risk assessment and FGI *Guidelines.*
- Provide designated handwashing sinks in addition to sinks used by patients.
- Ensure handwashing sinks are easily accessible to health care personnel and others.
- Ensure that facilities for disposal of liquid waste are easily accessible, so that handwashing sinks are not used for waste disposal.
- Although the minimum acceptable distance between sinks and patient beds has not been established, it would be prudent to install sinks more than 1 meter from the patient's bed.
- Consider installing a splash barrier between sinks and nearby preparation and medication areas.
- Choose sinks with basins deep enough to minimize splashing.
- Construct sinks and casework of materials that prevent leaks and are easily cleanable.
- Designate space near the sink to post instructions for correct handwashing technique.

Faucets

- Faucet design should be informed by FGI *Guidelines.*
- Install faucets that are operable without using hands (for example, with foot controls or wrist blades).
- Sensor-regulated faucets in areas housing immunocompromised patients.
- Where sensor-regulated faucets are used, they should meet user need for timing of flow and temperature, and should remain operable during a power outage.
- Ensure faucets direct water at an angle away from the drain and at moderate pressure.
- Avoid aerators on hand hygiene sink faucets.

Hand Towels and Dryers

- Choose paper towel dispensers that can be operated without touching the dispenser.
- Paper towel dispensers should be intuitive to use and easy to refill correctly.
- Install paper towel dispensers within arms' reach of the sink.
- Avoid air dryers in areas where noise or dispersion of bacteria would present a risk to nearby patients.
- If warm air hand dryers are installed, installing paper towel dispensers would provide desirable redundancy.
- Choose air dryers that can be easily cleaned to prevent build-up of lint and dust.
- Position garbage bins within arms' reach of paper towel dispensers.
- Garbage bins should not have lids.

Product Dispensers

- Automated dispensers are preferable to manual dispensers.
- Dispensers should employ disposable cartridge refills that do not require topping up.
- Choose product dispensers for soap, lotion, alcohol-based hand rub and surgical hand scrub that are easily distinguished from one another.

- Consider color-coding dispensers by type: pink for soap, yellow for lotion and blue for alcohol-based hand rub.
- All products—soap, lotion and alcohol-based hand rub—must be chemically compatible.
- Install a soap dispenser at every handwashing sink.
- Install a lotion dispenser at every handwashing sink.

Alcohol-Based Hand Rub

- Adhere to the NFPA 101: *Life Safety Code*® recommendations for volume of alcohol-based hand rub allowable in a single smoke compartment.
- Install one alcohol-based hand rub dispenser outside the doorway to every patient room, within arms' reach of the door.
- Install one alcohol-based hand rub dispenser at every patient bed, either wall-mounted within arms' reach of common health care personnel positions, or at the foot of the bed.
- Install alcohol-based hand rub dispensers in locations that are easily visible and consistent from room to room.
- Consider installing an additional alcohol-based hand rub dispenser just inside the doorway to every patient room.
- In areas housing patients who are suicidal or confused, consider issuing personal, wearable alcohol-based hand rub dispensers to health care personnel.
- Choose alcohol-based hand rub dispensers that have drip trays and flags to indicate when they are nearly empty.
- Install alcohol-based hand rub dispensers at a height of 85 to 110 cm above the finished floor.
- Instruct health care personnel to ensure alcohol-based hand rub has evaporated completely before igniting a match or lighter.

Electronic Hand Hygiene Monitoring Systems

Consider installing an electronic system for monitoring hand hygiene compliance. When making purchasing decisions for an electronic hand hygiene monitoring system, consider the following twenty questions:

1. Do existing dispensers need to be replaced?
2. Can all types of dispensers be monitored (for example, table-top and personal dispensers, soap and alcohol-based hand rub dispensers)?
3. Will re-wiring be necessary?
4. Will data be uploaded and stored automatically?
5. If wireless, will the system affect existing networks or medical equipment?
6. How will the system affect existing work flow patterns?
7. Will the system require health care personnel to change their behavior in any way (for example, to wear badge or respond to prompts)?
8. How are alerts or prompts delivered?
9. How often will batteries need to be replaced?
10. Does the system monitor individuals or groups?
11. Is the system acceptable to health care personnel?
12. How will data generated by the system be accessed, and by whom?
13. How will the data be used (for example, as part of annual performance reviews)?

14. What inputs will be needed to calculate hand hygiene compliance (for example, census or staffing data)?
15. How will information from the system reach front-line personnel (for example, automatically generated emails)?
16. Is the timing and format of reports customizable?
17. Does the system fit the mission and culture of the organization?
18. What has been the experience of other facilities that have installed this system?
19. Can the system be trialed in the facility before purchase?
20. What are the estimated initial and ongoing costs?

Construction Design Process

- Assemble an interdisciplinary team of advisers to guide changes to hand hygiene infrastructure.
- Discuss hand hygiene processes in explicit detail with the architect.
- Consider all processes associated with hand hygiene together (for example, consider gloves as part of hand hygiene).
- Conduct work flow analyses and interview or observe health care personnel to identify design deficiencies.
- Ask vendors for results of their usability studies for any new equipment being considered (for example, foot-controlled faucet).
- Conduct a small-scale test of any new product or design before full-scale implementation.
- Use a full-scale model to optimize hand hygiene infrastructure prior to construction.

Case Studies

Facility C: Adapting to a new work flow configuration

As an infection preventionist, Linda has been involved in many construction and renovation projects over the years at Hospital C. In the summer of 2016, the hospital began renovating its emergency department (ED) with the aim of improving patient flow and reducing wait times by building in efficiencies for clinical staff. The ED was built in the 1960s and had undergone several updates. There were 12 private rooms, two 2-bed rooms, and no open bays. There was a sink in every room; some were in the far corners of the rooms and others were at room entrances. The sinks had wrist blade faucets, and the paper towel dispensers were automatic. Linda did not recommend changes to these items. She is wary of electronically operated faucets because poor temperature and time control can be an issue for users, and the additional interior parts can develop biofilms. There are lotion dispensers at sinks in restrooms and at the nurses' station.

The new patient rooms would be designed to support a doctor on one side of the patient bed and a nurse on the other side, with essential supplies located within pivoting distance. The project involves minor renovations such as relocating fixtures, patching and painting. The rooms were closed and renovated one at a time. Each room had a different floor plan, necessitating an assessment of the best dispenser locations for each room.

Linda attended one planning meeting. She also conducted a walk-through after the first room was renovated. With the benefit of experience, Linda has learned that dispenser and glove locations should be decided by front-line staff after the project is nearly completed. She noted that since the *Life Safety Code*® was revised to allow for a large volume of alcohol-based hand rub within each smoke compartment, she was able to recommend an alcohol-based hand rub dispenser be mounted inside and outside the entrance to each patient room. On the day of her walk-through, Linda saw that the proposed dispenser locations (indicated by sticky notes) were not ideal. With immediate input from the emergency department nurses and physicians, she identified new dispenser locations. Staff in the emergency department are satisfied with the hand hygiene infrastructure in their newly renovated space.

Facility D: Low hand hygiene compliance in perioperative areas

In 2015, the perioperative areas at Hospital D were struggling with low hand hygiene compliance rates. The preoperative holding area and post-anesthetic care unit, which had been built more than 40 years prior, were configured as open bays with multiple beds separated by curtains. Dispensers of alcohol-based hand rub were located at the entrance to the unit, at the nurses' station and on desks around the periphery of the unit; however, there were no dispensers near the patients because wall space was very limited.

The infection preventionist Shawn sought the assistance of human factor and system engineers at his hospital to resolve this patient safety issue. The team invested time walking around the spaces, observing work flow and talking with front-line staff. They identified lack of access to alcohol-based hand rub at the point of care as a problem. They also suspected that the cluttered environment, which made the unit appear unorganized and not clinical, might be negatively influencing hand hygiene behavior.

Shawn and the team met with managers and directors and the vice president of medical affairs to discuss the challenges and possible fixes. In addition, Shawn asked the vendor of the alcohol-based hand rub product to source a delivery method that would suit the confined space. The automated dispensers in use in other areas of the hospital were too big to fit in the limited wall space of the perioperative units. The team's solution was to install wall brackets to hold pump bottles of alcohol-based hand rub at the head of each patient bed. In each cubicle, the dispensers were mounted on the wall opposite to where the curtains would be stacked back when open, to avoid hiding the dispensers. A colorful pinwheel was displayed above each new alcohol-based hand rub dispenser to draw attention to its availability. In addition, in the post-anesthetic care unit, mobile units of alcohol-based hand rub were clamped to the overbed table at each cubicle. Both units were decluttered.

Since the changes were made, Shawn has received positive feedback from staff, and none of the dispensers have had to be relocated. Hand hygiene compliance rates remained unchanged in the preoperative area, but have improved in the post-anesthetic care unit. Shawn attributes this success to using a team approach. Combining the user knowledge of front-line staff with the fresh, objective views of the human factors engineering consultants resulted in simple solutions.

Facility E: Constant construction

Hospital E is part of a large academic health care delivery system that is constantly evolving in concert with medical science. A continuous cycle of renovation and construction is part of that evolution. The rebuilding cycle presents problems for Hospital C on two levels. During construction, patients are at risk for infection because of mold-laden dust and utilities service interruptions. Even after construction is complete, the risk of infection can be indirectly increased if the design of the new space discourages good infection control practice.

To avoid design and construction problems, Hospital E dedicated one full-time infection preventionist to consult on all construction and renovation projects. Richard has been an infection preventionist for more than 30 years, and has specialized in construction and renovation for the last ten years. Each year he is responsible for about 100 projects at Hospital E and its affiliates. Richard ensures that hand hygiene infrastructure is not lost among multiple competing priorities. He is notified of every new project at the feasibility phase, and his signature is required at the design development phase. He participates in project meetings to ensure that optimal function is not sacrificed for aesthetic appeal, and that resources are directed to features that offer good infection prevention value for money. Although many of the project architects specialize in hospital design, they are not as familiar with the day-to-day work flow in clinical areas as Richard is.

Instituting a full-time infection preventionist to consult on renovation and construction has resulted in a built environment that supports good infection control practices. Alcohol-based hand rub dispensers are available inside and outside of every new patient room and between the beds in multi-patient rooms. Wall space is reserved for alcohol-based hand rub dispensers despite the need to also locate art work, signage, televisions, light switches, outlets, thermostats, glove box holders and sharps containers. Dispensers are placed in locations suggested by front-line personnel. Alcohol-based hand rub dispensers are located where there is no sink, rather than at the sink. Hand soap is dispensed from disposable cartridges rather than the prettier refillable soap dispensers originally suggested. Handwashing sinks are present in each new corridor despite the fact that they spoil the aesthetic line. Wherever possible, sinks are located in the same position in each new patient room even though a lack of variation is considered boring by designers. Renovated rooms are retrofitted with custom-made trapezoidal sinks. Such hand hygiene-friendly features would not have been incorporated into the building without the input of the infection preventionist.

Facility F: Visualizing work flow during the design of a new hospital

Hospital F is a new 270-bed hospital that accommodates patients needing complex continuing care, restorative rehabilitation, geriatric assessment, palliative care and behavioral health care. Jim and Kathleen, two of the infection preventionists at the old hospital, were part of the team responsible for overseeing the new build. Designated subject matter experts from other departments, including front-line clinical staff, were also on the team. The subject matter experts were happy to be able to have a say in how the new hospital was designed, but when asked for their comments during the initial design phase, team members had difficulty thinking beyond their current circumstances and existing work-arounds. For example, nurses asked that toilets in the new facility be positioned so that a commode could be wheeled into place over the toilet. They weren't aware that plans were already in place for the new hospital to have ceiling lifts in each patient room, with tracks going from above the bed into the bathroom, negating the need for a commode in many cases. Imagining work flow was difficult in light of multiple changes. The team also had difficulty visualizing designs that were presented in two-dimensional drawings. This resulted in problems deciding where to locate hand hygiene infrastructure such as dispensers, sinks and paper towel holders.

The solution was full-size model rooms. As part of the contract, the construction company built mock-ups of two patient rooms, as well as a pharmacy workroom, a clean utility room, a soiled utility room and a nursing station. The rooms included the exact dimensions and finishes that would be in the new building, including drywall and paint, flooring, millwork, plumbing fixtures, ceiling lifts and functioning windows. Hand hygiene dispensers were taped to the wall so that they could be tested in different locations. The mock-ups were built at the old hospital in a central location near the cafeteria, and were in place for more than two years. Patients, nurses, therapists, environmental service personnel, administrators and doctors toured the mock-ups and offered comments. Project managers were present to facilitate discussion and record decisions when groups of subject matter experts toured the mock-ups.

As a result of the mock-up rooms, team members were able to offer sound advice about hand hygiene infrastructure. For example, a detailed discussion about work flow in the pharmacy resulted in relocation of the handwashing sink. The original sink location in the soiled utility mock-up was also changed. In the patient room mock-up, alcohol-based hand rub dispensers were relocated away from the sinks and soap dispensers; other alcohol-based hand rub dispensers were moved lower on the wall to be accessible to patients in wheelchairs. Manual hand pumps of alcohol-based hand rub were changed to automated dispensers in areas housing geriatric patients with limited strength and mobility. Without the mock-ups, important design details such as these may have been missed, resulting in additional renovation after occupancy, with associated costs, delays and risks to patients.

Tools

Suresh and Cahill designed two checklists that can be used to evaluate the ergonomic fitness of hand hygiene infrastructure including sinks, waste receptacles, alcohol-based hand rub, and gloves (SWAG).[301] The first is a structural checklist and the second is a periodic assessment. Both tools assess the "hand hygiene-friendliness" of the setting. The SWAG structural checklist (see Figure 5) would be very useful to infection preventionists who want to look for gaps in hand hygiene resources in their existing facilities with a view to correcting deficiencies in a new or renovated space.

Cure, Van Enk & Tiong developed a method to evaluate various alcohol-based hand rub dispenser configurations for a given patient care unit.[302] The method involves two stages: first determining candidate locations and then determining optimal locations. Three criteria are used to evaluate potential locations: usability, standardization and conformity with regulations and organizational policies. Regarding usability, the authors present a seven-item checklist of characteristics of user-friendly dispenser locations (see Table 1). In stage one, planners identify components that are common to all rooms in the unit (for example, bed or examination table, cardiac monitor, computer, door), record work flow around these reference components and assess the usability of existing and candidate locations with the seven-item checklist. In stage two, planners enter the data obtained during stage one into a decision support model. The mathematical model involves complex formulas, and therefore stage two may not suit everyone's needs. The method may be used in any health care setting.

Chagpar and colleagues developed a toolkit for improving hand hygiene infrastructure, which is distributed by the Canadian Patient Safety Institute.[303] The kit is divided into three tools: an environmental assessment tool, a product selection tool and a maintenance process tool. The tools list the human factors rationale behind each recommendation so that facilities can adapt the recommendations to suit their needs and still adhere to the underlying logic. The toolkit can be downloaded from http://www.patientsafetyinstitute.ca/en/toolsResources/pages/human-factors-toolkit.aspx.

The WHO created a Ward Infrastructure Survey that is available at http://www.who.int/gpsc/5may/tools/evaluation_feedback/en/. The tool is a survey of basic hand hygiene infrastructure that should be available on all hospital units. It could be used to compare hand hygiene fixtures and supplies across different units or facilities, to prioritize renovation requirements. It could also be used as a foundation for assessing gaps in the existing environment with a view to correcting deficiencies in a new or renovated space.

Figure 5: SWAG* Tool for Assessment of Hand Hygiene Resources in Health Care Environment: Structural Assessment

Sinks

Easily visible: Upon entry into the patient room (or the aisle of an intensive care unit or an open ward), is the sink visible within a 180 degree field of vision?

Placed at optimal height: Measure the height of the rim. Is the rim 85–110 cm above the floor?

Hand-free operation: Can water be made to flow from the faucet without touching it with your hands (e.g. foot operated, elbow operated, photo-electric faucet)?

Easy to set desired water temperature: Can the faucet easily be made to deliver water at a comfortable temperature?

Easy access to soap dispenser: When standing at the sink, is the soap dispenser within hands reach without having to stretch or step to obtain soap?

Easy access to paper towel dispenser: When standing at the sink, is the paper towel dispenser within hands reach, without having to stretch or step to obtain a paper towel?

Sink with easy reach from patient's bedside: Can the sink be reached from the patient's bedside with two paces or less?

Unobstructed approach from patient's bedside: Is the path between the patient's bedside and the sink free of obstacles such as chairs, the patient's bed, and hospital equipment?

Waste Receptacles

Within easy reach: When standing at the patient's bedside, is the waste receptacle (trash can) at a distance of one pace or less?

Alcohol-Based Hand Rub Dispensers

Easily visible: Upon entry into the patient room (or the aisle of an intensive care unit or an open ward) is the dispenser easily visible within a 180 degree field of vision?

Placed at optimal height: Measure the height of the dispenser nozzle tip. Is it 85–110 cm above the floor?

Easy to actuate: Does the dispenser provide the alcohol based hand rub liquid or foam with gentle compression of the actuator (i.e., without the use of excess force or pressure)?

Redundant dispenser available: Is a second dispenser present close to the first one?

Within easy reach from patient's bedside: Can the dispenser be reached from the patient's bedside with one pace or less?

Unobstructed approach from patient's bedside: Is the path between the patient's bedside and the dispenser free of obstacles such as chairs, the patient's bed, and hospital equipment?

Glove Dispensers

Easily visible: Upon entry into the patient room (or the aisle of an intensive care unit or an open ward) is the dispenser easily visible within a 180 degree field of vision?

Placed at optimal height: Measure the height of the dispenser nozzle tip. Is it 85–110 cm above the floor?

Redundant dispenser available: Is a second glove dispenser present close to the first one?

Within easy reach from patient's bedside: Can the dispenser be reached from the patient's bedside with one pace or less?

Unobstructed approach from patient's bedside: Is the path between the patient's bedside and the dispenser free of obstacles such as chairs, the patient's bed, and hospital equipment?

Each question is answered with a "Yes," "No," or "Not applicable."

* SWAG, sinks, waste receptacles, alcohol-based hand rub dispensers; and gloves.

Table 1: Usabillity characteristics of dispenser locations with respect to patient care areas (patient rooms)

Usability characteristics
1. Easily visible upon entry
2. Easy and unobstructed access
3. Within arm's reach or less than one step from the entrance/exit
4. Visible from the (possible) point(s) or care
5. Along the (possible) physical workflow path(s)
6. Within arm's reach or less than one step from the point of care
7. Placed at optimal height (85–100 cm above the floor)

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CHAPTER 3: Reprocessing

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Introduction

Currently in the United States, the minimum standard for whether an item is reprocessed using low level disinfection, high level disinfection (HLD) or sterilization is determined by the Spaulding scheme.[304] Items touching intact skin or the environment need low level disinfection at a minimum (for example, a wheelchair, stethoscope, blood pressure cuff, pulse-oximeter, etc.). Items coming into contact with mucous membranes and non-intact skin receive HLD at a minimum (for example, vaginal ultrasound probe, endoscopes, etc.). If an item touches a sterile site it must be sterilized (for example, surgical instruments). HLD kills most organisms, although it will not kill 100 percent of bacterial spores. Sterilization is a process that destroys or eliminates all forms of microbial life including spores.

The sterilization process can be divided into five steps. The first step is gross decontamination. This is the removal of gross debris on the item and treating the item in a way that will not allow for the drying of the material on the device. Because timeliness is of the essence, there are no environmental requirements for where one can perform gross decontamination. The next four steps do have environmental requirements. These steps are decontamination, packaging for sterilization, sterilization and storage of the material for use. Each of these steps has unique requirements for the environment. For example, the decontamination room, where the instruments have the final rinse through before either being wrapped or entering a washer decontaminator, should be done in a location that has—at minimum—a three-bay sink.

The type of sterilizer used at a facility will determine to a large extent the facility's needs for heating, ventilation and air conditioning as well as area and room design. The most frequently used sterilizers in health care facilities can be divided into several groups: table top sterilizers, steam sterilizers, hydrogen peroxide plasma sterilizers and peracetic acid sterilizers. Table top sterilizers, because of their comparatively small size and capacity, have little in the way of infrastructure demand, while steam sterilizers have a need for separate access to the sterilizer for repair and maintenance issues as well as careful placement of the supply ducts for cool air. Poor placement of these ducts immediately above the sterilizer door can result in condensation forming on metal instruments (i.e., "wet load") rendering them no longer sterile.

The quality of steam and water supplied to a steam sterilizer is also important as "wet steam", which can cause the sterilization process to fail and "hard water" may also shorten the life of a sterilizer because of calcium deposit build up. Temperatures for hydrogen peroxide plasma sterilizers are lower and thus the demands on the facility infrastructure are lower. Ethylene oxide sterilizers were steadily losing market share in the United States until recent outbreaks related to duodenoscopes suggested this technology might be effective at stopping these events. However, because of the safety issues around ethylene oxide and the need for material having gone through the process to be stored for a period of time before use, the infrastructure demands around these machines are quite extensive. Peracetic acid sterilizers are usually small sterilizers that can be placed in many areas with limited infrastructure needs.

In addition to the various building codes and sterilizer requirements, the three documents reviewed below are the most frequently used when reviewing the guidance around the environmental needs for each of the steps of the sterilization process. These documents include

the Association for the Advancement of Medical Instrumentation (AAMI) ST79: *Comprehensive Guide to Steam Sterilization and Sterility Assurance in Health Care Facilities*, Healthcare Infection Control Practices Advisory Committee 2008 and guidance from the Association of periOperative Registered Nurses.

These documents set the minimum standards for water and air quality and temperature and humidity in these areas. In addition, they set standards for lighting needs; work flow, generally from to dirty to clean; air pressure relationships; and other design issues. Some of these requirements are based on scientific literature review, while other requirements are based on expert opinion and consensus.

Thoughts and standards around high-level disinfection are changing perhaps more rapidly than those around sterilization. Recent outbreaks have demonstrated that past approaches to high level disinfection put patients at greater risk than previously recognized. Additionally, the Spaulding scheme is being questioned for some items undergoing high level disinfection as instruments that are sterilized frequently have very low bioburdens on them after use, while endoscopes have very high bioburdens, meaning that high-level disinfection has a very thin margin of safety. Some items like vaginal probes continue to have high level disinfection as the unquestioned standard.

Some of the current standards around high-level disinfection air pressure requirements are changing because requirements for safety around spills of high level disinfection fluids imply one air pressure relationship with the surrounding rooms while current design standards suggest another.

The differences between vaginal probes and complex endoscopes result in different standards for these devices. For example, AAMI ST91: *Flexible and Semi-rigid Endoscope Processing in Health Care Facilities* and guidelines of the Society of Gastroenterology Nurses and Associates, Inc., can be consulted for endoscopes but these do not apply to vaginal probes, therefore, this chapter will deal with these devices separately.

The high-level disinfection process has four steps. The first is gross decontamination, and like the gross decontamination step in sterilization, this first step is usually done at the point of use immediately after patient care. In the case of endoscopes, this process may involve a few steps, while in the case of vaginal probes it may simply involve removing the condom sheath. The second step is cleaning the scope or vaginal probe; third is high level disinfection, and fourth, storage. The cleaning step for endoscopes involves at a minimum the use of a two-basin sink.

When an item has been exposed to high level disinfection, the chemicals that are toxic need to be removed. Most high-level disinfection for endoscopes today is done in automated endoscope reprocessors. Most modern automated endoscope reprocessors have filters to remove bacteria normally found in potable water from the water used for rinsing. Automated endoscope reprocessors also have specific water pressure needs. For institutions that do not use automated endoscope reprocessors for all their scopes and also reprocess manually, a plumbed source of fresh water should exist. Additionally, most automated endoscope reprocessors now have a cycle that flushes air through the scope to ensure drying, but if that is not available, a source of medical grade air should be available. Disposal of the high-level disinfectant can also require deactivation before discharge to sanitary sewer. This depends in part on the manufacturer’s instructions for use and the local water authorities regulations.

Several basic actions that will minimize error in the steps described above have been established. Decontamination in the sinks for either high level disinfection or sterilization requires that all visible debris be removed from the object; functionally this means that the area where this is performed requires excellent bright lighting with a minimum of shadows.

For decontamination for both high level disinfection and sterilization, staff must wear personal protective equipment that is waterproof or water-resistant. This personal protective equipment is not breathable, meaning that staff can quickly overheat and as a result become distracted and not perform in the same manner as if they were comfortable. The concern over staff comfort has resulted in different room standards for temperature ranges. Unfortunately, personal protective equipment does not allow for cool outside air to penetrate and reduce the heat load of the staff working in that area.

The decontamination area for both sterilization and high-level disinfection should be an area designed to withstand copious water exposure without promoting fungal growth. Materials such as wood or pressboard should not be used in these areas. Additionally, walls should be made of a material that will not allow for fungal growth if it is saturated with water.

The design of decontamination and processing areas for both high level disinfection and sterilization needs to reduce staff interruption and distraction. This functionally means the areas should be restricted from others entering, which can be accomplished by installing a numeric keypad lock or another lock that cannot be lost but that will prohibit unauthorized personnel from entering the area.

Some institutions have begun using borescopes during the reprocessing of endoscopes. They are traditionally used immediately before the scope is to be placed in the automated endoscope reprocessor (AER). These borescopes normally require a connection to a computer, so if borescopes are to be used, there will need to be space planned for the computer and related electrical needs.

Brief Literature Review

Specialized equipment used in high level disinfection and sterilization requires that some preplanning data gathering needs to be conducted. Water hardness needs to be evaluated for two reasons. For devices such as washer disinfectors used in decontamination for sterilization, hard water deposits can result in buildup that can obstruct water flow used to clean items inside the machine. Additionally, hard water can result in mineral deposits on the instruments being processed inside the machines, rendering the instruments unable to be used or sterilized. Hard water also reduces the rate of kill of some disinfectants because divalent cations such as magnesium and calcium in the hard water form insoluble precipitates when they come into contact with certain disinfectants.[305] Additionally, hard water may cause a buildup of deposits inside the automated endoscope reprocessors. Steps must be taken to evaluate whether the water is hard and mitigations have developed so that hard water does not negatively affect the sterilization and/or high-level disinfection processes.[306]

Water hardness is defined as the presence of calcium carbonate in the water in concentrations above 61 micrograms per liter. Water in with a concentration of 61-120 mg/l is considered moderately hard, 121-180 mg/l is defined as hard and above 180 mg/l is very hard[307].

Although fewer and fewer facilities are using ethylene oxide sterilization it has enjoyed a very modest increase in its use because of some high profile endoscopic retrograde cholangio-

pancreatography (ERCP) duodenosocpe outbreaks and Federal Drug Administration guidance.[308] Humidity outside of the range of 40 to 80 percent can cause failure of the sterilization process.[309] If an ethylene oxide sterilizer is being installed, a heating ventilation and air conditioning unit that is capable of maintaining this range without failure needs to be installed. Enclosed containment areas with additional ventilation requirements are recommended for ethylene oxide sterilizers and other chemical sterilizing agents.[310,311]

Automated endoscope reprocessors generally require an electrical source, a water source and ability to dispose of waste solutions via the sewer system. In the past, some high-level disinfectants like OPA (ortho-phthalaldehyde) have had requirements added after their introduction to inactivate the disinfectant before disposal. The automated endoscope reprocessors at the time had not planned for this additional step, so facilities had to design post-installation changes to allow for it. Planning for such space around an AER may be prudent.

Some newer automated endoscope reprocessors have cleaning claims, and these machines have higher washer pressure requirements than are traditionally found in most endoscopy suites. Whether these automated endoscope reprocessors will gain market share or not is unclear, but it is reasonable to consider that they may be used in any area where endoscopes are reprocessed and water pressure should be capable of handling their minimum demands.

