**Introduction:** Understanding and Preventing Transmission of Healthcare-Associated Pathogens Due to the Contaminated Hospital Environment

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**Introduction**

Understanding and Preventing Transmission of Healthcare-Associated Pathogens Due to the Contaminated Hospital Environment

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More than 20 years ago, Dr Robert Weinstein estimated that the source of pathogens causing a healthcare-associated infection in the intensive care unit was as follows: patients’ endogenous flora, 40%–60%; cross infection via the hands of personnel, 20%–40%; antibiotic-driven changes in flora, 20%–25%; and other (including contamination of the environment), 20%.

Over the past decade, substantial scientific evidence has accumulated indicating that contamination of environmental surfaces in hospital rooms plays an important role in the transmission of several key healthcare-associated pathogens, including methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant Enterococcus (VRE), Clostridium difficile, Acinetobacter, and norovirus (Table 1).

All of these pathways have been demonstrated to persist in the environment for hours to days (and, in some cases, months), to frequently contaminate the surface environment and medical equipment in the rooms of colonized or infected patients, to transiently colonize the hands of healthcare personnel (HCP), to be associated with person-to-person transmission via the hands of HCP, and to cause outbreaks in which environmental transmission was deemed to play a role. Furthermore, hospitalization in a room in which the previous patient had been colonized or infected with MRSA, VRE, C. difficile, multidrug-resistant Acinetobacter, or multidrug-resistant Pseudomonas has been shown to be a risk factor for colonization or infection with the same pathogen for the next patient admitted to the room.

Although pathogen transfer from a colonized or infected patient to a susceptible patient most commonly occurs via the hands of HCP, contaminated hospital surfaces and medical equipment (and, less commonly, water and air) can be directly or indirectly involved in the transmission pathways. These transmission pathways and methods to interrupt transmission have been diagramed. HCP have frequent contact with environmental surfaces in patients’ rooms, providing ample opportunity for contamination of gloves and/or hands. Importantly, hand contamination with MRSA has been demonstrated to occur with equal frequency when HCP have direct contact with a colonized or infected patient or through touching only contaminated surfaces. The most important risk factor for HCP hand and glove contamination with multidrug-resistant pathogens has been demonstrated to be positive environmental cultures.

To decrease the frequency and level of contamination of environmental surfaces and medical equipment in hospital rooms, routine and terminal disinfection with a germicide has been recommended. Unfortunately, routine and terminal cleaning of room surfaces by environmental services personnel and medical equipment by nursing staff is frequently inadequate. Multiple studies have demonstrated that less than 50% of hospital room surfaces are adequately cleaned and disinfected when chemical germicides are used. Similarly, inadequate cleaning of portable medical equipment by nursing staff has also been demonstrated. The implementation of enhanced education, checklists, and methods to measure the effectiveness of room cleaning (eg, use of fluorescent dye) with immediate feedback to environmental services personnel has been found to improve cleaning and lead to a reduction in healthcare-associated infections.

No-touch methods (eg, ultraviolet C [UV-C] light and hydrogen peroxide systems) have been developed to improve terminal room disinfection. UV-C light has been demonstrated to decrease the level of C. difficile spores on contaminated surfaces in patient rooms, while hydrogen peroxide systems used in rooms of patients colonized or infected with a multidrug-resistant organism has been shown to decrease the risk of a subsequent patient admitted to the room developing infection or colonization with any multidrug-resistant organism.

This special issue of Infection Control and Hospital Epidemiology is focused on the epidemiology and prevention of healthcare-associated infections associated with the hospital environment and includes 21 papers. Although space precludes describing each individual paper here, this issue details...
the remarkable progress that has been made in understanding the role the contaminated hospital environment plays in transmission of healthcare-associated pathogens and potential control methods.

