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The Impact of the Environment on Infections in Healthcare Facilities

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Abstract

Objective: To examine how nosocomial infections spread among hospitalized patients via environmental routes and whether the design of the hospital plays a part in preventing the incidence and spread of infections.

Methods: Literature review of peer reviewed journal articles and research reports published in medicine, infection control, architecture, and epidemiology publications. Interview with industry experts.

Key findings

Hospital-acquired infections, or nosocomial infections, are one of the leading causes of death in the United States and typically affect patients whose immune systems are compromised. Nosocomial infections are transmitted in hospitals through three main environmental routes — air, surface contact and water. Airborne infections are spread when dust and pathogens are released during hospital renovation and construction activities and due to contamination and malfunction of the hospital ventilation system. Providing clean filtered air and effectively controlling indoor air pollution through ventilation are two key aspects of maintaining good air quality. HEPA filters are highly effective in preventing airborne infections from entering the hospital environment. Most nosocomial infections are transmitted through contact with the hands of nurses and physicians, and poor handwashing compliance poses a serious problem in this regard. There is some evidence that environmental support for handwashing — by providing numerous, conveniently located alcohol-rub dispensers or washing sinks — can increase compliance. Single-bed rooms are strongly recommended from an infection-control perspective—it is easier to isolate infectious pathogens and disinfect single-bed rooms than multi-occupancy rooms once a patient has been discharged. Waterborne infections spread through direct contact (e.g., for hydrotherapy), ingestion of contaminated water, indirect contact, and inhalation of aerosols dispersed from water sources. Regular cleaning, maintenance, and testing of water systems and point-of-use fixtures is important for preventing the spread of waterborne infections such as Legionnaires' disease.

Conclusions

Careful consideration of environmental routes for transmission of infection — air, surface and water — can help in reducing nosocomial infection rates in hospitals.

Introduction

Hospital-acquired infections, or nosocomial infections, are one of the leading causes of death in the United States—killing more Americans than AIDS, breast cancer, or automobile accidents. In 1995 alone, nosocomial infections contributed to more than 88,000 deaths—one death every six minutes—and cost $4.5 billion (Weinstein, 1998).

Nosocomial infections typically affect patients who are immunocompromised because of age, underlying diseases, or medical or surgical treatments. According to Weinstein (1998), the highest infection rates are usually among intensive-care-unit (ICU) patients, with nosocomial infection rates in adult and pediatric ICUs being three times higher than anywhere else in the hospital (Weinstein, 1998).

Some of the key factors that have led to increasing nosocomial infection rates in American hospitals include

- low handwashing rates by staff between patient contacts,
- sicker and more immunocompromised patients in hospitals,
- infrastructure repairs and renovations to aging hospitals and new construction on existing campuses creating risk of airborne fungal diseases caused by dust and spores released during demolition and construction, and
- increasing antimicrobial use in hospital and long-term care facilities creating a large reservoir of resistant microbial strains (Weinstein, 1998).

Further, Weinstein (1998) found that at least one-third of nosocomial infections are preventable. A strong body of research shows that the built environment in particular influences the incidence of infection in hospitals and that, by careful consideration of environmental transmission routes — air, surface and water—in the design and operation of healthcare facilities, hospital-acquired infections can be reduced dramatically. This paper examines how nosocomial infections spread among hospitalized patients via environmental routes and how the design of the hospital plays a critical part in preventing the incidence and spread of infections.

Nosocomial infections

Are infections acquired in the hospital.

Account for more than 88,000 deaths every year.

Typically affect immunocompromised patients.

Are transmitted through three main pathways:

- air
- surface
- water

Air: Airborne pathogens and infection control

How are airborne infections transmitted?

Vulnerable patient populations are exposed to a variety of airborne infectious pathogens. Airborne pathogens are transmitted in three main ways.

- When an environmental reservoir of a pathogen (i.e., soil, water, dust, decaying organic matter) is disturbed, fungal spores (e.g., *Aspergillus*) may be released into the air and make their way into the hospital environment.
- Microorganisms can also be transmitted directly from person to person in the form of

droplets in the air. When droplets are produced during a cough or sneeze, a cloud of infectious particles is released into the air, resulting in potential exposure of susceptible persons within three feet of the source person (Sehulster & Chinn, 2003).