Cart washers are devices that wash carts used to transport dirty surgical equipment between the operating rooms and the sterile processing department. They have become standard in most newly constructed U.S. hospitals. Because these devices are automated, they largely eliminate the potential for a blood borne pathogen exposure to staff cleaning the carts and ensure a standard level of cleaning. Cart washers also minimize the need for an area to be set aside for manual cart cleaning. Again, since these devices use copious amounts of forced water, plans for the area should involve evaluating for hard water and, if necessary, remedying; access for repairing the cart washer, and sewering the runoff.

Larger steam sterilizers (not table top sterilizers) require several sets of criteria. The steam supply to the sterilizer must be through lines that have sufficient insulation to prevent “wet steam,” adequate (high) steam pressure to prevent “superheated steam” and drain lines with the capacity to handle the volume of water generated at the end of steam sterilization. Steam dryness should be between 97 and 100 percent. The level of noncondensable gases (that is, air), expressed as a fraction by volume, should be at a level of less than 3.5 percent v/v condensate. This level will not impair steam penetration into sterilization loads.[312] Steam should not reach a temperature above 25°C (77°F) of the saturation point.[313] The boiler feedwater source, treatment chemicals used and the design and maintenance of the steam supply system should minimize the presence of potential contaminants in the steam; this means treating hard water before it enters the boiler. Steam lines should be designed to eliminate any “dead legs.” Dead legs are areas without a continuous flow of steam and these legs can harbor and propagate contaminants, including microorganisms. The lack of a flow of steam can result in condensation that allows bacteria like *Pseudomonas* to reproduce and form a biofilm.[314] In-line filters should be installed as close to the sterilizer as possible, and they must include a drip leg or trap so condensate can be removed.

Steam sterilizers also require an access room so that repairs may be conducted. These rooms are under negative pressure to the surrounding areas. Because these rooms are not designed for staff regular use, they are often without adequate heating, ventilation and air conditioning

capacity. However, plans should include ways to minimize the extensive heat load in these rooms from affecting the temperatures in surrounding rooms. Additionally, the heat load and humidity in these rooms should not exceed the standards set by the local Occupational Safety and Health Administration jurisdiction for worker safety[315] as the areas become staff work areas for repairs maintenance. The cooling cannot be excessive in these rooms or the function of the sterilizer may be affected. The Facility Guidelines Institute (FGI) *Guidelines* of 2014[316] require ten air exchanges an hour for these rooms with a direct exhaust outside.

The steam sterilizers themselves generate heat that escapes the sterilizer once the door is open. As mentioned above, supplies of cool air cannot be placed so that cool air blows directly on still-hot sterilized packs, as that will compromise the sterilization process; however, this heat does need to be mitigated for the rest of the work area.

To be effective, high-level disinfectants require set temperature ranges. These can occur at temperatures slightly above some staff comfort zones. Most automated endoscope reprocessors will warm the disinfectants during their use. Some facilities still perform manual high-level disinfection. Manual high-level disinfection is a problem-prone process, and studies show that the process occurs as delineated in the endoscope instructions less than 2 percent of the time. Nevertheless, a facility may still perform high level disinfection manually, in which case additional electrical supply may be necessary for a warmer for the disinfectant and, in some cases, a hood to capture potentially harmful fumes from the disinfectant.

To this point the chapter has reviewed the factors that are generally agreed on and evidence based. The issues of room temperature, room humidity and pressure differentials between reprocessing areas and adjacent spaces takes us out of those elements.

Temperature, excluding the elements discussed above, has to do with staff comfort. Comfortable staff work more effectively, but what feels comfortable is unique to each individual. Attempts to formulate guidelines around temperature have resulted in some contradictory guidelines. AAMI ST79 (2013) listed temperatures for the decontamination room that were below and did not overlap the guidelines given by the FGI[317] and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).[318] This listing had to do in part with the experience of some of the members of the AAMI group working in those areas. Individual comfort can be influenced by the individual's age, physical fitness, body mass index and current workload; what is comfortable to a fit 90-pound young person in a decontamination area that only deals with relatively light eye sets in low volumes can be far too warm for an obese older person working to decontaminate heavy sets in a high-volume area. Additionally, as mentioned above, the personal protective equipment worn in decontamination for either high level disinfection or sterilization is not breathable and therefore the effect of lowering the outside temperature to increase staff comfort is marginal. Consensus on a group from the AAMI, Association for Professionals in Infection Control and Epidemiology (APIC), Association of periOperative Registered Nurses (AORN), FGI and ASHRAE studying this issue is that cooling vests worn by staff maybe a better answer to staff comfort than lowering the temperature of the decontamination area. This conflict was finally eliminated in the 2017 AAMI standard.

Another reason cited for lower temperatures in decontamination areas, specifically for sterile processing, is that cooler temperatures retard microbial growth. This ignores that some bacteria are psychrophilic (prefer cold), some are thermophilic (prefer hot temperatures) and many are mesophilic (prefer normal temperature ranges). Most pathogenic bacteria are mesophilic but

even these have bacteria that replicate well at temperatures within the range of the bottom of those in the AAMI guidelines.[319]

Humidity settings also have limited value in preventing infections. Clearly ranges and temperature combinations that cause condensation or precipitation are to be avoided, as the addition of water to a surface will promote growth of fungi and bacteria. Outside of these ranges, a review of the literature shows only prolonged (periods of days to weeks) exposures to high humidity has any meaningful increase in fungal growth. Short excursions into these ranges probably have negligible effects. Low humidity settings when offered have no effect on microbial growth. Short exposure can, however, affect the functional life of paper products used to wrap sterile items. If these papers are exposed to prolonged low levels of humidity they may become compromised.

Using pressure differentials to prevent contamination of items about to enter the sterilization process is an approach not supported by scientific studies. While such an approach can work for “clean rooms” where staff are completely encapsulated in a head-to-toe suit, the settings in the preparation and packaging area does not reflect such a work space. Staff routinely work in this area with clean clothes and exposed skin including face, arms and hands. No studies have demonstrated that bacterial loads on instruments entering the sterilizer have any meaningful increase in bioburden because of a failure to maintain positive pressure in this area. The total bacterial count on an instrument handled by bare hands with a person also shedding squamous cells is not meaningfully affected by any microbes floating into the room. Additionally, even if it were to cause a greater microbial load, these instruments are about to enter a sterilizer designed to kill any such microbes. The negative pressure for the decontamination area also has limited data to support its use except around airborne diseases where the source of the microbes is the human respiratory system and not the mechanical action of decontamination.

Lastly, the use of chemicals that may emit toxins on the positive pressure side is not unusual. If a large spill were to occur, the potential spread of the fumes from a positive pressure area into other populated areas may be a true concern.

Despite the lack of scientific support for current standards around humidity, temperature and pressure differentials, guidelines are written into all existing design and practice standards (AAMI, FGI, ASHRAE) and must be complied with.

Best Practices and Recommendations

Sterilization and Design from the Point of Use to Reprocessing Back to the Point of Use

The sterile processing that occurs in either outpatient surgery centers or acute care hospitals involves several rooms. These rooms must be planned for, although when noted they may not be necessary or may be incorporated into other rooms. The sterile processing area is the overall name for the area within a health care facility that sterilizes items and in some facilities processes and controls medical supplies, devices and equipment both owned and rented, sterile and not sterile, for some or all patient care areas of the facility. A determination of the role and responsibility of the department must be conducted before designing the space.

More facilities are moving away from a department that is responsible for both non-sterile supplies, rental equipment such as beds and sterile processing, because often at minimally staffed times these additional responsibilities will interrupt staff while they are performing

intricate multiple steps involved in sterilization, resulting in inadvertent compromising of the process.

The decasing/breakout area or space is the unpacking area or space where products are removed from their external shipping containers before being taken into the preparation and packaging area or the sterile storage area. This area may or may not include an area for the accepting of “loaner trays” from vendors. Loaner trays should be inventoried before the facility accepts them[320,321] and therefore a counter where this can be done should be provided if they are received in this department. A receiving, cleaning and decontamination area is another area where these trays may be received, but its largest volumes come from receiving reusable instruments, supplies, equipment and carts and sorting, cleaning and decontaminating. Generally, the area for cleaning carts and associated equipment should be proximal to the decontamination area. The personnel support area is where staff toilets, showers and locker facilities are available.

The preparation and packaging area is where items that have left the decontamination area as decontaminated instruments, or clean instruments, or other medical and surgical supplies are then inspected; assembled into sets and trays; and wrapped, packaged or placed into rigid sterilization container systems for sterilization. These are generally adjacent to the decontamination room and a pass-through window allows for items to move between. Washers/decontaminators also have an entry in both the decontamination room where dirty instruments are placed and the preparation room where they are removed from the machine once they have been through a successful decontamination cycle.

The sterilization area is the place where sterilization activities take place. Once items have been successfully sterilized they are moved to the sterile storage area. There they are stored and protected from contamination. This area may also be used to store clean items that are distributed by the department.

The equipment and cart holding area is the holding area for clean medical equipment and carts before storage or issue. If the department is also responsible for distribution of nonsterile equipment they will need an equipment storage area where clean medical equipment is stored until issued. An administrative area must exist for the department supervisor to handle human resources issues. An environmental services equipment storage area is where supplies and equipment for cleaning the sterile processing area are kept. Most facilities have moved away from reusable textiles for performing a sterile wrap but if a facility plans on continuing this practice then an area is needed for storage of the linens, inspection of the linens and, if also not outsourced, onsite laundering. Some space must also be designated for the temporary storage of sterilization records. This can be done in many of the areas described above.

The flow of these rooms should be unidirectional from dirty to clean. Additionally, the sterile processing areas should be in close proximity to the areas they serve. In cases where this may not be possible, such as when serving both the surgical suites and labor and delivery operating suites, the sterile processing area should be on the same floor as both of its customers. If that is not possible, then a dedicated dirty elevator and a dedicated clean elevator should exist between the sterile processing area and customers on other floors, in addition to a path of travel established allowing for dirty carts to arrive in the decontamination or receiving area in the event of elevator failure, and a path of travel established from the clean side to deliver sterile items back to the unit needing them.

General design issues for the sterile supply area should be constructed to create a flush surface with recessed, enclosed fixtures. Pipes and other fixtures above work areas should also be enclosed so as to not create a surface for dust to accumulate. Ceilings should be constructed of materials that are not of a particulate- or fiber-shedding composition, and in the decontamination area materials should be resistant to fluids.

Floors and walls should be able to withstand fluid exposure[322] and frequent cleaning and should not be adversely affected by the chemical agents typically used for environmental cleaning. Some sterilizer carts have blunt ends that can damage walls, exposing porous fibers that can shed into the environment and then, when washed, absorb water and cause fungal growth. Planning for wall damage from carts and ways to mitigate that damage is prudent. Floors should also be flat without groves as they are difficult to clean.

Before determining the space requirements for the sterile processing area, the services the department will provide must be defined as well as the expected inventory of sterile supplies (including disposables) as well as if any non-sterile items will be distributed from the department and how these will be distributed. Additionally, adequate space should be allocated for equipment, and the functional work areas should be designed accordingly. General consideration for the space needs of this area should include at a minimum:

- The anticipated volume of work and the units to be served (for example, operating room, anesthesia, delivery room, emergency room, trauma unit, burn units, outpatient clinics, specialty units).
- Whether washer-sterilizers, washer-disinfectors, washer decontaminators, single- or multi-chamber tunnel washers, cart washers, ultrasonic cleaners or endoscope processors will be used in the department.
- The types of packaging to be used (for example, disposable wraps and pouches, reusable wraps or rigid sterilization container systems. Most facilities today are moving toward rigid containers for many items.
- The technology to be used for sterilization (for example, ethylene oxide, other chemical sterilants, steam) in most cases departments use more than one type.
- The anticipated inventory storage.
- If an inventory tracking system is used, because plans for this affect the decontamination, pack and sterilization and storage areas.

Space is crucial as a cluttered or crowded space may not allow for staff to move items without recontaminating them. It can also make cleaning of the area difficult.

Several questions must be answered before the design of the decontamination area project can go forward. Some facilities have attempted to decentralize decontamination to the departments that are contaminating the instruments in need of sterilization. Such approaches may increase costs to the facility as the special ventilation needs described above have to be replicated throughout the facility. Additionally, challenges with staffing may arise as individuals who work in specific areas become familiar with only those instruments; when these specialized individuals are not present at work the skill level of the replacement staff may not be adequate. Whether the decentralized approach will be attempted must be addressed.

The Facility Guidelines Institute's *Guidelines* for 2014 requires six air exchanges an hour. The air should be exhausted directly outside and the area should be under negative pressure.

Staff use of personal protective equipment in the decontamination area can quickly fill large waste receptacles. An area for staff to don and doff personal protective equipment should be established. This area should be free of risk from being contaminated by accidental spraying occurring in the decontamination process. An eye wash station needs to be present in this area and not be likely to cause splash up or back from a contaminated surface. Staff must have access to instructions for use for all items they are decontaminating. Most facilities are moving toward having these be obtained from the Internet and so either Wi-Fi access for tablets (personal electronic devices) or a computer station should be in the design plans.

Ergonomic factors affecting worker safety and comfort should be considered when designing work spaces because fatigued or uncomfortable staff may not be as diligent in looking for compromises in the sterilization process. Additionally, the Occupational Safety and Health Administration has standards and expectations for sterile processing areas.[323]

For the comfort reasons cited above, sinks should not be so deep that personnel must bend over to clean instruments. Decontamination sinks ideally should be approximately 36 inches (91 cm.) from the floor and 8 to 10 inches (20 to 25 cm) deep. The sink should be of a width and length to allow a tray or container basket of instruments to be placed flat for pretreatment or manual cleaning. The sink should be constructed with three sections—the first for soaking, the second for washing and the third for rinsing—and it needs to have water ports to facilitate the flushing of instruments with lumens. Sinks should be large enough to contain the largest utensils and instruments used in the facility. A source of deionized, distilled or reverse osmosis water for final rinsing should be provided as this will eliminate the hard water issues discussed above and prevent recontamination by microorganisms and endotoxin typically found in potable water. Any minerals found in water used for manual cleaning will likely stay with the instrument through the sterilization process, impairing the instrument and potentially the sterilization process[324] However, automated washers can provide a final rinse with whatever grade of water is made available. Forced air should be provided at the sink, as well as faucets or manifold systems for flushing lumened devices. Sinks should have attached solid counters impervious to water on which to place soiled and clean items separately.

Far more important is the lighting for both the decontamination area and the packaging area. The recommendations are based in science and in a range of 1,000 lux (100 foot-candles) to 2,000 lux (200 foot-candles) so that the detailed work of removing bioburden and inspecting for bioburden can be successfully accomplished. Items such as the stainless-steel tables used in both decontamination and packaging, the color of walls and the age of staff must also be taken into consideration when evaluating lighting needs. Additionally, all lighting must be designed so as to not allow for dust accumulation and minimize staff shadows being cast on their work areas.

Hand hygiene facilities (sinks and/or waterless alcohol-based hand rubs) should be conveniently located. They should be located in or near all areas in which instruments and other devices are decontaminated and prepared for sterilization, as well as in all personnel support areas (for example, toilets and lounges) to allow staff to quickly reduce the bioburden on their hands.

AAMI ST79 recommends the air supply in this area be of the down draft design because of the copious amounts of lint generated in the area. Facility Guidelines Institute *Guidelines* require only 4 air exchanges an hour. The area should be under positive pressure.

Sterilizers should be located in a restricted access area to decrease contamination risk, minimize distraction and facilitate appropriate security/release of reprocessed instruments/equipment. The areas where the sterilizers are located should be free of sources of contamination and in low traffic areas. Immediate use (formerly known as flash sterilization) steam sterilizers should be located in the restricted area of the surgical space where personnel are required to wear full surgical attire, including covering all head and facial hair, including sideburns and necklines, and to wear masks in the vicinity of open sterile supplies. Because of guidance to follow the manufacturer cycles described in instructions for use including some non-standard cycles, consideration may be given to the installation of a separate steam sterilizer designated for use of these medical devices requiring non-routine cycles. The room by AAMI standards should have 10 air exchanges an hour and be under positive pressure. Ironically the FGI did not address this issue because of uncertainty of the relationship between operating suites and the area directly outside operating suites as sterilizers are placed directly outside operating suites and operating suites are under positive pressure.

The sterile storage area should be under positive pressure and adjacent to the sterilization room so that contamination cannot occur during transport of the items to this area. The bottom shelves of the storage area should ensure that no contamination occurs during floor care. Solid bottom shelves are preferable. Ideally, items should not be stored under overhead plumbing. The room should have adequate heating, ventilation and air conditioning and insulation so that if one or more of the walls is an exterior wall, external temperatures will not affect the still-warm items that have just been sterilized and cause condensation on any sterile sets.

Areas using table top sterilizers are much less restricted in their design requirements although they should be in a clean designated area.[325,326] Whether radiation sterilizers will penetrate the health care facility market is yet to be seen, but those sterilizers require their own set of rules specifically around staff safety rather than infection prevention.

One other consideration for sterile processing departments is that the area where biological indicators are incubated after use must be in a temperature and humidity controlled space in accordance to the manufacturer's instructions for use. The reason is so the results of these tests are accurate and compliance can be achieved either by controlling the overall environment or, in some cases, placing the unit in a humidor-like enclosure.

High Level Disinfection from Dirty to Clean Storage

Work flow in areas performing high level disinfection must be unidirectional.[327] The environment must support this by allowing adequate space for storage of newly contaminated scopes entering the area. To support infection prevention, the design of the work should incorporate

- Work flow.
- Anticipated patient and procedure volume.
- Number and types of endoscopes/equipment.
- Quantity and type(s) of processing equipment.
- Scopes/equipment storage requirements.
- Supply/chemical storage requirements.
- Traffic flow.
- Required utilities (for example, medical-grade air, water quality, ventilation).

As with sterilization, the pre-clean must occur immediately after the endoscope is used and thus occurs in the procedure room. The processing area must be physically separated from the patient procedure rooms. If an elevator is used for transport of scopes because the reprocessing area cannot be on the same floor as the procedural suites, a dirty elevator and a clean elevator should be dedicated to the transport of either clean or contaminated scopes only. The following items need to be in the endoscope reprocessing area: flat surfaces, lighting and utility support of electricity. The area should be designated solely for the reprocessing of endoscopes. It should have an area for receipt of scopes, cleaning (decontamination), disinfection or packaging and sterilization, and storage. Physical separation of these steps is preferred. An area should be defined at the incoming end of the unidirectional flow process for the receipt and temporary holding of devices before cleaning. This area should be far enough away from the processing sink to not interfere with that process.

The sink where leak testing and flushing of the endoscope are performed should be supported by two large flat surfaces on either side. These surfaces should be large enough to hold the longest scope in the inventory. The area should also be supported with cabinetry that holds disinfectants used to clean the flat surfaces in the receiving area or around the sink without requiring staff to leave the area to obtain the disinfectants. The backsplash on the sink shall extend at least one foot up from the sink. Sinks should be deep enough to allow complete immersion of the longest endoscope in the inventory. The sink should also be large enough (that is, 16 inches x 30 inches) to ensure the endoscope can be positioned without tight coiling but not so deep so that personnel have to bend over to clean instruments.

Three sinks or one sink with three separate basins should be used, so that each function is performed in a separate sink or basin. As most enzymatic cleaners used in the process are diluted per gallon, the sinks should come with pre-marked gallon fill levels so that staff can quickly determine the correct dilutions for enzymatic cleaning. The sink or sinks should have faucets and adapters that attach to the faucet, or other accessories that facilitate the flushing of instruments with lumens.

The sink and surrounding cabinetry should be impervious to water. Lighting should be placed above the sink and counter area so that personnel can adequately perform inspection activities as the endoscope is processed but not have their shadow cast into their work area. Light levels are the same as those described earlier in the sterile processing decontamination area. Ideally a small supply rack should be above the sink, protected from splashing from the sink, so that immediately needed brushes and other equipment are available to staff and not inadvertently placed in the dirty or clean area. Forced air with an upper limit of pressure as described in the endoscope manufacturer's written instructions for use should be provided at the sink for flushing lumened devices. Since these may vary by scope manufacturer, a way to regulate the pressure is needed. Floors and ceilings should comply with the guidelines described in the sterile processing area.

As mentioned above, some automated endoscope reprocessors come with a cleaning cycle that eliminates the need for the sinks used for this process. However, not all scopes are validated to be used in such automated endoscope reprocessors. In fact, for duodenoscopes, the Food and Drug Administration (FDA) currently requires that “the automated endoscope reprocessor cleaning cycle only be used as a supplement to thorough manual cleaning according to the duodenoscope manufacturer’s instructions,[328] functionally ensuring that for the foreseeable future manual cleaning will continue to play a role in endoscopy reprocessing.

Some facilities use a machine capable putting the scopes through a sterilization process (for example, STERIS 1E™). Scopes processed thus are not recommended for storage but for immediate use if sterility is to be maintained. If they are stored they should be reprocessed before use unless otherwise stated by the manufacturer.

Ideally, after the scopes have been decontaminated they should pass into a separate room where the automated endoscope reprocessors are located. This should be done through a pass-through window. If this is not possible, at an absolute minimum a distance of three feet should separate the dirty processing area and the clean work area. The scopes will then be placed in an automated endoscope reprocessor. This room should have a handwashing sink so staff can easily perform hand hygiene after touching a scope that has yet to be high level disinfected and before touching one that has been high level disinfected. If the AER does not have a final air blow through with or without alcohol for scopes that recommend that, then filtered air should be supplied in this area.

Once the scope has been removed from the automated endoscope reprocessor, it should from there be moved to a separate dedicated room where scopes are stored. Storage of scopes is an evolving issue. Consensus is that scopes should not touch the bottom of the scope storage cabinet. A scope cabinet should be able to allow vertical hanging of the longest scope. European scope cabinets with filtered air and drying claims may or may not have a future in the U.S. market. Recent studies showing that scopes having undergone alcohol and forced air are still wet suggest that the future may be moving towards the drying cabinet design[329]. In the event that these do gain market share, abundant electrical outlets in these areas should be available. All scope cabinets should be made of material that will not promote bacterial or fungal growth if scopes drip. Ideally the scope cabinet's floors should be made so that drips are easily visible as a quality check on the drying process.

Vaginal probes, because they lack lumens and do not generally encounter the level of gross contamination seen with endoscopes, do not have nearly as many guidance documents around them. Room lighting should be sufficient to detect debris on the probe. Cabinetry should exist for storing the disinfectant solution and the temperature range should be great enough to allow the high level disinfectant to work. A sink is generally needed to wash off the device after being submerged in the disinfectant. A sink to wash the probe prior to insertion in the high level disinfection is generally not required as most probe manufacturers only require the probe to be wiped off with a hospital disinfectant. Ventilation requirements are based more on the toxicity of the disinfectant used than any purported infection prevention benefits. If high level disinfection of these probes were to be performed in a patient care room, it would need to be unoccupied and the high level disinfection solution not be accessible to patients.

Multipurpose Rooms

Sterilization and high level disinfection are complex processes and the mixing of these complex processes with any other tasks or use areas is likely to result in inferior outcomes as distractions increase. Nevertheless, institutions frequently attempt to maximize existing space with mixed results.

The sterilization decontamination process generates copious amounts of water including splashes and requires staff to wear personal protective equipment and use negative pressure. This precludes the process from being mixed with patient care areas. Decontamination areas in older hospitals are often not spatially separated from the packaging area but in one contiguous

room. In fact the Facility Guidelines Institute's 2014 *Guidelines* recommends in such cases a four-foot distance from the edge of the sink to a clean work area or a screen four feet higher than the edge of the sink. This approach is clearly inferior as it does not account for distraction or human behavior that can result in cross contamination.

High level disinfection endoscope or vaginal probe decontamination and sterile processing decontamination can be done in the same room. Given the expensive and fragile nature of endoscopes, decontamination of an endoscope should not be attempted at the same time as the decontamination of any other device, such as a vaginal probe or surgical instruments. Attempting to perform decontamination for both instruments in the same space would require separate sinks not because of a risk for cross contamination but so that both could be done in a timely fashion.

High level disinfection (automated endoscope reprocessors specifically) and sterilization can be done in the same area. This is specifically seen in a cartoon of an office-based sterile processing area in AAMI ST79.

Some sterile items are routinely stored in patient care areas (patient rooms, emergency department treatment rooms, operating rooms), although this has caused some issues.[330] One needs to be aware of the temperature and humidity issues in these areas. Additionally, attempting to access these supplies may disrupt care.

High level disinfection and storage should not occur in the same area, and while sterilization rooms may be contiguous with storage spaces, they should have great spatial separation.

The most basic reference is the personnel who perform processing in these spaces. Designing an environment for high level disinfection or sterilization without their input will ensure frustration and possibly increased risk of disease transmission. In addition to state regulations, basic guidelines include the Facility Guidelines Institute, the American Society of Heating, Refrigerating and Air-Conditioning Engineers and AAMI ST91 (high level disinfection) and ST79 (sterilization). While these documents may occasionally stray from science out of an abundance of caution, they are the standards for infection prevention in these settings.

Case Study

Hospital G: High-level disinfection areas

In Hospital G, staff were struggling with the design of the disinfection area. For example, the facility's door allowed anyone to enter during the decontamination process. As staff worked at the sink, they could see the scopes accumulate for reprocessing, which unconsciously pushed them to work faster, which is a potential problem because working faster at an intricate job can cause mistakes. Physicians were able to enter the decontamination area through the door and urge the staff to rush. In addition, the visibility at the sink was not ideal, and it was difficult to see whether the brushes had debris on them, which could interfere with adequate brushing. The facility aimed to minimize this problem by bringing in a wheeled magnifying glass, but the area was so small that the glass was challenging to use. After decontamination, the scopes were taken across the hall to a room with automated endoscope reprocessors, but carrying the scopes across the hall posed a risk of staff bumping into someone coming out with a clean scope.

To address these challenges, a new design was created to minimize disruption and provide adequate space and visibility. To accommodate this new design, the reprocessing areas were expanded into other areas, which meant a loss of clinical space and some offices but allowed for proper reprocessing. The facility had to change the ventilation and upgrade these areas to reflect newer code requirements. A locking feature on the door has kept physicians from interrupting the reprocessing procedures and rushing processes. Although the new design cost the facility resources, it has led to improved reprocessing.

