

Current views of health care design and construction: Practical implications for safer, cleaner environments

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Infection preventionists (IP) play an increasingly important role in preventing health care-associated infection in the physical environment associated with new construction or renovation of health care facilities. The *Guidelines for Design and Construction of Hospital and Healthcare Facilities, 2010*, formerly known as "AIA Guidelines" was the origin of the "infection control risk assessment" now required by multiple agencies. These Guidelines represent minimum US health care standards and provide guidance on best practices. They recognize that the built environment has a profound affect on health and the natural environment and require that health care facilities be designed to "first, do no harm." This review uses the Guidelines as a blueprint for IPs' role in design and construction, updating familiar concepts to the 2010 edition with special emphasis on IP input into design given its longer range impact on health care-associated infection prevention while linking to safety and sustainability. Section I provides an overview of disease transmission risks from the built environment and related costs, section II presents a broad view of design and master planning, and section III addresses the detailed design strategies for infection prevention specifically addressed in the 2010 Facility Guidelines Institute edition.

Key Words: Health care design; construction; ventilation; water quality; operating room design; sustainability.

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INTRODUCTION

Infection preventionists (IP) are integral members of the team of professionals who design, construct, operate, and work in health care facilities. IP's subject matter expertise on prevention of cross transmission and design/operations of facilities aimed at safety of all occupants in the built environment initially led to the foundation of the infection control risk assessment (ICRA) process. The ICRA grew out of concern related to increasing reports of health care-associated infections (HAIs) caused by construction/renovation in facilities. Details of this have been reviewed elsewhere.¹

Despite a dramatic economic downturn in the US economy in 2008-2009, predictions point to resumption of construction/renovation at US health care facilities over the decade ahead.² This forecast plus increasing focus on prevention of HAIs are key developments that will call on continued expansion of the IP's scope of practice.³ This scope will include oversight of containment of microorganisms and contaminants under the ICRA but increasingly emphasize more proactive involvement in design of the environment of care (EoC) from concept to occupancy.⁴ This review will focus on the IP's expanding role in the development and operations of the built environment in the 21st century.

OVERVIEW OF DISEASE TRANSMISSION RISKS FROM THE BUILT ENVIRONMENT

Disease transmission risks

Air. Although the actual percentage of HAIs directly related to construction is unknown, the morbidity, mortality, and costs of mitigation are considerable. Vonberg and Gastmeier reviewed outbreaks of infection caused by *Aspergillus* spp and found that almost half were associated with construction or renovation in hospitals.⁵ In addition, a dose of only 1 colony forming unit/m³ was needed to cause infection in immunocompromised patients and highlights the critical need for isolation and containment of construction activities from other occupied spaces. Other pathogens transmitted during

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construction include *Bacillus* spp; *Legionellae*; other fungi including *Scedosporium*, *Histoplasma*, *Mucorales* (eg, *Rhizopus* spp); and moulds such as *Fusarium* spp and *Penicillium* spp.⁶⁻⁸ The latter can proliferate in moist environments (eg, water-damaged wood) and can cause infection when disturbed or removed.

Water. The reservoir of microbes of pathogens present in potable water and its delivery network are vast. These include gram-negative bacteria, eg, *Legionellae* and *Pseudomonas* spp, nontuberculous *Mycobacteria*, protozoa, and fungi.⁸ Disruption of water utility systems during construction or renovation can disrupt the biofilm present in water delivery pipes, posing a threat to patients, including those far away from an active construction zone.⁹ In addition, changes to the water distribution network from construction often creates dead ends where water stagnates, allowing microbes in the water to grow to very high concentration. Use of water as an architectural element also has been associated with disease transmission.¹⁰

Hota et al recently described release of planktonic bacteria, *P aeruginosa*, from handwashing stations in single occupancy intensive care unit (ICU) rooms as a cause of an outbreak of life-threatening infections.¹¹ This demonstrated that water can also directly contaminate the patient, equipment, and surfaces in an area and result in cross transmission. The IP can apply this evidence to assure both design and operational aspects incorporate strategies to protect the patient against waterborne infections.

Environmental surfaces and patient care equipment. The relative importance of the inanimate environment as a reservoir of organisms has undergone renewed emphasis, given the emergence of a wide range of microorganisms including multidrug-resistant organisms (MDROs) present in health care settings. Presence of MDROs on surfaces that appear relatively clean and transfer of these on hands of personnel has been described.¹² However, the presence of MDROs in the environment does not necessarily mean cross transfer to the patient will occur. Hardy et al found that only 35% of methicillin-resistant *Staphylococcus aureus* (MRSA) isolates recovered from the environment matched genetically to the strain recovered from patients.¹³ Therefore, the steps in cross transmission are more complex than mere presence of a MDRO.