- Other infectious diseases such as tuberculosis are transmitted via residuals of droplets that remain indefinitely suspended in the air and can be transported over long distances. The microorganisms in the droplet residuals persist in dry cool conditions with little or no exposure of light or direct radiation. Susceptible individuals who come in contact with high concentrations of the microorganism may get infected.

What are the sources of airborne pathogens?

Construction and renovation activities

Airborne pathogens such as *Aspergillus* survive well in the air, dust, and moisture present in healthcare facilities and are usually released into the air during site construction and renovation. Ulrich and colleagues (2004) identified several studies that have linked increased levels of atmospheric dust and fungal spores during renovation and construction activities with healthcare-associated infections in immunocompromised patients.

In one study, high spore counts were found within and outside construction sites in a hospital. After control measures were instituted, no further cases of disseminated aspergillosis were identified (Opal et al., 1986). In another study, a nosocomial (hospital-acquired) outbreak of invasive pulmonary aspergillosis (IPA) occurred in acute leukemia patients treated in a regular ward with natural ventilation during extensive hospital construction and renovation. The observed infection rate was 50%. At this point, some of the patients were moved to a new hematology ward with high-efficiency particulate air (HEPA) filters. During the following three years, none of the patients hospitalized exclusively in the hematology ward developed IPA, although 29% of leukemia patients still housed in the regular ward contracted IPA (Oren, Haddad, Finkelstein, & Rowe, 2001).

Airborne pathogen sources

Construction and renovation activities.

Ventilation system contamination and malfunction.

- Accumulation of dust and moisture in Heating, Ventilation and Air Conditioning (HVAC) systems.
- Failure or malfunction of HVAC systems.
- Pigeon droppings.

Ventilation system contamination and malfunction

Many incidents and outbreaks of nosocomial infection have been linked to malfunctions and contamination of the ventilation system in hospitals (Abzug et al., 1992; deSilva & Rissing, 1984; Kumari et al., 1998; Lutz, 2003; McDonald et al., 1998; Simmons, Price, Noble, Crow, & Ahearn, 1997; Uduman et al., 2002). Several studies have identified the type of air filter, direction of airflow and air pressure, air changes per hour in room, humidity, and ventilation-system cleaning and maintenance as factors related to air quality and infection rates.

Accumulation of dust and moisture within HVAC systems increases the risk for the spread of environmental fungi and bacteria. For example, in one study where six patients and one nurse were involved with an outbreak of epidemic methicillin-resistant *Staphylococcus* aureus (EMRSA-15), an environmental source was suspected, and the ventilation grilles in two patient bays were found to be harboring EMRSA-15 (Kumari, et al., 1998). The ventilation system, at that time, was working on an intermittent cycle from 4 p.m. to 8 p.m. Daily shutdown of the system created negative pressure, sucking air in from the ward environment into the ventilation system and contaminating the outlet grilles. The contaminated air blew back into the ward when the ventilation system was started. In another case, the source of infection was the exhaust ducting of the adjacent isolation-room ventilation system that allowed the contaminants to enter the unit via a partially open window positioned above a particular bed.

A failure or malfunction of the HVAC system may expose patients and staff to airborne contaminants. However, only limited information is available from studies on the infection-control implication of a complete air-handling failure or shutdown for maintenance. The American Institute of Architects' (AIA) *Guidelines for Design and Construction of Hospital and Health Care Facilities* prohibits U.S. hospitals and surgical centers from completely shutting down their HVAC systems except in the case of routine maintenance, filter changes, and construction (AIA, 2001). Even in such situations, required pressure relationships must be maintained (Sehulster & Chinn, 2003).

Pigeons, their droppings, and roost and are also associated with the spread of infections. There have been at least three outbreaks linked to contamination of the filtering systems from bird droppings (Burton, Zachery, & Bessin, 1972; Gage, Dean, Schimert, & Minsley, 1970; Kyriakides, Zinneman, & Hall, 1976).

How to control and prevent airborne infections

The importance of good air quality in controlling and preventing airborne infections in healthcare facilities cannot be overemphasized. Providing clean filtered air and effectively controlling indoor air pollution through ventilation are two key aspects of maintaining good air quality.

