Shoe Sole and Floor Contamination: A New Consideration in the Environmental Hygiene Challenge for Hospitals

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Article

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Editor's note: This is the first in a series on fomites in the healthcare environment that are under the radar but deserve renewed attention.

It sounds like the beginnings of a riddle: What do we wear and walk on daily but never truly think about, especially in terms of pathogen transmission? Shoe soles and healthcare facility floors are the workhorses of the environment, and yet their capacity for aiding and abetting infectious agents remains unclear. Recent research seems to confirm what common sense already tells us -- that items which contact the floor are contaminated and could serve as vectors; despite daily cleaning of high-touch surfaces such as floors, it has already been shown that bacterial and viral contamination returns rather quickly.

In 1967, Ayliffe, et al. observed the obvious: "The floors of hospital wards become contaminated with large numbers of bacteria, including Staphylococcus aureus, and are commonly assumed to be important reservoirs of hospital infection." They added, " Efforts are also commonly made to reduce the numbers of bacteria on the floors by manual or mechanical scrubbing or disinfection, but the results of such treatment have been disappointingly small. Ayliffe, Collins and Lowbury (1966) found that areas of floor protected against recontamination lost about 80 percent of their bacterial flora after mopping or mechanical scrubbing, and a significantly larger proportion (about 99 percent) after treatment with certain disinfectants. Since areas which were not protected against recontamination were often as heavily contaminated 1 hour after scrubbing or disinfection as they were before such treatment, there appeared to be little or no advantage in cleaning floors. On the other hand, frequent scrubbing or the use of disinfectants might be expected to keep the mean level of bacterial contamination lower than that which is present on an uncleaned surface. Even if regular disinfection of floors reduces the mean level of contamination, such treatment cannot be considered useful in preventing infection unless pathogens on the floor are transferred either by air or by contact to patients in the ward."

The researchers continue, "From this study we deduce that at most times daily disinfection contributes little or nothing to the bacteriological cleanliness of ward floors. In operating theaters and other areas with less contamination than that which occurs in wards, disinfection or cleaning might be expected to be more effective. The main function of disinfection, however, must be in the removal of sporadic local contamination which occurs when floors or walls become contaminated with sputum, pus, urine and other fluids, or when walls are touched by fingers of a heavy carrier of pathogens. Since the occasions when such contamination occurs often pass unnoticed, there is a case for regular disinfection to prevent this sporadic hazard in areas where the risk of contamination is high."

Guidance from the Centers for Disease Control and Prevention (CDC) issued in 2003 predates the most recent research; the agency's Guidelines for Environmental Infection Control in Health-Care Facilities proclaimed, "Extraordinary cleaning and decontamination of floors in healthcare settings is unwarranted. Studies have demonstrated that disinfection of floors offers no advantage over regular detergent/water cleaning and has minimal or no impact on the occurrence of healthcare-associated infections. Additionally, newly cleaned floors become rapidly re-contaminated from airborne microorganisms and those transferred from shoes, equipment wheels, and body substances. Nevertheless, healthcare institutions or contracted cleaning companies may choose to use an EPA-registered detergent/disinfectant for cleaning low-touch surfaces (e.g., floors) in patient-care areas because of the difficulty that personnel may have in determining if a spill contains blood or body fluids (requiring a detergent/disinfectant for clean-up) or when a multidrug-resistant organism is likely to be in the environment. Methods for cleaning non-porous floors include wet mopping and wet vacuuming, dry dusting with electrostatic materials, and spray buffing. Methods that produce minimal mists and aerosols or dispersion of dust in patient-care areas are preferred."

The recommendation from the dated CDC guidance is to "keep housekeeping surfaces (e.g., floors, walls, and tabletops) visibly clean on a regular basis and clean up spills promptly." Additionally, the CDC indicated, "After the last surgical procedure of the day or night, wet vacuum or mop operating room floors with a single-use mop and an EPA-registered hospital disinfectant." These guidelines have not been updated by HICPAC since their issuance.