The bioburden of an inpatient room has been studied given the concern over environmental reservoirs of MDROs. Huang et al found admission to a room previously occupied by a patient with MDROs increases the likelihood of acquisition of these organisms by subsequent patients.¹⁴ More recently, Hamel et al describe increased risk of acquisition and cross infection of 2 key MDROs and *Clostridium difficile* to roommates in multibed patient rooms.¹⁵ Equipment and devices used to

support electronic health records can also become contaminated with microbes; however, Lu et al demonstrated that the concentration of this contamination is low and often unrelated to strains recovered from patients.¹⁶ These investigations highlight the increasing importance of the inanimate surface and the need to assess risks and use of design features to enhance patient safety.

Construction trends and changes in health care delivery in US hospitals

Annual construction and design cost. United States trends indicate a continued major expenditure in health care construction and renovation even with economic downturn in 2008-2009. Changes in patient acuity, aging, and reduced capitol funds have affected construction expenditures in a number of ways. Recent trends show that dollars are spent primarily on inpatient specialty beds (eg, cardiac and cancer) along with increasing demands for assisted-living and skilled nursing centers. Construction for hospitals and clinics in the fourth quarter of 2008 totaled \$40.7 billion with three quarters of projects involving either expansion or renovation.¹⁷ Interestingly, among the top 5 design features incorporated into patient room design was an in-room handwashing sink (almost 50% of new construction), separate from that in the bathroom attached to the room. Looking ahead, there will likely be a stabilization in construction activities with modest growth as noted earlier, but the economic constrains may lead to a drop in the total square footage of built environment for the next several years.

Planning for future needs. The increasing age of US health care facilities generates a constant need for repair, remediation work (cabling, room additions), or replacement. These processes increase risks of environmental contamination, affecting air and water quality and sustainability.

Planning for surge capacity. Planning for surge capacity needed for potential airborne infectious agent releases or a major influx of patients with communicable disease such as an influenza pandemic is also challenging with increased numbers of single or variable acuity patient rooms. Some institutions include extra utilities, so some rooms, including ICUs, have essentially 2 head walls with duplicate utilities needed for such critical circumstances that could require 2 patients in each room.

DESIGN AND MASTER PLANNING SAFETY AND INFECTION PREVENTION

Design layout trends

New elements being incorporated into design and master planning of health care facility construction

include technology-driven features such as wireless devices for communication, devices for order/entry into electronic health record, and newer methods for imaging and procedures. Other trends include individual room temperature control and larger room size for single-patient rooms.²

Designs aimed at environmental sustainability are also being used in over 80% of active projects based on a survey from 2008, and this is likely to continue.² These green design features include enhanced efficiency of heating, ventilation, and air conditioning (HVAC) systems; building utilities (power and water); surface and finish treatments that lessen use of volatile organic compounds; and use of natural lighting, low-emission glass, and waste reclamation. Contractors frequently reclaim/recycle materials produced during demolition.

Addressing economic challenges while maintaining quality and safety of patient care has led to increasing use of Six Sigma Lean methods and principles. The goal of Lean is to create maximum value for patients by reducing waste through improved quality, efficiency, and safety. It employs a range of performance assessment and improvement tools and depends heavily on data-driven decision making. Lean principles have been adopted widely by health care planners and are increasingly making an impact on design of the built environment, supporting the goal of increased efficiency and waste elimination.¹⁸

Ulrich et al have summarized available evidence and added the term “evidence-based design” to the lexicon of persons interested in design of the built environment.¹⁹ This concept is familiar to IPs given the emphasis on application of evidence to prevent HAIs and the notable HAI prevention successes that have been achieved in a variety of settings.²⁰⁻²² Table 1 summarizes the relationship between design elements and outcomes of care illustrating the need to apply scientific evidence, when available, to improve care.¹⁹ Details of select design trends are outlined below.

Patient-centered care. Patient-centered care has emerged as the norm in acute care settings. As a result, hospitals have adapted the EoC to accommodate increasing presence of family and other visitors, including lessening of restrictions in visiting hours. In lieu of this trend, the American College of Critical Care Medicine and the Society of Critical Medicine have published recommendations to support family involvement in care of their critically ill loved ones.²³ Many of these impact EoC design and include the following:

- Open visitation but determined collaboratively between caregivers and family;
- single-bed rooms with space for families; and

- opportunity to participate in patient care rounds by clinical personnel.

Universal or acuity adaptable and single occupancy patient care rooms. Introduction of the concept of a “universal” or “scalable acuity” room—defined here as the ability of the environment to accommodate a variety of patients, including those who are critically ill—minimized the need for multiple room transfers.²⁴ Evidence supports this concept because transfer of critically ill patients can increase risk of ventilator-associated pneumonia.²⁵ There has been a parallel movement to decentralize nursing care to facilitate close proximity of the nurse to the patient.²⁶ Decentralization has resulted in creation of units in a “racetrack” configuration: single occupancy rooms on the periphery of a common corridor with workstations (including viewing windows) in between every 2 rooms, increased entry of natural lighting, and zones of space dedicated for personnel and family.