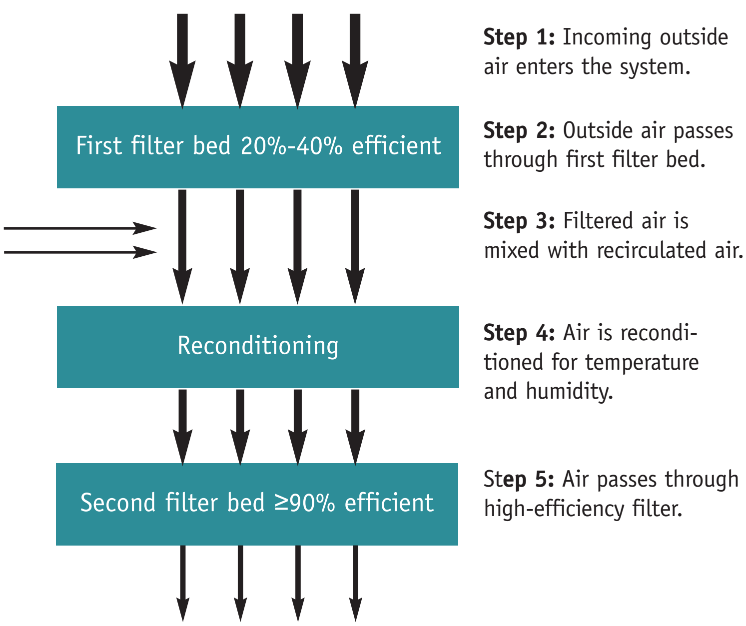

Figure 1: Steps involved in providing clean filtered air in the hospital (Source: Author)

HEPA filtration

The control of air pollutants (microorganisms, chemicals, dust, and smoke) at the source is the most effective way to maintain clean air. *Filtration*, the physical removal of particulates from air, is the first step to achieving acceptable indoor air quality (Sehulster & Chinn, 2003). The figure below shows the steps involved in providing clean filtered air in the hospital.

The second filter bank (Figure 1) usually consists of high-efficiency filters. This filtration system (90% efficiency filters) is quite adequate for most patient-care areas in ambulatory-care facilities and hospitals, including the operating-room environment and areas providing central services (Sehulster & Chinn, 2003). Once the frames for the filters are in place, it is possible to increase the efficiency of the filters by adding HEPA filters for special-care areas of the hospital such as surgical areas, burn ICU units, and protective environments for immunocompromised patients (Petska & Yeong, 2006). HEPA filters are at least 99.97% efficient for removing particles 0.3 µm (as a reference, *Aspergillus* spores are 2.5–3.0 µm in diameter) (Sehulster & Chinn, 2003). The filter efficiency can be increased to 99.99% where needed.

HEPA filter costs

32-bed unit with 90% efficiency filters

Additional first cost is about $15,000.

Additional operating cost is about $4,000 per unit per year for increased power.

HEPA filter replacement is about is $6,000 per year for materials and labor (Petska & Yeong, 2006).

There is convincing evidence that immunocompromised and other high-acuity patient groups have lower incidence of infection when housed in HEPA-filtered isolation rooms (Passweg, et al., 1998; Sherertz, et al., 1987; Sherertz & Sullivan, 1985). In one study, bone-marrow transplant recipients were found to have a tenfold greater incidence of nosocomial *Aspergillus* infection, compared to other immunocompromised patient populations, when assigned beds outside of a HEPA-filtered environment (Sherertz, et al., 1987). HEPA filters are suggested for healthcare facilities by the Centers for Disease Control and Prevention (CDC) and Healthcare Infection Control Practices Advisory Committee (HICPAC), but are either required or strongly recommended in all construction and renovation areas (Sehulster & Chinn, 2003).

The health benefits of infection-control measures are undeniable. But often, when considering state-of-the-art infection-control measures, hospital administrators are forced to also consider the costs. Some infection-control measures, such as preventing and controlling surface transmission of infection can be addressed relatively cheaply through staff education, number and location of handwashing sinks, and careful selection of materials and appropriate cleaning strategies. Other measures, on the other hand, are more costly. For example, using HEPA filters is a reliable way to reduce airborne infections. However, HEPA filters are more expensive than standard 90% efficient filters and are also more expensive to maintain. According to Sehulster and Chinn (2003), the life of HEPA filters can be increased by approximately 25% by using in-line disposable prefilters. Alternatively, if a disposable prefilter is followed by a filter that is 90% efficient, the life of a HEPA filter can be increased ninefold. This concept, called progressive filtration, allows HEPA filters in special-care areas to be used for 10 years (Sehulster & Chinn, 2003). From an operational standpoint, HEPA filters need a powerful fan to operate—which leads to increased energy costs as compared to less-efficient filtration systems.

