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State of the Science Review

Beyond high-touch surfaces: Portable equipment and floors as potential sources of transmission of health care–associated pathogens

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Efforts to improve environmental cleaning and disinfection typically focus primarily on high-touch surfaces in patient rooms. This review highlights evidence that portable equipment and other shared devices and floors may be underappreciated as sources of dissemination of health care–associated pathogens. Practical approaches to address these sites of contamination are emphasized.

BACKGROUND

Effective disinfection of contaminated surfaces is essential to prevent transmission of pathogens such as *Clostridioides difficile*, methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and norovirus.[1] Efforts to improve disinfection usually focus primarily on surfaces in patient rooms that are frequently touched by the hands of health care workers or patients (eg, bed rails, call buttons); however, there is evidence that portable equipment and other shared devices may contribute to pathogen transmission.[2] In addition, there is emerging evidence suggesting that health care facility floors could be an underappreciated source of pathogen dissemination. This review examines the evidence that portable equipment and other shared devices and floors may contribute to dissemination of health care–associated pathogens. Practical approaches to address these sites of contamination are discussed.

PORTABLE EQUIPMENT AND OTHER SHARED DEVICES

Portable equipment and other shared devices in health care settings

Many high-touch items in health care settings are shared among personnel or patients.[3] These include keyboards, tablets, touchscreens, pens or styluses, and portable equipment (eg, vital signs equipment, bladder scanners, electrocardiogram machines, wheel chairs, workstations on wheels). Many of these devices make direct contact with patients (eg, wheel chairs, vital signs equipment), but indirect interactions between patients and equipment are also common (eg, hands of personnel move between equipment and patients). In intensive care units and on medical-surgical wards, frequent direct and indirect interactions occur between patients and medical equipment and other fomites.[3] Moreover, some types of equipment are widely shared among hospitalized patients, long-term care facility (LTCF) residents, and outpatients. For example, Figure 1 shows a network graph of more than 800 wheelchair transports of patients in a medical center over a 3-day period.[4] The graph demonstrates frequent movement of wheelchairs among inpatient wards, LTCF units, outpatient clinics, radiology, and physical therapy.

Many studies have demonstrated that portable equipment and other shared items are often contaminated with health care–associated pathogens.[1-10] These include *C difficile*, MRSA, VRE, and multidrug-resistant Gram-negative bacilli. Much of the contamination may occur when equipment is used during medical procedures and patient care activities. For example, in an evaluation of shedding of MRSA by colonized patients during procedures, contamination was detected on 32% of surfaces touched by personnel and on 25% of portable equipment used for the procedures or care activities.[10]

Evidence of pathogen transmission by portable equipment and other shared devices

In several outbreak investigations, shared medical equipment has been implicated as a potential vector for transmission of health care–associated pathogens.[2] The types of equipment linked to transmission have included thermometers, respiratory care equipment,