Single occupancy room. The Facility Guidelines Institute (FGI) Research committee commissioned a study led by Chaudhury et al to assess the benefits of single-patient rooms as a design element.²⁷ Key findings from their literature review included improvements in patient care, a reduction in the risk of cross infection, and greater flexibility in operation. “First costs” of the single-patient room were found higher compared with multibed rooms, but benefits for safety and comfort of the patient over the life of this room balance this up-front investment. Other benefits such as enhanced privacy/noise abatement, support for patient-centered care, fewer room-to-room transfers, flexibility with adaptable acuity, and spatial separation to mitigate cross transmission of pathogens have been described.²⁸

More recent evidence has found infection prevention benefits from use of single-patient rooms. Bracco et al identified that the risk of acquiring pathogens such as MRSA, *Pseudomonas* spp, and *Candida* spp was lower for those cared for in private compared with open ward or multibed rooms.²⁹ Others replicated this finding for select pathogens.^{30,31} Rushton et al, using computer modeling of cross transmission of 5 pathogens, found that contact with colonized/infected patients by personnel and the number of patient-bed movements were important predictors of transmission for all pathogens, except for *Pseudomonas* spp.³² Hardy et al provided indirect support for private rooms, showing that the number of roommate exposures per day was associated with acquisition of MRSA, vancomycin-resistant *Enterococcus* (VRE), and *Clostridium difficile*.

The literature on single-patient rooms is not conclusive, however. Others have not found an association

Table 1. Summary of the relationships between design factors and health care outcomes

Design strategies or environmental interventions	Single-bed rooms	Access to daylight	Appropriate lighting	Views of nature	Family zone in patient rooms	Carpeting	Noise-reducing finishes	Ceiling lifts	Nursing floor layout	Decentralized supplies	Acuity-adaptable rooms
Health care outcomes											
Reduced hospital-acquired infections	**										
Reduced medical errors	*		*				*				*
Reduced patient falls	*		*		*	*			*		*
Reduced pain		*	*	**			*				
Improved patient sleep	**	*	*				*				
Reduced patient stress	*	*	*	**	*		**				
Reduced depression		**	**	*	*						
Reduced length of stay		*	*	*							*
Improved patient privacy and confidentiality	**				*		*				
Improved communication with patients and family members	**				*		*				
Improved social support	*				*	*					
Increased patient satisfaction	**	*	*	*	*	*	*				
Decreased staff injuries								**			*
Decreased staff stress	*	*	*	*			*				
Increased staff effectiveness	*		*				*		*	*	*
Increased staff satisfaction	*	*	*	*			*				

*Indicates that a relationship between the specific design factor and health care outcome was indicated, directly or indirectly by empirical studies reviewed in this report.

**Indicates that there is especially strong evidence (converging findings from multiple rigorous studies) indicating that a design intervention improves a health care outcome.

between frequency of cross transmission and HAIs, duration of hospitalization, or use of devices, suggesting there are other factors such as the patient's endogenous flora and underlying disease(s) that contribute to risk of infection.⁵³ In addition, Hota et al described an outbreak in an ICU wherein all rooms were single-patient occupancy, but the design of the handwashing station inside the room represented a reservoir for infection.¹¹ Overall, the single-patient room is likely to remain a significant design element and remains a minimum requirement in the FGI's 2010 Guidelines.⁵⁴

Environmental sustainability and leadership in energy and environmental design. Motivated by growing public interest in environmental sustainability, most construction has incorporated green principles into construction and renovation projects. The components include planning energy and resource-efficient principles into design and management of facilities as part of an overall environmental stewardship. Green facilities are cost-effective over the life use of a building because they operate more efficiently and use less water, fossil fuels, and materials. Safer materials, natural daylight, and improved air quality improves worker performance and reduces absenteeism.

Leadership in Energy and Environmental Design (LEED) was developed by the US Green Building Council, which provides third-party verification that a construction project was designed and built using environmental sustainability strategies. The certification process promotes accountability and greater attention to sustainability issues among contractors, building owners, and building occupants.⁵⁵ Once built, green concepts also have been developed to support principles of sustainability during operation of a facility. Details of these operational aspects have been published.^{36,37} Sustainability concepts are now standard and considered in the ICRA discussed elsewhere, such as selection of materials supporting sustainability, safety, and infection prevention. Expectations today presume that IPs can and will assist ICRA panels in resolving potential conflicts between "green and clean."

However, LEED concepts must be approached with some caution because of lack of evidence for certain infection-related outcomes. For example, water collection reservoirs are subject to freezing, leakage, and maintenance problems. Facilities are currently learning the challenges as well as rewards of green design. Similarly, IPs must monitor the impact of new designs on ventilation as well as water quality and publish the lessons learned as well as successes.