Ventilation

After filtration, the second most effective way of controlling the level of pathogens in the air is through ventilation. Ventilation guidelines are defined in terms of air volume per minute per occupant and are based on the assumption that occupants and their activities are responsible for most of the contaminants in the conditioned space. Most ventilation rates for healthcare facilities are expressed as room air changes per hour (ACH). Peak efficiency for particle removal in the air space occurs between 12 ACH–15 ACH (Sehulster & Chinn, 2003). Ventilation rates vary among different patient-care areas of a healthcare facility, and ventilation standards are provided in the AIA guidelines (American Institute of Architects, 2001) or the *American Society of Heating, Cooling and Air-conditioning Engineers (ASHRAE) Standard 62, Ventilation for Acceptable Indoor Qualit*y (American Society of Heating, Cooling and Air-conditioning Engineers, 1999).

Air contamination is least in laminar airflow rooms with HEPA filters, and this approach is recommended for operating-room suites and areas with ultraclean-room requirements such as those housing immunocompromised patient populations (Alberti et al., 2001; Arlet, Gluckman, Gerber, Perol, & Hirsch, 1989; Dharan & Pittet, 2002; Friberg, Ardnor, & Lundholm, 2003; Hahn et al., 2002; Sherertz et al., 1987). Laminar flows are very even, smooth, low-velocity airflows that are used in clean-rooms and other settings where high-quality ventilation is critical.

Single-bed rooms

Single-bed rooms are clearly superior to multibed rooms in preventing the transmission of airborne pathogens from one patient to others. This is because of the ease in isolating a patient and providing high-quality HEPA filters, negative room pressure to prevent a patient with an aerial-spread infection from infecting others, or maintaining positive pressure to protect an immunocompromised patient from airborne pathogens in nearby rooms.

A study by Passweg, et al. (1998) found that the combination of room isolation and HEPA filtration reduced infection and mortality in bone-marrow transplant patients and significantly increased their one-year survival rates. Ulrich and colleagues (2004) identified several research studies that showed that single-bed rooms and good air quality substantially reduce infection incidence and reduce mortality among burn patients. They also found studies that showed that, for contagious airborne diseases such as influenza, measles, and tuberculosis, placing patients in single-bed rooms is safer than housing them in multibed spaces (Ulrich, et al., 2004).

Multibed spaces were extremely inadequate for controlling and preventing severe acute respiratory syndrome (SARS) outbreaks both for patients and healthcare workers in Asia and Canada. SARS is transmitted by droplets that can be airborne over limited areas. Approximately 75% of SARS cases in Toronto resulted from exposure in hospital settings (Farquharson & Baguley, 2003). Most Canadian and Asian hospitals have multibed spaces in emergency departments. That, taken with the scarcity of isolation rooms with negative pressure, severely hindered treatment and control measures. Toronto hospitals were forced to create additional negative-pressure isolation rooms by quickly constructing wall barriers to replace bed curtains and making airflow and pressure adaptations (Farquharson & Baguley, 2003).

Effective control measures during construction and renovation

Other than providing good quality air and ensuring adequate ventilation in patient-care areas, instituting effective prevention and control measures during construction and renovation is critical. Effective measures include

- using portable HEPA filters,
- installing barriers between the patient-care and construction areas,
- using negative air pressure in construction/renovation areas relative to patient-care spaces, and
- sealing patient windows.

Airborne infection control
Provide HEPA filters in key patient-care areas.
Use well-maintained and operated ventilation systems.
Provide single-bed rooms.
Employ effective control measures during construction and renovation.