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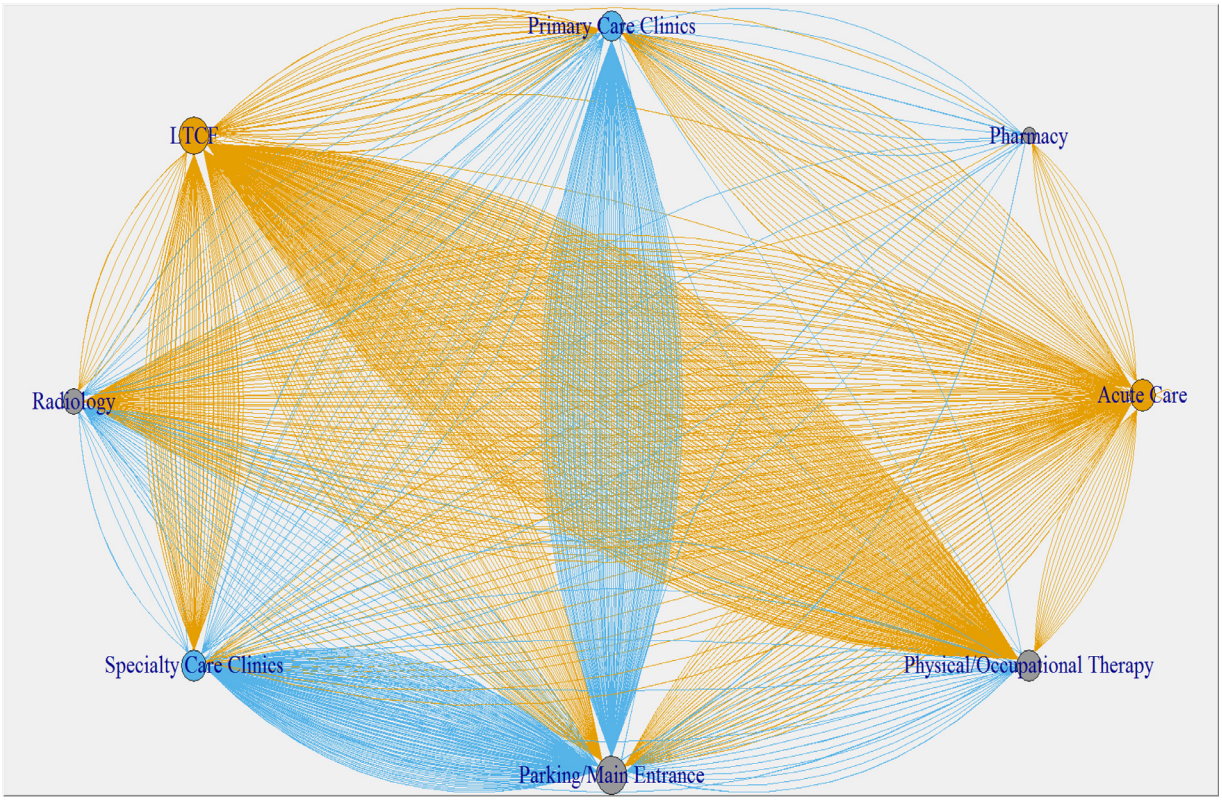

Fig 1. Network graph of wheelchair movement within the facility during a 3-day period. Transports including inpatient origins or destinations are shown in yellow, and all other trips are shown in blue. *LTCF*, long-term care facility. Reprinted from Jencson et al.[4]

ultrasound probes, pressure transducers, and electrocardiogram leads. For many of these outbreaks, there has not been definitive evidence linking contaminated equipment to pathogen transmission; however, contamination of equipment has been demonstrated, and correcting deficiencies in cleaning and disinfection of equipment has been associated with reductions in colonization or infection with pathogens.[2]

The devices most strongly linked to pathogen transmission are shared electronic thermometers. The earliest report linking thermometers to cross-transmission was published in 1947.[11] In the 1990s, shared thermometers, including rectal and oral thermometers, were linked to the transmission of VRE, *C difficile*, and *Enterobacter cloacae*.[12-15] In these outbreaks, it was demonstrated that thermometer handles were contaminated and it was suspected that contamination on the handles was transferred to patients via the hands of personnel. Moreover, substitution of single-use disposable thermometers for shared electronic thermometers was associated with significant reductions in *C difficile* infection (CDI) or VRE colonization.[14,16,17] Based on these findings, guidelines for the prevention of CDI in acute care hospitals include a recommendation that single-use disposable thermometers be used in the care of CDI patients.[18] In the *E cloacae* outbreak attributed to contaminated thermometers, inadequate disinfection practices were identified, and correction of these practices led to control of the outbreak.[15]

Recently, transmission of the emerging fungal pathogen *Candida auris* has also been linked to shared temperature probes.[19] The reusable probes were wiped between patients with quaternary ammonium compound wipes, but it was noted that the probes were difficult to clean and disinfect with wipes due to their design with a two-layer rubber sheath protecting the distal end of the wire adjacent to the sensor. The relatively poor activity of quaternary ammonium compounds against *Candida* species may have also contributed to inadequate disinfection.[20] Discontinuation of the use of the temperature probes was associated with resolution of an outbreak.[19]