HVAC: ventilation designs

Operating room HVAC. The 2006 and 2010 editions of the FGI Guidelines recommend that operating rooms

(ORs) be designed so that primary nonaspirating supply diffusers provide airflow that is *unidirectional* and moves vertically downward with *average velocity* 25 to 35 cubic feet per minute (CFM) per square foot or 25 to 35 cfm/ft² (127 L/s/m² to 178 L/s/m²). (This is not the same as high velocity laminar airflow.) Supply diffusers need to be concentrated to provide this airflow pattern over the patient and surgical team.³⁸ The area of the primary supply diffuser needs to extend a minimum of 12 inches (305 mm) beyond the footprint of the surgical table on each side. **Figure 1** visually demonstrates this design.³⁰ The foundation is based on landmark studies using computational fluid dynamics (CFD), or airflow modeling, to assess dispersion of particles (which include contaminants such as microorganisms) in the OR. The power of CFD studies is that several variables can be modified and the impact of each can be studied in detail as compared with challenges for this control in a real world OR. The OR CFD analysis found that a significant effect of the heat from both the patient and other devices creates a thermal plume that actually prevents deposition of particles into the surgical site. In addition, using this analytical tool, the study found that increasing the number of air changes/hour did not improve protection of the site because deposition requires that particles must be released close to the site. Parameters of this design include maintaining positive pressure with respect to all adjoining spaces. Optimal location of returns (exhaust) vents is spacing 2 low sidewall vents at opposite corners with the bottom of these grills installed approximately 8 inches (203 mm) above the floor.

Airborne infection isolation room and protective environment. Airborne infection isolation room and protective environment (PE) are addressed in detail in other publications (eg, Association for Professionals in Infection Control and Epidemiology, Inc [APIC] text) and will not be detailed in this review. Recent work, however, reinforces the importance of a tightly sealed room in the "bundle of elements" essential for PE rooms to truly protect patients, along with monitoring.^{39,40}

Alternative HVAC designs

Displacement ventilation. Displacement ventilation (DV) has been under active investigation as an alternative to traditional mechanical or overhead ventilation (OHV) in health care facilities. DV and OHV have equivalent filtered air sources but distribute the air differently. OHV systems generally supply air from the ceiling, resulting in a mechanical mixing at relatively high velocity of all air inside a room. DV, by contrast, introduces air at low velocities and at a low level on the sidewalls of the room and has been used in

commercial buildings. This design uses natural buoyancy and convective forces (created by heat sources such as people, lighting, equipment, and others) to move contaminants and heat upwards from the occupied zone to the return located in the ceiling. The driver for DV is reducing initial capital and operational costs, improving energy expenditure, environmental comfort, ventilation effectiveness, and controlling airborne particulates.

A 2-phase research study that utilized CFD modeling has been completed on the benefits of DV.⁴¹ The results are being presented in support of an amendment to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers' (ASHRAE) health care ventilation standard 170, clarifying that the standards do not preclude the use of DV as a design strategy for mechanical engineering HVAC design in health care.⁴² Although 2 pilot tests have been conducted on patient rooms, practical applications or unintended consequences if used on a large scale remain a concern. A number of large architectural/engineering firms have suggested that large clinical tower projects incorporate such ventilation changes as a benefit for infectious disease control. However, if IPs are not involved during the ICRA process, serious consequences can occur. For example, recent studies demonstrate that air movement and air transit time are affected when return/exhausts are blocked. Consideration must be given to providing free space in a wall that would deliver the air-flow without being blocked. IPs could suggest simple solutions such as requiring the inclusion of brackets to prevent blockage of the return/exhaust grills. It is likely that DV will gain support over the next decade because it supports sustainability principles in energy conservation and must, therefore, include IP involvement.

Natural ventilation. Natural ventilation (NV), meaning using outdoor air to change and condition indoor air, has been considered for some occupancies. Except for a few temperate climates found in several regions in North America, the severe climatologic changes preclude use of this in most facilities. Some evidence exists demonstrating that NV can be used to promote removal of airborne contaminants in buildings that lack traditional OHV systems.⁴³ This applies, most typically, to facilities located in under-resourced countries. The World Health Organization (WHO) has published a guideline on control and prevention of tuberculosis (TB) in facilities that discusses mechanical ventilation (MV) and NV.⁴⁴ Specifically, the WHO recommends that the choice of ventilation system be based on facility assessment and informed by local climatic, programmatic, and socioeconomic conditions. Simple NV can be optimized by maximizing the size of window openings and locating them on opposing walls for

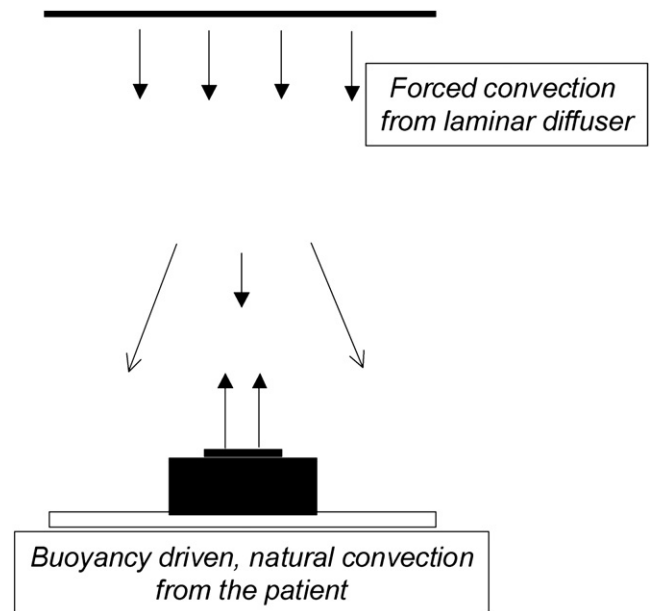


Fig 1. Dominant driving forces in OR affecting surgical site.