There is strong evidence of the impact of using HEPA filters for air intakes near construction and renovation sites (Loo, et al., 1996; Mahieu, De Dooy, Van Laer, Jansens, & Leven, 2000; Opal, et al., 1986; Oren, et al., 2001). A study by Humphreys et al. (1991) demonstrates that HEPA filters are not by themselves an adequate control measure and must be employed in conjunction with other measures such as enhanced cleaning, the sealing of windows, and barriers. Cornet et al. (1999) concludes that carefully directed airflow (e.g., laminar airflow) is important. However, in their extensive literature review, Ulrich and colleagues (2004) were unable to find and document cost-benefit analysis in the literature to justify the expense versus effectiveness of laminar airflow for patient-care areas near construction and renovation sites. The CDC and HICPAC guidelines (Sehulster & Chinn, 2003) emphasize the importance of a multidisciplinary team (including environmental services, employee health, infection control and design, and construction teams) approach to coordinate the various stages of construction activities.

Surface: Contact pathways of infectious pathogens

Although infection caused by airborne transmission poses a major safety problem, most infections are now acquired in the hospital via the contact pathway (Bauer, Ofner, Just, Just, & Daschner, 1990; Institute of Medicine, 2004). Microbiologically contaminated surfaces can be reservoirs of pathogens. However, these surfaces are generally not associated with the direct transmission of infection to patients or staff (Sehulster & Chinn, 2003). It is the hands of healthcare staff that is the principal cause of contact transmission from patient to patient (Larson, 1988). The importance of assiduous handwashing by healthcare workers, accordingly, cannot be overemphasized for reducing hospital-acquired infections. In this context, the fact that rates of handwashing by healthcare staff are low represents a very serious patient-safety challenge. Some facts regarding handwashing practices among staff and physicians (Ulrich, et al., 2004):

- Compliance rates in the range of 15%–35% are typical, rates above 40% to 50% are the exception.
- Rates are lowest among physicians and nursing assistants.
- Rates are lower in units that are understaffed, have a high patient census or bed occupancy rate, or have high-acuity patients.
- Rates are lower in units with automated sinks.

Infections transmittal
Contaminated surfaces can be reservoirs of pathogens.
Surfaces are not generally linked to direct transmission of infection.
Infections are transmitted through hands of healthcare staff.

Education programs have not been successful in increasing handwashing compliance among healthcare workers. Even intensive education or training programs (classes, group feedback, for example) produce only transient increases in handwashing (Conly, Hill, Ross, Lertzman, & Louie, 1989; Dorsey, Cydulka, & Emerman, 1996; Dubbert, Dolce, Richter, Miller, & Chapman, 1990). Behavioral interventions, including environmental design, that make handwashing practices easier and more convenient may be more effective in producing sustained increases in handwashing compliance.

Along with providing environmental support to improve hand hygiene to reduce the transfer of pathogens to patients, the choice of materials for environmental surfaces and proper cleaning and disinfecting of surfaces is critical to reducing their potential contribution to the incidence of infection.

Environmental support for handwashing

Hospital staff report several reasons for poor handwashing compliance including inconvenient sink location, shortage of sinks, lack of time, lack of soap or paper towels, and not thinking about it/forgetfulness (Pittet, 2000). These factors clearly have environmental implications, and designing healthcare facilities to make handwashing practices more convenient may increase compliance.

Barriers to handwashing

- Inconvenient sink location.
- Lack of time.
- Lack of soap or paper towels.
- Not thinking about it/forgetfulness.

Environmental implications

- Location, accessibility, and number of handwashing sinks and soap dispensers.
- Conveniently located sinks in single-bed rooms.

Ulrich and colleagues (2004) identified six studies that examined whether handwashing is improved by increasing the ratio of the number of sinks or hand-cleaner dispensers to beds and/or by placing sinks or hand-cleaner dispensers in more accessible locations. According to the authors, there is some support for the notion that providing numerous, conveniently located alcohol-rub dispensers or washing sinks can increase compliance. In particular, the evidence suggests that installing alcohol-based hand-cleaner dispensers at bedside usually improves adherence (Ulrich, et al., 2004).

In one study, a combination of bedside antiseptic hand-rub dispensers and posters to remind staff to clean their hands was effective in increasing compliance (Pittet, 2000). On the other hand, Muto and colleagues (2000) found that placing alcohol-gel dispensers next to the doors of patient rooms was not effective. When sink-to-bed ratio was higher, a higher frequency of handwashing was observed (Kaplan & McGuckin, 1986; Vernon, Trick, Welbel, Peterson, & Weinstein, 2003). Providing automated water/soap sinks, however, appears not to increase handwashing rates compared to traditional nonautomated sinks (Larson, et al., 1991; Larson, Bryan, Adler, & Blane, 1997).