More recently, Koganti, et. al. (2016) observed, "â€¦ hospital floors are often heavily contaminated but are not considered an important source for pathogen dissemination because they are rarely touched. However, floors are frequently contacted by objects that are subsequently touched by hands (e.g., shoes, socks, slippers). In addition, it is not uncommon for high-touch objects such as call buttons and blood pressure cuffs to be in contact with the floor (authors' unpublished observations)." The authors posited that floors may be an "underappreciated reservoir for pathogen transmission" and set out to examine the potential for the dissemination of microorganisms from floors of isolation rooms to the hands of patients and to high-touch surfaces inside and outside of rooms.

Ten ambulatory patients in contact precautions for C. difficile infection or carriage of MRSA were enrolled in this study. For each patient, a section of the floor adjacent to the bed was inoculated with sterile water containing a bacteriophage and allowed to dry. Patients were not aware of the precise area of inoculation and hospital personnel were not aware of the study. The protocol for cleaning of contact precautions rooms included daily disinfection of high-touch surfaces with bleach wipes each morning but floors were cleaned only if visibly soiled; compliance with daily disinfection was monitored with fluorescent markers with more than 85 percent of sites demonstrating marker removal during the study. Preliminary experiments demonstrated that the inoculum persisted on wood laminate floors for at least three days, with a 1 to 2 log decrease in recovery attributed to desiccation.

The authors found that of the 10 patients on four wards, seven had samples collected for three days; two patients were discharged after one day and one patient was discharged after two days. Inoculum was detected on multiple surfaces of all patient rooms by one day after inoculation. On days 1 and 3, the concentration of inoculum was higher for surfaces less than or equal to 3 feet vs more than 3 feet from the bed and more sites were contaminated at less than or equal to 3 feet. Inoculum contamination was not significantly different at less than or equal to 3 feet vs more than 3 feet on day 2.

Contamination was common on high-touch surfaces in adjacent rooms, in the nursing station, and on portable equipment. Portable equipment included wheelchairs, medication carts, vital signs equipment, and pulse oximeters. All negative control swabs were negative for inoculum.

As Koganti, et. al. (2016) observed, "It is likely that both patients and healthcare personnel contributed to dissemination of the virus. [Inoculum] present on patients' footwear was probably acquired during direct contact with the contaminated floor site adjacent to the bed. During removal of footwear, patients could easily acquire the virus on their hands, with subsequent transfer to touched surfaces and to other skin sites. The finding of contamination in adjacent rooms and in the nursing station clearly suggests that healthcare personnel contributed to dissemination after acquiring the virus during contact with contaminated surfaces or patients."

The researchers added, "Our findings have important implications. Studies are needed to assess the potential for modes of dissemination from floors other than footwear. For example, wheelchairs and other wheeled equipment could disseminate pathogens. If additional evidence demonstrates dissemination from floors, studies will be needed to assess the efficacy of current floor cleaning strategies and to evaluate other methods to interrupt dissemination. Because non-sporicidal disinfectants are often used on floors in rooms of patients with C. difficile infection, there is need for data on how effectively the burden of spores is reduced on floors. Finally, studies in non-hospital settings are needed. For example, floors in community households have been shown to be frequently contaminated with C. difficile spores."

Deshpande, et al. (2017) made a strong argument for a new focus on floors with their survey of five hospitals. They found that floors in patient rooms were frequently contaminated with pathogens and high-touch objects such as blood pressure cuffs and call buttons were often in contact with the floor. Contact with objects on floors frequently resulted in transfer of pathogens to hands.

In this study, researchers cultured 318 floor sites from 159 patient rooms (two sites per room) in five Cleveland-area hospitals. The hospital rooms included

both C. difficile infection (CDI) isolation rooms and non-CDI rooms. Researchers also cultured hands (gloved and bare) as well as other high-touch surfaces such as clothing, call buttons, medical devices, linens, and medical supplies. The researchers found that floors in patient rooms were often contaminated with Methicillin-resistant Staphylococcus aureus (MRSA), VRE, and C. difficile, with C. difficile being the most frequently recovered pathogen found in both CDI isolation rooms and non-CDI rooms.
Of 100 occupied rooms surveyed, 41 percent had one or more high-touch objects in contact with the floor. These included personal items, medical devices, and supplies. MRSA, VRE and C. difficile were recovered from 6 (18 percent), 2 (6 percent), and 1 (3 percent), respectively of bare or gloved hands that handled the items.