Simulation studies demonstrating transmission from contaminated portable equipment

Benign surrogate markers, such as nonpathogenic viruses and viral DNA, provide a powerful tool to study routes of pathogen transmission.[21] In several recent studies, these surrogate markers have been used to investigate the potential for portable equipment to serve as a vector for dissemination of microorganisms.[22-24] In a medical and surgical intensive care unit, it was demonstrated that a viral DNA marker inoculated onto shared portable equipment disseminated widely to surfaces in patient rooms and provider work areas and to other types of portable equipment.[22] Subsequent studies have demonstrated similar dissemination of viral DNA surrogate markers from computer touchscreens and from thermometer handles in a LTCF and on hospital wards.[23,24]

One striking observation from many studies using highly discriminative molecular typing methods is that genetically related organisms are often detected in patients with no shared exposure on the same ward.[25,26] Because personnel and equipment often move between wards, it is plausible that portable equipment might serve as a vector for dissemination of health care–associated pathogens between wards. In an observational simulation study, a viral DNA marker inoculated onto portable equipment on a medical ward was disseminated to other wards when equipment was shared and to a physician work area and the hospital cafeteria by personnel.[26] Figure 2 provides an illustration of transfer of the marker from a contaminated cardiac monitor and electrocardiogram machine to surfaces on 2 other wards when the patient was transferred. These findings highlight the

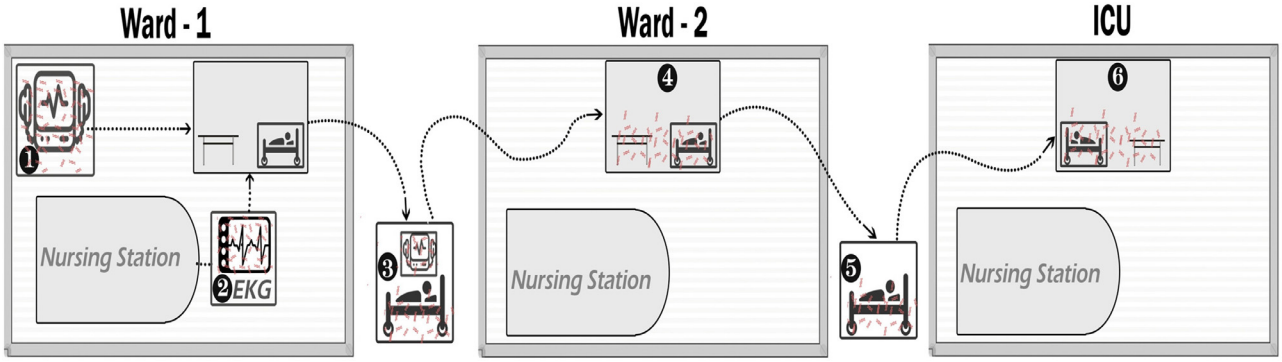

Fig 2. Transfer of a viral DNA surrogate marker (red helices) from an inoculated cardiac monitor and electrocardiogram (EKG) machine on one medical ward to environmental surfaces on another ward. The contaminated cardiac monitor (1) and EKG machine (2) were used while caring for a patient on ward 1 who was then transferred with the cardiac monitor attached (3) to ward 2 (4) and then without the monitor to the intensive care unit (ICU) (5 and 6), resulting in detection of DNA markers on the surfaces in each ward. Reprinted from Alhmidi et al.[26]

importance of considering the potential for portable equipment to disseminate pathogens among wards in investigations of pathogen transmission.

Potential interventions to address contamination of portable equipment and shared devices

Current guidelines recommend that medical equipment that comes into contact with intact skin should be cleaned and decontaminated after each patient use;[27] however, cleaning and disinfection of portable equipment may be inadequate in many health care settings. Nurses and ancillary staff are often given responsibility for cleaning and disinfection of portable equipment after each use even though they are unlikely to have received education on cleaning and disinfection and may not have easy access to disinfectants. In a tertiary care hospital, Havill et al[28] reported that portable equipment was often not cleaned and disinfected between each patient use according to written protocols.