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CHAPTER 4: Cleaning and Disinfection of Environmental Surfaces

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Introduction

In today's health care environment, environmental cleaning and disinfecting of surfaces is a critical component in the prevention of healthcare-associated infections. Surfaces form part of the environmental reservoir that are highly susceptible to contamination to many different dangerous pathogens.[331,332] Three approaches exist for routine disinfection of hard, non-porous surfaces in patient rooms: chemical disinfection with manual cleaning; using "self-disinfecting" surfaces that are impregnated or coated with metals such as copper, silver, and germicides and no-touch technology such as ultra violet light (UV-C) or fogging with hydrogen peroxide vapor or mist.[333]

Multiple studies suggest that environmental contamination plays a key role in the transmission many dangerous pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* spp. (VRE) and *Clostridium difficile*.[334,335] All three of these pathogens survive for prolonged periods of time in the environment, and infections have been associated with surface contamination in hospital rooms and of health care personnel's hands.[336] Specifically *C. difficile* requires enhanced cleaning interventions to effectively reduce the presence of *C. difficile* spores on high-touch environmental surfaces in patient rooms.[337,338,339]

A patient room where the prior occupant was infected with MRSA, VRE or *C. difficile* significantly increase the odds of the next patient acquiring one of those bacteria. Healthcare-associated infections represent the most common adverse event in the intensive care unit; ICU rooms have been found to confer a 40 percent increased risk of acquiring MRSA and VRE, presumably, in part, through environmental contamination.[340,341]

By using the best practices and recommendations outlined in this guide, health care leaders can identify environmental process deficiencies, develop an action plan for correcting these deficiencies, implement the action plan and monitor the plan for positive outcomes. For both existing and new facilities, a multidisciplinary team comprised of administration, nursing, environmental services, infection prevention, facility management, materials management and biomedical engineering should be formed for a successful environmental program. Collaboration between the hospital and health system infection prevention and control practitioner and the environmental services professional is paramount to the success of the environmental cleaning and disinfection program. Creating and sustaining a successful cleaning and disinfection program should include several key components using a bundle approach and will require ongoing commitment from health care leaders. Key components of this bundle should include establishment and reporting of metrics to validate environmental cleaning, policies and procedures to delineate cleaning responsibilities among staff, selection of appropriate cleaning products and determination of the application method for the products, and education, monitoring and feedback for the staff.[342]

The multidisciplinary team has many tools and resources at their disposal to help the bundle to be successful, including the Association for the Health Care Environment (AHE) practice guidance for health care environmental cleaning for evidence based-cleaning and disinfecting processes;[343] the APIC's infection-prevention environmental services competencies and environmental services infection control committee report for environmental services[344]; the Centers for Disease Control and Prevention toolkit for evaluating environmental cleaning and disinfection checklist[345] and the AHE's certification for front-line environmental services with the Certified Healthcare Environmental Services Technician program.[346]

Pathogens are most commonly transferred via health care personnel's contaminated hands from one infected patient to a susceptible patient. When the hands of health care personnel come into contact with contaminated room surfaces or medical equipment, frequently the hands and/ or gloves become contaminated. Studies have shown hand contamination with MRSA occurred with the same frequency whether the health care personnel had direct contact with the infected patient or only touched contaminated surfaces.[347] Importantly, *C. difficile* hand contamination of health care personnel is directly tied with the intensity of the environmental contamination; hand contamination was 0 percent when the environmental contamination was 0 to 25 percent, 8 percent when the environmental contamination was 26 to 50 percent, and 36 percent when the environmental contamination was greater than 50 percent.[348]

Multiple studies have shown that environmental surfaces in a room with a patient that is infected with MRSA were contaminated 1 percent to 27 percent of the time and from a few percent to 64 percent of the time in burn units with MRSA patients.[349] Patients colonized with VRE found the frequency of environmental contamination to reach 60 to 70 percent, and patients that used a couch or chair were found to be positive for VRE 36 to 56 percent of the time.[350] For patients in a room infected with *C. difficile*, the environmental contamination was shown to be widespread with a range of 2.9 to 75 percent contamination.[351] Commonly contaminated surfaces and equipment include bed rails, bedside tables, surfaces of ventilators, sinks, suction equipment, mattresses, resuscitation equipment, curtains, slings for patient lifting, mops, buckets, door handles, stethoscopes, incubators and computer keyboards.[352]

Numerous studies have shown that environmental surfaces are often inadequately cleaned when manual cleaning is conducted with chemicals. Researchers marked high-touch surfaces in rooms with a marker visible only under ultraviolet (UV) light to determine whether the surfaces had been cleaned.[353] In one of those studies, 1,404 surfaces in 157 patient rooms were checked after routine cleaning, and only 47 percent of the surfaces had actually been cleaned; 44 percent of the surfaces in the intensive care unit had been cleaned during discharge cleaning.[354,355] Eliminating environmental surface contamination as a source for patient to patient transmission of pathogens will require multiple interventions, which was illustrated in a recent study that dramatically reduced the frequency of positive surface cultures of *C. difficile*.[356]Interventions to improve surface cleaning and disinfection include improving education of the environmental services team on the cleaning processes, creating a checklist to ensure that all surfaces are cleaned and disinfected and using a method to audit and assess the cleanliness of the environment with immediate feedback to the environmental services team. These interventions have been demonstrated to improve the frequency of adequate cleaning to the range of 71 percent to 77 percent.[357,358] The number of healthcare-associated infections that may have been prevented by improving the cleanliness of the environmental surfaces in

hospital rooms is unknown. By understanding how these surfaces can contribute to the possible transmission of these dangerous pathogens, health care leaders can identify which surfaces may become contaminated, assess current practices and enhance disinfecting processes of these surfaces as another strategy for infection prevention.

Brief Literature Review

Many of the surfaces in the room of an infected patient are contaminated and then serve as a reservoir for microbial growth. Environmental surfaces that are likely to be contaminated by one of these pathogens can be divided into two groups: those frequently touched by hand contact (doorknobs, bedrails, light switches, overbed table, nurse call box, etc.) and those with minimal hand contact (for example, floors, ceilings, walls). The hands of health care personnel come into contact with these high-touch surfaces, and then come in contact with another device or surface, contaminating that as well. Once a surface is contaminated, dangerous healthcare-associated pathogens can survive for prolonged periods of time if no regular surface disinfection is performed. MRSA and VRE can survive for days and months on dry surfaces, while *C. difficile* (spores) can survive months (Table 2).[359]

Table 2: Survival of common healthcare-associated pathogens

Organism	Duration of Survival
Clostridium difficile	>5 months
Vancomycin-resistant *Enterococcus* spp. (VRE)	5 days to 4 months
Methicillin-resistant *Staphylococcus aureus* (MRSA)	7 days to 7 months
Acinetobactor spp.	3 days to 5 months

Environmental contamination is an important factor in patient-to-patient transmission; data from a number of studies have found that patients admitted to a room in which the prior occupant was infected with a particular pathogen are significantly more likely to acquire that same pathogen during their hospital stay than patients who are admitted to a room in which the prior occupant was not infected.[360,361,362] Since the patients had no direct contact, the risk is associated with the environment of the patient room. Overall, the odds of acquiring the organism were more than 1.5 to 2 times higher among patients admitted to the rooms in which the prior occupant was infected with *C. difficile*, MRSA and VRE.[363,364,365] These findings suggest that frequent environmental contamination poses a real risk to the next patients who are admitted to these contaminated rooms. Therefore, proper disinfection of the surfaces and equipment that patients and health care personnel touch frequently is required to reduce exposure in these rooms.

Several new technologies have entered the health care market that have the potential to close this gap and enhance the containment of multidrug-resistant organisms. These technologies include improved chemical disinfection, self-disinfecting surfaces and engineered “no touch” automated disinfection systems.[366,367,368]

An evaluation of improved chemical disinfection using a new activated hydrogen peroxide wipe disinfectant was used to disinfect 10 high touch surfaces in 72 patient rooms and significantly improved disinfection of the surfaces.[369] The evaluation revealed that after cleaning, 99 percent of surfaces yielded less than 2.5 colony-forming units/cm^2, 75 percent yielded no growth and 70 percent yielded adenosine triphosphate (ATP) counts of less than 250 relative light units. Another study showed improved hydrogen peroxide was significantly superior to a standard hydrogen peroxide cleaner at the same concentrate and superior or similar to the quaternary ammonium compound.[370]

Self-disinfecting surfaces can be created by coating or impregnating surfaces with heavy metals (for example, copper or silver) and germicides (for example, organosilane compounds). Other miscellaneous methods (for example, light-activated antimicrobials) can be used. Copper ions are lethal to a wide range of pathogens. One study showed that patients cared for in intensive care unit rooms with copper alloy surfaces had a significantly lower rate of incident healthcare-associated infection and/or colonization with MRSA or VRE than patients treated in standard rooms.[371] For the study, patients were randomly placed in available rooms with or without copper alloy surfaces, and the rates of incident healthcare-associated infection and/or colonization with MRSA or VRE in each type of room were compared. The rate of healthcare-associated infection and/or MRSA or VRE colonization in intensive care unit rooms with copper alloy surfaces was significantly lower than that in standard intensive care unit rooms (0.071 vs 0.123; P = .020). For healthcare-associated infections only, the rate was reduced from 0.081 to 0.034 (P = .013). Copper was also found to consistently limit surface bacterial burden before and after cleaning through its continuous antimicrobial activity.[372] Silver has long been recognized for its antimicrobial properties: it has been used to purify drinking water, treat medical conditions and prevent the spread of disease. Research has shown that surfaces constructed of stainless steel with silver-based antimicrobial coatings have the potential to reduce MRSA rates. Copper along with other self-disinfecting surfaces require further studies to determine whether their use reduces healthcare-associated infections.

The third group of technologies, “no-touch” automated disinfection systems, has been developed to enhance terminal and discharge room cleaning. These systems commonly use either ultraviolet light or hydrogen peroxide, although there are a variety of systems and chemicals available in automated format. One type of device emits UV light, and another produces a mist or vapor of hydrogen peroxide. Germicidal Ultraviolet light uses UV-C wavelength light, which is germicidal and involves breaking down the molecular bonds in DNA, thereby rendering the organism sterile. Germicidal Ultraviolet light has microbicidal activity against a wide range of pathogens, including *C. difficile*. Hydrogen peroxide misting is the aerosolizing of dry-mist hydrogen peroxide or vapor to decontaminate a room. Hydrogen peroxide systems have also shown to have microbicidal activity against a wide range of pathogens, including *C. difficile*. One study was performed to determine the effectiveness of an ultraviolet light-emitting device to eliminate clinically important healthcare-associated pathogens in a contaminated hospital room.[373] The results of the study showed UV-C light reduced the counts of vegetative bacteria on surfaces more than 99.9 percent within 15 minutes, and the reduction in *C. difficile* spores was 99.8 percent within 50 minutes. A study was conducted to determine whether hydrogen peroxide misting decontamination could reduce environmental contamination.[374] The results showed that 11 of 43 (25.6 percent) cultures of samples collected by sponge from surfaces before hydrogen peroxide misting yielded *C. difficile*, compared with 0

of 37 cultures of samples obtained after hydrogen peroxide misting decontamination (P < .001). Another study compared ultraviolet light and hydrogen peroxide misting. The processes were performed in 15 patient rooms; five high-touch sites were sampled before and after the processes and aerobic colony counts were determined.[375] The results showed that ultraviolet light and hydrogen peroxide misting reduce bacterial contamination, including spores, in patient rooms, but hydrogen peroxide misting was significantly more effective. Ultraviolet light was significantly less effective for sites that are out of direct line of sight. Multiple studies have proven the efficacy of these no-touch room decontamination systems and suggest that they may be more reliable in reducing transmission of healthcare-associated infections. These technologies should be considered for use in the health care setting as a supplement and do not replace standard manual cleaning and disinfecting of surfaces.

Best Practices and Recommendations

The cleanliness and disinfection of the health care environment is important for infection prevention and the patient's well-being. This effort starts with hospital leaders forming a multi-disciplinary team that should include the people with the knowledge and experience to make decisions aimed at improving the cleaning and disinfection of the environment throughout the entire organization.[376]The following disciplines should be included on the team: administration, infection prevention and control, nursing, environmental services professionals and facility management. The team's focus should be on developing and sustaining a successful cleaning and disinfection program. Multiple stages need to be followed to develop a successful program, and sustaining the program will require the ongoing commitment of everyone in the organization.

Stage 1

Stage one of the program is determining what chemicals will be used to clean and disinfect the various surfaces in the health care environment. Disinfectants that are to be used in the health care setting must be registered with the Environmental Protection Agency for that use. The environmental services team generally performs intermediate-level disinfection and low-level disinfection functions in a health care facility. [377] The most commonly used chemical disinfectants are quaternary ammonium compounds (referred to as quats) for routine cleaning and disinfection. They are bactericidal, virucidal against enveloped viruses and fungicidal, but not sporicidal and generally not mycobactericidal or effective against nonenveloped viruses. Sodium hypochlorite (commonly known as bleach) is bactericidal, fungicidal, virucidal, mycobactericidal and sporicidal and is generally recommended for surfaces or objects contaminated with *C. difficile* spores. Accelerated hydrogen peroxide has been recently introduced for surface disinfection with generally short contact times; it is bactericidal, virucidal, fungicidal, sporicidal and mycobactericidal.

When selecting products for cleaning and disinfection, many factors must be considered. First, consider the disinfectant's spectrum of activity (kill claim), in other words, the pathogens against which it has been proven to be effective. For example, quaternary ammonium compounds are often recommended for multiple drug resistant organisms such as MRSA and VRE, while sodium hypochlorite or an Environmental Protection Agency (EPA)-registered sporicidal disinfectant is recommended to kill *C. difficile* spores. An EPA-registered disinfectant labeled as a tuberculocidal will also be needed. Look for products that have short contact times, a one-step cleaner and disinfectant that is compatible with surfaces, non-corrosive and that has long shelf

life. Information on these qualities can be found in the manufacturer's technical data sheets and safety data sheets. Follow the product manufacturer's recommendations for use on certain surfaces and use the correct dilution ratio.

Once the chemical selection is completed and guidelines are set on when to use what chemical for a specific pathogen, a determination will need to be made on how the disinfectant will be applied to the surfaces. The disinfectants can be applied with cotton cloths, microfiber cloths or disposable wipes. The disinfectant may be wiped with a moistened cloth, sprayed or applied with a saturated cloth soaked in a disinfectant filled bucket. The most important factor is that the disinfectant be applied liberally enough to achieve the appropriate wetness to ensure that the disinfectant contact time is achieved per the label's instructions. A method for achieving the correct chemical dilution will need to be decided; most chemical vendors offer automated dispensing and mixing systems to ensure accurate dilution ratios each time. Other methods include ready to use bottles and ready to use wipes, although there is a substantial additional cost associated with these methods.

Stage 2

Stage two of the program is defining policies and procedures, and every discipline that has any role in the cleaning process needs to be represented at this stage so that policies and procedures can be effectively defined.[378] The policies need to clearly define the cleaning task, the responsible department to perform the task, the cleaning frequency and the products to be used.[379] Table 3 is an example of a grid that defines the cleaning task within the policy.[380]

Table 3: Cleaning tasks defined

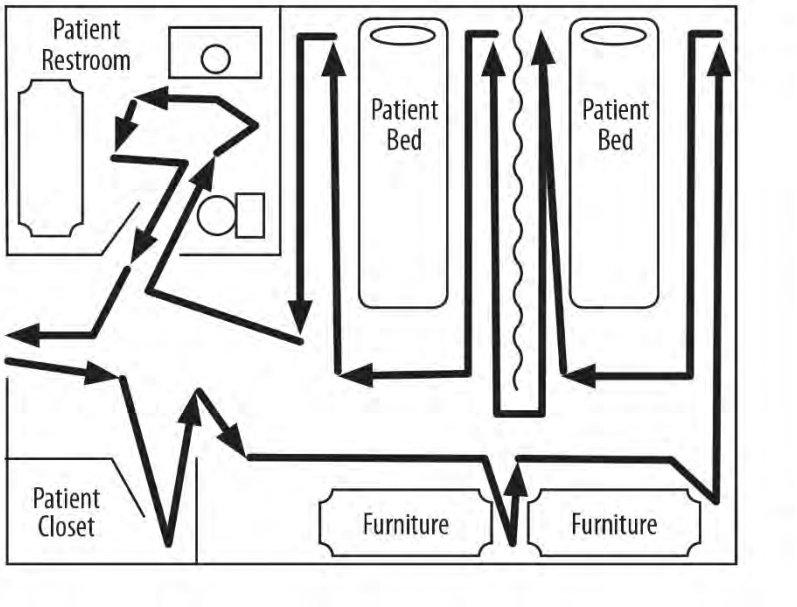
Type of Cleaning	Responsible Service	Items to be Cleaned	Product Used to Clean	Comments
Computers (excluding terminals in patients rooms	All users NEW	1. wipe down computer keyboard and mouse	1. EPA/ICC hosp quat* or bleach wipe**	Clean after use
Routine Daily Cleaning of Patient Room	Environmental Services	1. dust window ledge 1. spot clean furniture (chairs) 2. wipe down over-bed table 3. wipe down side rails 4. wipe down TV control 5. wipe down bathroom fixtures (faucets, grab bar, shelf, etc.) 6. clean sink and toilet 7. wipe down door handles (room and bathroom 8. mop bathroom and patient floor 9. remove trash	1.–9. EPA/ICC hosp quat* or 1.–8. EPA/ICC hosp bleach wipe** for Contact CD and Enterie Precaution 9. EPA/ICC hosp quat*	10 Step daily cleaning process
Transfer/Discharge Cleaning of Patient Room, and Any Patient Room at Nurse's Request (when room is empty)	Environmental Services NEW	1. strip bed of all linen, clean bed frame, side rails, mattress NOTE: after nursing has removed all patient belongings (i.e. clothing in closets, hearing aids in bedside table or over-bed table) and nursing equipment (i.e. halter monitors, blood glucose meters, pulse oximeters) 1. clean bedside table, over bed table, phone, call bell, TV control 2. wipe down flow meters 3. wipe down regulators 4. dust/clean lighting fixtures 5. clean outside canister (clean) of suction container 6. clean and wipe down IV poles and pumps that need to remain on the unit, apply sani-strip ✤ 7. wipe down furniture 8. dust all ledges 9. clean around sharps containers and glove boxes 10. wipe down step stools 11. wipe down walkers 12. wipe down canes 13. clean bedside commode, (once emptied by nursing) apply sani-strip ✤ 14. clean bathroom fixtures, sink, shower, and toilet apply sani-strip ✤ 15. mop bathroom and patient floor 16. pull trash 17. change out privacy curtains if soiled or on request	1.–16. EPA/ICC hosp quat* or 1.–15. EPA/ICC hosp bleach wipe** for Contact CD and Enterie Precautions 16. EPA/ICC hosp ¶ see cleaning instructions provided by Clinical Engineering, below ✤ apply sani-stip, see notes below	10 Step discharge cleaning process

Using the Spaulding classification, which categorizes levels of disinfection based on the object's intended use and the risk for infection with the use of that item, noncritical items in the health care setting are those that only touch intact skin, and these require low-level disinfection, and an intermediate-level disinfection for *C. difficile*. Equipment should be disinfected between patients

if shared or at least daily and at terminal cleaning.[381] Protocols for cleaning these noncritical items are to be consistent, such as cleaning and disinfecting of all high touch surfaces (bed rails, overbed table, nurse call button etc.). These high touch surfaces that frequently come in contact with the hands of patients or health care personnel should be cleaned and disinfected daily (or more frequently) and at terminal cleaning. Identify which areas might call for less frequent cleaning because they are not likely sources of contamination (walls, ceilings, window sills); these noncritical surfaces need cleaning only when visibly soiled and periodically. Outline the steps employed for cleaning occupied patient rooms and terminal cleaning of patient or procedure rooms. [382]

When defining cleaning and disinfection protocols, follow predetermined guidelines for the cleaning path (top to bottom, clockwise/counterclockwise, clean to dirty); this will ensure that no areas are skipped and help prevent pathogens from being transferred from a dirty area to a clean area.[383] The restroom in the patient room should always be cleaned last to reduce the likelihood of spreading contaminants and to increase efficiency and safety.[384,385,386,387,388] To maintain quality and consistency among environmental technicians, the environmental services professional should predetermine the logical cleaning path to be followed.[389] Figure 6 is an example of a predetermined cleaning path for a semi-private room.[390]

Figure 6: Cleaning path for semi-private room



When it comes to assigning responsibility for cleaning equipment, environmental services, nursing and infection control should collaborate to decide who is going to clean and disinfect specific non-critical equipment. Examples of non-critical equipment to consider may include infusion pumps, sequential compression device pumps, glucometers, blood pressure monitors, mobile computers or workstations and handheld tablets or smartphones (and the cleanable protective cases that often accompany such equipment). Once all parties agree on who will be responsible for cleaning each type equipment, compile a list. The list should have the following outlined on it: the equipment name, the standard of cleaning (for example, after use or when visibly soiled), method of cleaning and type of disinfectant, the group responsible for cleaning

and any additional comments. The standard of cleaning should be determined by the infection control committee, while the method of cleaning should be determined by the manufacturer's instructions and, at a minimum, non-critical equipment should be disinfected when visibly soiled, prior to use on a patient and on a regular basis. Incorporate this list of responsibilities into new hire orientation and training for environmental service technicians and staff to prevent confusion about who is responsible for cleaning specific equipment.

Checklists and daily assignment sheets should be developed that will help the environmental services technicians properly complete the tasks that they are performing. Checklists are a useful tool to standardize the daily cleaning and disinfecting practices and encourage the technician to adhere to the cleaning process. The cleaning checklist should include low- or intermediate-level disinfectants specific to the type of isolation the technician may encounter. The daily assignment sheet should have all areas listed for that assignment and have the amount of time the technician has to complete the cleaning in each area. The time for completing each area should be sufficient to allow a thorough cleaning, accounting for adequate contact time for cleaning agents. Checklists and daily assignment sheets can be easily implemented. Figure 7 is an example of a daily assignment sheet.

Figure 7: Sample daily assignment sheet

	3 East All		Scope Of Service			Min
	Break	Clock In:	Clock In & report to coordinator	break		15
	A 9:45a B 10:00 a	Get:	Phone: 6663; Recap Sheet; Keys	lunch		30
	Lunch	Log In:	Section: # Zone: 31	Huddle		15
	A 12:30 B 1:00P	Set Up	Cart #5 In EVS 3150	Setup		10
#	RM #	DAILY	ROOM NAME	D/C	ISOL	
1	Charge Nur.	A	Get Report			1
2	Halls	A	Police 3 East Hall			3
3	Lobby	A	Public Side Elevator Lobby			5
4	Lobby	A	Public Side Elevator Lobby			3
5	3167 F	A	Nurses Station Front			10.6
6	3147	A	Clean Supply Front			3
7	3145	A	TEAM BATHROOM BY 3101			5
8	3101	A	Patient Room and Bath			10.6
9	3102	A	Patient Room and Bath			10.6
10	3103	A	Patient Room and Bath			10.6
11	3104	A	Patient Room and Bath			10.6
12	3105	A	Patient Room and Bath			10.6
13	3106	A	Patient Room and Bath			10.6
14	3107	A	Patient Room and Bath			10.6
15	3108	A	Patient Room and Bath			10.6
16	3109	A	Patient Room and Bath			10.6
17	3110	A	Patient Room and Bath			10.6
18	3111	A	Patient Room and Bath			10.6
19	3112	A	Patient Room and Bath			10.6
20	3113	A	Patient Room and Bath			10.6
21	3114	A	Patient Room and Bath			10.6
22	3115	A	Patient Room and Bath			10.6
23	3116	A	Patient Room and Bath			10.6
24	3117	A	Patient Room and Bath			10.6
25	3118	A	Patient Room and Bath			10.6
26	3119	A	Patient Room and Bath			10.6
27	3120	A	Patient Room and Bath			10.6
28	3167 B	B	Nurses Station Back			10.6
29	3166 A	B	Office Back			3
30	3166 B	B	Office Back			3
31	3164 F	B	Clean Supply Back			3
32	3121	B	Patient Room and Bath			10.6
33	3122	B	Patient Room and Bath			10.6
34	3123	B	Patient Room and Bath			10.6
35	3124	B	Patient Room and Bath			10.6
36	3125	B	Patient Room and Bath			10.6
37	3126	B	Patient Room and Bath			10.6
38	3127	B	Patient Room and Bath			10.6
39	3128	B	Patient Room and Bath			10.6
40	3129	B	Patient Room and Bath			10.6
41	3130	B	Patient Room and Bath			10.6
42	3131	B	Patient Room and Bath			10.6
43	3140	B	Soiled Holding			3
44	3148	B	Charting			3
45	3149	B	Equipment Cleaning			3
46	3154 F	B	Storage (Equipment Supply)			3
47	3159 F	B	Charting			3
48	3165 F	B	TEAM BATHROOM			3
49	3162 F	B	Soiled Holding			3
50	3153 F	B	Nourishment			3
51	3152 F	B	Charting			3
52	3143	B	Code Cart			3
53	3151 F	A	POC			3
54	3155 F	A	Office			3
55	3161 F	A	Charting			3
56	3160 F	A	Team (Multi-purpose room)			3
57	3163 F	A	Nourishment			3
58	3143	A	Stairwell "A" Landing			3
59	3142 A	A	TEAM BATHROOM			3
60	3142 B	A	TEAM BATHROOM			3
61	3142	A	Team Locker Room			3
62	3150	A	EVS			2
	Clean Up:		Cart #5 In EVS 3150			10
	Log Out:		Section: 30 Zone: 31			5
	Turn In:		Phone: 6663; Recap Sheet; Keys			
	Clock Out:		Report to coordinator and Clock out			

When performing cleaning for an isolation room, follow the same procedures as used for a regular room cleaning. In addition, a few more detailed steps will be included. Don appropriate personal protective equipment for the particular isolation precaution following the isolation sign instructions and check for proper fit before entering the room.[391] Use the specified disinfectant for the type of isolation—for example, quaternary ammonium compounds are often recommended for multidrug-resistant organisms such as MRSA and VRE, while sodium hypochlorite or an EPA-registered sporicidal disinfectant is recommended to kill *C. difficile* spores. Other types may require an EPA-registered disinfectant labeled as a tuberculocidal.[392] These special procedures should be included in the cleaning and disinfection protocols as they relate to isolation cleaning: use low- or intermediate-level disinfectants that are specific to the type of isolation, consider potential contamination of items that need to be cleaned, only leave the room when cleaning is completed, adhere to proper removal protocols of personal protective equipment as it is critical to avoid contamination and exposure to the pathogens, avoid touching the outside of items where infectious organisms may have settled, immediately perform hand hygiene and disinfect cleaning equipment before returning it to the cart.[393]

Specifically, when performing cleaning and disinfection of *C. difficile* isolation, enhanced cleaning strategies should be considered. Studies have shown that using a germicidal bleach wipe and conducting cleaning and disinfection education with the environmental services staff improved the decontamination of surfaces in the room.[394] Another study evaluated additional bleach cleaning in two intensive care units following an increase in patients with *C. difficile*. The extra cleaning was delivered to all parts of one intensive care unit, including rooms used only by staff. Clinical equipment was cleaned with hypochlorite-containing cloths twice a day. The second unit introduced enhanced bleach cleaning in isolation rooms accommodating patients already infected with *C. difficile*. Both units witnessed a decrease in infection rates over the next few months, which remained at a lower level for at least two years after the bleach cleaning program.[395] Another study evaluated daily cleaning with germicidal bleach wipes on wards with a high incidence of hospital-acquired *C. difficile* infection. The intervention was associated with a reduction in hospital-acquired *C. difficile* incidence by 85 percent, from 24.2 to 3.6 cases per 10,000 patient-days, and prolonged the median time between hospital-acquired *C. difficile* cases from 8 to 80 days.[396] As shown in the studies, the use of bleach wipes and increased cleaning frequencies may be associated with a decrease in the rates of *C. difficile* infections in the hospital and should be considered when defining the specific cleaning and disinfection protocols for *C. difficile*.