“Efforts to improve disinfection in the hospital environment usually focus on surfaces that are frequently touched by the hands of healthcare workers or patients,” observe Deshpande, et al. (2017) “Although healthcare facility floors are often heavily contaminated, limited attention has been paid to disinfection of floors because they are not frequently touched. The results of our study suggest that floors in hospital rooms could be an underappreciated source for dissemination of pathogens and are an important area for additional research.”

In their study, Rashid, et al. (2016) implicated the shoes of healthcare personnel as a potential vector. The researchers reviewed the literature to assess the evidence that shoe surfaces are vectors for infectious disease transmission and to evaluate the evidence for the efficacy of disinfectants to decontaminate shoe surfaces.

As the researchers note, "Despite a high likelihood of microbiological contamination, shoes are not often considered a vector for infectious diseases transmission. A search identified no systematic review of this topic â€¦ After a thorough bibliographic search, studies were identified that showed high rates of bacterial shoe sole contamination in the hospital-, community, and animal worker areas. Although several chemical and nonchemical decontamination strategies have been tested, none have shown to be able to consistently decontaminate shoe bottoms."

They comment further, "In this review, many of the most common microbiologic pathogens including MRSA, Enterococcus, Cl. difficile, and Gram-negative bacteria were identified on shoe soles. Disease transmission of MRSA has been shown to be increased in hospitals with increased patient sharing between hospitals as opposed to hospitals that do not share patients (Chang, et al. 2016). Movement of MRSA from hospital to hospital was commented to be likely due to patient spread; however, it is possible that shoe bottoms could have also accounted for the vector spread based on findings from this meta-analysis. All these hypotheses will require generation of a transmission dynamic model from the bottoms of shoes to a patient. All of these data should be tested in the context of proper handwashing and other proven infection control practices."

As Rashid and VonVille, et al. (2016) observe, "From the floor, it is plausible that air currents, human movements over the floor and other factors that aerosolize or provide an airborne opportunity for the organism may occur, thus causing human infections via inhalation, horizontal or cross-contamination from other persons, clothing or equipment that the organism resettles upon. It is furthermore plausible that due to the existence of these microbiological pathogens on shoe soles that the rapid spread of these organisms in the healthcare environment can be directly related to the organisms on floors getting picked up and carried by shoe soles and retransferred to floors in other areas by human movement. This potential transmission dynamic requires validation. Shoes become contaminated from a dirty floor and parallel methods to decontaminate flooring is also required. Perhaps most surprising finding from this study was the relative lack of consistent efficacy to decontaminate shoe bottoms using either chemical or nonchemical strategies. Although, most strategies had variable success, the complexity of maintaining sterility of the disinfectant strategy appeared to be the most complex and difficult to optimize component of the decontamination strategy. For example, Langsrud, et al. (2006) reported that chlorine-containing foo baths may act as a source of bacterial contamination in food factories. Taken together, these results suggest the shoe soles can be a likely vector for infectious diseases transmission and an effective decontamination strategy is direly needed."

Shoes are not the only culprits. A few studies also indicate some risk from floors and that protective shoe coverings don't necessarily help.

Gupta, et al. (2007) examined the efficacy of protective footwear on bacterial floor colonization. The study was carried out in the intensive care unit (ICU) of a tertiary-care hospital and was divided into two phases of two weeks each, phase I with and phase II without use of protective footwear. Samples were taken at six sites: footwear exchange area; visitors /staff route; partitioned patient cubicle; central monitoring area; open patient cubicle and scrub areas. Floor and air samples were taken at different times of the day; bacteria were identified and colony forming units (CFUs) measured from floor and colony forming units/metre3 (cfu/m3) from air sample cultures. Gupta, et al. (2007) isolated a total of 9,521 bacterial CFUs from 192 samples in phase I from the floor samples and 9971cfu from 192 samples in phase II. From 96 air samples in each phase, a mean of 262 cfu/m3 in phase I and 220cfu/m3 in phase II were isolated. The difference between the two phases was statistically not significant (p value > 0.05 for both). The researchers reported that floor and air colony counts showed no significant difference in the two phases with and without protective footwear and concluded that protective footwear had no significant impact on bacterial contamination of floors.