Ulrich and colleagues (2004) identified three studies that suggest that providing single-bed rooms with a conveniently located sink in each room reduces nosocomial infection rates in ICUs, such as neonatal intensive-care or burn units, compared to when the same staff and comparable patients are in multibed open units with few sinks. The authors (Ulrich, et al., 2004) indicate that handwashing frequency was not measured in these studies. However, the studies identified increased handwashing as an important factor in reducing infections in the units with single-bed rooms and more sinks. A comparison of an ICU converted from an open unit with few sinks to single-bed rooms with one sink per room found a nonsignificant tendency for handwashing to increase (from 16% to 30%), but no decline in infection incidence (Preston, Larson, & Stamm, 1981). These results are perhaps explainable by the fact that several sinks in the single-bed unit were placed in comparatively inaccessible or inconvenient locations, such as behind doors or away from staff work paths.

Despite the encouraging overall pattern of findings in these studies, it is not clear how much of the effectiveness in terms of increased handwashing or reduced infection rates can be attributed to the installation of more numerous and/or accessible sinks and alcohol-gel dispensers.

How to control and prevent surface contamination

While most infections are not directly transmitted to patients from environmental surfaces, these surfaces come in contact with the hands of caregivers frequently. As discussed earlier, low hand-washing compliance is a problem in healthcare facilities. Hence, regular cleaning and disinfection of environmental surfaces as appropriate is critical to controlling surface contact transmission of infections.

Environmental surfaces that are likely to get contaminated by pathogens can be divided into two groups—those with frequent hand contact (such as surfaces of medical equipment and high-touch housekeeping surfaces such as doorknobs, bedrails, light switches, wall areas around the toilet in the patient room, and edges of privacy curtains) and those with minimal hand contact (e.g., floors and ceilings). The number and type of organisms present on the surface depends upon (Collins, 1988)

- the number of people present in the environment,
- amount of moisture,
- amount of activity,
- presence of material capable of supporting bacterial growth,
- rate at which organisms suspended in the air are removed (ventilation), and
- type of surface and orientation (horizontal or vertical).

High-contact surfaces in patient-care areas need to be cleaned and disinfected more frequently than minimal contact surfaces. Typically, the infection-control specialists in the organization use a risk-assessment approach to identify high-touch surfaces and then coordinate an appropriate cleaning and disinfecting strategy and schedule with the housekeeping staff. The CDC and HICPAC *Guidelines for Environmental Infection Control in Healthcare Facilities* (Sehulster & Chinn, 2003) provides recommendations for cleaning and maintaining different types of environmental surfaces to prevent the spread of infection.

Compared to single-bed rooms, multibed rooms are far more difficult to decontaminate thoroughly after a patient is discharged, and, therefore, worsen the problem of multiple surfaces acting as pathogen reservoirs. Because different staff members who enter a room can touch the same contaminated surfaces, the risk of a nurse unknowingly becoming contaminated should be greater in multi-bed rooms (Ulrich, et al, 2004). Circumstantial support for this point is provid-

Prevention and control

Careful selection of materials —cleanability is a key consideration.

High-contact surfaces need to be cleaned and disinfected more frequently than minimal contact surfaces.

Single-bed rooms are easier to decontaminate.

ed by research on contamination of nurses in units having patients infected by MRSA. Boyce et al. (1997) found that 42% of nurses who had no direct contact with an MRSA patient but had touched contaminated surfaces contaminated their gloves with MRSA.

The ease of cleaning is clearly an important consideration in the choice of materials for health-care facilities, and this applies to materials for floors, ceilings, and walls as well as furniture and furnishings. But the kind of material to use is not always clear-cut. For example, the type of flooring—carpet or vinyl—is one area that is often discussed.

Using carpet

Advantages
Noise reduction.
Ease of walking.
Reduction in falls and injuries.
Homelike ambience.
Disadvantages
Supports growth of fungi and bacteria.
Effect of cleaning is transient.
Air over carpeted areas tends to have higher pathogen levels as compared to hard flooring.
Verdict
There is little evidence linking carpet contamination with nosocomial infection in patients.
Guidelines
Avoid carpet use where spills are likely to occur and in high-risk patient-care. Employ appropriate carpet-cleaning methods.
Use vacuum cleaners fitted with HEPA filters.