Stage 3

The next stage, or stage three of the program, is environmental cleaning education for the environmental staff and any other health care personnel designated to clean certain equipment. Ensuring competence of environmental services staff and those assigned to clean equipment is critical and a hospital should have a competency-based training program in place. The Centers for Disease Control and Prevention recommends “structured education,” where the training includes the technician’s role in improving patient safety.[397,398,399,400,401,402] The program should reinforce the importance of cleaning and disinfecting and be specific about the expectations and the necessary skills. The environmental team and those assigned to clean equipment must understand the “why” behind their everyday actions and the key role

environmental services technicians and those that clean equipment play in preventing the spread of infection.[403] Environmental services technicians must be given an abundance of information to perform their daily tasks effectively. They must be educated on the types of pathogens and understand how infection is spread and how they can prevent that spread. They need education on the proper cleaning and disinfecting practices of the required items they are to clean, the frequency of cleaning of those specific items, the guidelines about the order in which to clean those items, the right cleaning/disinfection chemical to be used for the organism, the proper dilution ratio of the products they are using and the correct dwell time to achieve disinfection of the surface they are cleaning.[404]

New hire training should include classroom training that covers department policies and procedures, and should include a knowledge assessment, like a written quiz. Training should define how the quality and consistency of their work will be monitored and audited on both a daily and yearly basis. Once classroom training is complete, new hires should train with a preceptor for five to seven days. Once preceptor training is completed, a direct observation assessment should be conducted by environmental services management or the infection control professional at the facility. The assessor should ensure new hires follow environmental cleaning procedures, donning and doffing of personal protective equipment, daily room cleaning, a standard discharge room cleaning and a *C. difficile* discharge isolation cleaning. New hires should perform two discharge cleanings on their own and have an assessment done once completed. One approach to assessing competency is to have the technician pass an ATP assessment. After environmental services management conducts the assessment, the new hire can work an assignment on their own or if necessary go back for more training based on the assessment outcome. Ongoing monitoring of cleaning should be used for retraining purposes and should not be done as a punitive measure.

In addition to new hire training, ongoing training should be provided to maintain competency of existing environmental services staff and those health care personnel assigned to clean equipment. This training should be held monthly, include written exams and attendance should be tracked by management. The training program should include yearly competencies to measure the technicians' and health care personnel's technical skill as it relates to cleaning and disinfecting.

Achieving a professional certification is one way for environmental services staff to demonstrate expertise. The Association for the Healthcare Environment offers the Certificate of Mastery in Infection Prevention for Environmental Services Professionals; this robust certificate program provides the requisite knowledge for a "trained" professional in infection prevention and control specific to the clinical environment of care. The AHE offers the only certification for front-line technicians that validates their knowledge and technical skills.[405] The Certified Healthcare Environmental Services Technician designation sets national standards specifically for environmental services technicians working in health care.

Table 4 is an example of some training and assessment guidelines that environmental services management can follow. Table 5 is a sample of infection control competencies for environmental services.[406]

Table 4: Sample training and assessment guidelines

New Hire Competency Assessments	Training and Retraining
Classroom training, with written quizzes	Conduct trainings and administer written exams at monthly meeting
Preceptor training	Deliver trainings for team members that fail audits
Observation of PPE donning and doffing	Review new recommended practices
Observation of daily cleaning	Review necessary cleaning procedures at daily huddles
Observation of discharge cleaning	Review competencies tested during new hire training annually
Observation of *C. difficile* isolation discharge	

Table 5: Sample infection and control competencies for environmental services personnel

Cluster Area of Competency	Competency Statement	Terminal Objective
Basic Microbiology	**1. Describe the role of microorganisms in disease**	
		a Describe the different types of microorganisms (bacteria, viruses, fungi, etc.), and their role in healthcare-associated infections. b. Describe antimicrobial resistance and its importance in healthcare associated infections.
Modes/ mechanisms of infection/ disease transmission	**2. Describe how microorganisms are transmitted in healthcare settings.**	
		a. Identify the links in the chain of infection b. Differentiate between transmission routes of microorganisms in the healthcare setting (e.g., airborne, contact, droplet). c. Describe the role the environment plays in microorganism transmission in healthcare settings. d. Apply principles of asepsis (e.g., clean vs. dirty tasks, sterile vs. non-sterile procedures). e. Distinguish between clean, disinfected and sterile patient care items. f. Describe the difference between a product that cleans and one that disinfects.
Standard and transmission-based precautions	**3. Demonstrate standard and transmission-based precautions for all patient contact in healthcare settings.**	
		a. Describe the principles of standard precautions. b. Demonstrate proper hand hygiene. c. Describe appropriate use of hand hygiene products (soap and water, antimicrobial soap, surgical scrub, waterless alcohol agent) and when to use each. d. Describe the categories of transmission-based precautions and when to initiate the preventive activities of each category. e. Demonstrate how to verify negative pressure function of patient environment. f. Describe appropriate patient placement (e.g., room type, comforting) relative to the category of transmission-based precautions. g. Describe appropriate interventions required during patient transport relative to the category of transmission-based precautions. h. List the appropriate personal protective equipment items for each category of transmission-based precautions. i. Demonstrate how to put on and take off personal protective equipment. j. Demonstrate fit check (user seal check) of NIOSH approved respirator. k. Describe appropriate disposal of personal protective equipment. l. Describe the signs, symptoms and diagnoses that would alert a healthcare worker to initiate transmission-based precautions (e.g., fever with cough, fever with skin rash/ lesion, fever with other respiratory symptoms, gastrointestinal symptoms).

Table 5: Sample infection and control competencies for environmental services personnel (continued)

Occupational Health	**4. Describe occupational health practices that protect the healthcare worker from acquiring infection.**	
		a. Demonstrate safe handling and disposal of sharps. b. Demonstrate appropriate use of safety devices. c. Explain methods to safely handle blood and body fluids to prevent exposure. d. Describe the first aid for cut/puncture exposures, or fluid exposures to the eyes, nose or mouth. e. Articulate the process for reporting blood/body fluids exposure in the workplace. f. Describe appropriate disposal of items soaked/saturated with blood/body fluids or other potentially infectious materials. g. Describe regulated waste versus general trash and the appropriate disposal of each.
Patient Safety	**5. Describe occupational health practices that prevent the healthcare worker from transmitting infection to a patient**	
		a. Describe work practices that reduce the risk of infection transmission (e.g., immunization, not coming to work sick, hand hygiene). b. Explain the importance of healthcare worker participation in immunization programs. c. Describe how the staff member with and infectious condition can pose a risk to other healthcare worker, patients, and visitors. d. Describe signs, symptoms and diagnoses that require absence from work or work restrictions (e.g., fever with cough, fever with skin rash/lesion, fever with other respiratory symptoms, gastrointestinal symptoms.
Critical Thinking	**6. Demonstrate ability to problem-solve and apply knowledge to recognize, contain, and prevent infection transmission.**	
		a. Explain how to access infection control resources including policies and procedures. b. Discuss own role in infection prevention and control (e.g., recognizing unsafe activities, intervening when breaches in infection control are identified). c. Describe practice changes (e.g., altered standard of care) in the event of limited resources.
Emergency Preparedness	**7. Describe the importance of healthcare preparedness for natural or man-made infectious disease disasters.**	
		a. Explain own role in the facility disaster plan. b. Demonstrate participation in facility drills and exercises. c. Describe practice changes (e.g., altered standard of care) in the event of limited resources.

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Stage 4

Next the multidisciplinary team will need to determine how the environmental cleaning will be audited and monitored. The Centers for Disease Control (CDC), Association for Professionals in Infection Control and Epidemiology (APIC) and other professional associations recommend that health systems monitor their cleaning to ensure the adequacy of their cleaning practices.[407] Four current methods available to monitor cleaning practices include direct observation, aerobic colony counts (contact plates, swab/wipe-rinse, etc.), fluorescent marker systems and ATP bioluminescence assays. Visual assessment after a room has been cleaned can only assess visible cleanliness such as removal of organic debris and dust, not the microbial contamination. Visual assessment alone is not adequate, and another method for measuring surface cleaning

needs to be selected.[408] Direct observation is the covert monitoring of disinfection cleaning of the individual environmental services staff or those health care personnel assigned to clean equipment and provides an assessment of the individual technician's adherence to cleaning processes, establishes variations in amount of time spent cleaning and determines if the environmental staff are allowing disinfectants to remain wet on the surfaces for the appropriate dwell time.[409] Aerobic colony counts require the use of a microbiology laboratory, which can be costly and may involve sending counts to a commercial laboratory if the clinical lab is not equipped to test environmental samples. Fluorescent marker systems can be used in a powder or gel form to mark high-touch surfaces before room cleaning and disinfection. The gel form is the most commonly used because it dries to a transparent finish on surfaces, is not easily disturbed and is abrasion resistant. The gel is applied as a dot to the surface and if cleaning is adequate no fluorescence is detected when the dotted surface is exposed to black light, but the fluorescence dot will appear if not cleaned properly. The gel is designed to show the physical removal (wiping of the surface) of an applied substance but does not determine if the surface was disinfected. Advantages to the florescent surface markers include the ease of implementation and low cost when used as a feedback tool for environmental services staff.

ATP bioluminescence assays detect the presence of organic debris on a surface. A specific swab is used to sample the surface and placed into luminometer with the results defined in relative light units (RLU). Some studies have shown that certain disinfectants can interfere with the ATP readings.[410] ATP monitoring is commonly used as tool to monitor environmental cleanliness because it is easy to use and can provide direct, rapid feedback for on-the-spot education to environmental services technicians. ATP monitoring systems also have software to help environmental services managers analyze trends and generate reports.

Direct observation, the florescent marker system and ATP are monitoring methods that are relatively easy and cost effective to implement within the health system. The team will need to make careful consideration of the advantages and limitations of the cleaning monitoring approaches prior to deciding which system or combination of systems best meets the needs.[411,412] In 2010 the CDC put out a checklist with recommended surfaces to monitor after terminal cleaning as shown in Table 6.[413]

Table 6: CDC environmental checklist for monitoring terminal cleaning

CDC Environmental Checklist for Monitoring Terminal Cleaning[1]	
Date:	
Unit:	
Room Number:	
Initials of ES staff (optional):[2]	

Evaluate the following priority for each patient room

High-rough Room Surfaces[3]	Cleaned	Not Cleaned	Not Present in Room
Bed reals/controls			
Tray table			
IV pole (grab area)			
Call box/			
Telephone			
Bedside table handle			
Chair			
Room sink			
Room light switch			
Room inner door knob			
Bathroom inner door knob/plate			
Bathroom light switch			
Bathroom handrails by toilet			
Bathroom sink			
Toilet sit			
Toilet brush handle			
Toilet bedpan			

Evaluate the following additional sites if there is equipment present in the room:

High-rough Room Surfaces[3]	Cleaned	Not Cleaned	Not Present in Room
IV pump			
Multi-module monitor controls			
Multi-module monitor touch screen			
Multi-module monitor cables			
Ventilator control panel			

Mark the monitoring method used:

☐ Direct observation ☐ Fluorescent gel
☐ Swab cultures ☐ ATP system ☐ Agar slide cultures

[1]Selection of detergents and disinfectants should be according to institutional policies and procedures.
[2]Hospitals may choose to include of individual environmental services staff for feedback purposes.
[3]Sites most and touched by patients and/or healthcare workers.

Stage 5

Next in the program, or stage five, is feedback to the environmental services team and those assigned to clean other equipment. Providing feedback is extremely important in the success of the environment cleaning program and has been shown to improve cleaning and disinfection practices. The CDC recommends discussing the results of the monitoring programs and interventions as a "standing agenda item for the Infection Control Committee." Feedback of the results of the monitoring program should be shared with the environmental services team, unit level leadership, and hospital administration.

One study demonstrated significant improvement after feedback was provided to environmental services regarding the results using the fluorescent marker system, before and after study, in 36 acute care hospitals. Fourteen types of objects were included; of the 20,646 standardized environmental surfaces only 9,910 (48 percent) were cleaned at baseline. After structured educational and procedural interventions and objective performance feedback to the environmental services staff, an improvement of 7,287 (77 percent) of 9,464 standardized environmental surfaces were cleaned (P<.001).[414]

Monitoring of cleaning practices needs to include items that have been designated to be cleaned by nursing services. In one study, five distinct surfaces were sampled on all devices from all of the medical and surgical wards in the institution that were to be cleaned by nursing in between each use.[415] Surfaces sampled included the control buttons on the front of the device, the electronic thermometer, the blood pressure cuff, the top of the machine handle and the pulse oximeter. The median results of the ATP assay for the pulse oximeters scored four times higher than the proposed clean cut off value. The equipment was not being disinfected as per protocol and education and feedback to nursing were warranted to improve disinfection of medical equipment.

Planning for New Construction and Renovations

The multi-disciplinary team focus should be on making recommendations on design to help provide an easier means of cleaning. Simple design concepts such as single-patient rooms can reduce the risk of infection. These rooms compared to multi-bed rooms are far easier to decontaminate thoroughly after a patient is discharged due to less surfaces acting as a pathogen reservoirs. The room layout should also be considered with the restroom close to the room entrance to allow for a proper cleaning path to be followed where the restroom is cleaned last (Figure 6). The ease of cleaning is an important consideration the team should look at when choosing materials for flooring, walls, counters and other room surfaces. Consider the following furniture surface characteristics in Table 7 when choosing surfaces:

Table 7: Furniture surface characteristics

Durability	Furnishings should be easy to maintain and repair. Fabrics that are torn allow for entry of microorganisms and cannot be properly cleaned. Items that are scratched or chipped allow for accumulation of microorganisms and are more difficult to clean and disinfect.
Cleanability	Furnishings must be able to withstand cleaning and be compatible with hospital-grade detergents, cleaners, and disinfectants. Upholstered furniture must be covered with fabrics that are fluid resistant and non-porous.
Inability to Support Microbial Growth	Materials such as fabric and wood that hold moisture are more likely to support microbial growth. Materials such as metal and hard plastics are less likely to support microbial growth. Wet organic substrates (e.g. wood) should be avoided in hospital areas with immunocompromised patients
Surface Porosity	Microorganisms have been shown to survive on porous fabrics such as cotton, cotton terry, nylon, and polyester, and on plastics which are considered porous substrates. Porous upholstered furniture should not be used in care areas, particularly in areas with immunocompromised patients
Absence of Seams	Seams trap bacteria and are difficult areas to clean.

Some floor surfaces have obvious infection control benefits over others. For example, hard flooring would be the natural choice for patient areas over carpeting because they are much easier to clean and maintain than carpeting. Curtains are widely used in hospitals to provide privacy, although there is uncertainty about the role curtains play in the transmission of pathogens, eliminating curtains for private rooms should be considered and is a low-cost step to eliminate hand contact. The multi-disciplinary team should review the research literature on evidence-based health care design when planning for new construction and renovations to make design decisions.

Case Studies

Hospital H: Multidisciplinary stakeholder coordination

Hospital H, a large urban health care facility that offers a wide range of medical-surgical services, can be viewed as an example of how carefully coordinated infection control measures, such as consistent surface cleaning and proper hand hygiene routines, can drastically improve a given environment's health care conditions. Through the conjoined efforts of Hospital H's environmental services manager and infection control coordinator, the hospital's *C. difficile* infection rate within its medical-surgical units was reduced to zero. This was accomplished within a six-month period and was made possible through a multidisciplinary approach that was spearheaded by environmental services and infection control. Initially, environmental services and infection control educated other members of the organization in matters of patient safety and available solutions. Environmental services and infection control then collaborated with the CDC and its local state-run department of public health to incorporate multidisciplinary perspectives into the strategy. Ultimately, these initial efforts resulted in an integrated understanding and application of these effective environmental hygiene interventions, and subsequently significantly improved health care conditions within the institution.

Regularly cleaning high-use surfaces and implementing proper hand hygiene procedures are two powerful, cost-effective health care solutions that can be adopted by institutions through the coordinated efforts of key stakeholders. While the efficacy of these environmental hygiene interventions is well known, the way in which key stakeholders in health care organizations can adopt them for the betterment of their own institutions is not as commonly understood. Hospital H's ability to overcome its own internal *C. difficile* infection issue through education and multidisciplinary action can be seen as a model for how institutions of all sizes and backgrounds can promote and implement effective and relatively simple health care interventions to positive results. As cases similar to that of Hospital H become more widely known, the quality of public health in general is likely to increase through the group-oriented efforts of health care providers everywhere.

Tools

- Centers for Disease Control Toolkit: Guh, A., Carling, P. & Environmental Evaluation Workshop. (2010). Options for Evaluating Environmental Cleaning. Retrieve from https://www.cdc.gov/hai/toolkits/Evaluating-Environmental-Cleaning.html
- Association for the Healthcare Environment. From Top To Bottom: The Environmental Services Series [DVD/Video]. Retrieve from http://envisioninc.net/series/show/5
- Association for Professionals in Infection Control and Epidemiology. (2011). Infection Prevention and Control Competencies for Environmental Services Personnel. Retrieve from http://www.apic.org/Resource_/TinyMceFileManager/Resources/Infection-Prevention-Competencies_Env-Services.pdf
- Association of Professionals in Infection Control and Epidemiology. (2011). Infection Prevention and Control Committee Report: Environmental Services. Retrieve from http://www.apic.org/Resource_/TinyMceFileManager/Resources/Environmental-Services-Report-Template.pdf

Guidelines

- Association for the Healthcare Environment. (2012). *Practice guidance for healthcare environmental cleaning*, 2nd ed. Purchase from American Hospital Association at https://ams.aha.org/EWEB/DynamicPage.aspx?WebCode=ProdDetailAdd&ivd_prc_prd_key=529ab0ff-718f-401d-8433-175d01bef546
- Association for the Healthcare Environment. *Recommended Practice Series: Environmental Services Equipment and Supplies.* Purchase from American Hospital Association at http://ams.aha.org/EWEB/DynamicPage.aspx?WebCode=ProdDetailAdd&ivd_prc_prd_key=e48e168b-08fe-494c-b444-3f280c5249ac
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CHAPTER 5: Water-Related Environmental Infection Control for Public and Patient Health Care Areas

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Introduction

Infectious risks inherent in premise plumbing—that is, the plumbing system within the building that delivers water to the user—are largely associated with the development of biofilm on protected inner surfaces of pipes, valves and fixtures, especially joints, dead legs (see Chapter 3), encrustations (e.g., crusting, coating or scale) and plumbing enhancements (e.g., decorative water features, electronic faucets) that prevent the inner surfaces from being smooth and contiguous.[416]

Opportunistic pathogens of premise plumbing, bacteria that grow well in drinking water distribution systems and can cause human disease, share several qualities: They grow in ambient temperature (often stagnant) water; have a strong association with biofilms and other microorganisms (such as amoeba and protozoa); can be transmitted by aerosols, ingestion or contact (direct and indirect), depending on the pathogen; and can be linked with water disruptions, including construction and water main breaks. Water disruptions can be as subtle as increased water demands during high-demand periods, or as obvious as a complete water shutdown. Any disruption can cause opportunistic pathogens of premise plumbing to be released into the water supply. That said, even well-maintained water systems can contain opportunistic pathogens of premise plumbing. *Legionella* spp., a bacterium that causes a severe form of pneumonia called Legionnaires' disease, is ubiquitous in freshwater sources and grows well in building water systems that are not adequately managed.[417]

The design of health care facility plumbing must intentionally avoid the features that foster growth and dissemination of opportunistic pathogens of premise plumbing such as *Legionella* spp., pseudomonads, nontuberculous mycobacteria (NTM) and fungi.[418] Patients with invasive devices (for example, central venous lines, urinary catheters, ventilators) and patients with impaired immune systems (for example, malignancies, solid organ transplant, extremes of age) exposed to tap water are at increased risk for infection from opportunistic pathogens of premise plumbing. Exposure occurs through bathing, showering, drinking water or ice and coming into contact with contaminated medical equipment rinsed with tap water or that holds nonsterile water. Other possible sources for aerosolization of contaminated water include cooling towers, whirlpools and decorative fountains/water features.

Absolute prevention of opportunistic pathogens of premise plumbing is unlikely, necessitating the development of a water safety program that includes monitoring and a plan for mitigation when monitoring or measurement values are outside control limits, as determined by the program. Recommended practices for mitigating waterborne pathogen growth in new construction and established facilities have been published.[419,420,421,422] This chapter will incorporate recommended practices for personnel tasked with water safety in the built health care facility environment.

Worldwide, the most frequently reported water-related health care associated outbreaks result from nontuberculous mycobacteria, *Pseudomonas aeruginosa* and *Legionella* spp.[423,424,425,426,427,428,429,430,431,432] These pathogens have been recovered from a wide range of potable water sources and are likely transmitted to patients, health care personnel and visitors from water through ingestion, contamination of injectable medications, bathing, inhalation of aerosols, aspiration or indirect contact with moist surfaces (for example, by the hands of health care personnel). In addition, water (often in the form of mist) from sources such as bathing or tub immersion, decorative water fountains, dialysis water, faucets (electronic or manual), heater-cooler units and other medical devices, wastewater systems, ice machines, showers, sinks, toilets, wash basins, water-damaged materials and water-saving devices can transmit tiny water droplets containing pathogens. The number of reported cases of Legionnaires' disease is increasing in the United States. From 2000 through 2014, the rate of reported Legionellosis increased from 0.42 to 1.62 per 100,000 persons (286 percent increase over 15 years, totaling 5,300 cases in 2014). Four percent of reported cases were associated with a known outbreak. The Centers for Disease Control (CDC) notes that the increased reports of Legionnaires' disease could be attributed to a number of factors including increased testing or an actual number of increased cases.[433,434] It is also noteworthy that a multistate point-prevalence survey of healthcare-associated infections does not even include *Legionella* as a significant causative pathogen in its findings.[435]

Water systems in urban, suburban and rural locations are susceptible to colonization by a variety of naturally occurring water microorganisms, some of which are potential or opportunistic pathogens that have caused significant morbidity and mortality in patients and health care personnel. Existing and newly constructed water systems alike are at risk for becoming colonized with these organisms. These opportunistic pathogens have been recovered in all types of plumbing, and especially where scale, concretions, joints and dead legs provide protected areas (stagnant water) in which biofilm can develop. Stagnation allows organisms to attach to surfaces and develop biofilms. Biofilm is a multispecies community that is embedded in "slime," a self-produced extracellular polymeric substance (EPS) that may be found on surfaces exposed to water. EPS is composed of extracellular DNA, proteins and polysaccharides.[436] This biofilm protects these waterborne pathogens from the action biocides and environmental stresses (two common mitigation strategies), provides nutrients and supports the growth of organisms that may harbor pathogens such as *Legionella* spp*.,* which grow in amoebae or protozoa. Particulates and organic matter ("sludge") provide nutrients for pathogen growth.[437,438,439]

The most frequently demonstrated cause for waterborne pathogenic disease in health care facilities has been associated with under maintained plumbing systems. However, aqueous solutions and moist environments in the health care facility support the growth of opportunistic pathogens of premise plumbing and are significant contributors to morbidity and mortality,[440] and even well-maintained water systems can cause healthcare-associated infections.

One product of a water management program is a water safety plan for health care facilities. Such a plan is necessarily complex, as the built environment is complex. However, once the framework is in place, baseline strategies have been implemented and those with responsibility to enact the plan share a common goal (water safety), maintaining the ongoing program can provide the health care facility with standard responses to positive findings and water disruptions, long-term understanding of the buildings' water characteristics and a measure of legal protection.[441] A two-part strategy for health care facility water safety includes:

1. A multidisciplinary water management program team to plan, build, maintain and monitor all aspects of the health care facility water system, including equipment that holds water.
2. Clinical surveillance for diseases caused by opportunistic pathogens, to detect and remediate an outbreak swiftly.

The key strategies to address and ensure safe health care facility water systems can be encapsulated in the four steps below. However, these four steps represent a mature team with open communication, continuous investigation, development and execution of a detailed plan with ongoing critical review and course correction:

1. Perform a risk assessment for all types of water systems and water-containing equipment in the facility.
2. Develop and execute an action plan to mitigate the identified risks and thereby prevent sources of disease.
3. Perform surveillance to determine whether disease is reduced in patients served by the institution—that is, preventing disease.
4. Monitor key metrics to demonstrate that the mitigation strategies are performing as intended and are actually mitigating the risks (for example, water temperatures and disinfectant levels are in the desired range).[442,443]

These strategies may be most thoroughly and efficiently implemented through a multidisciplinary team of health care personnel with interest and accorded responsibility for ensuring the environment of care is safe for health care personnel and patients alike. This chapter describes a model for water management program team composition and responsibilities, tools for developing and implementing a water safety program, monitoring strategies, recommended metrics, reporting suggestions and action thresholds.

Brief Literature Review

Bacteria, fungi/molds and viruses have been detected in plumbing and heating/ventilating/air conditioning systems, in devices that hold water and in and on items and surfaces stored in water. Measures to control viruses, according to the treatment techniques in the U.S. Environmental Protection Agency's Surface Water Treatment Rule, also may control *Legionella*.[444] Techniques to control *Legionella* spp. growth may control many other opportunistic pathogens of premise plumbing.[445]

Both tap and bottled water may reasonably be expected to contain at least small amounts of some contaminants,[446] but not at levels that pose a health risk. Potable water supplied to health care facilities should comply with the Environmental Protection Agency (EPA) and local, state/territory standard limits for microorganisms, among other contaminants (for example, organic/inorganic compounds, disinfectants and their byproducts, radionuclides, lead).[447] However, even with appropriate treatment, opportunistic pathogens of premise plumbing are ubiquitous.[448,449] Biofilm can develop in well-maintained health care facility water systems, which in turn provides protection and nutrients for the pathogen. Water walls and decorative water fountains represent unacceptable risk in hospitals serving immunocompromised patients, even with standard maintenance and sanitizing methods.[450,451,452,453]

The Association for Professionals in Infection Control and Epidemiology (APIC) Text[454] summarizes diseases reported to be associated with exogenous opportunistic pathogens of premise plumbing. Another report of waterborne pathogen-associated disease and outbreaks from 1997 to 2015 nicely organizes those findings into two tables, the first describing

characteristics of waterborne pathogen outbreaks and the second summarizing key prevention strategies. Table 8 and Table 9 are excerpts from the two tables. [455,456,457,458,459,460,461,462,463]

Table 8: Characteristics of waterborne outbreaks and infections in health care settings, 1997 January–2015 June

Reservoir	Organism(s)	Transmission	Patient Population	Type of infection	Molecular Typing	Study Type	First Author, Year
Bathing and tub immersion (bathing tub drain)	*Pseudomonas aeruginosa*	Tub immersion water contaminated from drain when whirlpool bathtub filled	Patients with hematological malignancies (leukemia)	Bloodstream infection, pneumonia, UTI	PFGE	Outbreak – strong causation	Berrouane, 2000 [6]
Bathing and tub immersion (showering)	*Mycobacterium mucogenicum*	Water contamination of CVCs during bathing or showering	BMT and oncology patients	Bacteremia	RAPD	Outbreak – strong causation	Kline, 2004 [7]
Bathing and tub immersion	*Legionella pneumophila*	24 h bath water contaminated	An elderly patient with dementia admitted to a nursing home	Pneumonia	PFGE	Case report (single) – strong causation	Mineshita, 2005 [8]
Bathing and tub immersion (bathing mattress)	*Alcaligenes xylosoxidans*	Bathing procedures and hydrotherapy in burn unit	Bum patients	Cholecystitis, meningitis	PFGE	Case report (single) – strong causation	Fujioka, 2008 [9]
Decorative water fountain	*Legionella pneumophila*	Exposure to contaminated water from decorative fountain	Allogeneic stem cell transplant patients	Pneumonia	PFGE	Outbreak – strong causation	Palmore, 2009 [10]
Deionized water from the hospital pharmacy	*Exophiala jeanselmei*	Contaminated deionized water solution that was used to prepare antiseptic solutions	Hematological malignancies	Fungemia	RAPD	Outbreak – strong causation	Nucci, 2002 [11]
Dialysis water supply	*Burkholderia cepacia*	Inadequate cleaning and a leak in the reverse osmosis tubing connect ion	Hemodialysis patients	Bacteremia	RAPD	Outbreak – strong causation	Souza, 2004 [12]

Table 9: Summary of key issues and infection prevention strategies against waterborne outbreaks by major water reservoir in health care settings

Reservoir	Key Issues	Infection Prevention Strategies
Potable water, tap water, and hospital water systems	• Potable water is not sterile, and pathogenic waterborne organisms may exist in potable water at acceptable levels of coliform bacteria (<1 coliform bacterium/100 ml). • Healthcare-associated outbreaks have been linked to contaminated potable water. • Semicritical devices are often rinsed with potable water, which may lead to contamination of the equipment and subsequent healthcare-associated infections. • Common pathogens include nonenteric gram-negative bacilli (e.g., *Pseudomonas aeruginosa*), *Legionella*, NTM.	• Follow public health guidelines. • Hot water temperature at the outlet at the highest temperature allowable, preferably >51°C. • Water disruptions: post signs and do not drink tap water. • Maintain standards for potable water (<1 coliform bacterium/100 mL). • Rinse semicritical equipment with sterile water, filtered water, or tap water followed by alcohol rinse. • Some experts have recommended periodic monitoring of water samples for growth of *Legionella*. • *Legionella* eradication can be technically difficult, temporary and expensive. • Potential methods of eradication include filtration, ultraviolet, ozonization, heat inactivation (>60°C), hyperchlorination, and copper-silver ionization (>0.4 ppm and >0.04 ppm, respectively).