In a more recent study, 40 disposable medical shoe covers were briefly exposed to the surgical floor and were found by Galvin, et al. (2016) to be contaminated by a large number of bacteria. This study also demonstrated live bacteria, including pathogens attached to contaminated shoe covers, can be subsequently transferred to surgical bedsheets. As Galvin, et al. (2016) note, "The hospital floors in the day surgery unit were cleaned daily and appeared clean by visual observation. Nevertheless, the shoe covers worn for 5 minutes picked up substantial amounts of live bacteria. This highlights the ability of microorganisms to be present in seemingly clean environments. This study also demonstrated that the live bacteria attached to contaminated disposable medical shoe covers can be subsequently transferred to bedsheets. This has the implication of all patients being equally susceptible to infection regardless of their waiting time prior to surgery, especially if they get into and out of their bed on multiple occasions. The transmission of bacteria from the day surgery floor to the bedsheet opens up the possibility of a patient developing an SSI."

The researchers add, "We suggest an infection control policy should be considered to prevent patients returning to their bed with contaminated disposable shoe covers because this simple measure may reduce surgical bed contamination and the number of SSIs and their associated detrimental impact."

Ali, et al. (2014) sought to examine the role of using shoe covers by medical staff and visitors on infection rates, mortality and length of stay in the ICU. The researchers measured the rates of infection (by checking patients for common ICU pathogens), mortality and length of stay of patients admitted in MICU and SICU for three consecutive months in the spring. Use of shoe covers was abandoned during this period. The same parameters were measured for the patients admitted for another three-month period in the summer, the period during which shoe covers were strictly used by all the staff members and visitors. The data was then analyzed and compared.

A total of 1,151 patients were studied in the six-month period. Among the two groups of patients, managed with and without using shoe covers in the ICU, statistically significant decrease was seen in terms of length of ICU stay in patients managed in duration of shoe covers. However, the time period in which shoe covers were used the infections with three common ICU pathogens -- MRSA, VRE and Acinetobacter -- were statistically significant more than the periods in which shoe covers were not used. There was no significant difference in mortality for both groups.

Mahida and Boswell (2016) also considered the impact of non-slip socks. As they explain, "Non-slip socks are single-use medical device items but the frequency with which they should be changed is unclear. Hence patients may wear these socks for a short period of hours or possibly several days. In addition, investigators noted that patients not only use them to walk to various parts of the hospital during the inpatient journey, including toilets, radiology departments, coffee shops, restaurants, but also wear them in bed.

These socks are made of cotton and polyester, terrycloth lined, with treads added to improve underfoot traction."

Solutions to Floor Contamination

Floor cleaning and disinfection is an essential component of a larger, effective environmental hygiene program in the hospital. There are a number of steps that experts suggest to keep floors from serving as a vector of potentially infectious microorganisms. Daily maintenance involves the routine removal of dry soil and damp/wet soil through vacuuming, dust/damp mopping and other bioburden removal processes. A good floor-care disinfection program comprises use of effective disinfectants/detergents, tools and procedures. All three elements must be present to be successful in physically and chemically removing soil and microorganisms. Many experts emphasize that so-called 'extraordinary' attempts to disinfect floors are usually unnecessary, as the actual physical removal of soil and microorganisms is probably at least as important as the germicidal activity of the disinfectant used.

Low-level, hospital-grade disinfectants are the recommended products for floor-care disinfection in healthcare settings. The Environmental Protection Agency (EPA) regulates and registers all low-level disinfectants. When selecting a disinfectant, first review technical research bulletins provided by vendors. These bulletins will identify the different microorganisms that the disinfectant has been tested against. Then match the tested microorganisms against those most prevalent in your particular environment. In addition to the microorganisms most prevalent, a disinfectant should have a broad range of kill; it should be capable of killing Gram-positive and Gram-negative bacteria, fungi, and viruses. Second, compute the parts per million (PPM) of active disinfectant. This computation simply translates the percentage of active ingredients into parts per million. This computation is: % of active ingredients X 10,000 Dilution Rate. The resulting number can be used to determine how effective a disinfectant will be as you introduce soil load. As the EVS worker mops a floor and immerses the mop into the bucket of disinfectant solution, the solution will degrade. At a certain point, approximately 300 to 350 ppm, a disinfectant will be rendered ineffective. Therefore, it is recommended to change the soiled disinfectant solution on a routine basis, usually every three to four rooms. Exceptions to this rule would include isolation cases, discharges, cleaning in surgery or delivery, and cleaning of blood spills.