One of the guiding principles of infection prevention is that objective monitoring of staff compliance with regular feedback on performance is needed to ensure adherence to protocols. Health care facilities should develop protocols for cleaning and disinfection of portable equipment and monitor practices.[28,29] The protocols should define when and how equipment should be cleaned and disinfected and identify the responsible personnel. Direct observations and interviews with staff members are essential to understand current practices and to appreciate issues that may limit effective cleaning and disinfection (eg, availability of supplies for non-environmental services personnel).[29] In our facility, we recommend that medical equipment that comes into direct or indirect contact with patients should be cleaned and decontaminated after each patient use by the personnel using the equipment; disinfectant wipes are made widely available at points of equipment storage. Fluorescent markers may be useful to monitor thoroughness of cleaning of equipment, and adenosine triphosphate assays can assess removal of organic material; however, because limited data are available on cleaning and disinfection of equipment, further studies are needed to assess the effectiveness of current approaches and to identify effective methods for monitoring.

"No-touch" devices could potentially be useful as an adjunctive method for decontamination of shared items and equipment.[23,30,31] Many facilities that use room decontamination devices encourage staff to place portable equipment in the room when decontamination cycles are being completed. Smaller devices that utilize ultraviolet (UV) light with relatively short cycle times (90 seconds or less) are also available.[23,30] For most of the UV devices that are designed for decontamination of small items, the UV cycle is delivered in an enclosed area such that there is minimal or no risk to personnel.[23,31]

FLOORS

Evidence supporting floors as a potential source of pathogen transmission

In culture surveys conducted in health care facilities, floors are often heavily contaminated with health care–associated pathogens, including *C difficile* spores and multidrug-resistant organisms.[32] However, floors have not traditionally been considered a likely source of pathogen transmission because they are rarely touched. Thus, efforts to improve cleaning and disinfection in health care facilities have rarely included a focus on floors. In fact, many health care facilities clean floors with detergents that do not provide antimicrobial activity.

Several recent studies have raised concerns that floors in health care facilities might be an underappreciated source for transmission of pathogens.[32-38] These studies have provided several types of indirect evidence supporting the potential for transfer of pathogens from floors to patients. First, shoes and socks often become contaminated with pathogens from floors.[32,35-37] Figure 3 provides an illustration of MRSA acquired on the socks of a patient and the shoes of a health care worker after walking inside a MRSA isolation room. It is plausible that such pathogens might be acquired on patients' hands when socks or shoes are removed.

Second, many items that are touched come in contact with the floor in patient rooms. In a point prevalence survey, high-touch objects were frequently observed on the floor in patient rooms.[33] These included items such as call buttons, pulse oximetry finger probes, blood pressure cuffs, canes, bed linens, and bed pans. Moreover, it was demonstrated that touching these objects could result in the transfer of pathogens to hands. Based on these findings, it was recommended that health care personnel and patients should be educated to avoid placing high-touch objects on floors when possible and to clean and disinfect items that do contact floors.[33]

Third, a simulation study provided evidence that a live microorganism could disseminate from floors in patient rooms.[32] In the study, a nonpathogenic virus inoculated onto floors in hospital rooms disseminated rapidly to the footwear and hands of patients, to surfaces in the room, to adjacent rooms, and to nursing stations. These results suggest that patients and personnel contributed to virus dissemination. Patients may have transferred virus particles from their footwear to their hands and to surfaces in their room. The finding of contamination in adjacent rooms and in the nursing station clearly

