Contract Final Report

Understanding the Role of Health Care Facility Design in the Acquisition and Prevention of HAIs

Executive Summary

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Project Overview

At any one time in the United States, health care-associated infections (HAIs) occur in 1 in 20 hospital patients. In addition, the Department of Health and Human Services reported in 2012 that HAIs are associated with increased morbidity and mortality and are responsible for $28 to $33 billion in preventable health care expenditures annually. Efforts to reduce the number of HAIs have begun to expand beyond standardizing best practices in health care processes to include addressing the built environment.

The built environment refers not only to the structure of the hospital; it also includes the fixed components within the facility with which health care workers, patients, and families touch or interact as a part of the health care process. As such, it is increasingly recognized as an important component in the transmission of pathogens. This report describes and examines the role of the built environment in the acquisition and prevention of HAIs through:

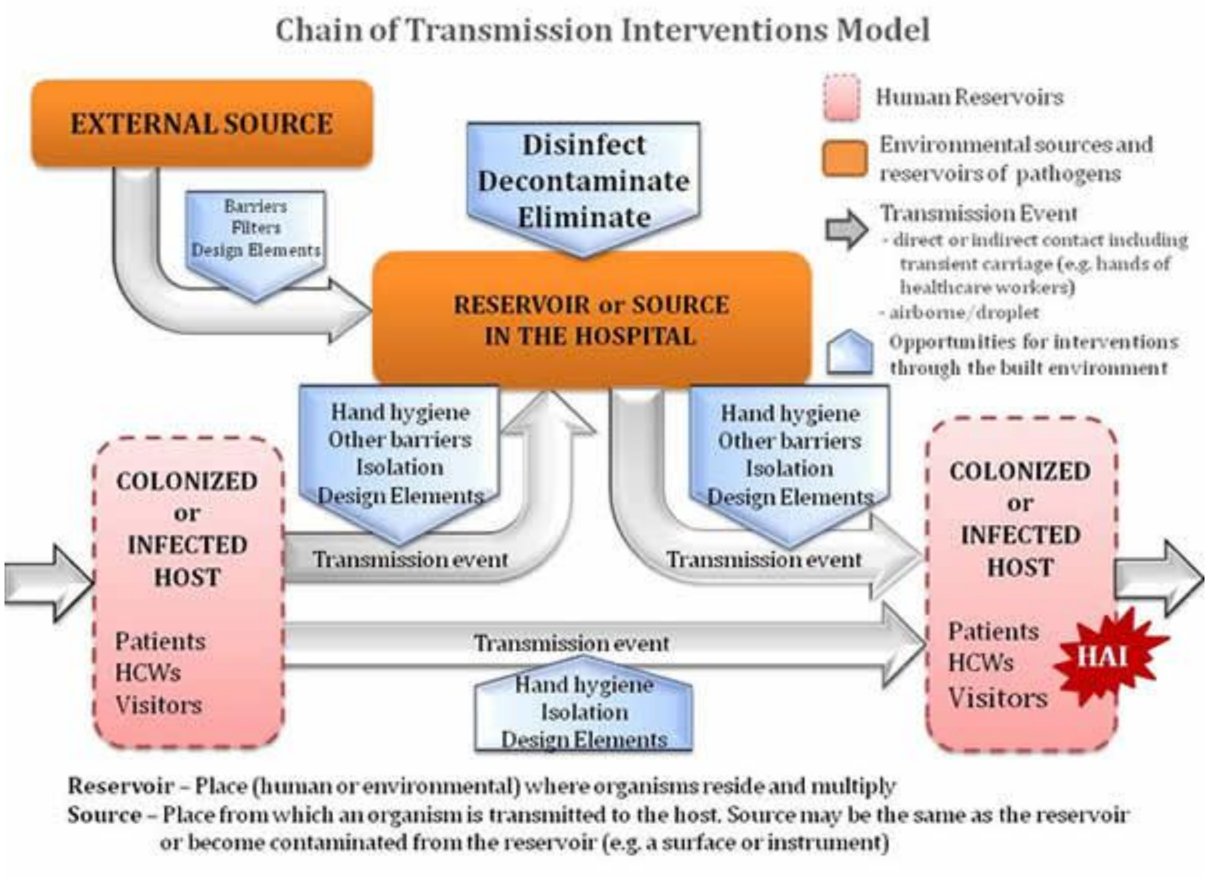
- Creation of a conceptual model that illustrates the linkages between design elements and the acquisition and prevention of HAIs.
- An in-depth literature review.
- Interviews with a diverse group of experts in the fields of infection control, air and water quality, hospital administration, design, and architecture.