facilities located in countries lacking resources to operate mechanical ventilation systems. It is unlikely that NV will be utilized in US acute care facilities because it compromises building envelope integrity, allowing in nonfiltered air with outdoor air contaminants such as fungal spores. In addition, NV is not compatible with modern life safety and infection prevention principles.

DESIGN STRATEGIES: PREVENTION OF CONSTRUCTION-ASSOCIATED HAI AND FGI

Facility guidelines: blueprint for enhancing infection prevention in design

Introduction. The original *General Standards of 1947* used as regulations for the Hill-Burton program have evolved into today's *Guidelines for Design and Construction of Hospital and Healthcare Facilities, 2010*, under the guidance of the FGI founded in 1998 to ensure a process to keep the Guidelines current.³⁴ The change to "FGI Guidelines" highlights the multidisciplinary aspect of the 116 member "Healthcare Guidelines Review Committee" (HGRC)—the group that carries out the revision through consensus. The HGRC steering committee has always included an infection prevention expert representative.

Framework for health facility design. The Guidelines recognize that the built environment has a profound effect on health, productivity, and the natural environment and require as a minimum standard that health care facilities be designed within a framework

that recognizes the primary mission of health care, including “first, do no harm.” The Guidelines consider the larger context of enhanced patient environment, employee effectiveness, and resource stewardship, identifying broad issues that must be considered by all facilities, and requires IPs to be included early in the planning and implementation process, well before the ICRA requirements for specific projects.

Key 2010 guidelines update for infection prevention and control

The summary of changes is provided in terms of the Guideline organization into 6 parts according to facility type. Changes made in hospitals affecting infection prevention have been aligned in the other facilities, as applicable, so only selected Parts are addressed here.

Part I: general. “Part I: general” addresses issues applicable to *all* health care projects and facility types and includes a reorganized ICRA and new risk assessments involving IPs based on the ICRA; namely the Patient Safety Risk Assessment or PSRA, and the Patient Handling and Movement Assessment or PHAMA. During the programming phase, a PSRA panel must identify specific physical hazards, the likelihood of their occurrence, and the degree of potential harm to patients; this panel interfaces with ICRA panel and must produce a report on features of design. The PHAMA panel also calls for IP involvement and is a major element of all new designs as more portable and permanent patient handling and movement equipment is being added to the health care environment.

Part 2: hospitals. “Part 2: hospitals” includes new and significantly revised material of IP interest. Chapter 2.1 (Common Elements) provides new language on handwashing station and sink design with special attention to environmental surfaces and general requirements for design and ventilation of airborne infection isolation rooms (AIIR). Chapter 2.1 (General Hospital) includes PE revisions, introduces the term “combination AII/PE room,” and clarifies the design of stem cell transplant units.

Parts 3-5 repeat the same key issues noted in Parts 1, 2, and 6 as appropriate to setting.

Part 6: ventilation of health care facilities. One monumental change in the 2010 edition is the incorporation of the 2008 edition of American National Standards Institute/ASHRAE/American Society for Healthcare Engineering Standard 170: Ventilation of Healthcare Facilities into the 2010 FGI the Guidelines.⁴² The HGRC voted to retire the Guidelines ventilation table, partner with the ASHRAE, and adopt ASHRAE’s Standard 170 (S.170) along with all subsequently issued addenda as a part of the Guidelines. This removes having 2 standards addressing identical design issues and

any potential for significant conflict. S.170, part of the Guidelines, is now the standard on health care ventilation systems. The committee revising S.170 includes HGRC members, particularly clinical and IP representatives, to ensure alignment with evidence-based, infection-related guidelines. Some elements of the FGI Table 2.1-2 not yet incorporated into S.170 are listed in an abbreviated FGI Table 2.1-2.¹²

Design elements

ICRA. The overarching theme of infection prevention permeates the FGI Guidelines in all chapters. The most prominent feature and “backbone” for infection prevention in the Guidelines, the “infection control risk assessment,” or ICRA, introduced in 1996, has developed through several editions and come to maturation in the 2010 Guidelines. Chapter 1.2 requires the ICRA in all chapters and maintains the design as well as mitigation features. Therefore, decisions on numbers of AII rooms, handwashing sinks, and hand sanitation dispensers are based on the organization’s ICRA in all facilities, not just hospitals.