Jensen (2016) advises, "Using the appropriate tools and chemicals for each part of the floor care process will avoid damage to the floor care surface. Using the wrong product will void the floor manufacturer's warranty and could mean significant expense to replace any damaged flooring. In general, floor care maintenance is divided into three frequencies. As the name suggests, daily maintenance is a routine process of removing dry soiling such as dust and dirt through vacuuming, dust mopping and damp mopping. By following these simple processes frequently, the hospital can extend the time between more aggressive and costly processes. The first step is to remove the dry dust and soil not removed by the matting. This is most efficiently accomplished by vacuuming carpeted surfaces and dust mopping, then damp-mopping hard floors. This should be performed daily at a minimum and more often when conditions require. The dirt removed at this point in the process doesn't have to be removed later with more aggressive processes and expense. This daily cleaning should be performed more frequently at all entrances and less frequently farther into the center of the facility. Microfiber products are effective when used dry or with water because microfiber cleans surfaces mechanically, not chemically, by scraping the surface with microscopic precision. The best chemical for mopping most hard-surface floors is a neutral - pH between 6 and 7 - floor cleaner that has no strong alkaline ingredients that might remove polish. Outside of surgical and invasive practice areas, floors in patient areas are not typically considered sterile environments. If a healthcare institution requires that disinfectants be used on floors, a quaternary product should be used, followed by a neutral floor cleaner to rinse the floor after the disinfectant has dried. ES managers should ensure proper dilutions of all chemicals to prevent excess chemical residue on the dried floor."

Jensen (2016) continues, "Periodic maintenance consists of more aggressive methods, which incorporate scrubbing, buffing and burnishing. Depending on the traffic volume or location of the particular floor, this could require daily maintenance, or it might be performed weekly or semi-weekly. Again, higher-frequency scrubbing is performed in locations closer to facility entrances and in high-traffic areas vs. locations toward the center. When creating floor-cleaning schedules, this methodology should be utilized to ensure that time is spent where needed. All floors should be dust mopped prior to using a floor-scrubbing process to prevent excess dirt from accumulating on the scrubbing pads and equipment and being sucked into the vacuum motor system or scrubbed into the floor finish. After placing safety or caution signs in the area, the floor is ready to be cleaned. The floor scrubber uses a process of placing water or cleaner on the floor, scrubbing with moderately abrasive nonwoven pads, and then removing the water with a vacuum. This is typically done in one continuous process as the machine passes over the floor. A pH-neutral floor cleaner or similar product can be used in the floor scrubber. If there are individuals with respiratory sensitivity in the area, water can be used. The operator should make overlapping passes with the machine in the center of hallways and corridors where most traffic occurs, and only one pass near the walls where there is less traffic. If this is performed late in the evenings, nursing can be consulted to see if patient room doors can be closed to limit disturbances."

In addition to manual cleaning of floors, a few studies have shown some benefit of adjunct technologies. For example, UV-light is being employed in a number of other devices that are designed to kill and/or inactivate the vast majority of exposed microorganisms, including bacterial and viral pathogens, on the soles of shoes in short amounts of exposure time. By adding a UV-C shoe sole disinfection device to an existing infection control program, the facility could decrease the overall microbial load. These devices are a potential new way to help decrease the aerosolizing, migration or transfer of pathogenic organisms that may lead to higher healthcare-associated infection (HAI) rates. Many of these devices pose virtually no workflow interruption or require additional staff or monetary cost to operate.