Carpet versus vinyl

The advantages of using carpet include noise reduction, ease of walking, and possibly reduction in falls and resultant injuries (Counsell et al., 2000; Willmott, 1986). The other benefit of carpet is that it provides a more homelike/non-institutional ambience as compared to vinyl (Cheek, Maxwell, & Weisman, 1971; Glod et al., 1994). One study found that family and friends stayed substantially longer during visits to a rehabilitation unit when patient rooms were carpeted rather than covered with vinyl flooring (Harris, 2000).

However, the decision to use carpet in patient-care areas often meets with resistance from staff during design committee meetings. This is because, compared to hard floor surfaces, carpet is more difficult to keep clean, especially after spills of body and blood substances. Staff also experience difficulty in pushing carts, gurneys, and wheelchairs down carpeted hallways.

Several studies have documented the presence of different fungi and bacteria in carpeting in hospitals (Anderson, Mackel, Stoler, & Mallison, 1982; Beyer & Belsito, 2000; Gerson, Parker, Jacobs, Creger, & Lazarus, 1994; Skoutelis, Westenfelder, Beckerdite, & Phair, 1994). New carpeting becomes contaminated very quickly, and the effect of cleaning carpet is transient—bacterial levels soon return to precleaning levels. Bacterial contamination increases with higher levels of activity, and soiled carpet that is damp or wet provides the ideal setting for bacteria to proliferate. Studies have also found that the air above carpeted areas tended to have more consistent concentrations of microorganisms as compared to the air above hard flooring (Anderson, Mackel, Stoler, & Mallison, 1982).

But, there is little epidemiological evidence linking carpet contamination with incidence of nosocomial infection among immunocompromised patients. The CDC and HICPAC guidelines (Sehulster and Chinn, 2003) provide no recommendations against use of carpeting in patient-care areas. However, the guidelines suggest avoiding the use of carpet in areas where spills are likely to occur (e.g., laboratories, sinks, and janitor closets) or where patients may be at greater risk of infection from airborne pathogens (e.g., burn units, ICUs, and operating rooms).

In this context, proper methods of carpet cleaning are critical to minimize or prevent production of aerosols and dispersal of carpet microorganisms into the air. This includes maintenance of vacuum cleaners to prevent dust dispersal and using vacuum cleaners fitted with HEPA filters, especially in patient-care areas.

One study provides limited evidence that chemically treated carpet may have helped to keep the rates of nosocomial aspergillosis low in one patient-care unit (Gerson, Parker, Jacobs, Creger, & Lazarus, 1994). In general, carpet treated with bactericidal and fungicidal chemicals has not proven to be effective in reducing the rates of hospital-acquired infection among immunocompromised patients, and the CDC HICPAC guidelines provide no recommendations regarding the use of such carpets.

How are waterborne infections spread?

Waterborne microorganisms proliferate in moist environments and aqueous solutions, especially under warm temperature conditions and presence of a source of nutrition. Waterborne infections spread through

- direct contact (e.g., for hydrotherapy),
- ingestion of contaminated water,
- indirect contact, and
- inhalation of aerosols dispersed from water sources.

Waterborne infections caused by gram-negative bacteria and nontuberculous myobacteria (NTM) are transmitted via the first three modes. Inhalation of aerosols from water sources contaminated with *Legionella* spp. may cause a respiratory illness called Legionnaires' disease—a multisystem illness with pneumonia, especially among immunosuppressed patients (e.g., transplant patients, cancer patients), immunocompromised patients (e.g., surgical patients, patients with underlying chronic lung disease, dialysis patients), elderly persons, and patients who smoke (Sehulster & Chinn, 2003).

What are the sources of waterborne infections?

Potable water, water used for treatment (such as dialysis), lab solutions, ice, and hydrotherapy tanks may harbor gram-negative bacteria and NTM that then infect the individuals through the routes described above. The CDC and HICPAC guidelines (Sehulster & Chinn, 2003) recommend against using tap water for medical care (e.g., in direct patient care, for diluting solutions, as a water source for medical equipment and instruments, and for disinfection of instruments) as this might directly expose patients to these pathogens.

How to prevent waterborne infections

An important aspect of preventing contamination through the water supply involves designing the water supply system to minimize stagnation and back flow as well as provide temperature control to prevent growth of bacteria.