ICRA recommendations. Based on the results of the initial stage of the ICRA, the organization must provide 2 types of recommendations: *design* aspects of the ICRA with long-range implications for infection prevention and *mitigation* recommendations, which apply in the short-term to projects and commissioning processes.

Design. The design aspects are spelled out but may be overlooked because many organizations tend to focus only on the mitigation aspects required during actual construction. However, elements related to design will have the greatest impact on infection prevention over time. Key issues of ventilation and water systems must be considered as well as number and placement of airborne infection isolation rooms, sinks, and hand sanitation dispensers. The ICRA panel looks to IP guidance regarding selecting materials for cleanability and resistance to bacterial or fungal growth. The Guidelines state that, when selecting surfaces and furnishings, there is an expectation to ensure that surfaces meet necessary code requirements, while also looking for characteristics that support sustainability and infection prevention.

Mitigation. Infection control risk mitigation recommendations (ICRMRs) are written plans that must describe the specific methods by which transmission of air- and waterborne biologic contaminants will be avoided during construction as well as during commissioning when HVAC and plumbing systems and equipment (eg, ice machines, steam sterilization systems) are started and restarted. The 2010 ICRA maintains requirements for documentation of the ICRA and ICRMR,

Table 2. Sink design features from FGI: Guideline for design and construction of health care facilities, 2010

Sink design features	
<p>Sinks in handwashing stations <i>shall</i> be designed with deep basins to prevent splashing; designed to prevent splashing to areas where direct patient care is provided, particularly those surfaces where sterile procedures are performed and medications are prepared.</p> <p>The number and location of handwashing stations <i>shall</i> be determined by the functional program and the ICRA.</p> <p>Handwashing stations <i>shall</i> be convenient and accessible for health care personnel and other users.</p> <p>Sinks <i>shall</i> have well-fitted and sealed basins to prevent water leaks onto or into cabinetry and wall spaces.</p> <p>Sensor-regulated water fixtures <i>shall</i> meet user need for temperature and length of time the water flows. Electronic faucets <i>shall</i> be capable of functioning during loss of normal power.</p> <p>Hand towels shall be dispensed so that users need touch only the towels and not the dispenser.</p>	<p>Basin: porcelain, stainless steel, or solid surface materials.</p> <p>If the basins are set into plastic laminate countertops, at a minimum, the substrate <i>shall</i> be marine-grade plywood (or equivalent) with an impervious seal.</p> <p>The water pressure at the fixture <i>shall</i> be regulated. (Pressure <i>should</i> be adjusted to reduce forceful discharge into the sink at maximum flow.)</p> <p>Design of sinks <i>shall</i> not permit storage beneath the sink basin.</p> <p>Faucets <i>should</i> not discharge directly above the drain as this causes splashing (ie, water <i>should</i> be angled away from the drain).</p> <p>Design of sinks <i>should</i> accommodate ADA requirements for clearance under the sink basin.</p> <p>Sink size and depth: ANSI standards <i>should</i> be considered for sink design.</p>

NOTE. Features using *shall* are requirements; features using *should* are appendix language for consideration. ADA, American Disability Act; ANSI, American National Standards Institute; ICRA, infection control risk assessment.

monitoring, and documented communication of changes to the original design. The ICRMR is particularly important when design/remediation includes *occupied* critical risk areas such as operating rooms or when mold and/or water damage needs to be remediated. Updated plans must be continuously shared among the ICRA team members and the owner. ICRA design and mitigation details may be found in the APIC 2009 text chapters on Construction and Renovation, HVAC, and Water issues.^{1,40,45}

Hand hygiene and related equipment

Handwashing sinks: location. CDC and WHO hand hygiene guidelines have identified that inconvenient location or lack of handwashing stations contribute to suboptimal adherence with hand hygiene by personnel.^{46,47} FGI Guidelines for *new* construction address a number of these issues and more, requiring the minimum number of handwashing facilities for single-patient rooms as one in the toilet room and one in the patient room to ensure caregivers can carry out standard precautions. Having a handwashing sink in a patient room as well as in the toilet room supports essential infection control practices; having a sink outside the room does not replace one inside. IPs play a critical role in recommending the proper location of sinks.

Sink design. The report published by Hota et al describing the role sinks played as the source of an ICU HAI outbreak serves as an important reminder that, whereas proximity of handwashing stations to the bedside is important to support hand hygiene, placement too close to the bedside can be a risk as well.¹¹ Notably, the shallow depth of the basin resulting in splashing of

contaminants from the drain to surfaces adjacent to the handwashing sink and directly onto the patient were factors that resulted in an outbreak of serious infections and fatalities in the ICU. Ideally, sink size and depth should include a gentle slope where the water from the spigot should fall to prevent splashing. This slope “rinses” the front side of the sink surface to flush to the drain. Hitting the drain with the flow can cause splashing of existing bacterial contaminants. Placement of sinks in the ICU must consider staff use as well as proximity to patient and clean equipment. The Guidelines also describe permissible types of sink controls throughout the book.