Conceptual Model

Transmission of pathogens in a hospital is complex, with multiple potential transmission pathways, hosts, reservoirs, and sources. Pathogens can enter the hospital through infected or colonized humans, including patients, or come from external sources, such as construction projects. Some infections are caused by organisms that patients harbor prior to hospital admission. Pathogens have varying abilities to persist and to cause disease, posing the greatest risk to immunocompromised patients. Environmental sources or reservoirs in hospitals may go undiscovered, as many common pathogens causing HAIs can survive for weeks to months on surfaces.

The transmission of pathogens is affected by variations and practices of human behaviors, such as hand hygiene compliance or the effectiveness of room cleaning. There are multiple opportunities within the built environment to interrupt the transmission of pathogens, including reducing or preventing contamination of surfaces or water sources, providing barriers to interrupt transmission events, and influencing human behavior, such as by promoting hand hygiene compliance (Figure).

Figure. Opportunities within the built environment to interrupt the transmission of pathogens



The figure is a conceptual model that illustrates the linkages between health care facility design elements and the acquisition and prevention of HAIs. It shows how infectious agents can be brought into hospitals by colonized or infected hosts or other external sources and lead to HAIs. It also illustrates how various barriers and decontamination can be designed to prevent such infections.

Current State of the Evidence

Understanding the role of the environment in the transmission of pathogens is challenging. Similarly, assessing the impact design features have in mitigating transmission also can be difficult. Most studies of design interventions assess intermediate endpoints, such as the reduction of environmental contamination by known pathogens. Studies that look at the acquisition of organisms by a patient are more difficult to conduct and are confounded by other factors that contribute to the spread of organisms, including human behavior, such as hand hygiene compliance. Studies that use the development of infections as the outcome are difficult to conduct because of the relative infrequency of infections. Despite the inherent difficulties in establishing definitive links between the built environment and HAIs, sufficiently strong evidence exists to inform design and design guidelines. Interventions involving the built environment can generally be divided into three categories:

1. Interventions that prevent transmission by direct or indirect contact.
2. Interventions directed at eliminating transmission of pathogens through airborne routes.
3. Interventions aimed at eliminating water sources of infection.

This executive summary briefly describes a multidisciplinary assessment of the current state of knowledge about HAIs within the context of the built environment. Major findings from the literature review are summarized here.

Contact

Contact transmission, either via person-to-person contact or with the environment as an intermediary, is the primary mechanism by which organisms are transmitted in health care settings. Contact with contaminated surfaces can lead to transmission of pathogens, with health care workers often acting as the transmitting agent. Current environmental cleaning processes are suboptimal, primarily because of inconsistent application of disinfectants. Alternative surface materials, such as copper alloys, provide continuous antimicrobial activity; although promising, the impact of copper high-touch surfaces on infection risk is unclear. Novel technologies, such as in-duct ultraviolet germicidal irradiation (UVGI) and hydrogen peroxide applied as a mist or vapor, merit continued investigation as potential strategies to enhance environmental cleaning. These technologies have been shown to decrease organisms recovered from surfaces, although their impact on acquisition of organisms and infection risk is less clear. Both technologies are used as part of room cleaning at the time of patient discharge and thus have limited impact on reducing day-to-day contamination.

The built environment can decrease contact transmission through the use of barriers and spatial separation, including private rooms. An optimized environment can also support behaviors that minimize contact transmission; an example is the promotion of hand hygiene through strategic placement of alcohol hand-rub dispensers in highly visible locations. Some elements in the built environment, such as curtains and carpets, offer increased privacy, noise reduction, fall reduction, and aesthetic value, but there is a tradeoff between these beneficial effects and infection risks. Although curtains and carpets are easily contaminated, hard to clean, and linked to outbreaks of HAIs, their role in the spread of pathogens is unclear. Curtains made from novel antimicrobial materials can partially resist contamination and may prove to be of value. Presently, carpets are not recommended in rooms designated for patients with impaired immune systems.