Waterborne infection prevention
Ensure regular maintenance and inspection of water supply system to minimize stagnation and back flow and for temperature control.
Use proper water treatment.
Regularly clean and maintain faucet aerators to prevent and control for *Legionella*.
Avoid decorative water fountains in high-risk patient-care areas.
Where fountains are used, water temperature should be kept cold, and fountains should be regularly cleaned and maintained.

Regular maintenance and inspection of water in holding tanks is also recommended (Sehulster & Chinn, 2003).

Legionella enter healthcare facilities most often through aerosols generated by cooling towers, showers, faucets, respiratory therapy equipment, and room-air humidifiers. Factors that encourage the colonization and amplification of *Legionella* in water sources include stagnation and warm temperature (77ºF–107 ºF). To prevent growth of *Legionella* and other bacteria in the water system, healthcare facilities are required to maintain cold water at a temperature below 68ºF and hot water at a minimum temperature of 124ºF. In addition, other methods, such as chlorine treatment or copper-silver ionization and UV light, may be used to treat water that is distributed in healthcare facilities (Sehulster and Chinn, 2003).

Point-of-use fixtures, such as sinks, showers, aerators, and toilets, may serve as reservoirs for pathogens such as *Legionella*. The wet surfaces by these fixtures and production of aerosols during use may result in multiplication and dispersion of microbes into the air.

Many studies have linked aerosols from shower heads and aerators with the outbreak of infection including Legionnaires' disease among immunocompromised patients (Bollin, Plouffe, Para, & Hackman, 1985; Cordes, A.M., & Gorman, 1981; Kappstein, Grundmann, Hauer, & Niemeyer, 2000; Weber, Rutala, Blanchet, Jordan, & Gergen, 1999). Healthy immunocompetent individuals (e.g., staff) were not infected when exposed to *Legionella* in shower water. ASHRAE (2000) recommends regular cleaning and disinfection of faucet aerators, especially in areas with high-risk patients to prevent and control for *Legionella*.

Decorative fountains and water features are increasingly being incorporated in healthcare facilities. They serve as landmarks, wayfinding elements, and create positive distractions. Many designers believe that water and water features provide a connection to nature for patients and help reduce the stress of a hospital visit (Rogers, 2006). However, such features are often strongly opposed by the infection-control department in the hospital on the grounds that water fountains and water features may harbor microorganisms that may cause nosocomial infections due to inhalation of aerosolized bacteria such as *Legionella*. According to a recent review by Rogers (2006), there are no documented cases of hospital-acquired Legionnaires' disease or any other waterborne infectious diseases that resulted from the indoor placement of a water fountain or water feature in hospital spaces. The only documented outbreak of Legionnaires' disease was among a group of older adults in a hotel. This was associated with a decorative water fountain that was not properly maintained and was lit by submerged lighting that caused the water to become warm—providing the ideal condition for the growth of *legionella* bacteria (Hlady et al., 1993).

According to Rogers (2006), decorative fountains would pose minimal risk in healthcare settings if facilities were to follow basic precautions.

- Keep water temperature cool to cold and avoid the use of submerged lighting.
- Perform routine fountain cleaning and maintenance in accordance with manufacturer's instructions.
- Avoid placing water fountains in areas that house high-risk patients.
- Install a glass barrier or maintain an appropriate distance between the water feature and the general public to minimize potential contact with droplets or aerosols.

Summary

Infections are transmitted in the hospital environment through air, surface, and water. Some key considerations for preventing and controlling the spread of nosocomial infections in hospitals include the following.

- Careful design and maintenance of the HVAC system including incorporation of HEPA filters reduces the threat of airborne diseases.
- Proper precautions during design and construction activities are also critical to preventing the spread of airborne infections.
- Single-bed rooms are strongly recommended from an infection-control perspective—it is easier to isolate infectious pathogens and disinfect single-bed rooms than multi-bed rooms once a patient has been discharged.
- The threat of infections spread through contact transmission of pathogens is also reduced in single-bed rooms.
- An important aspect of reducing infections spread through surface contact involves providing environmental support for handwashing—visible, conveniently placed sinks, handwashing liquid dispensers, and alcohol rubs.
- Regular cleaning, maintenance, and testing of water systems and point-of-use fixtures is important for preventing the spread of waterborne infections such as Legionnaires' disease.

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