FGI design elements. The FGI HGRC considered and incorporated lessons learned from the Hota et al¹¹ experience and other supporting evidence, requiring or recommending handwashing stations design features in the ICUs and other patient care settings. Table 2 lists these features.

Alcohol-based hand rubs. The HGRC also supported greater attention to use of alcohol-based hand rubs (ABHR) during planning to facilitate adherence to hand hygiene. The Guidelines require master programming, undertaken by architects in collaboration with direct care personnel, IPs, and health care epidemiologists, be the basis for identifying location, number, and design of hand hygiene equipment including ABHR dispensers. Importantly, ABHR dispensers are not intended to supplant the inclusion of plumbed handwashing stations for use by personnel.

Water activation. The Guidelines permit several types of hands-free water activation for sinks: automatic versus paddle/foot/knob activated. Long blade handles are intended to be used with the back of the hand to minimize contamination from soiled fingers

but are not optimally utilized. Interest remains in sensor-operated water flow for hygiene and control of water usage. Careful consideration for sink paddles includes temperature adjustment for comfort as well as modifications that permit flushing stagnant water in the lines as needed. Studies have found that the initial water out of a spigot *regardless of type of activation* may contain higher bacteria levels depending on when last the sink was used. Therefore, the use of that initial water may increase bioload on hands or in containers. Fortunately, bacteria levels drop drastically with flow after the stagnant water is flushed.⁴⁸

Dialysis. Patient care rooms need water access and connections for acute care dialysis treatments. Overflow from plugged lines or hoses falling out of drains can cause water damage and subsequent mold growth. Dialysis boxes should be constructed with waterproof material, especially below the box itself. More discussion may be found elsewhere.^{8,45}

Toilet rooms and management of human waste disposal

Design issues. The Guidelines still require each patient to have access to a toilet room without having to enter a corridor, and, unless located in a toilet room, bedpan-washing fixtures must be installed in dedicated utility rooms, separate from patient care areas. The Guidelines require a flushing rim sink or bedpan hopper in soiled utility rooms and a toilet room in patient rooms.

ICU toilet rooms. Prior to 2010, toilet rooms were not required in ICUs, except in coronary care units, because patients are usually too ill to use them. In the 2010 edition (new construction), each ICU room must now have direct access to an enclosed toilet room *or* a soiled utility room with a clinical (flushing rim) sink for disposal of bodily waste. The change developed out of concerns for patient privacy and staff exposures to contamination as discussed below, meaning, at minimum, a toilet room and toilet equipped with a bedpan washer or a soiled utility room with a flushing clinical sink between every 2 ICU rooms. Newer evidence points to the importance of getting patients out of bed even in ICUs, so, in the future, availability of a toilet may not be an issue solely for coronary care units.⁴⁹ Clinicians, IPs, and architects may need to consider the cost benefit of single rooms plus a toilet room.

Concerns and options for patients and staff

Patients. The HGRC considered patient dignity and privacy as well as the potential for staff and environmental contamination. Pullman or swivette-type toilets inside the ICU room were considered unreliable, subject to leakage, and too low to the floor for use by

patients and personnel, posing a theoretical concern for contamination of the environment when flushed.⁵⁰

Staff. The current reality is that most ICU patients need bedpans, and, without additional plumbing options, ICU nurses must carry full bedpans from the patient room to the unit's soiled utility room for disposal. Along with risks of spillage, ICU patients often require such close observation that nurses are unable to leave the bedside for a distant utility room. Toilets that swivel out from under the handwashing sink may come with a sprayer nozzle to rinse the bedpan or, if no nozzle, may even be rinsed in the handwashing sink, risking contamination of staff and adjacent surfaces. Such designs are suboptimal practices for environmental infection control. Even with protective garb, emptying bedpans in utility rooms poses exposure risks.

Improved ICU waste management. Because human waste is a fact of everyday ICU life, better methods are needed to manage it. New technology and products are available to improve waste management in even existing patient rooms for bed-bound patients.

Bedpan washer-disinfectors. Companies do make bedpan washers that can be recessed into the wall or designed like a dishwasher under a sink counter. In new construction or major renovation, such units would fit easily into a toilet or utility room. Models available today are made to accept a full bedpan or urinal and can be adjusted to handle suction containers, intravenous fluid bags, and chest tube drainage. The door is closed on the full container, and, after the cleaning cycle, the equipment is sanitized with steam with built-in steam generators, not dependent on hospital steam. One company can synchronize data to a palm pilot for maintenance checks and machine diagnostics. Decreasing contamination of the environment with pathogens such as *C difficile* and VRE is likely and has a positive impact on patient safety as well as the environment by saving on the disposal of bedpans, urinals, and suction canisters and related costs. Because the disinfection process renders these patient care items clean, each room could maintain a set of these items that is disinfected and reused indefinitely. Selection of bedpan cleaners should include design analysis and ensure the plumbing design does not create a dead-end connection permitting the harboring of legionella in the water feed to that system. IPs along with facility staff must ensure such considerations for safety and maintenance of labor-saving inventions. Well-designed in-room waste disposal saves nursing time and steps, increases direct patient care time, decreases environmental contamination, and is environmentally friendly in terms of overall waste management.