Rashid and Poblete, et al. (2018) sought to demonstrate that shoe soles can be vectors for healthcare-associated infection, and to investigate if a UV-C shoe sole decontamination device would decrease this risk effectively. Staphylococcus aureus, Enterococcus faecalis and Escherichia coli as well as a non-toxigenic strain of Clostridium difficile were spiked onto standardized rubber-soled shoe soles and then selected at random for UV-C exposure or no

UV-C exposure. Experiments were performed to test the efficacy of the UV-C device to decontaminate shoe soles and flooring. E. faecalis was spiked onto shoes to assess colonization of a simulated healthcare environment and patient. The researchers found that the UV-C device decreased shoe sole contamination significantly for all tested bacterial species, and decreased floor contamination significantly for all floor types and species tested. The log10 reduction was the highest for E. coli, followed by E. faecalis, S. aureus and C. difficile. Exposure of shoe soles to the UV-C device decreased contamination significantly -- a mean log10 reduction. Proportions of samples from furniture, bed and patient dummy samples decreased from 96 percent to 100 percent positive in controls to 5 percent to 8 percent positive in UV-C device experiments.

Room decontamination robots powered by UV-C can also play a role in floor decontamination. Mustapha, et al. (2018) demonstrated that manual post-discharge cleaning by environmental services personnel significantly reduced floor contamination, and an automated ultraviolet C room disinfection device was effective as an adjunct to manual cleaning.

During the study period, environmental services (EVS) personnel cleaned high-touch surfaces in all post-discharge rooms with bleach wipes, whereas floors were mopped with a quaternary ammonium-based disinfectant. Mop heads were changed between rooms. During admission, floors were cleaned only if visibly soiled. The researchers examined the effectiveness of floor cleaning and decontamination in rooms of a convenience sample of patients under contact precautions for MRSA colonization or infection. They collected cultures from the floor before post-discharge cleaning, after completion of manual post-discharge cleaning by EVS personnel, and after adjunctive use of a UV-C room decontamination device. The UV-C device was operated for 3- to 5-minute cycles by research personnel as recommended by the manufacturer. The cultures were collected from areas at three sites in the room, including just inside the door, beside the bed, and in the bathroom next to the toilet; separate but adjacent sites were sampled for the three time-points. The swabs were cultured for MRSA, C difficile, and Candida spp. They also assessed the efficacy of the UV-C device for reducing MRSA on steel disks placed on the floor versus at a height of 0.91â□□m; the goal of this comparison was to determine if the UV-C device was as effective in killing bacteria on floors as at a height of 3 feet, which is the approximate height of bed rails and bedside tables that are typically cultured when evaluating the efficacy of UV-C devices.

The researchers found that of the 27 rooms cultured (81 total sites), the percentages with â¥1 positive precleaning floor cultures for MRSA, Candida spp, and C difficile were 33 percent (9/27), 30 percent (8/27), and 33 percent (9/27), respectively. For each of the pathogens, Mustapha, et al. (2018) discovered there was a statistically significant reduction in the percentage of positive cultures after cleaning by EVS personnel; for Candida spp and C difficile, all floor cultures were negative after EVS cleaning. For MRSA, 9% (7/81) of floor sites had positive cultures after EVS cleaning versus 1 percent after operation of the UV-C device.

As Mustapha, et al. (2018) summarize, "As has been reported previously, we found that floors in patient rooms prior to post-discharge cleaning were frequently contaminated with important health careâ" associated pathogens. We demonstrated that manual post-discharge cleaning by EVS personnel in our facility significantly reduced floor contamination with MRSA, Candida spp, and C difficile. A UV-C room decontamination device was effective in reducing floor contamination in laboratory testing and reduced residual MRSA contamination on floors in patient rooms. These findings suggest that manual cleaning can be effective in reducing floor contamination in health care facilities and UV-C may be useful as an adjunctive measure." They continue, "One caveat of our findings is that the efficacy of manual cleaning in reducing floor contamination is likely to vary with different cleaning products and with differences in the quality of cleaning by EVS personnel. In our facility, ongoing interventions are in place to monitor and improve cleaning performance by EVS personnel. In addition, floors are mopped with a quaternary ammoniumâ" based disinfectant and mop heads are changed between rooms. In contrast, Wong et al. demonstrated that aerobic colony counts on floors increased after manual cleaning when a neutral detergent was used, and the solution and mop head were only changed after every third room. Although we found that manual cleaning resulted in a reduction in C difficile floor contamination, the reduction must be attributable to mechanical removal because quaternary ammonium disinfectants have no activity against spores. If mop heads are not changed between rooms, spores could easily be transferred from room to room."

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