Hospitalized populations affected include typically at-risk populations, such as extremes of age (>50 years, <1 year),[464,465] immunocompromised patients (transplant, critically ill, especially those who are mechanically ventilated)[466,467,468,469] and patients with chronic illness, such as patients who smoke, have diabetes or undergo hemodialysis. Other at-risk populations include those who are exposed to undermaintained plumbing, such as health care personnel; people who receive tap water-contaminated medications; surgical patients undergoing cosmetic surgery, LASIK surgery and surgical implants.[470]

Maintenance of the potable water system is frequently described as compromised in reports of disease caused by opportunistic pathogens.[471,472,473,474] New construction and existing plumbing alike demonstrate vulnerability to colonization. Stagnant water at ambient temperatures, such as in cooling tower holding tanks, preoccupancy building plumbing, or water-containing equipment, can support opportunistic pathogen growth, attachment and biofilm production. Once biofilm is present, opportunistic pathogens are available for delivery to people as a result of events causing the biofilm (and resident OPPPs) to slough.

Best Practices and Recommendations

Water System Management

1. Review clinical microbiology results for clusters of opportunistic pathogens of premise plumbing from clinical specimens. If opportunistic pathogens appear in the facility's infection profile, an investigation into a water source should be considered.
2. If clusters are seen, conduct an iterative risk assessment (Table 10). [475,476]
3. Implement elements of an appropriate water safety management plan addressing risks identified in the risk assessment.[477]
   a. If opportunistic waterborne pathogens have not been recovered from clinical specimens, ongoing disease surveillance and monitoring the water system control processes may be sufficient.

b. If opportunistic waterborne pathogens have been recovered from clinical specimens and adjudged to be health care onset, a robust response and disease management plan is critical. This may include testing water beyond routine parameters, such as culturing for pathogens of epidemiologic concern and/or more rigorous testing for disinfectant levels. A remediation strategy and control plan should be put into place in response to a defined outbreak.

Table 10: Health care facility water system risk assessment elements

Risk	Recommendations/Options
Waterborne pathogen disease surveillance	1. Evaluate testing methods used for clinical culture/test to determine if those methods detect opportunistic pathogens of premise plumbing of interest 2. Analyze routine surveillance for previously unrecognized waterborne pathogen-related disease 3. Include routine review for disease caused by opportunistic pathogens of premise plumbing in patient surveillance 4. Review physician ordering and available microbiology testing strategies for disease (e.g., is *Legionella* urine antigen or culture routinely ordered for patients who develop health care-associated pneumonia?)
Water source	Work with the potable water supplier; review their regulated requirements for monitoring; review water supplier (e.g., municipal) reports for service disruptions and disinfection strategies. Pay attention to main breaks and boil water alerts for any potential clinical correlation. If chemical disinfection, determine 1. disinfectant level at the connection entry point, and 2. frequency of monitoring Review water source action plans for water disruption and recovery. Seek routine notification from water supplier when planned or unplanned disruptions occur (e.g., water main break, "code dry," renovation/construction causing >72-hour water stagnation or jarring of plumbing systems).
Water inlets (connection[s] to water mains)	Monitor disinfectant* efficacy: 1. In response to low disinfectant level, review findings with the authority having jurisdiction for the water supplier. If adjustments to disinfectant do not result in adequate levels, determine the root cause, and responses indicated by the water supplier (e.g., boosting station closer to the facility) 2. Employ adjunct disinfecting measures as necessary, such as: a. Heat (to >55°C) b. Add chlorination (consider effect of this strategy on facility's status as a small drinking water utility) c. Ultraviolet light d. Copper-silver ionization 3. Plan disinfecting strategy a. Routine (consider effect of this strategy on facility's status as a small drinking water utility) b. Strategic response to action plan thresholds c. Strategic response to water source disruption
Flow	Construct diagram/map to show all water pathways from health care facility connection with main water source(s) to final exit from the facility. Include 1. Points in the system for adjunct disinfection injection, temperature monitoring, sampling 2. Locations with rare water use, which should have a regularly scheduled flushing program (e.g., eye wash stations, emergency showers) Maintain "as built" renderings: 1. Label unused dead legs in as-built renderings (hard or soft copy) and in physical location to drive future use only after appropriate isolation, testing, disinfection. 2. Document all change decisions and designs for future reference. 3. Limit dead legs to no greater than twice the diameter of the pipe—this allows the water in the dead

Table 10: Health care facility water system risk assessment elements (continued)

Stagnation	Identify where water may be stagnant: 1. Pools, tubs, jetted features 2. Water features (e.g., fountains, water walls, reflecting pools) 3. Cooling towers 4. Water heaters 5. Showers 6. Drains 7. Cold water holding locations: establish a. strategies for protecting against fouling by humans or animals b. strategies for protecting against detritus collection c. schedule for verifying protection strategies d. schedule for cleaning e. schedule for testing 8. Hot water holding; establish a. minimum/maximum temperatures attainable b. target temperature range c. Schedule for cleaning d. Schedule for testing 9. Include any program flex applications from local or state health jurisdiction (e.g., for heating/holding water higher than local code allows) 10. Medical equipment (e.g., cardiopulmonary bypass heater-cooler units): a. Follow manufacturer's instructions (IFUs) for type of water to use (at minimum, use water that meets drinking water standard and has passed through a bacteriologic or ultra filter), disinfection, and document compliance with IFUs. b. Observe routine and emergent use c. Sequester effluent/efflux/exhaust, if present
Heat transference	1. Identify where hot water may be cooled, or cold water may be heated: a. Ice machines: Ensure sufficient space and ventilation behind ice machines to dissipate heat and limit warming of water supply lines; use bacteriologic filters to filter inlet water; granular activated carbon (GAC) filters (with which ice machines may come equipped) may remove chlorine and allow microbial growth b. Cold and hot water lines proximal and insufficiently insulated: 2. Ensure hot water lines are insulated in locations where cold and hot water lines travel in proximity to prevent heat exchange between the systems that might cause both systems to be in the opportunistic pathogen growth range.
Water disruption	Planned: 1. Ensure alternate hand washing and patient hygiene strategies (e.g., pre-moistened, no-rinse towelettes, alcohol-based hand rub) 2. Plan for hyper chlorination and flush, or 3. Plan for hot (55C°/130°F) water flush 4. Flushes required throughout affected location Unplanned: 1. Execute water safety plan for recovery immediately on water restoration

Table 10: Health care facility water system risk assessment elements (continued)

Faucets/showers/ drains	**Action levels**[479,480,481,482] for *Legionella* spp. may be based on percentage of distal sites positive rather than quantitative results from any one site. When percent positivity exceeds 30 percent, disease is more likely to occur in immune-competent people. A lower percentage (facility-specific) should be used for locations housing immune-compromised patients. **Faucets:** Opportunistic pathogens of premise plumbing have been recovered from both manual and electronic faucets 1. Manual faucets with wrist blades are both ADA compliant and less complex (fewer interior surfaces to support biofilm growth) 2. Electronic faucets show far greater waterborne pathogen recovery, likely because of longer valve-to-tap (longer column of stagnant warm water), reduced water flow (reduced flushing effect) and plastic valves/pipes (*P. aeruginosa* adheres more readily) 3. Gooseneck faucets accommodate point-of-use filters without obscuring handles or sensors 4. Aerators and water restrictors on faucets may provide a surface for deposit build-up. If these devices are in place, a routine cleaning or replacement protocol is best practice. **Showers:** Hand-held showers can hang down or up after use; if they are allowed to hang down (eliminates one dependent loop, significance unquantified), the shower head should hang at least 8 inches from the shower floor **Drain** maintenance requirements: 1. If in compliance with the authority having jurisdiction, install drains that seal from the top (unrecessed)483 2. Periodic flushing 3. Periodic disinfection, such as use of drain gels 4. May best be enfolded with routine bathroom cleaning, including unoccupied rooms **"Antimicrobial"** fixtures: (e.g., copper, silver, sharklet) have not been shown to reduce health care-associated infections. 1. Durability and longevity of antimicrobial effect is unknown 2. Antimicrobial effect persists between cleaning activities
Pre-occupancy (new structure) and reoccupancy (post-renovation) water treatment	Consider "dry pipes" during construction and renovation as long as possible 1. Drain existing plumbing at start of renovation work 2. Maintain "dry pipes" throughout construction phase as long as possible 3. Consider bringing up "zones" of plumbing to conserve energy, water and work hours Once water has been introduced, perform routine flushing of all taps and toilets; If water has not been flushed during construction/renovation, consider immediate pre-occupancy hyper chlorination and/ or thermal (>140°F) flush Plan for and execute pre-occupancy water sampling of heterotrophic plate count of premise plumbing. 1. Consider turn-around time between sample collection and resulting 2. Ensure sufficient time to implement remediation and confirmatory testing prior to occupancy.
Fire suppression	Not routinely included in water safety program; firefighters are trained to wear protective gear.
Hemodialysis water supply**	See Layman-Amato, R. L., Curtis, J., & Payne, G. M. (2013). Water treatment for hemodialysis: An update. *Nephrology Nursing Journal*, 40(5), 383-404, 465. Kasparek, T., Rodriguez, O.E. (2015). What medical directors need to know about dialysis facility water management. Clinical *Journal of the American Society of Nephrology*, 10(6), 1061-1071. (http://cjasn.asnjournals.org/content/10/6/1061.full.pdf+html)

* *Monochloramines are usually used only by municipalities, but may be used in some health care facilities. Consider strengthening surveillance for Pseudomonads and NTMs in locations where monochloramines are used as the water disinfection strategy.*

** *Hemodialysis water safety is a science unto itself, and is not addressed fully in this chapter.*

4. Routinely review water quality reports from the authority having jurisdiction (AHJ) for water entering the facility.
   a. Determine the AHJ's disinfectant, target concentrations and reported levels.
   b. Develop the health care facility's routine building material selection, adjust disinfection and monitoring strategies.
   c. Develop a notification strategy with the AHJ to report water system interruptions and unusual findings that may affect populations served by the water supply.
5. Assess and adjust the disinfection method to maintain satisfactory results.
   a. A locally adapted, evidence-based approach allows assessment of the efficacy and disadvantages of control measures over time.
   b. Several effective strategies for controlling opportunistic pathogens of premise plumbing are available, and summarized in Table 11.
6. Establish lower limits for chemical disinfectants at representative health care facility taps, and response strategy.
   a. Assume and plan for chemical disinfectant degradation in water systems.
   b. Representative taps should be distal to a disinfection input (for example, distal riser), and a variety of representative taps should be sampled over time, to include hot and cold water taps in staff and patient areas, environmental services sinks, showers (including emergency showers), eyewash stations, ice machines and cooling towers.

Table 11: Summary of water disinfection strategies, advantages, disadvantages and other considerations[478]

Disinfection Strategy	Advantages	Disadvantages	Other Considerations
Chlorine dioxide[485,486]	- Easy to generate - Biocidal properties not influenced by pH - More effective than chlorine and chloramines for inactivation of viruses, *Cryptosporidium*, *Giardia* and *Legionella* - Highly effective oxidant; provides excellent residual disinfection action and biofilm control[487] - Chlorine dioxide provides residuals - Oxidizes iron, manganese and sulfides - May enhance the clarification process - Controls taste and odors from algae, decaying vegetation, and phenolics - Halogen-substituted DBPs are not formed in the absence of excess chlorine)	- Forms the specific byproducts chlorite and chlorate[488] - Can cause excess chlorine to be fed at the application point, which can potentially form halogen-substitute DBPs - Costs associated with training, sampling, and laboratory testing for chlorite and chlorate are high - Cost of the sodium chlorite is high - Explosive, so it must be generated on-site - Decomposes in sunlight - Can lead to noxious odors in some systems	Chlorine-tolerant strain of *Legionella pneumophila* was reported in one facility after 9 years of use[489]
Copper-silver ionization[490,491,492,493,494]	Effective as long as the recommended pH and solids levels are maintained	- Expensive to implement - No effect on biofilm - Can cause local corrosion on steel	- Low levels of copper may be detrimental to aquatic species - Phosphates reduce effectiveness of copper and silver ions[495,496] - Silver nitrate failed to eradicate *Pseudomonas aeruginosa*[497]
Hyper chlorination	- Most widely used chemical for water disinfection in the United States - Highly effective oxidizer	- Can be corrosive - Can produce carcinogenic trihalomethanes	- Chlorine-tolerant *Legionella* identified in an Italian university hospital - Hailed as "the major public health achievement of the 20th century"[498]
Monochloramines	- Highly effective oxidant - Remains in the water longer than chlorine - Most effective when the pH value is 7 or higher (when water is more alkaline, which is more protective of plumbing)	Forms few organic compounds (trihalomethanes, or THMs) and other possibly carcinogenic byproducts (halogenic acetic acid, or HAA)[499]	Has been shown in one facility to be associated with an increase in nontuberculous *Mycobacterium* infections with monochloramine concentrations at 2 mg/L, but none at 3 mg/L[500,501]

Table 11: Summary of water disinfection strategies, advantages, disadvantages and other considerations (continued)

Point of use filtration[502,503, 504,505,506,507]	- Effective strategy - Can be focused to problematic areas - Can be used in conjunction with other strategies - nominal pore sizes < 0.2 µ	- May require replacing some faucet hardware - May not be compatible with sensored faucets - Unfiltered municipal water may cause premature filter loading	May be used as a temporizing measure while systematic controls are established or may be the only option in some populations (e.g., malignant hematology, NICU)
Thermal control (>120ºF at the tap)[508,509,510,511, 512]	- Effective - Inexpensive - May be episodic or continuous	- May contribute to premature failure of equipment and piping system - Hot water flush is labor-intensive	- Misses the cold water side (more of a consideration in warmer climates) - May require significantly higher heating/holding temperatures depending on length of hot water run - May require scald controls, such as notification to users, mixers in taps
Ultraviolet light[513,514]	- Water taste and odor not affected - No chemical byproducts produced - Installation is relatively straightforward	- Lack of residual protection distal to the light - Reduced disinfecting efficacy at higher water temperatures and turbidity - Quartz sleeves housing the lamps are susceptible to scale and mineral deposits and must be cleaned regularly. - Operational problems subsequent to start up include electrical and mechanical malfunctions such as insufficient lamp intensities, lamp burnout and short circuits - Experienced technicians are needed for the electrical problems. - Water leaks can occur from broken quartz sleeves or loose rubber seals.	Lamps must be replaced based upon hours in operation (see IFUs) Ultraviolet light is more practical closer to the point of use
Hydrogen peroxide (50%)[515]	Has been reported as adjunct to UV		
Replace plumbing structures[516, 517,518,519,520]	For systems that have failed all other methods	- Expensive - Disruptive - May become colonized swiftly	

The Water Management Program Team

A multidisciplinary water management program team should be developed in all health care facilities. The water management program team should include people with expertise and knowledge to make and carry out decisions aimed at improving or maintaining the safety of the water used throughout the organization, and be deemed authority to implement decisions

regarding water acquisition, holding, flow, testing and maintenance, including water held in equipment used for patient care. The water management program team (WMPT) should develop standardized operating procedures, including action thresholds for waterborne pathogen detection through water testing results and/or healthcare-associated disease in patients/clients and health care personnel, depending on the surveillance strategies implemented. The WMPT should be included in all new building planning, as tension between "green" structures and water safety exists.

A water management program team has very specific tasks to complete and maintain, including:

1. Map the water system(s) in all buildings of the organization.
2. Conduct surveys and analyses of hazards within the water system.
3. Develop mitigation strategies for all identified hazards.
4. Monitor to ensure mitigation strategies are carried out and function as designed.
5. Establish:
    a. Metrics to be monitored over time, such as:
        i. Epidemiologic evidence of opportunistic pathogens of premise plumbing recovered from clinical specimens in clusters (temporally or geographically) or at recovery rates greater than historical baseline
        ii. Opportunistic pathogens recovered from water system sampling sites (based on epidemiologic indication)
        iii. Disinfection concentration at point of use
        iv. Water temperatures at point of use
        v. Building-specific risk factors (e.g., susceptible populations, locations where aerosols can be generated)
        vi. Engineering practices and controls (e.g., water treatment, extent of "dead legs," hot water recirculation)
        vii. Frequency for measuring
    b. Frequency for measuring metrics:
        i. Baseline for designated sampling sites, then,
        ii. Risk assessment-driven sampling frequency (e.g., rotating quarterly; sampling under representative conditions, such as during usual and unusual weather conditions, during and after recovery from water disruptions)
    c. High and low action levels, such as:
        i. Water temperature too high (cold) or too low (warm)
        ii. Insufficient disinfectant
        iii. Recovery of clinically significant waterborne pathogens that suggest an epidemiologic concern may indicate adjunct disinfecting remediation should be implemented
        iv. Water sampling for pathogens of interest may be implemented based on risk assessment performed by the facility's water management team; if implemented, establish facility-specific percent positive sites for action and identify options for response in the water management plan. Presence of organisms in water does not always correlate with disease. A focus on process measures for water system control is of primary importance.
6. Report routine and urgent/emergent findings, effectiveness of mitigation strategies, patient/resident/client/health care personnel outcomes and adjustments to the plan.
7. Enact policies and procedures that identify hazards and guide personnel in safely interrupting water flow and returning water flow to normal.
8. Identify and map out hazards in the design planning phase for new building or renovation.

9. Conduct surveillance for disease in patients, residents, clients and health care personnel in the organization.

To be successful, a water management program team should include key representatives with assigned roles and responsibilities. Table 12 demonstrates one way to assign roles and responsibilities; personnel may fill multiple roles. Regardless of who actually is part of the water management program team, these roles and responsibilities are critical to an ongoing water safety program. A multidisciplinary team encourages sharing from a variety of experiences and helps socialize the importance of the water safety program.

Table 12: Example of a Water Management Program Team's representation and responsibilities

Personnel[1]	Key Responsibilities	Frequency[2]	Response/Mitigation
Biomedical or Clinical Engineering	1. Test IFUs3 prior to acquiring equipment 2. Ensure water-containing equipment is maintained accordingly 3. Scan for recalls of or updates regarding water-holding equipment 4. Ensure vendor claims are substantiated with rigorous evidence	Review annually	1. Ensure manufacturers' IFUs are aligned with facility's cleaning, maintenance and use strategies. 2. Educate users to required maintenance frequency and procedures 3. Launch recall policy as indicated.[4]
Design & Construction, Infrastructure Designer, Architect	1. Develop and implement building standards for plumbing system materials to withstand incoming water conditions (e.g., disinfectants, pH, corrosion control chemistry) 2. Develop and implement building standards for durable, non-porous finishes and fixtures that are easily cleanable with current facility chemicals and strategies (e.g., eliminate faucet aerators, finishes that can withstand quaternary ammonium, UV light, vaporized H2O2) 3. Develop and implement building standards for storage solutions and spaces to drive cleanable surfaces around water features (e.g., hand washing sinks, tubs), containment lids on toilets/hoppers (evaluate with environmental services) 4. Include dead leg elimination and hot/cold water separation in contracts 5. Design water systems with sampling and injection ports, isolation zones, monitoring systems (temperature, pressure, residual disinfectant), safety releases, dead leg elimination 6. Maintain current "as built" schematics 7. Ensure vendor claims are substantiated with rigorous evidence 8. Ensure compliance with local, state, federal building requirements.	Review and update standards annually Predesign, each project Throughout each water system related project	1. Evaluate, test and recommend new marketplace plumbing options 2. Review all demolition, renovation and new build project designs with water management program team 3. Ensure contractors' adherence to standards and facility policy 4. Design out flaws or risks to the extent possible prior to project bid 5. Review claims and evidence from manufacturers of water system elements and water safety devices to ensure target pathogens are tested and proven to be mitigated 6. Ensure water holding devices have continuous flow 7. Design in locations and mechanical strategies to allow for easy water sampling and adjunct disinfection additions that will not interrupt the water system. Include sampling points at juncture of municipal (or other) water to the facility, hot water tanks, ends of hot water risers 8. Design in mechanical strategies to separate potable water (e.g., for drinking and bathing) and non-potable water (e.g., for cooling towers) throughout the system 9. Monitor construction progress to ensure the water system is built as designed

Table 12: Example of a Water Management Program Team's representation and responsibilities (continued)

Environmental Health and Safety, Industrial Hygienist	1. Perform water testing of defined metrics 2. Develop monitoring schedule based on findings 3. Ensure vendor claims are substantiated with rigorous evidence 4. Develop action thresholds and plans for anticipated failures and waterborne pathogen detection in the system or in humans 5. Perform preoccupancy testing of defined metrics in new construction and renovated locations; consider turnaround time for cultures (if done); build in time for remediation and follow-up testing prior to occupancy	Review and update policies annually Testing as scheduled	1. Ensure manufacturers' IFUs are aligned with facility's cleaning, maintenance and use strategies 2. Ensure testing is performed as scheduled 3. Analyze and report testing results 4. Review chemicals/safety policies 5. Monitor adherence to safety measures 6. Execute response plan when action thresholds are reached
Environmental Services	1. Develop policies for effective disinfection and cleaning surfaces, drains, equipment at risk for transmitting opportunistic pathogens 2. Evaluate current and planned fixtures and finishes for cleanability 3. Assess proposed changes to basic appointments (e.g., containment lids	Review annually and ad hoc	1. Ensure manufacturers' IFUs are aligned with facility's cleaning, maintenance and use strategies 2. Ensure safe and effective cleaning for all cleanable surfaces
Executive Sponsor	1. Receive routine reports 2. Communicate with other key health care facility personnel 3. Ensure a. Water safety is included in long-term/ capital project planning b. All decisions are documented for future reference c. High and low action levels are established d. Action plans for out-of-range levels are established e. Verification that safety strategies are implemented f. Validation that safety strategies are functioning as designed (e.g., metrics are met) g. Metrics are established and reported h. Routine water management program team meetings occur	Quarterly and ad hoc	1. Ensure resources to mitigate positive findings 2. Develop communications strategies to reach all sectors of facility personnel 3. Consider: determine percent positivity for Legionella spp. of sampled distal taps that is indicative of disease risk

Table 12: Example of a Water Management Program Team's representation and responsibilities (continued)

Epidemiologist	1. Develop policy for appropriate testing and surveillance for health care-acquired disease caused by opportunistic pathogens 2. Establish metrics 3. Evaluate and interpret water system monitoring reports a. Ensure appropriate actions are taken b. Verify that safety strategies are implemented c. Validate safety strategies are functioning as designed (e.g., metrics are met) 4. Ensure vendor claims are substantiated with rigorous evidence	Ongoing	1. Ensure microbiology testing strategies identify in clinical cultures/tests those opportunistic pathogens recovered in routine water system monitoring 2. Evaluate clinical disease in patients and health care personnel potentially related to facility water system
Facilities or Plant Management, Engineering, Stationary Engineers	1. Identify construction, maintenance, demolition work that will affect water system 2. Review plans for work affecting water systems with team 3. Develop standard operating procedures and policies to safeguard the water system during routine and emergent plant/facility work 4. Respond to water intrusions 5. Review AHJ's water quality reports 6. Respond to AHJ notifications of water interruption or emergency 7. Ensure vendor claims are substantiated with rigorous evidence 8. Develop action thresholds and plans for anticipated failures and waterborne pathogen detection in the system or in humans.	Monthly and ad hoc Annually	1. Ensure manufacturers' IFUs are aligned with facility's cleaning, maintenance and use strategies 2. Consider in-plumbing systems for mitigating obstruction 3. Ensure hot water risers maintain water at target temperatures throughout their run
Hemodialysis (HD)	1. Ensure water quality testing is performed per AAMI or CMS Conditions for Participation as specified by facility policy recommendations 2. Report results of water testing and mitigation efforts 3. Develop policies for responding to out-of-range results 4. Develop strategies for hemodialysis to occur in isolation rooms (e.g., if handwashing sink is occupied by HD machine, plan alternative handwashing strategy)	Annually and ad hoc	1. Ensure manufacturers' IFUs are aligned with facility's cleaning, maintenance and use strategies 2. React to out-of-range testing results and follow policies for mitigation

Table 12: Example of a Water Management Program Team's representation and responsibilities (continued)

Infection Prevention and Control	1. Perform surveillance for diseases caused by opportunistic pathogens 2. Evaluate health care facility policies, action thresholds and mitigation strategies against published reports 3. Review and approve water system designs 4. Review and approve mitigation strategies 5. Ensure vendor claims are substantiated with rigorous evidence 6. Develop action thresholds and plans for anticipated failures and waterborne pathogen detection in the system or in humans.	Ongoing Predesign, each project	1. Identify, investigate and report health care-associated disease in patients and health care personnel 2. Analyze water testing report findings 3. Ensure manufacturers' IFUs are aligned with facility's cleaning, maintenance and use strategies 4. Ensure vertical health care facility reporting of testing, mitigation, cleaning effectiveness
Regulatory Affairs, Accreditation Manager	1. Receive and evaluate reports of waterborne disease associated with health care facility 2. Receive reports demonstrating effectiveness of water safety program	Annually and ad hoc	1. Develop response policies for cases of health care-associated waterborne disease 2. Participate in investigation of health care-associated waterborne disease 3. Facilitate reporting per AHJ requirements
Risk Manager	1. Receive and evaluate reports of waterborne disease associated with health care facility 2. Receive reports demonstrating effectiveness of water safety program	Annually and ad hoc	1. Develop response policies for cases of health care-associated waterborne disease 2. Participate in investigation of health care-associated waterborne disease

1. *Personnel may have different titles; ad hoc guests to provide periodic input may include: purchasing, supply chain management, material services and equipment users. Ensure that communications are complete throughout the acquisition and use continuum.*
2. *Frequency of reporting is dependent on the health care facility's size, program progression and intensity, findings and mitigation activities. For example, in a facility with demonstrated disease in patients, activities and reports are likely to be more frequent. In a facility with no findings or disease and a mature response program, reporting may be less frequent.*
3. *IFU: Manufacturers' instructions for use: directions for equipment cleaning, maintenance, repair and use.*
4. *Facility recall policy should identify responsible parties for ensuring collection and disposition of recalled equipment.*

Case Studies

Academic Medical Center I: Episodic Legionnaires' disease in existing buildings

In Health Care Facility I, Legionnaires' disease was identified in one patient in each of the years 1987, 1995, 1996, 1998 and 2013; two health care personnel developed Legionnaires' disease in 1993. Clinical and water system cultures revealed *Legionella pneumophila* serotypes 2 and 3 in 1993 and 2013, respectively, not matching the clinical isolates. *Legionella pneumophila* serotype 1 has not been identified in patients, nor has it been recovered from robust water sampling over many years. Because of these findings, urine antigen testing, a recommended testing strategy to detect *Legionella pneumophila* serotype 1 in patients who develop healthcare-associated pneumonia, was not implemented in that health care facility, as urine antigen testing could lead to the mistaken conclusion that the facility does not harbor *Legionella* spp. in its water system, and prompts for *Legionella* spp. testing could be missed. The appropriate test for patients in that health care facility who develop healthcare-associated pneumonia is clinical culturing to detect any *Legionella pneumophila* serotype.