The frequency of contamination of room surfaces with aerobic gram-negative bacilli has been less studied than contamination due to MRSA, VRE, and *C. difficile*. After optimization of laboratory techniques, Judge et al.23 in a small study (ie, 6 room sites and 3 extended-spectrum \(\beta\)-lactamase (ESBL)—positive patients) found 4 of 18 surface sites in one patient’s room to be positive for ESBL-producing *Klebsiella pneumoniae*. In a prospective study, Ajao et al.24 report that a prior room occupant’s ESBL status was not significantly associated with acquisition of an ESBL-producing organism, although 6 (18%) of 32 of patients subsequently admitted to the room acquired a bacterial strain that was the same as or closely related to a strain from the prior room occupant. Thus, the data suggest a less important role for contaminated environment in the transmission of ESBL-producing bacteria than for MRA, VRE, and *C. difficile*. In contrast, Munoz-Price et al.25 report a high frequency of environmental contamination in the rooms of patients colonized or infected with *Acinetobacter baumannii*, compared with *A. baumannii*—negative patients (ie, 39% rooms positive vs 10%).

The most commonly used germicides for surface and equipment disinfection in hospital rooms have been quaternary ammonium compounds and phenolics. Fertelli et al.26 report similar effectiveness for equipment disinfection using an electrochemically activated saline solution containing 0.05% hypochlorous acid. Boyce and Havill27 report excellent effectiveness of an improved hydrogen peroxide wipe product for both surface and medical equipment disinfection.

This issue contains an excellent review of methods to improve environmental cleaning and disinfection by Carling and Huang.28 In a small study, Guerrero et al.29 demonstrated that prior education and silent direct observation of environmental service workers resulted in significant improvements in environmental cleaning, as measured by a reduction in surfaces contaminated with *C. difficile* spores. In an excellent study, Sitzlar et al.30 demonstrated a dramatic reduction in the frequency of surface cultures positive for *C. difficile* by means of sequential cleaning and disinfection interventions (ie, monitoring of cleaning by fluorescent markers with feedback, use of a UV-C room disinfection device, and enhanced standard disinfection of *C. difficile* rooms that included a dedicated daily disinfection team).

As noted above, no-touch methods have been developed to improve terminal room disinfection. In this issue, Varma et al.31 report an approximately 1-log reduction in total aerobic colony-forming units (CFUs) using a handheld UV device, while Anderson et al.32 report a 1–2-log decrease in target pathogens (ie, *C. difficile*, *Acinetobacter*, and VRE) on room surfaces using a UV-C device designed for room decontamination. A major limitation of no-touch methods of terminal disinfection is the time required for room disinfection (shorter with UV devices than with those generating hydrogen peroxide). Rutala et al.33 report that using a nanostructured UV-reflective wall coating can significantly reduce the time needed to inactivate MRSA (from 25 to 5 minutes) and *C. difficile* (from 44 to 9 minutes). Whether to routinely discard packaged items stored in rooms of patients under contact precautions is unclear, but studies have demonstrated that they may become contaminated with pathogens. Otter et al.34 report that 7%–9% of supplies were contaminated with 1 or more multidrug-resistant pathogens and that hydrogen peroxide vapor room disinfection inactivated the multidrug-resistant pathogens on the packaging of all supplies in treated rooms.

Self-disinfecting surfaces are currently being assessed as a measure to reduce the bioburden of pathogens on room surfaces and prevent infection and colonization with healthcare-associated pathogens. Compared with no-touch methods, they have the advantage of continuously decreasing the bioburden and being able to be used throughout a patient’s room occupancy. In this issue, Schmidt et al.35 show that copper bed rails reduced the bioburden on the rails by approximately
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for terminal room disinfection, and potentially the use of
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1–2-log10 CFUs and that, unlike standard disinfection, a re-
duced bioburden was maintained for hours after standard
cleaning. In an important study using a randomized trial,
Salgado et al55 reported that the installation of multiple copper-
coated surfaces in hospital rooms reduced the rate of healthcare-associated infections by more than 50%. A limi-
tation of their study was the failure to assess the frequency
of HCP hand hygiene and the effectiveness of routine and
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