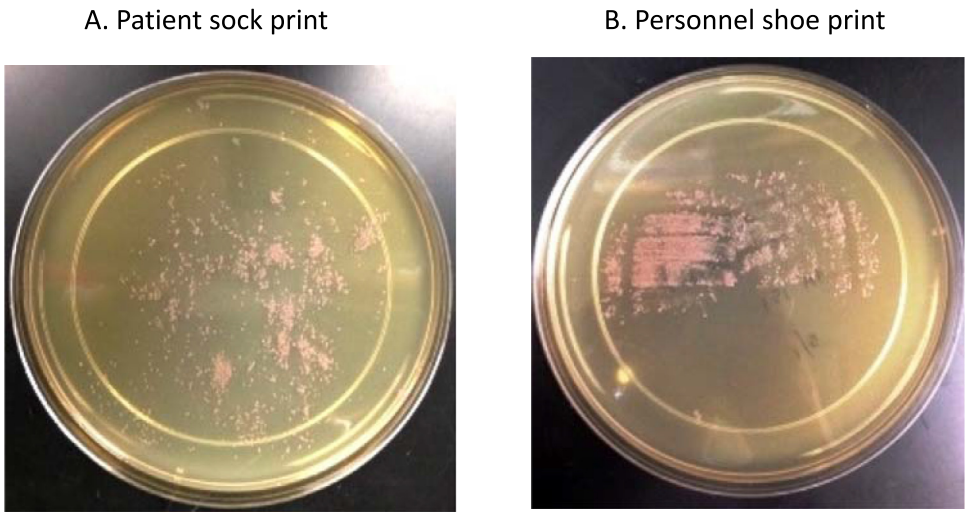

Fig 3. Culture plates showing methicillin-resistant *Staphylococcus aureus* (MRSA) colonies transferred from the sock of a patient (A) and from the shoe of a health care worker (B) after walking inside an MRSA isolation room. The sock and shoe were imprinted onto media selective for culture of MRSA, and colonies were confirmed to be MRSA.

suggests that health care personnel contributed to dissemination after acquiring the virus during contact with contaminated surfaces or patients.

Finally, devices with wheels may pick up pathogens from floors and could serve as a vector for widespread dissemination in health care facilities. As noted previously, shared wheelchairs in a hospital and affiliated long-term care facility frequently carried patients among inpatient wards, LTCF units, outpatient clinics, radiology, and physical therapy.[4] A culture survey demonstrated that the shared wheelchairs were frequently contaminated with health care–associated pathogens, including *C difficile* spores.[4] These results highlight the potential for shared wheelchairs to serve as vectors for pathogen dissemination.

Potential interventions to address floor contamination

Although there is increasing evidence that floors could be a potential source of pathogen dissemination, further evidence will be required to convince health care facilities to invest substantial efforts in cleaning and disinfection of floors. There are currently no randomized trials that have examined floor disinfection as an infection control measure. One previous quasi-experimental study examined disinfectant substitutions for floor and furniture disinfection.[39] In that study, an active oxygen-based compound was substituted for a detergent for daily cleaning and disinfection of floors and furniture, and a quaternary ammonium compound was continued for floors on a second ward. The active oxygen-based product was associated with better eradication of bacteria from surfaces but no reduction in nosocomial bloodstream infections or MRSA colonization and infection.[39]

Although there is insufficient evidence to focus substantial efforts on cleaning and disinfection of floors, there are some common sense measures that infection prevention programs might consider. As noted previously, it is reasonable to educate health care personnel and patients about not placing high-touch objects on floors whenever possible and to clean and disinfect any items that do contact floors.[33] It is also reasonable for control programs to review current floor cleaning and disinfection methods to ensure that practices minimize the risk for the spread of pathogens from room to room. In a recent study, it was demonstrated that floors in hospital rooms were more contaminated than high-touch surfaces, and paradoxically floors had a higher bacterial burden after versus before manual cleaning (Fig 4).[40] It is likely that the increase in bacterial burden after cleaning was attributable to the floor cleaning practices in the facility. A neutral detergent with no antimicrobial activity was used, and the solution and mop head were changed after every third room. These practices could result in the buildup of bacterial burden in detergent solutions and on mop heads, with transfer of organisms from room to room. Notably, adjunctive use of a room decontamination device was effective in reducing the bacterial bioburden.[40]