Hot water flushing was accomplished in 1987 and again in 1993 when two healthy health care personnel became ill with Legionnaires' disease, which was eventually traced to the air handling system in a medical office building radiology reading room. The water to that building was "superheated" to 140ºF at the hot water holding tanks to achieve 132ºF at the taps throughout the building. The entire building was flushed with the "superhot" water, with all hot water taps opened for a minimum of 30 seconds.

When patient cases were identified in the mid-1990s in the hospital proper, a point source for *Legionella* spp. could not be identified. Ultraviolet light technology and copper-silver ionization as adjunctive measures to treat incoming water were investigated and feasibility studies launched, but the more economical "superhot" water solution that had been successful in the medical office building was selected. The health care facility applied for and was granted a "program flex" from the state department of public health to continuously "superheat" the water to 140ºF at the tanks, and to achieve 132ºF at the taps. The department of public health required the health care facility to post "HOT WATER" in 2-inch tall letters at every hot water tap to mitigate scalding. No reports of scalding have been reported since the hot water strategy was implemented in 1987. Water culturing and patient surveillance continued unabated until 2006. No positive water cultures were identified between 1992 and 2013; the last positive healthcare-associated clinical culture with municipal water treated with chlorine was reported in 1998.

The municipal water authority changed its disinfecting chemical from chlorine to monochloramine in 2004. The infection control committee of the health care facility reviewed the literature, historic data and current (conflicting) recommendations to inform the decision to cease water culturing for *Legionella* spp. Clinical suspicion for Legionnaires' disease in patients who developed healthcare-associated pneumonia continued, with no healthcare-associated Legionnaires' disease identified until 2013 in an immunocompromised patient. Unfortunately, no source was identified for that case.

In response to that 2013 case, however, a robust water management program team, plan and execution were developed and continue as of this writing. As new health care facility buildings are built and older buildings renovated, the strategy of "superhot" water in all buildings has been implemented, with "program flex" approved by the state department of public health. The water safety plan has been implemented with close oversight by the multidisciplinary water

management program team. No positive results from either water or clinical cultures have been reported since 2013. Although no distal premise plumbing sites have returned positive, this facility's risk assessment defines it as critical to implement appropriate monitoring, action thresholds and robust response.

The health care facility approaches the risk of health care facility-associated waterborne-pathogen disease aggressively, with point-of-use 0.2 micron water filters maintained on all faucets and showerheads in inpatient malignant hematology units, flushing all taps in patient rooms with every cleaning, routine tap flushing in locations undergoing renovation and pre-occupancy flushing and hyperchlorination. This "belt-and-suspenders" approach provides peace of mind to the institution and consumers, as *Legionella* spp.-associated disease is rare, but the risk is acknowledged.

Case Study J: International point-source investigation of extracorporeal bypass equipment associated with Mycobacterium chimaera infection

Mycobacterium chimaera was first identified in 2004, previously having been grouped with *Mycobacterium avium* complex.[479] Nontuberculous mycobacteria, including *M. chimaera, M. simiae,*[480] *M. mucogenicum* ,[481] *M. fortuitum*[482] and others are known to form biofilms, and are demonstrated in health care facility water systems. In 2015, the results of an investigation reported by Sax et al. initiated a global investigation of widely used extracorporeal bypass equipment (heater-cooler units) developed for warming and cooling externally circulated blood during open chest surgeries requiring "heart-lung bypass."[483] Cases of *M. chimaera* infections were identified retrospectively to 2012 by the authors of this report, and have been reported contemporaneously with the writing of this chapter. The systematic investigation undertaken by Sax et al. eliminated other hospital-based water sources for *M. chimaera.*

Sommerstein et al. investigated the ability of heater-cooler units transmitting *M. chimaera* via aerosolization by observing smoke patterns in an ultraclean air ventilation system, measuring anemometer readings and recovering the pathogen on settle plates in the operating environment.[484] Gotting et al. describes the incompletely contained contaminated water in the equipment as aerosolized by the machine's exhaust fan.[485] The customary orientation of the equipment, with exhausting toward the sterile field, is a "perfect storm" for the contaminated droplets to be deposited onto the surgical wound, the sterile field and the anesthesiology equipment. Recommendations have been made to turn the heater-cooler unit so the exhaust is oriented away from the sterile field, or to contain it entirely in another room.

Garvey et al. describes polymicrobial bacterial and fungi recovery from heater-cooler units maintained according to the manufacturer's instructions for use.[486] University Hospitals Birmingham, NHS Foundation Trust, tested the heater-cooler unit filtered water after each of a series of three instructions for use updates by the manufacturer. After initially recovering >300 CFU/100 ml from the heater-cooler unit water maintained as per instructions for use, the final method for decontaminating the heater-cooler units included first replacing the biofilm-coated internal tubing (one completely plugged by biofilm, creating a dead leg), followed by daily addition of medical grade 3 percent (100 ml) hydrogen peroxide to the filtered water and weekly peracetic acid treatment. The final disinfecting regime demonstrated a reduction of recovered pathogens 0 CFU/100 ml.

Although the infected case counts attributed to nontuberculous mycobacteria associated with heater-cooler units are small (<1 percent of all patients undergoing open chest surgery with a heater-cooler unit have been reported to be infected with nontuberculous mycobacteria), the high mortality rate (approaching 50 percent) and the severity of invasive disease requiring replacement of both tissue and mechanical implants, and systematic patient polyantimicrobial treatment for long duration elevates the biofilm-associated infection potential from inadequately maintained heater-cooler units to critical importance and should be attentively monitored by the water management program team from both the mechanical disinfection and patient disease perspectives.

The infections associated with water-containing heater-cooler units demonstrate the importance of identifying and critically assessing all other equipment that stores water used in the health care facility. The reports of the implicated heater-cooler units should cause the water

management program team to critically evaluate the condition of water-storing equipment used around hospitalized patients.

Case Study K: Electronically activated faucets or manually operated faucets?

Electronically activated, or sensor, faucets have been marketed as water sparing, and therefore cost-effective and environmentally economic, as well as supportive of more compliant hand hygiene, because of the absence of potentially contaminated handles. Those two reasons have prompted some hospitals to preferentially install sensor faucets. However, several reports have revealed unintentional consequences of electronic, low-flow faucets, in the form of waterborne pathogen colonization, transmission and disease in vulnerable patients[487] (see also the literature review on faucets in Chapter 2: Hand Hygiene Infrastructure).

Pneumonia caused by *Legionella* spp. and pneumonia and bloodstream, urinary tract and surgical site infections caused by *Pseudomonas* spp. have been associated with water sources in premise plumbing of health care facilities such as faucets, both electronic and manual (refer to Table 13). These health care facility-associated infections are costly in terms of patient well-being, treatment and hospitalization and in terms of remediation by the facility.

One academic medical center's infection prevention and control department used the evidence below to persuade the office of statewide health planning and development to change the state's building code, which, in a previous iteration, had banned the use of manual faucets entirely from new hospital building.[488,489] The building code was amended to allow wrist, knee or foot controls on manual faucets in new health care building.

The faucet/pathogen interface was the focus of an investigation in a large, academic medical center that had installed new electronic faucets with a "hygiene flush" (three-minute automatic flush every 12 hours) in an existing building to improve performance and maintenance of the new faucets, as well as to test the bioburden of the new faucet against the existing manual faucets. The municipality used chlorine for disinfection, which was augmented by chlorine dioxide injections by the health care facility to continuously maintain 0.5 parts per million (ppm) chlorine.

Ultimately, 20 electronic faucets and 20 manual faucets were tested. Early in the evaluation, the municipal water pressure was disrupted and chlorination decreased. In response, the health care facility increased their chlorine dioxide to achieve 5.0 ppm for 6 hours ("remediation").

Results of this investigation revealed a higher rate and frequency of heterotrophic plate counts and *Legionella* spp. recovery for the electronic faucets than for the manual faucets (see Table 13*).*

Table 13: Frequency of isolation of *Legionella Species* and significant Heterotrophic Plate Count (HPC) growth from water samples collected from nontouch electronic faucets and manual faucets

	Total, proportion (%)			Before ClO_2 remediation, no. (%)			After ClO_2 remediation, no. (%)		
	Manual faucet samples	Electronic faucet samples	P[a]	Manual faucet samples	Electronic faucet samples	P[a]	Manual faucet samples	Electronic faucet samples	P[a]
HPCs[b]	6/45 (13)	15/58 (26)	.14	4 (27)	7 (23)	1.0	2 (7)	8 (29)	.04
Legionella species	11/75 (15)	54/108 (50)	<.01	10 (22)	50 (63)	<.01	1 (3)	4 (14)	.19
L. anisa	2/75 (3)	29/108 (27)	<.01	1 (2)	26 (33)	<.01	1 (3)	3 (11)	.34
L. pneumophila	9/75 (12)	25/108 (23)	.08	9 (20)	24 (30)	.29	0 (0)	1 (4)	

NOTE . ClO_2, chlorine dioxide.
[a] x^2 or Fisher's exact test.
[b] At least 500 colony-forming units per milliliter was considered significant.

In conclusion, the investigators stated:

> We also found a trend toward continued higher rates of bacterial contamination of electronic faucets after chlorine dioxide remediation, suggesting that electronic faucets may be more difficult to disinfect with standard procedures. All electronic faucet internal components tested in this evaluation grew *L. pneumophila,* with some components showing continued growth of *L. pneumophila* after chlorine dioxide remediation. In addition, the internal components of electronic faucets exhibited significant HPC bacterial growth before and after chlorine dioxide remediation, again suggesting an inability to fully disinfect electronic faucets.

Trautmann et al. reviewed prospective studies of water samples in intensive care units published between 1998 and 2005.[490,491] Their analysis revealed 9.7 percent to 68.1 percent of randomly taken tap water samples were positive for *P. aeruginosa*, and 14.2 to 50 percent of infection/colonization episodes in patients resulted from genotypes found in intensive care unit water faucets. They found that point-of-use disposable filters installed on faucets are an easy and effective preventive strategy to reduce water-to-patient transmissions of this important healthcare-associated pathogen.

Hargreaves et al. report that electronic faucets were colonized with opportunistic pathogens of premise plumbing at a rate two to three times that of manual faucets, and colonization persisted at a rate five times that of manual faucets after hyper chlorination treatment that was intended to eliminate opportunistic pathogens.[492] When new electronic faucets were placed, they revealed positive cultures for opportunistic pathogens within several weeks. A hand-controlled faucet was placed to determine if the internal plumbing was the source for the bacteria, and returned with no bacterial contamination.

Merrer et al. report "technical characteristics of electronic faucets might lead to heavy contamination of the device."[493] That article goes on to describe the unsuccessful results of hyperchlorination in an effort to eliminate colonization by hydrophilic pathogens; "Once in hospital A (hematology ward), an electronic faucet remained heavily contaminated with *P. aeruginosa* despite two successive decontaminations. In the neonatal ICU of hospital B, three electronic faucets still harbored *P. aeruginosa* 4 to 12 days after hyperchlorination."

Sydnor et al. performed side-by-side comparisons of electronic faucets and manual faucets receiving water from the same source.[494] They found that 95 percent of the electronic faucets evidenced *Legionella* spp. from at least one water sample, whereas 45 percent of manual faucets evidenced *Legionella* spp. growth. After chlorine dioxide remediation, the electronic faucets grew *Legionella* spp. four times more than manual faucets, and evidenced four times higher heterotrophic plate count (HCP) growth.

Halabi et al. compared colonization of electronic (no-hands) faucets versus manual (conventional) faucets.[495] That study reported 100 percent of electronic faucets were positive for *Pseudomonas aeruginosa,* while 0 percent of the conventional faucets were positive for *P. aeruginosa.* Cultures of the component parts of the electronic faucets demonstrated *P. aeruginosa* growth from the magnetic valve, mixing valve and the outlet, but none at the junction of the faucet to the plumbing. *Legionella* spp. was present in 100 percent of the electronic faucets, and in 30 percent of the conventional faucets. Halabi et al. suggest local contamination of fittings within the electronic faucets is a result of the low amount of water that flows through the outlet, the low water pressure and the relatively longer column of stagnant, 35ºC (95ºF) water, thus providing nearly ideal growth conditions for *P. aeruginosa* and *Legionella* spp. Rubber and polyvinylchloride in the fittings of the electronic faucets enhance the adhesion of *P. aeruginosa* and thus the production of biofilms.

Case Study L: Decorative water features

The desire to create calming, interesting and health-promoting environments in health care facilities has led architects, administrators and donors to include decorative water features (for example, water walls, fountains, reflecting ponds and interactive water features) in locations where heightened anxiety might be anticipated, such as in cancer treatment locations (for example, clinics, radiation oncology, stem cell transplantation), pediatric facilities, lobbies and presurgical environments. Although the sight and sound of water features have been marketed as making health care settings more inviting, the risk of pathogen availability to vulnerable patients has been reported sufficiently to prompt critical risk assessments by the water management program team before installing such a feature. If decorative water features exist in a health care facility, the water management program team should review the maintenance procedures and frequency, and the results of surveillance for waterborne pathogen-related healthcare-associated infections. *Legionella* spp. is the primary pathogen reported from water features.

Haupt, et al. reported a *Legionella* spp. outbreak involving eight patients exposed to a water wall decorative fountain installed in a hospital lobby.[496] The two-year-old fountain had been properly maintained with routine biocide application, levels tested and monthly cleaning of component parts; yet the foam support for the rock base was found to have high counts of *Legionella* spp. genetically identical to seven of the clinical isolates. This hospital's experience was the basis for guidelines stating, "Fountains and other open decorative water features may represent a reservoir for opportunistic human pathogens; thus they are not recommended for installation within any enclosed spaces in health environments."

Palmore et al. reported a 2007 cluster of two patients from a stem cell transplantation unit.[497] A decorative fountain was installed in a radiation oncology waiting lobby and was active 15 hours per day. The decorative fountain, despite being equipped with a filter and ozone generator for disinfection, was found to have *Legionella* spp. genetically identical to the patients'. Palmore's conclusion states, "Fountains are a potential source of nosocomial Legionnaires' disease despite standard maintenance and sanitizing measures. In our opinion, fountains present unacceptable risk in hospitals serving immunocompromised patients." The authors found that the capricious fashion and lethal potential of water features must inform the facility's decision regarding installing, testing, maintaining and ensuring the safety of all patients.

Tools

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CHAPTER 6: Flow of Patients, Personnel, Equipment and Waste

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Introduction

Transmission of infection or infectious agents is a complex process. Multiple modes or mechanisms of transmission require multiple prevention strategies. Some strategies involve improving health care personnel behaviors such as hand hygiene and correct use of personal protective equipment. This may be accomplished by designing the health care environment to support optimal practice by providing easy access to alcohol-based hand sanitizer or hand-washing stations and making personal protective equipment readily available at the point of use. Other strategies include designing the built environment in ways that facilitate ease of cleaning and disinfection to limit opportunities for transmission.

Health care facility design can contribute either in a positive way by contributing to prevention of infection or negatively by contributing to transmission. An example of a positive impact on prevention is when an operating room supply diffuser array and airflow are designed according to current published recommendations,[498] providing the optimal airflow over the surgical site thus decreasing the risk of introducing airborne particles into the sterile field. An example of a negative impact would be handwashing sinks not designed according to current published recommendations[499] to minimize risk of splashing onto nearby countertops where staff prepare medications or dressings, resulting in surface contamination that may lead to infection.[500]

This chapter will review current literature and supporting evidence, describe best practices, present case studies and provide tools to help guide design decisions to support best practices for both renovation and new construction in health care facilities. A summary of recommendations can be found in Appendix A (new construction) and Appendix B (existing facilities).

Importance for New Construction

Groups that are planning construction of new health care facilities need to understand infection prevention principles and have access to relevant literature and tools when planning in order to design spaces and building systems that will support good infection prevention practice. New health care construction begins with the development of a descriptive document known as the "functional program." The functional program, as detailed in the Facility Guidelines Institute's *Guidelines for Design and Construction of Hospitals and Outpatient Facilities,*[501] details the purpose of the project including services to be provided, the project type and size of the health care facility proposed and architectural space required.

The functional program drives design of the facility and many of the space requirements will be based on this. For example, if there will be a bone marrow transplant program, then positive pressure, protected environment rooms will be required. If surgical services will be provided, then a central sterile processing area must be included in the design. To ensure safe design from an infection prevention perspective, an infection control risk assessment must be completed as part of the overall safety risk assessment process. These risk assessment processes must be completed during the planning phase of the project. As part of the infection control risk assessment process, decisions are made about many of the design requirements that are critical to infection prevention, such as the numbers, types and locations of isolation rooms required. Also, decisions about the numbers and locations of handwashing stations needed, along with sink design and decisions about surfaces and furnishings, are also made.

Plumbing and heating, ventilation and air conditioning systems are also important for infection prevention; these systems are reviewed to ensure they are designed to meet current published codes and standards. The best practices reviewed within this chapter can help inform the risk-assessment process and these decisions.

Importance for Existing Facilities

Understanding these principles and best practices is also critical for hospital leaders and department managers involved in management and renovation of existing facilities. They need to be able to assess current operations and work flows within the existing built environment and determine whether they are consistent with current infection prevention and control recommendations.

Facilities are becoming outdated because of advances in technology; these factors are driving hospital renovations, additions and expansions. Building new facilities or renovation of existing spaces provides an opportunity to update facility infrastructure and improve existing design to incorporate new recommended best practices for infection prevention into renovated spaces.

Intensive care units need to understand these principles to evaluate their existing spaces to determine if current design and work flows are consistent with infection prevention best practices. Examples of some questions that could be asked include:

- Is there an appropriate, negative pressure airborne infection isolation room to isolate patients with airborne diseases or a positive pressure protected environment room for severely immunocompromised patients?
- Are these types of rooms necessary based on current or anticipated patient populations?
- Are there handwashing stations accessible at the entrances to rooms housing patients with *C. difficil*e, and if not what are the options for staff?
- Is there a room that is closest to a hallway sink that can be prioritized for a *C. difficile* patient?
- What are the provisions for safe disposal of human waste and body fluids? Are in-room "swivettes" still in use, and if so, are they cleaned effectively and maintained? Does staff close the door before flushing or are they designed to prevent flushing with the door open? Are in-room "hoppers" used and if so, do they have covers? Most importantly, is there a plan to eliminate swivettes or hoppers from the patient room and provide an accessible toilet room or soiled utility room with a hopper for waste disposal?

Emergency departments can use information provided to develop work flows and procedures for screening, rapid triage and isolation of patients presenting with symptoms consistent with a communicable disease. Some facilities currently have no airborne infection isolation rooms or an insufficient number in their emergency departments or on inpatient units; the "Tools" section of this chapter provides a reference on how to work with the infection prevention and engineering departments to determine what alternative environmental controls can be implemented to create temporary negative pressure isolation.

The Tools section also provides information for ambulatory facilities about screening and isolation of potentially infectious patients and how to safely separate clean and soiled items and the correct use of soiled and clean workrooms. Health care traditionally provided in the hospital is being shifted to the ambulatory setting as a result of economic factors and changes in technology that allow for some invasive diagnostic procedures to be performed outside the hospital setting. Ambulatory facilities need to be able to complete risk assessments of their

existing spaces to determine whether current facilities can safely accommodate procedures they were not originally built for, or if renovations are needed to meet current standards.

In general, all health care facilities can use the information provided in this chapter to understand the infection prevention principles associated with the flow of patients, personnel and materials to evaluate existing conditions and work flows, to identify potential failures in infection prevention practices and to identify resources for solutions.

How Can this Chapter Help Hospitals Improve Infection Prevention and Control?

New Construction

New construction presents an opportunity to design spaces that meet the most current published guidelines and evidence-based design recommendations for health care construction, as well as to design spaces that support work flows that minimize risk for cross contamination, limit exposure to communicable diseases and support good infection control practice. This chapter pulls together information on a variety of design and operational questions that need to be asked when planning for new construction.

In new construction, hospital leaders are faced with many decisions. Factors such as type of facility, cost, available land and goals of the project all influence design decisions. Understanding the principles of separation of clean and dirty work flows; the appropriate flow of patients, personnel, materials and waste; and the importance of these concepts to the prevention of healthcare-associated infections will help to inform critical design decisions.

Existing Facilities

For existing facilities, material in this chapter can help in evaluating the environment and the flow of patients, personnel, materials and waste, including emergency department design for triage and isolation of patients. Information provided can also help to identify opportunities for improvement through renovation of existing spaces or mitigation of risk by modifying operational procedures. Examples include implementing a system for identifying soiled patient care equipment and patient-ready equipment or installing splash guards next to sinks to protect clean supplies.

Brief Literature Review

Physical separation of people actively ill with an infectious disease or those who have been exposed from those who are well and unexposed, known as isolation and quarantine, has been successfully used to prevent the spread of infection since the Middle Ages. Isolation and quarantine help protect the public by preventing exposure to people who have or may be incubating a contagious disease. The Centers for Disease Control and Prevention defines *isolation* and *quarantine* as follows:

1. Isolation separates sick people with a contagious disease from people who are not sick.
2. Quarantine separates and restricts the movement of people who were exposed to a contagious disease to see if they become sick.

In order to protect public health, the federal government by law has the ability to isolate and quarantine specific diseases (see Table 14).

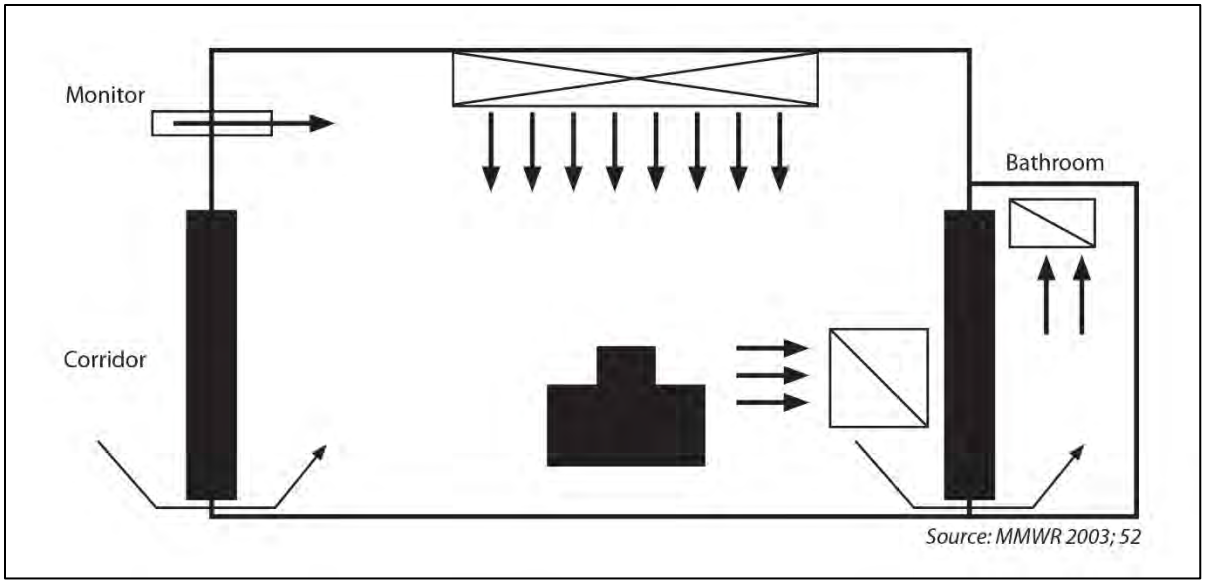
Table 14: Federal isolation and quarantine are authorized for these communicable diseases

Cholera
Diphtheria
Infectious tuberculosis
Plague
Smallpox
Yellow fever
Viral hemorrhagic fevers
Severe acute respiratory syndromes
Flu that can cause a pandemic
Federal isolation and quarantine are authorized by Executive Order of the President. The President can revise this list by Executive Order.

Isolation of patients with an airborne infectious disease in an airborne infection isolation room with negative airflow (see Figure 8) and with dedicated exhaust protects other patients and staff from exposure to that disease.[502] According to the CDC's 2005 "Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Settings," the risk for healthcare-associated transmission of tuberculosis (TB) varies by setting, occupational group, prevalence of TB in the community, patient population and effectiveness of TB control measures.

Healthcare-associated transmission of TB has been linked to close contact with persons with TB disease during aerosol-generating or aerosol-producing procedures, including bronchoscopy.[503] For this reason, hospitals conduct a risk assessment annually both to evaluate the volume of TB cases the facility sees and to determine if there have been instances of TB transmission. This risk assessment is the foundation for each facility's TB exposure control plan, a document that details measures in place in the facility to prevent transmission of TB, including the numbers and locations of airborne infection isolation rooms, mechanisms and procedures for ensuring they are working as designed, and procedures for early identification and isolation of potential TB cases.

Figure 8: Example of airborne infection isolation room with negative pressure airflow to control the spread of airborne diseases



According to the Centers for Disease Control (CDC), isolating patients that are colonized or infected with multidrug-resistant organisms in a single room reduces the risk of horizontal transmission to other patients. Cohorting of patients with the same organism in a double patient room is allowed, however cohorting is only recommended when single patient rooms are not available to isolate infected or colonized patents.[504] Thus, single patient rooms are preferred and can reduce the risk of healthcare-associated infections.[505]

Beyond isolation and quarantine, “source control” measures can also be effectively used to limit the spread of infection. Failure to implement simple source control measures with patients, visitors and health care personnel with respiratory symptoms was identified to have likely contributed to severe acute respiratory syndrome (SARS) transmission.[506] From this experience came the development of the concept of “respiratory hygiene/cough etiquette” by the CDC. (This concept, which should be in place at all points of entry to health care facilities, encourages patients and visitors to self-identify if they have a cough or a fever. Through the use of visual cues and signage, symptomatic patients and visitors are encouraged to cover their coughs with tissues and to perform hand hygiene (see Figure 9).

Figure 9: Example of signage promoting source control



A study that looked at health care personnel adherence to CDC-recommended respiratory infection control practices in primary care clinics and emergency departments of five medical centers in King County, Washington[507] reported poor compliance with published recommendations for the control of respiratory infections in ambulatory care and emergency department settings. The study concluded that "practical strategies are still needed to identify and reduce barriers to implementation of these strategies."