Flooding disasters and mitigation. Care must also be taken to consider management of human waste during disasters that involve extensive power loss and

subsequent loss of water or sewer utilities. It is critical to ensure backup-powers. Other internal disasters from flooding and water intrusion can be from toilet fixtures or devices used to manually clean bedpans as well as basins used for bathing patients. Advances in patient cleansing techniques, eg, waterless, premoistened disposable cleaning cloths have helped improve skin care, lessen presence of microbes on skin and even prevent device-associated infections. However, inappropriate disposal of disposable cloths into toilets and sanitary sewer systems can block water flow and result in backup of plumbing fixture or floor drains. Not only can this contaminate the ICU environment, but residual water damage to wallboard can lead to mold contamination. Proper disposal into regular waste can avoid this situation and illustrates the important connection between the EoC and human occupants.

Surfaces, furnishings, and antimicrobials

Surfaces and furnishings: Design, contribution to environmental contamination. The 2010 HGRC made a concerted effort to offer guidance in helping facilities select environmentally friendly materials, with a major focus on infection prevention and healthy outcomes for patient, workers, and the environment. Ideal features of surfaces that satisfy sustainability, infection prevention, and safe patient outcomes include cleanability, resistance to moisture, and reducing the risk of fungal contamination.⁸ Several studies reveal that the persistence of microbes in the environment after patient room cleaning are found to often be related to the thoroughness of cleaning protocols.⁵¹⁻⁵³ These findings supported the Guidelines increased emphasis on selecting easily cleanable surfaces.

Wall surfaces. The 2010 Guidelines continue to require that wall finishes be washable, noting that design for a healthy and productive indoor environment can be accomplished through measures such as the use of low volatile organic compounds finishes and reduced moisture entrapment and cannot conflict with health care safety and infection control codes and standards. This aspect and related topics are discussed at length in the APIC 2009 text on ventilation.⁴⁰

Floor coverings. Selecting hard or soft floor covering materials poses major dilemmas for all facilities, considering material that is easily cleaned but also enhances patient comfort, noise, and safety. Newer floor coverings focusing on sustainability better address the balance of concerns with patient comfort (noise), patient safety (reduced slips, falls, and injury), staff back injury (rolling beds, carts, stretchers), life cycle costing (maintenance and replacement), and cleaning (equipment and staff). However, studies on methods for assessing cleaning processes have highlighted the importance of selecting cleanable surfaces. All of these

concerns are raised in the Guidelines, requiring decisions by the ICRA panel.

Soft coverings. Carpeting has not been directly associated with HAIs.⁵⁴ Recent studies have found that, although bacterial contamination per unit of carpet may be higher than for hard surface floors, they have failed to implicate carpeting as the source of HAIs, although patient population needs and location are crucial components to factor into the final decision.⁵⁵ Some studies suggest it is possible to strike the right balance of padding, low pile, and larger wheels to minimize the problem of mechanical friction and staff back injury, although carpeting, if used, should have an impermeable backing and heat or chemically welded seams.^{19,56-58}

Hard flooring. In terms of hard floors, there are many more selections today of resilient floor coverings such as rubber that are easily cleaned, do not need waxing or stripping, and are environmentally friendly.⁵⁹ Selection of flooring should also provide specifications for mildew resistance and integral coving designs that will prevent risks of water damage during routine cleaning and avoid becoming a source of mold growth. The Guidelines support floor surfaces that can withstand frequent cleaning/heavy traffic and permit cleaning without the use of hazardous chemicals.

Materials and impregnated antimicrobials. Given the notable increase in either replacement or extensive renovation of health care facilities in the United States, there has been interest in designing an environment that promotes safety but also prevents cross transmission of infectious agents. Current evidence demonstrating the efficacy of antimicrobials when applied or incorporated into or onto inanimate surfaces, patient care equipment, fixtures, or finishes, including carpeting, specifically for prevention of HAI is lacking. The Guidelines emphasize cleanability and do not support antimicrobial treatments; rather, they support privacy curtains that are washable, or more preferable, a wipeable fabric with a smooth surface. The Guidelines similarly do not support hard metal surfaces with antimicrobial claims such as copper. More evidence is needed that copper surfaces would decrease actual HAIs.¹

CONCLUSION

The IP is a key member of a multidisciplinary team of professionals and health care personnel involving the design and construction of the built environment. Hand hygiene remains a cornerstone of design to support infection prevention, but there are a growing number of elements that will require increasing engagement of the IP. These include safety, sustainability, surface treatments, HVAC, water systems, and others. The key is employing critical thinking skills and

published evidence in the context of an overall facility-based risk assessment/infection prevention plan. When these are applied, there is great opportunity to enhance the safety and quality of care for all health care facility occupants.

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