Air

The optimal ventilation system for most hospital areas is unknown. Laminar, unidirectional, turbulent, and displacement airflow systems have been tested in selected settings, particularly operating rooms, without clear evidence of superiority of a single system. Each has strengths and weaknesses, which are influenced by factors such as adequate system size, placement of intakes and vents, and the system’s ability to maintain appropriate air changes per hour. Filtration technologies can augment the ability of ventilation systems to eliminate airborne pathogens. High efficiency particulate (HEPA) filters remove 99.97 percent of particles in the air, but they are costly to replace and require significant energy to run. In-duct UVGI is a technology that not only inactivates harmful bacteria, but can help increase the efficiency of HEPA filters.

Water

Common approaches for controlling waterborne pathogens include maintaining optimal water temperatures and chlorination levels and eliminating "dead ends" in plumbing systems to inhibit the growth of Legionella and other pathogens. In outbreak settings, superheating and flushing or hyperchlorination are recommended, although these strategies can be difficult to implement, and hyperchlorination can be corrosive to plumbing. Copper silver ionization is strongly supported by recent literature, but adoption of this technology has been slowed by high costs and unknown long-term implications. Several longitudinal studies have shown that UVGI in water systems is effective in controlling *Legionella*. These two newer technologies appear to have roles in controlling waterborne pathogens when multiple trials of first-line approaches, such as hyperchlorination and superheating and flushing, have failed. Point-of-use filters are also highly effective at eliminating pathogens and have the advantage of immediate efficacy, but they are costly to install. Disposable filters produce significant waste, and reusable filters require training on proper handling to prevent recontamination.

Certain sink and faucet designs have been implicated in outbreaks of waterborne pathogens. Faucets should not be located directly above the drain to prevent splashing. Elements in some electronic faucets may also be predisposed to bacterial growth and contribute to the spread of microorganisms. Decorative fountains are controversial; the few reports linking outbreaks to these water features have been highly publicized. Common features of outbreaks traced to decorative fountains include design flaws and inadequate maintenance.

Expert Interviews

Clear themes emerged from the expert interviews and triads, despite a broad range of specialties, roles within hospitals, and experiences with HAIs. Most prevalent is the assertion that the term "evidence-based design" is misleading because of the paucity of rigorous research directly linking a design feature or strategy to a reduction in infections. Most experts agreed that the term "evidence-influenced design" is a more accurate characterization of the approach used in the majority of today's health care settings, meaning that decisionmakers must use a combination of research and practical experiences to inform design strategies. This necessitates a more collaborative, holistic approach to decisionmaking, replacing the less informed "siloed" design process. Many experts stressed that no single intervention will be highly effective in mitigating HAI risk, and that multiple interventions, including those involving the built environment, are needed. Experts emphasized the importance of targeting human behavior, as it can render even the best evidence-informed designs ineffective.

Conclusions

Our literature review found evidence that:

1. Poor design and suboptimal maintenance of the built environment can increase the risk of transmission of pathogens and can lead to outbreaks.
2. Even with contemporary design and maintenance, the built environment contributes to some transmission events within hospitals.

3. Novel and best-practice technologies, materials, and design strategies may directly decrease the risk of transmission of pathogens by decreasing the burden of microorganisms in the environment.
4. Optimal design may indirectly decrease the development of HAIs by influencing human behaviors to decrease person-to-person transmission.

More research is needed, as the best methods for leveraging strategies and design features aimed at interrupting the transmission of pathogens remain unresolved; this sentiment was echoed in the expert interviews.

The project also showed the value of cross-disciplinary collaboration in research and in design. Increased multidisciplinary dialogue during facility design, planning, and construction phases is needed to fully analyze the benefits and drawbacks of new design strategies. This requires developing a mutual understanding among stakeholders to facilitate informed, optimal decisionmaking. It will not be easy to merge discipline-specific perspectives through collaboration, but such open dialogue will lead to improved application of evidence and experience to reduce design-related health care infections.