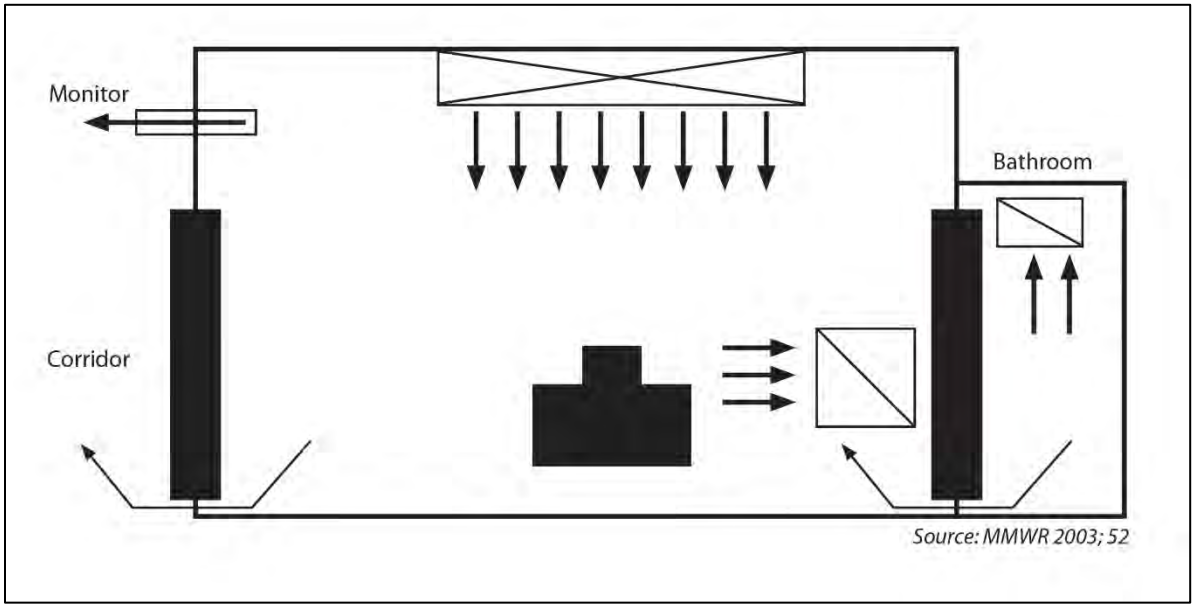
These challenges associated with ambulatory care settings are noted in the Centers for Medicare & Medicaid Services State Operations Manual Appendix A, which states, "Ambulatory care settings, including emergency departments, present unique challenges. Patients remain in common areas, often for prolonged periods of time and infectious patients may not be recognized immediately. In addition, examination or treatment rooms are turned around quickly with minimal cleaning."[508]

Other potentially infectious illnesses beyond respiratory infections such as acute gastroenteritis (nausea, vomiting and diarrhea) are frequently seen in emergency departments and add pressure to patient flow through the emergency department. The nature of these symptoms requires early isolation pending identification of the cause to prevent secondary transmission to other patients or health care personnel; however, isolation in a single room is often difficult given volume constraints. A recent Danish study of patients presenting in the emergency department with acute gastroenteritis identified that while all patients that presented with these symptoms were isolated, only one in four was determined to have an infectious cause. The study concluded that better methods for identifying which patients require isolation are needed along with rapid testing modalities to more quickly rule out infectious causes.[509]

In addition to the challenge of early identification and isolation of patients, patient flow in general in emergency departments has been the focus of much research in recent years. In 2005, the American Hospital Association reported that 69 percent of urban emergency departments are over capacity, resulting in crowded conditions and ambulance diversions.[510] Expanding space and adding capacity alone may not improve patient flow in the emergency department, as was identified in a study that looked at administrative data in the period before and after expansion of an emergency department in an academic medical center. The conclusions were that the increased capacity was associated with no significant change in the percentage of patients who left without being treated, and had an unintended consequence of an increase in emergency department's boarding hours.[511] An article about using data to drive the design of emergency departments[512] attempted to synthesize the growing data regarding emergency department operations. The author proposed that "EDs can optimize their functioning by marrying good processes to good design." The article summarizes novel ideas to managing patient flow in the emergency department including the use of pods and zones and ideas such as a "low flow/high flow" model where both the space and operational procedures for triage "flex" to accommodate changes in volume.[513]

In health care facilities, isolation is not always for the purpose of containing infection. Isolation may also be used to protect specific categories of patients from exposure to environmental pathogens. Isolation of highly vulnerable, immunocompromised patients, such as bone marrow transplant patients, in high efficiency particulate air (HEPA)-filtered positive pressure rooms protects these patients from exposure to airborne fungi and reduces the risk of invasive fungal disease.[514] These rooms are known as protected environment rooms (see Figure 10).

Figure 10: Example of positive-pressure room for protection from airborne environmental microbes



Another example of a specialized environment designed to isolate and protect vulnerable patients is an operating room. The risk of surgical site infection is reduced with the use of positive pressure to ensure that air flows from the operating room to adjacent spaces, plus a high number of air changes per hour to remove particulates and an air supply design that distributes air over the surgical field in a specific way.[515] In addition, minimizing traffic in the

operating room reduces the volume of airborne particulates that could potentially contribute to surgical site infections.[516]

Environmental waste, both regulated medical waste and general waste, can be a reservoir for pathogens and a potential source of health care personnel exposure to infectious diseases such as blood borne pathogens. If waste is not managed appropriately, that is, contained and separated from clean areas, pathogens can potentially be transmitted via direct contact, in the air or by vectors including insects and human vectors such as health care personnel. For these reasons, management of waste in health care facilities is regulated. There are requirements for segregation and containment of biohazardous waste in accordance with the Occupational Safety and Health Administration (OSHA) blood borne pathogens standard,[517] a regulation that was promulgated in 1991. At that time, OSHA determined that "...employees face a significant health risk as the result of occupational exposure to blood and other potentially infectious materials because they may contain blood borne pathogens."[518] In addition to these federal regulations, local public health regulations for transport and disposal of waste are in place to protect the general public. The overall importance of preventing contamination of the health care environment is codified by the Centers for Medicare & Medicaid Services (CMS) in the following Condition of Participation 482.42: "The hospital must provide a sanitary environment to avoid sources and transmission of infections and communicable diseases."

Safe disposal of human waste and body fluids (both solid and liquid) remains a challenge in health care facilities. In an article that reviewed design of the environment of care in intensive care units as it relates to the safety of patients and health care personnel, Bartley and Streifel state "Patient care personnel should not risk spills/exposures from carrying human waste long distances to a soiled utility room with a flush sink for disposal."[519] The authors further note that "Design elements should provide for emptying bedpans without leaving the patient room area, i.e., minimal travel distance to a toilet or clinical/flushing rim sink."[520] Note that swivettes are no longer allowed in ICU design, and while they do provide an in room disposal option, they are not an optimal choice and create many other contamination risks.

Ensuring that facilities for disposal of waste are readily accessible to patient rooms addresses the transport of waste long distances through hospital corridors; however, it does not address another concern, which is the contamination of surfaces in the patient bathroom or shared toilet room resulting from the flushing of waste in a toilet or a flush rim clinical sink, also known as a "hopper." Ample evidence suggests that this activity results in surface contamination.[521,522] An association between inhaled toilet aerosols and infection transmission has been proposed, however thus far, "...epidemiological studies have been unable to distinguish between risks of contact versus airborne transmission that may result from exposure to toilet flush aerosols."[523] A third concern, also not addressed by direct access to a toilet room, is the potential for contamination of health care personnels' clothing when emptying and manually cleaning a soiled bedpan. Manual cleaning involves the use of handheld hoses used by staff to rinse waste from bedpans. Use of these hoses along with flushing action creates a risk for clothing contamination. The practice of standard precautions,[524] required of all health care personnel, dictates the use of personal protective equipment such as a fluid-resistant gown when performing tasks with a risk of exposure to excretions to prevent contamination of health care personnel uniforms; however, health care personnel adherence to standard precautions is suboptimal,[525] thus, for patients who are not on contact isolation, where a gown would be required, it is likely that staff clean bedpans without wearing appropriate protection, resulting in likely contamination of clothing with fecal organisms. Health care personnel uniforms are frequently contaminated with potentially pathogenic bacteria[526]; however, the role of health care attire in the spread of healthcare-associated infections has not been clearly established.[527]

The response of the United States to the 2014 Ebola virus disease outbreak in West Africa placed a significant focus on the role of the environment in transmission of infection. While the role of the environment in the spread of the Ebola virus has not been fully defined, indirect exposure to blood and body fluids (via fomites) has been implicated in transmission but is not common. As noted by the CDC, given the high virus titers in the blood of ill patients and disease severity, precautions are warranted to reduce the potential risk associated with contaminated surfaces in the patient care environment.[528] CDC guidance for facilities caring for patients with the Ebola virus or persons under investigation includes a focus on frequent and meticulous cleaning of the patient care environment and the room where personal protective equipment is removed. Cleaning is to be performed by clinical staff to limit the numbers of persons at risk of exposure. In addition, health care personnel work flow is designed such that they move from a clean area to the patient care area (dirty) to the personal protective equipment removal area and then out to the clean area again after personal protective equipment removal. This concept of unidirectional flow is implemented to minimize health care personnel risk for self-contamination.

Best Practices and Recommendations

New Construction

Planning for construction or renovation of health care facilities is a complex process. Ensuring a design that promotes the optimal flow of patients, personnel, materials and waste with a goal of reducing the risk of healthcare-associated infections is just one of many goals faced by the team. Other goals include patient and staff safety, reducing medical errors, increasing patient satisfaction, ensuring sustainability and flexibility and planning for disasters and surge capacity. All of these goals are coupled with the obligation to complete the project on time and within budget. Adding to this challenge may be constraints such as a limited footprint for new construction and for renovations; exiting conditions such as fixed building components and mechanical systems may impose limitations.

As noted earlier in this chapter, the process begins with the development of a functional program and completion of an infection control risk assessment. During this critical planning phase, a multidisciplinary team meets to develop and agree on the future state of the facility. Many issues must be considered and decisions made. At a minimum, the design plans should meet standards for the built environment as set forth by local regulatory authorities. If waivers for regulatory requirements are being requested, they should be reviewed by the infection prevention team to validate that the proposed alternative meets the intent of the regulation in terms of infection prevention.

For the purpose of this section, the focus will be on best practices related to infection prevention for new construction and will be organized according to the following three topic areas associated with the flow of patients, personnel, materials and waste:

1. Identifying, isolating and containing communicable diseases and transmissible infectious agents in the emergency department in a timely manner.
2. Ensuring clean spaces (for example, clean and sterile supply, pharmacy clean rooms, protected environment rooms, operating rooms) and clean supplies are protected from dust and moisture and other contaminants.
3. Ensuring the separation of clean and dirty functions to prevent cross contamination and maintain a sanitary environment

Identifying, Isolating and Containing Communicable Diseases and Transmissible Infectious Agents in the Emergency Department

As previously noted, emergency departments across the country are facing increasing volumes. Nearly half of emergency departments report operating at or above capacity, and 9 out of 10 hospitals report holding or "boarding" admitted patients in the emergency department while they await inpatient beds.[529] As a result, current emergency department design both operational and physical is focused on the following concepts:

- Throughput and managing volume.
- Creating flexible spaces that are able to care for different types of patients.
- Areas that open and close as patient volume and acuity fluctuate. This concept of flexing up or down has been referred to as the "breathing emergency department."[530]
- Combining triage and non-urgent, fast-track areas.
- Strategies to keep low acuity patients "vertical" by placing them in recliners.
- Placing physicians in triage areas to decrease "door to doc" times and enable rapid discharge of non-acute patients.
- Moving higher acuity patients to other pods or zones where more complex care is provided.

While much of the literature in this area focuses on efficient throughput and providing the right care in the right location, incorporating infection prevention into the design has also become part of the planning process as it relates to disaster preparedness and planning for surge capacity. This includes planning for epidemic or pandemic infectious diseases in addition to the threat of biological warfare. Because of ongoing concerns about the overall preparedness of health care facilities for these types of events across the United States, in a rule finalized in September of 2016, CMS mandated that all facilities that participate in the Medicare and Medicaid programs must develop a plan, based on a risk assessment, using an "all hazards" approach, which is an integrated approach focusing on the capacities and capabilities critical to preparedness for a full spectrum of emergencies and disasters.[531]

The concept of focusing on capacity and capability, along with facility protection from external threats, was highlighted in a research initiative known as "Project ER One" at the Washington Hospital Center in Washington, D.C. The goal of this project was to develop design strategies to deal with the medical consequences of disasters, epidemics and terrorism.[532] One of the primary outcomes of the project was the approach to the actual design process. The process included a threat and vulnerability analysis to understand the potential threats and vulnerabilities specific to the region, a description of the role of a facility in responding to these threats and then relevant disaster planning as part of the emergency department design. While Project ER One never led to the actual construction of the proposed emergency department that was developed; several concepts that came from the work have been incorporated into emergency departments built since then.[533]

Some of the ER One concepts for emergency department design, specific to infection prevention, included the following:

- The idea of "entry portals" or areas where initial patient assessment, such as temperature scanning, could be accomplished while isolating the patient in a self-contained, self-decontaminating space. While this concept may be futuristic and not

easily accomplished for the majority of facilities, the idea of locating airborne infection isolation (negative pressure) rooms near triage at points of entry, coupled with effective screening protocols, can facilitate early isolation of patients and prevent exposure of large numbers of people to infectious diseases in the emergency department.
- The identification of dedicated entrances and quarantine zones for the management of infectious patients in epidemic situations. This concept could be planned for in design or implemented operationally at the time of an epidemic or pandemic event.
- Use of a modular, compartmentalized ventilation system. With this system, negative pressure could be possible in all rooms allowing the effective isolation of any room or even a small section of the facility if needed.

The ability to isolate the airflow from entire sections of an emergency department in the event of the identification of a highly infectious disease could help to contain an outbreak and is worth investigating when designing a new emergency department. At a minimum, new emergency department construction must comply with existing guidelines[534] for emergency department design that already require that waiting rooms and triage areas be negatively pressurized with respect to adjacent areas.

While hospitals across the United States have plans in place for surge capacity and pandemic response, only a very small number actually have dedicated units designed for the care of patients with a highly infectious disease. This type of unit has been referred to as a biocontainment patient care unit.[535] A biocontainment patient care unit is a facility specifically designed to minimize transmission of highly infectious diseases and uses engineering and safety measures similar to biosafety level 3 and 4 containment laboratories. Some of these measures include negative air pressure ventilation systems for entire units, disinfectant pass-through boxes and an autoclave for sterilizing waste and other infrastructure not usually seen in hospitals.

In 2004, the European Network of Infectious Diseases met to develop a framework for the design and operation of what they called a high-level isolation unit (HLIU).[536] Similarly, in 2008, representatives from the only three biocontainment patient care units that existed in the United States at the time (the US Army Medical Research Institute of Infectious Diseases (USAMRID), Emory University Hospital and the University of Nebraska Medical Center) along with other experts convened a group to develop consensus guidance for other facilities that might be planning for patients with highly infectious diseases.[537]

Both these groups proposed several categories of recommendations; some recommendations were operational such as designated leadership and training programs in addition to recommendations for the built environment. The recommendations for the built environment included:

- Building units that are physically separated from other patient care areas with controlled access.
- Designing heating, ventilation and air conditioning systems that maintain the area under negative pressure.
- Designing heating, ventilation and air conditioning systems that are independent from other hospital systems with redundant fan systems to ensure that negative airflow is maintained at all times
- Ensuring the entrance for health care personnel is large enough to allow clothing change and storage of personal items and clean personal protective equipment, and providing a

separate staff egress with shower-out capability.
- Providing for an external, securable area for ambulance parking and decontamination.

This concept of unidirectional flow of health care personnel, (e.g., entering one door and exiting another) is intended to ensure that the space in which health care personnel don personal protective equipment remains clean and is not contaminated by exiting health care personnel as they doff (remove) contaminated personal protective equipment. This concept was included in Ebola treatment units in West Africa during the 2014 Ebola outbreak and is in place in some of the U.S. facilities that cared for Ebola virus disease patients. While this is not an existing requirement for a standard airborne infection isolation room used to house patients with common airborne diseases such as TB or chickenpox, it is a concept that might be explored in facilities that are planning spaces to be used to care for patients with novel, highly infectious diseases. It is a concept that could also be explored for standard patient rooms as a way of decreasing the transmission of contact spread organisms such as *Clostridium difficile* or multidrug-resistant organisms such as methicillin-resistant Staphylococcus aureus (MRSA) and carbapenem-resistant *Enterobacteriaceae* (CRE).

At a minimum, whether caring for patient with highly infectious diseases or providing care to patients with common contact spread organism's, having adequate space for donning, doffing and safely discarding personal protective equipment is essential to preventing cross contamination.

The 2014 Ebola outbreak caught many by surprise and caused emergency departments, urgent care centers and outpatient clinics across the United States to evaluate their procedures for identifying patients that require isolation. The CDC provided guidance in the form of an algorithm titled "Identify, Isolate, Inform: Emergency Department Evaluation and Management of Patients with Possible Ebola." The tool is no longer in use but it highlighted the need for clinicians, in particular those at the entry points to health care facilities such as emergency departments, urgent care sites and other outpatient locations to screen for symptoms of infection to facilitate early isolation of infectious diseases.

Early identification of patients that require isolation to contain common communicable diseases such as influenza or chickenpox and contact-spread pathogens such as multidrug-resistant organisms is a major challenge in all emergency departments and other outpatient locations. Early detection requires a combination of astute clinician assessment in identifying the potential infection; an electronic health record alert for patients with a history of multidrug-resistant organisms; knowledge of the appropriate isolation requirements and the availability of the required isolation space whether it be a standard single room, bay or cubicle for patients requiring contact or droplet isolation or a room with negative airflow (airborne infection isolation room) for patients requiring airborne isolation for airborne spread diseases.

Improving the ability of health care personnel in the emergency department to consistently identify these infections requiring isolation in a timely manner will decrease the risk of healthcare-associated infections related to these infections. It can also potentially improve the ability to quickly identify, isolate and prevent further spread of a novel highly infectious disease in the early stages of an emerging epidemic. Achieving this goal requires clear and readily accessible screening protocols along with effective health care personnel training on the use of these protocols, as well as a facility design that can effectively separate (both physical and airspace) these patients and potentially their families from other patients early in the visit, preferably at triage. Considerations for new construction include:

- Creating an entrance design that keeps new patients separated from others until they can be screened for symptoms of infection.
- Including a separate waiting area for patients with a febrile cough or rash illness on arrival can prevent exposure of susceptible patients and visitors in other waiting areas.
- Displaying respiratory hygiene/cough etiquette informational signage on the route leading into the emergency department and other outpatient locations, in languages relevant to the communities served, instructing patients and visitors to cover their coughs and to self-identify to triage health care personnel that they have a cough or a fever.
- Ensure that tissues, alcohol-based hand sanitizer and masks are readily available at triage and in waiting rooms, along with waste receptacles for tissue disposal.

Ensuring Clean Spaces and Clean Supplies Are Protected from Dust, Moisture and Other Contaminants

Several spaces in health care facilities are designated as “clean areas”; however, among these spaces is a range of protective requirements based on the function of the area. For example, a clean equipment room where patient care items such as IV poles, walkers and commodes are stored need only be a finished room with cleanable surfaces, sized to accommodate the volume of equipment intended to be stored there. In contrast, a clean and sterile supply room requires positive airflow and a minimum number of air changes per hour; this design feature is intended to minimize accumulation of dust on supplies. An even higher level of protection is required in central sterile supply where sterilized, wrapped or containerized surgical instruments and supplies are stored. This area has requirements for positive pressure and established ranges for temperature and relative humidity.[538] These parameters are intended to protect from dust and maintain the integrity of sterile packaging which can be affected by extremes of temperature and humidity, potentially compromising the sterility of surgical instruments and supplies.

In addition to ensuring that clean supply areas are designed correctly in terms of heating, ventilation and air conditioning requirements and finishes, many other questions need to be answered by the planning and design team to ensure that supplies are operationally managed in a way that protects from contamination. Questions that need to be asked include:

- Will there be supply carts or cabinets in the patient room that are stocked with frequently used items or will staff need to leave the room for supplies?
- If supplies are stocked within the patient room, what physical or operational measures will be in place to prevent them from becoming contaminated by staff touching them with unclean hands?
- Will supplies be discarded at patient discharge or will they be considered clean and be used for the next patient?
- Will there be a central clean supply room or will clean supply storage be decentralized to decrease nursing time spent gathering supplies?

Clinicians will always find ways to facilitate their work flows. If supplies are not readily accessible, they will stock patient rooms inappropriately including storing supplies next to or under sinks or on window sills. This can compromise the integrity of clean and sterile supplies, especially when stored within the splash zone of a sink (4 ft.) or in the potentially moist area under a sink.

At this time, there is not one “best practice” approach to solving this challenge and much depends on the type of unit, size and layout, volume and types of supplies needed, hospital

policies and unit culture. An approach to planning that can facilitate understanding staff work flows is using human factors engineering methods to analyze tasks as they are performed in existing spaces.[539] Asking the question, "What design features contribute to the lack of compliance?", can help planners work with health care personnel to design spaces and systems that support both efficient work flows for health care personnel and ensure that clean and sterile supplies are stored in a manner that protects them from contamination.

Pharmacy compounding rooms are another clean space that need protection from dust, moisture and other contaminants. Requirements for these rooms are detailed in the United States Pharmacopeia (USP) standard 797. United States Pharmacopeia is an organization that sets standards for the identity, strength, quality and purity of medicines; standards are enforced by the U.S. Food and Drug Administration. These design requirements include specifics for surfaces, airflow filtration and layout that ensures that air flows from the cleanest area to less clean areas. Staff and materials workflow must ensure that staff and materials move into clean spaces in a manner that minimizes contamination of the space. When planning for this type of space in new construction, it is important that both pharmacists and designers with expertise in USP 797 requirements are involved. Consideration should also be given to where this specialized area is located within the overall layout of the facility so the access to the pharmacy is from a clean corridor. While the containment of hazardous drugs is not an infection prevention issue, additional pharmacy design and operational requirements codified in USP standard 800 must be included when designing pharmacies that will be compounding medications covered by this new hazardous drug standard.

Protected environment rooms and operating rooms are also considered clean spaces and are designed to protect specific groups of patients from environmental sources of contamination. As noted previously, protected environment rooms are positively pressurized with HEPA-filtered (either centrally or at point of use) supply air at a prescribed rate of air changes (12 air changes per hour). This design minimizes risk of exposure to airborne fungi such as *Aspergillus*. Fungi are ubiquitous in the natural environment and are not harmful to persons with intact immune systems. However, bone marrow transplant patients and others with severely compromised immune systems are susceptible to serious infections if exposed to these organisms so they must be protected from exposure when hospitalized.

Potential sources of fungi in the hospital environment include:

- Clothing of staff and visitors.
- Fresh flowers and plants.
- External shipping containers.
- Wet or moldy building materials or construction dust.
- Poorly maintained or compromised heating, ventilation and air conditioning systems.

Inclusion of protected environment rooms in new health care facility construction will be based on whether the facility will provide services that include these patient populations. There are clear published guidelines[540,541] for how these rooms must be designed and engineered including a requirement for a local visual indicator that demonstrates if positive differential pressure is not maintained. As important as correct design and construction is, the ongoing plan for monitoring and maintenance of heating, ventilation and air conditioning systems, including regular inspections and replacement of filters to ensure parameters, continue to be met. Health care personnel training on how the room works, what to do if the visual indicator shows a loss of

positive pressure and the importance of keeping the door closed to maintain pressurization is also extremely important.

Operating rooms are designed to protect surgical patients from developing surgical site infections that can occur when bacteria or fungi are introduced into the surgical wound at the time of the procedure. Sources of bacteria in the operating room include the patient and health care personnel in the room. Human beings regularly shed bacteria-laden skin cells (skin scales or particles) into the air. These are shed regularly from exposed regions of skin and can be caught in air currents and deposited in the open operative site. Requirements for the design of an operating room air supply diffuser array, along with face velocity of supply air over the operative site and location of return grilles have been published[542] and are based on research using computational fluid dynamics to determine the behavior of particles around the surgical wound with multiple different air supply and return configurations.[543] Design teams planning new operating rooms should ensure, at a minimum, that design meets these requirements. In addition, the location of equipment in the room and how it potentially affects airflow should be considered. Again, equally important as correct design and construction is the ongoing plan for monitoring and maintenance of heating, ventilation and air conditioning systems, to ensure parameters continue to be met along with health care personnel training on how the room works and the importance of keeping the door closed to maintain pressurization.

Ensuring the Separation of Clean and Dirty Functions to Prevent Cross Contamination and Maintain a Sanitary Environment

Maintaining separation between clean and dirty functions is fundamental to infection prevention in health care and includes basic practices such as ensuring that patient care unit design includes space for accumulation and holding of regular and medical waste. These areas must be adequately sized to the needs of the unit and be located away from the flow of patients, personnel and supplies. These soiled holding locations must also be designed to have negative airflow to contain odors and contaminants. This is consistent with the overarching infection control principle of ensuring that air flows from clean to less clean areas.

Bulk waste storage carts are common in hospitals and are used in the collection and removal of clinical wastes. They are sometimes staged in common areas within hospital buildings to receive waste from clinical departments. A study by Blenkharn examined 23 in-use carts in a London hospital and discovered significant soiling including bloodstains and free fluids. Pathogens were also identified on the carts including two that were heavily contaminated with *Aspergillus*.[544] The risk of cross contamination from these types of carts is significant; if used, such carts should be stored in an area separated from patient care, in a dedicated soiled holding room with negative airflow.

Maintaining separation between clean and dirty functions is also true for loading docks where supplies are delivered and waste is picked up. Thoughtful planning is required to ensure that delivery of clean materials (for example, medical supplies and clean linen) is separated from the process of waste removal to prevent potential cross contamination of materials on the loading dock that can ultimately make its way to patient care areas. These processes should be done in separate areas that are also separate from the usual travel paths of staff and patients. Decisions will need to be made about space for unboxing and transport of medical supplies to clean areas of the hospital. This is especially true for supplies being delivered to the surgical suite. Clean and sterile items being delivered to the surgical suite should be transported in a manner that preserves package integrity and protects items from contamination along the route. Because external cardboard shipping containers collect and generate dust and are exposed to

dirt and insects in warehouses and in transport vehicles, supplies must be removed from these boxes before being brought to the surgical suite. This is specifically required by required by Association for the Advancement of Medical Instrumentation (AAMI) Standard ST79.

Ideally, all supplies should be removed from external cardboard shipping boxes prior to being transported to any patient care area. If this is not possible, supplies must be removed from these boxes before being placed into clean and sterile supply rooms on patient care units, in clinics or other ambulatory care locations. Cardboard shipping boxes must then be removed from the unit. Failure to provide space for this activity on the loading dock or on the patient care units can result in dirty, external shipping containers and pallets finding their way into clean and sterile storage areas.

In addition, adequate storage should be available on patient care units for reusable, non-critical patient care equipment such as IV pumps, mobility devices, commodes and IV poles. For these items the questions that need to be asked are:

- Where will this equipment be cleaned and disinfected between uses, and by whom?
- Where will it be stored once cleaned?
- How will staff know when equipment is clean and patient ready?

Options are tagging equipment once cleaned or storing in dedicated rooms or alcoves with clear signage identifying the space as a clean equipment storage location.

While these basic design features might seem to be fundamental, space and budgetary constraints often result in compromises during the design phase and spaces intended for this type of storage are repurposed for additional clinical space or offices. These types of decisions can result in high-risk practices such as storing clean, reusable patient care equipment in a soiled holding room or soiled workroom or leaving it in unit hallways unlabeled with no means of identifying if it is clean or dirty. This becomes an infection risk as staff may use a piece of equipment that has not been cleaned and disinfected. It can also compromise life safety resulting from excessive corridor storage.

To avoid this type of error, the multidisciplinary planning team needs to discuss the best approach to supply and equipment management across the continuum to include the following:

- Purchasing
- Receiving
- Unboxing
- Transport
- Storage
- Use and reuse (including cleaning and disinfection) in the patient care area

Design should include either dedicated space or procedural mechanisms for removing clean supplies from external shipping containers. If equipment will be unit owned and managed, they will need a soiled workroom or soiled utility room where soiled equipment can be taken to be cleaned and disinfected and then moved to a clean space for storage. Another approach is for this equipment to be managed centrally. In this model, used equipment is aggregated in a soiled holding room or soiled utility room and then transported, preferably on a covered cart, to a central location for cleaning and disinfection and then placed back into use.