In another study from our facility, the use of a cleaner/disinfectant with 2 or more disposable mop heads per room resulted in substantial reductions in MRSA on floors in patient rooms, and *C difficile* and *Candida* species were reduced to undetectable levels (Fig 5).[34] Based on these results, we recommend that a cleaner/disinfectant be used on floors for post-discharge rooms and that mop heads be replaced between each room. In the same study, it was demonstrated that an ultraviolet-C (UV-C) room decontamination device was effective in reducing pathogens on floors, and adjunctive use of the UV-C device resulted in a further reduction of residual MRSA on floors (Fig 5).[34] Thus, the study findings suggest that manual cleaning and disinfection can be effective in reducing floor contamination in health care facilities and UV-C may be useful as an adjunctive measure. As noted

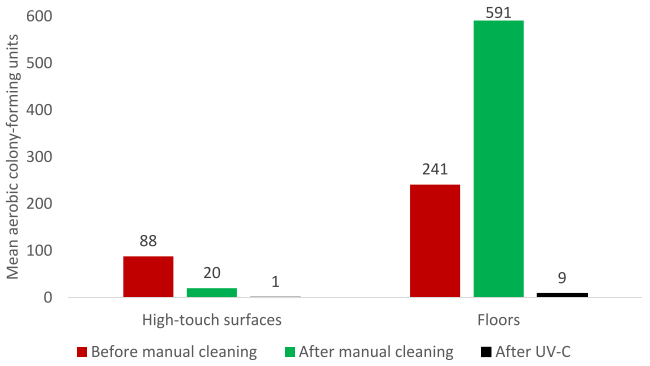

Fig 4. Mean aerobic bacterial colony-forming units recovered from hospital room floors before post-discharge manual cleaning, after post-discharge manual cleaning, and after adjunctive use of an ultraviolet-C (UV-C) device. For floor cleaning, a neutral detergent was used, and the solution and mop head were changed after every third room. Adapted from Wong et al.[40]

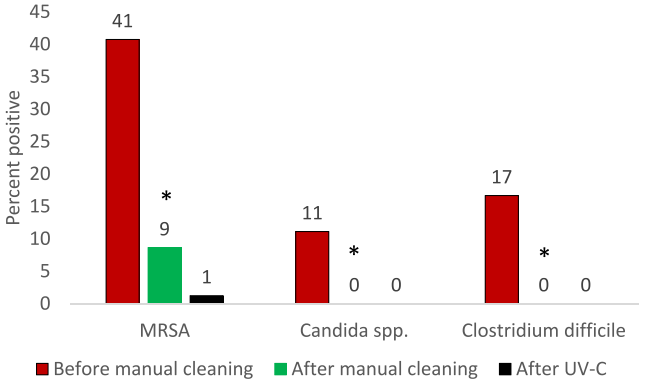

Fig 5. Percentage of positive cultures (number of sites positive/number of sites cultured) for methicillin-resistant *Staphylococcus aureus* (MRSA), *Candida* spp, and *Clostridium difficile* from hospital room floors before post-discharge cleaning, after post-discharge cleaning by environmental services personnel, and after operation of an ultraviolet-C (UV-C) device for 5 minutes. *$P < .01$. Reprinted from Mustapha et al.[34]

previously, Wong et al[40] also demonstrated that use of a UV-C device reduced bacterial bioburden on hospital room floors. A UV-C decontamination device designed to decontaminate shoe soles has also been shown to reduce pathogens on shoe soles with subsequent decreased dispersal to floors and other surfaces in a simulated clinical environment.[38]

CONCLUSIONS

Efforts to improve cleaning and disinfection in health care facilities typically focus primarily on surfaces in patient rooms that are frequently touched; however, as reviewed here, there is considerable evidence that portable equipment and other shared devices may contribute to pathogen transmission. In addition, there is emerging evidence that health care facility floors could also serve as a source of pathogen dissemination. There is evidence that both manual cleaning and disinfection and "no-touch" decontamination devices can be effective in reducing contamination of portable equipment and floors. Further studies are needed to determine if practical interventions to improve cleaning and disinfection of portable equipment and floors will be helpful in reducing dissemination of health care–associated pathogens.

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