Other opportunities for cross contamination related to equipment that must be considered and planned for include the reprocessing of reusable instruments or devices that are frequently used in patient care areas, for example, suture sets, ultrasound devices and bronchoscopes. In most acute care facilities these types of devices are routinely used at the bedside on inpatient units or in exam rooms in outpatient locations, yet how they are managed immediately after use is not planned for. This often results in delays in reprocessing and poor compliance with best practices for sterilization and disinfection. Questions that need to be asked include:

- Will devices be used that require sterilization or high-level disinfection, and how will they be collected, contained and transported for reprocessing?
- How will initial steps in reprocessing at the point of use be accomplished?
- Will sterilization facilities be on-site or off-site?
- How will instruments be transported?

If reprocessing will be on-site, the team must ensure that the reprocessing area supports the flow of soiled equipment from dirty to clean without risk of cross contamination. See Chapter 3, Reprocessing, for a more detailed review of this topic. If reprocessing is outsourced, a soiled workroom will need to be designated where initial decontamination and packaging for transport can safely occur. Soiled workrooms are another space that requires negative airflow (air flow from clean to less clean areas***)*** to contain odors and contaminants.

Separation of clean and dirty functions within the patient room also presents a significant challenge. The patient room is considered inherently contaminated as this is where the patient spends the majority of their time and it is well established that surfaces in the patient care environment rapidly become colonized with the patient's flora. This raises the question of where staff will prepare for clean or sterile procedures such as placing intravenous or urinary catheters or setting up a sterile field for dressing changes. Providing stable, cleanable, horizontal work surfaces such as carts or countertops (separated from water sources) can provide these necessary surfaces. In the absence of dedicated work surfaces, staff will use overbed tables or even the bed itself for these purposes. While overbed tables are able to be cleaned and disinfected before use, they are often cluttered with patient belongings and food and drinks. The surface may not be cleared or cleaned adequately to safely use for clean or sterile procedures. Consideration should also be given to adequate storage space for patient belongings such as shelves or cabinets to minimize clutter on surfaces and facilitate ease of cleaning.

As noted in the literature review, safe management of human waste is a challenge both within the patient room bathroom (toilet with bedpan sprayer) and within a soiled utility or toilet room (flush rim sink/hopper). Current methods of waste disposal and bedpan cleaning in many hospitals can result in contamination of both the environment and health care personnel clothing. Some newer approaches to bedpan management can potentially reduce this risk. These methods include:

- The use of disposable, odor blocking sleeve-type bedpan covers to contain and dispose of the waste in regular trash.
- Point-of-care automated bedpan cleaning devices, installed in the patient bathroom, where the waste is discharged directly into the sanitary sewer followed by a cleaning and disinfection cycle.
- Single-use paper-based bedpans or urinals coupled with a macerator disposal system.
- Placement of lids or barrier shields on flush rim sinks/hoppers if used.

Currently little evidence in the literature demonstrates that these approaches to waste disposal reduce healthcare-associated infections. However, ample evidence demonstrates the role of surface contamination in the spread of infection and the impact of effective surface cleaning and disinfection in reducing these infections. Thus, it follows that other methods of reducing surface contamination could also contribute. These new approaches are worth exploring when planning new facilities.

Existing Facilities

Renovation of existing spaces provides an opportunity to update facility infrastructure and improve existing design to incorporate new best practices for infection prevention. If existing conditions and/or budget constraints limit the ability to make physical modifications to spaces, operational changes may be able to reduce the risk of healthcare-associated infections related to the built environment.

When renovating an existing unit or department, consider the following:

- Complete a critical review of existing work flows. New space design should not reflexively recreate existing work flows or spaces.
- At times, a department may be functioning in a space that was not originally designed for the services currently provided. In addition, practice expectations may have changed over time and as a result the existing space doesn't support current best practice.
- Analyze tasks in clinical areas to determine if some design features are barriers to compliance with infection prevention practices and modify if possible; for example, insufficient handwashing sinks or hand sanitizer dispensers.
- If supplies must necessarily be stored next to a sink, install splash guard barriers between sinks and clean supplies.
- If health care personnel persist in storing clean supplies under sinks, replace "drop in" sinks and cabinets with wall-hung sinks or remove cabinet doors and install a panel that is screwed in place that prevents storage but still allows facilities staff access to plumbing.
- Include an infection preventionist in the design discussions. Relying entirely on unit staff for input on work flows can perpetuate incorrect practice as they may not be aware that their current practice is not acceptable.

An example of a practice that is no longer acceptable in ambulatory or outpatient settings is when health care personnel wash instruments in a handwashing sink in the soiled workroom because a separate sink for instrument cleaning was not provided. This practice was not uncommon in the past; however, it is not consistent with current best practice and should be addressed in renovated spaces. If instrument reprocessing is going to continue, a second sink should be added. If this is not possible because of existing conditions, then staff should be instructed to clean and disinfect the sink each time is it used for instrument washing, leaving it clean for hand washing.

An example of a common challenge in the inpatient setting is storage for clean equipment. Before renovating an inpatient nursing unit, consider the following:

- Evaluate current practice for storage of items such as crutches, IV poles and clean commodes. If these are being stored in a shower room with the floor drain covered by plywood or in a back corridor that may be an egress, this is evidence that the unit does

not have adequate clean equipment storage space and may not need a shower room.
- If existing conditions don't allow for the addition of clean equipment storage space, protocols should be developed for identifying clean equipment that is stored in hallways, or the shower room could be renovated to have appropriate finishes and airflow and be converted into an acceptable clean equipment storage room.
- Ensure that where heating, ventilation and air conditioning systems are designed specifically for infection prevention purposes (for example, airborne infection isolation or protective environment rooms, operating rooms and central sterile supply), that the ventilation system provides appropriate pressure relationships, air-exchange rates, filtration efficiencies, relative humidity and temperature and that facility staff monitor and maintain these systems.
- Ensure that policies and procedures are in place for validation of correct airflow for airborne infection isolation and/or protective environment rooms when in use, and that a visual indicator is placed to demonstrate correct airflow.

While isolation rooms in new construction or major renovation must be built as either positive or negative and have a visual indicator that confirms airflow direction, existing facilities may still have rooms that are switchable and can be either positive or negative based on manual activation of directional airflow. If a facility still has these switchable rooms, ensure that:

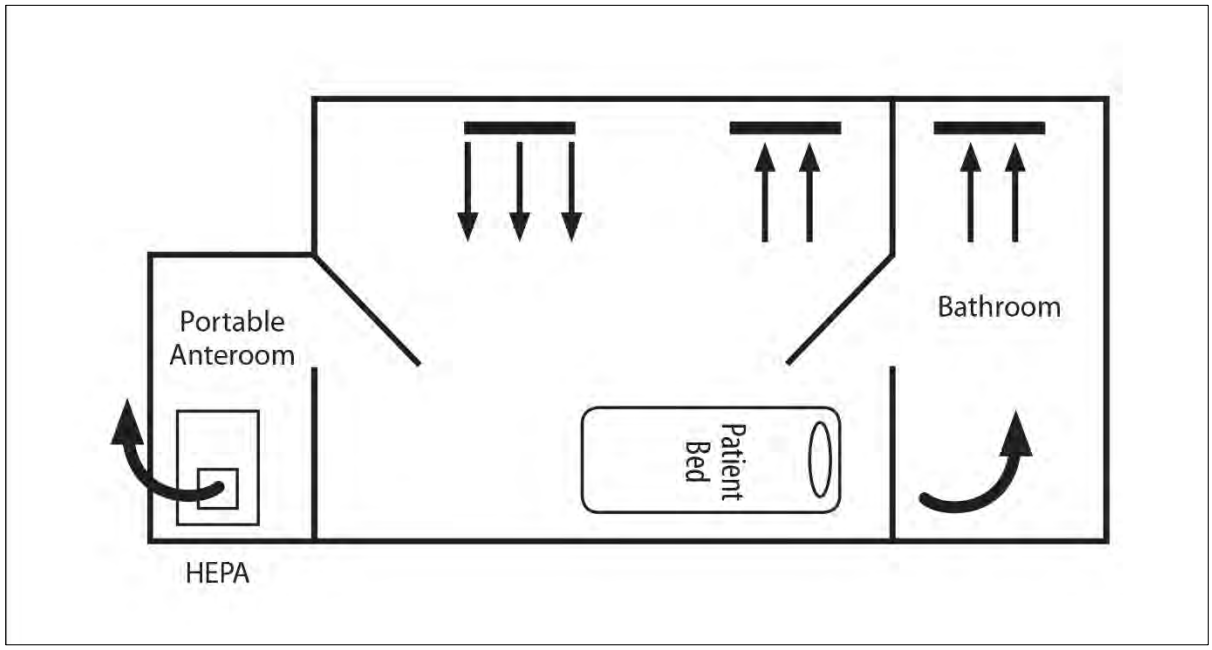
- A clear policy for activation exists.
- Staff understand how to activate the desired airflow.
- A process exists for validating the correct desired airflow direction, either with an installed visual indicator or via a manual test (for example, tissue test, smoke test or use of a differential pressure gauge).

These types of rooms are generally at neutral pressure when not in use as an isolation room.

Per current design standards,[545] isolation rooms may or may not have an anteroom. Anterooms provide a location for both storage and disposal of personal protective equipment and donning and doffing of personal protective equipment. When an anteroom is not included, ensure that staff has access to and a means for disposal of personal protective equipment at entrances to isolation rooms. This is also true for standard patient rooms, as these are used for patients on contact or droplet isolation, neither of which require negative airflow.
As with new construction, existing emergency departments and ambulatory sites should display respiratory hygiene/cough etiquette informational signage, in languages relevant to the communities served, instructing patients and visitors to cover their coughs and to self-identify to triage health care personnel that they have a cough or a fever to facilitate early isolation. Ambulatory sites should also ensure that tissues, alcohol-based hand sanitizer and masks are readily available at triage and in waiting rooms along with waste receptacles for tissue disposal to limit environmental contamination. Operationally they should consider implementing screening tools or clinical decision-making algorithms to identify and isolate infectious patients early in the evaluation process.

In circumstances where there are inadequate numbers of airborne infection isolation rooms in the emergency department or on inpatient units, health care personnel should work with infection prevention and engineering to determine what alternative environmental controls can be implemented to create temporary negative pressure isolation. Detailed guidance on this topic is available from the Minnesota Department of Public Health and include approaches such as the use of portable anterooms (Figure 11) among other techniques.[546]

Figure 11: Example of portable anteroom



Operationally, placing a mask on the patient can temporarily act as a source control mechanism and will isolate the patient until they can be relocated to an appropriate isolation room. In situations where emergency department overcrowding results in patients on stretchers in hallways, ideally health care personnel should prioritize placement of patients known to have multidrug-resistant organisms and/or suspected communicable infectious diseases into single patient rooms or bays to limit opportunities for transmission.

To summarize, best practices related to infection prevention and the flow of patients, personnel, materials and waste for both new construction and renovation will take into consideration the following:

- Identifying, isolating and containing communicable diseases and transmissible infectious agents in the emergency department in a timely manner.
- Ensuring clean spaces (e.g., clean and sterile supply, pharmacy clean rooms, protected environment rooms, operating rooms) and clean supplies are protected from dust, moisture and other contaminants.
- Ensuring the separation of clean and dirty functions to prevent cross contamination and maintain a sanitary environment.

Case Studies

Hospital M: Aiming for all single-bed inpatient rooms and optimizing flow of patients, staff and materials

An academic medical center in a large urban area, Hospital M, is undergoing a major campus transformation. Part of this multiphase, multiyear project is a new 374-bed patient tower. This 830,000-square-foot building is planned to open in 2018 and will connect directly to an existing patient building. The two buildings will work together and connect on new procedural and imaging floors and will then share central sterilization and other support services. Centralizing sterilization allows for standardization of processes, development of a consistently trained and competent staff along with close monitoring of this highly technical function that is critical to patient safety. The new layout will also ensure that the flow of soiled instruments from the operating rooms to central sterile processing will be separated from the delivery of clean instruments and supplies to the operating rooms. Another effort at separating clean and dirty in the design of the new building is on the loading docks where the delivery of clean supplies and linen is separated from the pickup of soiled linen and waste, something which prior to this was all together in one area.

The new building will also offer all single-bed same-handed inpatient rooms and once open will allow for the eventual transition of existing two-bed rooms in the older hospital building to change to single- bed rooms. Aiming for all single-bed inpatient rooms was an overall goal of the project to enhance infection control practices, allow for a more efficient workflow for staff and to better accommodate family and visitors. In addition, each single-bed room will have a point-of-use, automated bedpan waste disposal and sanitizing device installed in the patient bathroom. This will allow for containment of the waste disposal process, minimizing the risk for contamination of surfaces in the patient bathroom and the contamination of staff clothing that occurs when a bedpan is manually emptied into the toilet and rinsed using a hand-held bedpan washing sprayer device. Senior leadership was looking for a solution for waste management to eliminate manual bedpan cleaning in the patient bathroom or the need for staff to walk through a corridor with a bedpan to dispose of waste in a soiled utility room.

Another design feature intended to support staff workflow and optimize infection control is the placement of supply closets immediately outside the patient rooms that will be stocked with a par level of the most used supplies so that they are close by for nurses but not in the room itself. This approach will potentially minimize nursing time gathering supplies and also prevent staff from storing supplies inappropriately in the patient room. Additionally, these cabinets will contain locked medication which means that the pharmacy will be able to restock the shelves without entering the patient rooms, thereby eliminating disturbance to the patient and reducing unnecessary visits to the patient room. Alcohol-based hand rub is placed nearby to enable and encourage hand hygiene immediately before touching supplies.

One-hundred percent of patient rooms have no privacy curtains as the decision was made early on to eliminate privacy curtains wherever possible as they are known to become contaminated with pathogenic bacteria. Acute patient rooms are afforded privacy by the closing of the room entry translucent glass sliding door either fully or partially. On the ICU floors the sliding doors have electronic glass, which when activated is clear, and when not is opaque, thus fulfilling the visibility requirements into the room, and allowing for the privacy requirements when requested.

Under the direction of the hospital epidemiologist, the design of the room entry/exit was also arranged to support best practice on entry/exit by providing space for disposal of personal protective equipment and linen and access to a sink and hand sanitizer at the room entry/exit. Additionally, a staff terminal station is strategically located so the nurse is able to notify others that the room is ready for cleaning, turnover, bedding change or other.

Another element within the room being considered is the patient controls where the patient can control their environment from a single source. In this case it is an “I-pad”- like device the patient can use to control the thermostat, the lighting and the solar shade. They can also order their meals, select educational videos and speak to their caregivers. This approach provides autonomy for the patient and may also decrease the number of times that staff may contact high touch surfaces such as light switches. These devices will be either decontaminated between patients in a disinfecting charger station or if an economical version can be found, it may be given to the patient at discharge.

Eventually in the final configuration, travel paths will separate patients from the flow of staff and materials and also ensure that patients are not routinely transported through public hallways to afford more patient privacy when they are being transported to test or procedures.

Case Study N: "All-hazards" disaster planning

A well-known research initiative known as "Project ER One" at the Washington Hospital Center in Washington, D.C. looked at emergency department (ED) design strategies to deal with the medical consequences of disasters, epidemics and terrorism. While Project ER One never led to the actual construction of the proposed ED that was developed, a significant "menu" of concepts was developed. As a demonstration project, a 10-bed ED addition was built that incorporated many of the ER One design concepts that came from the research into half of the rooms to compare the design features of the ER One concepts to standard room design over time. The space became known as both the literal and metaphorical "Bridge to ER One" as it was built in an area that would have been an actual bridge to the site where the new ED would have been built. The Bridge to ER One area has been open since 2008 and has increased from 10 beds to 14 and is still used as a living lab.

Rooms were made intentionally large with two headwalls to have the ability to flex from single to double rooms as needed to accommodate more than one patient during a surge event. While this was a design feature intended to facilitate a response to a surge event, increasing volume has over time caused these rooms to routinely be used as 2-bed rooms. One room was built with a boom with multiple medical gas and power outlets able to support up to 5 patients in the event of a large surge. The boom is able to be pushed off to the side for standard occupancy. The entire area was designed to have the ability to be isolated from the rest of the hospital; in addition, each individual room was designed to be capable of being made negative pressure. This was particularly useful during the 2014 Ebola outbreak as this was the area where persons under investigation (PUI) for Ebola were evaluated. The intervention rooms also included an attached bathroom which makes them desirable when evaluating patients with gastrointestinal symptoms. A point of care laboratory was also included in preparation for being able to potentially test patients with a highly infectious disease without sending specimens through the hospital's tube system.

Non-intervention rooms were built with standard finishes such as vinyl flooring, painted walls, standard textiles and standard drop-in sinks and millwork. Intervention rooms were built to facilitate ease and thoroughness of cleaning with solid surface walls, seamless poured rubber flooring and a one-piece seamless sink and apron. In addition, equipment was kept up off the floor. Antimicrobial curtains were also used in these rooms initially, however over time it was too difficult to keep track of these curtains and ensure they were placed back in the correct rooms after laundering. An ER One concept that was considered but was not successfully implemented was the placement of ports into each intervention room into which hydrogen peroxide vapor would be introduced to terminally disinfect a clean room. As an alternative, the facility has a contract with a vendor that provides hydrogen peroxide disinfection on a routine basis.

What was learned from the intervention rooms was that they were able to be cleaned in half the time of standard rooms, and when rooms were audited using a marker to assess effectiveness of cleaning, the marker was removed more effectively and more high touch surfaces were consistently cleaned. Facility staff have also determined these rooms are much easier to maintain as the solid wall surfaces are reparable and do not require frequent patching and painting as sheetrock walls do. Staff has also learned that patients prefer these rooms as they are more modern looking, are quieter and have an attached bathroom. Because of the ease of cleaning and the dedicated bathroom, intake staff actively triages to these rooms potentially infectious patients such as those with gastrointestinal illness, flu symptoms, fever or rash.

The other major design change in the ER One areas was the nurses station. The process for design was based on development of a “mock-up” and evaluation and feedback from staff. The existing bullpen design was crowded and inefficient. The updated design turned the bullpen inside out, with nurses on one side and physicians on the other, which improved verbal and visual communication. Staff enjoyed working in this test area so much that since then the nurses station in the main ED has been renovated to match the Bridge to ER One area.

Tools

The following resources are available to help groups planning for design, construction and renovation of health care facilities. These groups include architects, engineers, infection preventionists, hospital administrators, facility directors, users and others.

Texts

- Facility Guidelines Institute. (2014). *Guidelines for Design and Construction of Hospitals and Outpatient Facilities.* Purchase from http://www.fgiguidelines.org/
- ASHRAE. (2013). ANSI/ASHRAE/ASHE Standard 170-2013: *Ventilation of Healthcare Facilities* (included as Appendix to 2014 FGI *Guidelines* or as a stand-alone document). Purchase at https://www.ashrae.org/resources--publications/bookstore/health-care-facilities-resources.
- American Society for Health Care Engineering. (2013). *HVAC Design Manual for Hospitals and Clinics.* Purchase from https://www.ashrae.org/resources--publications/bookstore/hvac-design-manual-for-hospitals-and-clinics
- Association for Professionals in Infection Control and Epidemiology. (2015). *Infection Prevention Manual for Construction and Renovation.* Purchase from http://www.apic.org/APICStore/Products/Product?id=SLS9808
- APIC. (2014). Text of Infection Control and Epidemiology, chapters 112 to 116. Purchase from http://www.apic.org/APICStore/Products/Product?id=SLSTXT14
- Huddy, J. (2016, April). *Emergency Department Design: A Practical Guide to Planning for the Future*, Second Edition., Atlanta, GA: American College of Emergency Physicians.

Checklists

- Center for Healthcare Design. (2015, August). Patient Room Design Checklist and Evaluation Tool. Retrieve from https://www.healthdesign.org/insights-solutions/patient-room-design-checklist-and-evaluation-tool.
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CDC Guidelines

- 2003 Guidelines for Environmental Infection Control in Health-Care Facilities. Retrieve from http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_hcf_03.pdf
- 2007 Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings. Retrieve from http://www.cdc.gov/hicpac/pdf/isolation/Isolation2007.pdf

- 2014 Infection Prevention and Control Recommendations for Hospitalized Patients Under Investigation (PUIs) for Ebola Virus Disease (EVD) in U.S. Hospitals. Retrieve from http://www.cdc.gov/vhf/ebola/healthcare-us/hospitals/infection-control.html
- 2015 Interim Guidance for Environmental Infection Control in Hospitals for Ebola Virus. Retrieve from http://www.cdc.gov/vhf/ebola/healthcare-us/cleaning/hospitals.html

Miscellaneous Resources

- Minnesota Department of Public Health. (2007, February). Airborne Infectious Disease Management: Methods for Temporary Negative Pressure Isolation. Retrieve from http://www.health.state.mn.us/oep/training/bhpp/airbornenegative.pdf
- National Ebola Training and Education Center http://netec.org/
- U.S. Pharmacopeial Convention (USP) http://www.usp.org/reference-standards

Chapter 6 Appendix A: Summary of Recommendations for New Construction

Identifying, isolating and containing communicable diseases and transmissible infectious agents in the emergency department
1. Complete an infection control risk assessment (ICRA) during the planning phase; include infection prevention staff as part of a multidisciplinary planning team.
2. Complete a threat and vulnerability analysis to understand potential threats and vulnerabilities in the region and the facility's' role in response to events.
3. Review literature on emergency department design. Analyze current emergency department volume and work flows with a goal of linking processes to design to facilitate patient flow.
4. Consider locating airborne infection isolation rooms (negative pressure) near triage at points of entry; ensure space for storage of personal protective equipment and an area to safely don and doff personal protective equipment.
5. Consider designing an airborne infection isolation room/area that enables unidirectional flow of health care personnel entering/exiting for patients with highly infectious diseases.
6. Incorporate planning for a surge of infectious patients by creating flexible spaces and spaces where airflow can be made negative to adjacencies.
7. Consider identification of dedicated entrances and quarantine areas for the management of infectious patients in epidemic situations.
8. Consider mechanisms to establish separation from other areas with measures such as controlled access and heating, ventilation and air conditioning systems that maintain the area under negative pressure. These systems should be independent from other systems with redundancy to ensure negative airflow is maintained.
9. Consider location of the ambulance entrance in terms of security, ability to isolate the area, plans for decontamination and space for emergency medical services to remove personal protective equipment and dispose of waste.
10. At a minimum, comply with existing guidelines[2] for emergency department design which require that waiting rooms and triage areas be negatively pressurized with respect to adjacent areas. Consider including a separate dedicated waiting area for patients with a febrile, cough or rash illness (or an area that can be converted to this function as needed).
11. Evaluate optimal locations and display options for placement of respiratory hygiene/cough etiquette informational signage, in languages relevant to the communities served that instructs patients and visitors to cover their coughs and to self-identify that they have a cough or a fever. Ensure that tissues, alcohol-based hand sanitizer and masks are readily available along with a waste receptacle for tissue disposal.
Protect clean spaces and clean supplies from dust and moisture
1. Ensure "clean" spaces meet published design criteria for pressurization, air changes per hour, temperature and relative humidity (where required) and that heating, ventilation and air conditioning systems, including filters and filter racks, are monitored and maintained.
2. Ensure that staff understands the airflow design, how to interpret the visual indicators used and the importance of keeping doors closed to maintain pressurization.
3. Include pharmacists and designers with expertise in United States Pharmacopeia standard 797 & USP 800 requirements when designing pharmacy clean rooms and locate them off clean corridors.
4. Review current literature on operating room design[18] and ensure heating, ventilation and air conditioning (HVAC) design meets recommendations[1] for air supply and return locations and other HVAC parameters, taking into consideration location of equipment in the room.

5. Use human factors engineering methods to analyze tasks as they are performed in existing spaces. Ask “what design features contribute to the lack of compliance?” Work with health care personnel to design spaces/systems that support efficient work flows for health care personnel to access clean supplies while still protecting clean and sterile supplies from contamination.
Ensure the separation of clean and dirty functions to prevent cross contamination and maintain a sanitary environment
1. Include space for accumulation/holding of regular and medical waste, adequately sized to the needs of the unit, located away from flow of staff/patients.
2. Keep bulk waste storage carts clean and stored in an area separated from patient care, in a dedicated soiled holding room with negative airflow.
3. Ensure that the delivery of clean materials (e.g., medical supplies and clean linen) is separated from the process of waste removal on the loading dock.
4. Provide space for removal of supplies from external shipping boxes (e.g., on loading dock or other dedicated space) prior to being transported to any patient care area. Items delivered to the surgical suite should be transported in a manner that preserves package integrity and protects items from contamination.
5. Ensure adequate storage on patient units for reusable, patient care equipment (e.g., IV pumps, mobility devices, commodes). Determine where equipment will be cleaned/disinfected and by whom, and where it will be stored. Ask, how will staff know when equipment is clean and patient ready?
6. Ask, will devices be used that require sterilization or high-level disinfection and how will they be collected, contained and transported for reprocessing? Will initial steps in reprocessing occur at the point of use and will sterilization facilities be on or offsite? Ensure appropriate soiled utility space for pre-cleaning if needed.
7. Explore new technology or simple containment approaches for the disposal of human waste.

Chapter 6 Appendix B: Summary of Recommendations for Existing Facilities

1. When renovating an existing unit or department, complete a critical review of existing work flows and include an infection preventionist in the design discussions
2. Analyze tasks in clinical areas to determine if there are design features that are barriers to compliance with infection prevention practices and modify if possible, e.g., insufficient handwashing sinks or hand sanitizer dispensers
3. If supplies must necessarily be stored next to a sink, install splash-guard barriers between sinks and clean supplies.
4. To eliminate storage under sinks, replace “drop in” sinks and cabinets with wall hung sinks or remove cabinet doors and install a panel that is screwed in place to allow facility staff access to plumbing.
5. Ensure that heating, ventilation and air conditioning systems designed specifically for infection prevention purposes (e.g., airborne infection isolation or protective equipment rooms, operating rooms and central sterile supply) provide appropriate pressure relationships, air-exchange rates, filtration efficiencies, relative humidity and temperature and that facility staff monitors and maintains these systems.
6. Ensure that policies and procedures are in place for validation of correct airflow for airborne infection isolation and/or protective environment rooms when in use and that a visual indicator is in place to demonstrate correct airflow direction.
7. If switchable isolation rooms (positive and negative) still exist, ensure that staff understands how to activate positive or negative airflow if rooms must be manually activated and that there is a process for validating airflow direction.
8. Ensure that staff has access to and a means for disposal of personal protective equipment at entrances to the rooms of patients requiring isolation.
9. In circumstances where there are inadequate numbers of airborne infection isolation rooms in the emergency department or on inpatient units, work with infection prevention and engineering to determine what alternative environmental controls can be implemented to create temporary negative pressure isolation.
10. In situations where emergency department overcrowding results in patients on stretchers in hallways, prioritize placement of patients known to have multidrug-resistant organisms and/or suspected communicable infectious diseases into single patient rooms or bays.
11. Post respiratory hygiene/cough etiquette informational signage, in languages relevant to the communities served, that instructs patients and visitors to cover their coughs and to self-identify that they have a cough or a fever. Ensure that tissues, alcohol-based hand sanitizer and masks are readily available along with a waste receptacle for tissue disposal.

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