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Concise Communication

Effectiveness of ultraviolet-C light treatment of shoes in reducing the transfer of pathogens into patient rooms by shoes of healthcare personnel

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Abstract

Contaminated shoes are a potential vector for dissemination of healthcare-associated pathogens. We demonstrated that healthcare personnel walking into patient rooms frequently transferred pathogens from their shoes to the floor. An 8-second treatment of shoes with a UV-C decontamination device significantly reduced the frequency of transfer of vegetative bacterial pathogens.

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Floors are increasingly recognized as a potential source for the transmission of healthcare-associated pathogens.[1–4] In patient rooms, a nonpathogenic virus inoculated on the floor disseminated to the footwear and hands of patients, to surfaces in the room, to adjacent rooms, and to nursing stations.[3] In rooms of newly admitted patients, healthcare-associated pathogens rapidly contaminated the floor as personnel entered the room, with subsequent detection on patients' sock bottoms, bedding, and high-touch surfaces.[4] In 2 recent studies, *Clostridioides difficile* strains recovered from the shoes of personnel and from the stool of infected patients were genetically linked based on whole-genome sequencing analysis.[5,6]

Liquid disinfectants or ultraviolet-C (UV-C) light can reduce the burden of pathogens on floors.[7] However, contamination can rapidly reaccumulate as personnel or wheeled equipment enters the room. Thus, new approaches are needed to reduce the risk for acquisition of pathogens from floors. In a previous simulation study, use of a UV-C light shoe-decontamination device reduced pathogen contamination on floors, surfaces, and a patient dummy.[8] We examined the frequency of transfer of pathogens onto floors in patient rooms via shoes of personnel, and we tested whether a UV-C shoe decontamination device would reduce pathogen transfer.

Methods

UV-C light shoe decontamination device

The HealthySole PLUS UV-C light shoe-decontamination device (HealthySole, Incline Village, NV) provides an 8-s cycle of UV-C light to the soles of shoes. Pictures of the device are shown in Supplementary Fig. 1 (online). Individuals stand on a specified area on a platform with shoe placement identified by outlines of shoes. The UV-C treatment is initiated when 4 infrared sensors indicate that 2 shoes are in place over the UV-C delivery area. The device is calibrated to operate only if shoes are women's size 6 or greater. A screen display indicates when shoe placement is correct and when the cycle is in process, and a buzzing noise indicates cycle completion.

Efficacy of UV-C treatment in reducing the transfer of pathogens from shoes to floors

We evaluated the effectiveness of the UV-C shoe-decontamination device in empty patient rooms that had been cleaned and disinfected by environmental services personnel. Research personnel completed additional cleaning and disinfection of a 2-m-wide area of the floor extending from the doorway to the patient bed using a commercial bleach wipe containing 5,500 parts per million sodium hypochlorite. After a 5-minute wet contact time, the cleaned floor surface was wiped with paper towels moistened with water to remove residual bleach and was allowed to air dry.

In our experiment, 32 healthcare personnel were asked to walk into and out of the room on the disinfected floor following a specified 1-m-wide path extending from the doorway to the bed. After exiting the room, the personnel stood on the UV-C shoe decontamination device for one 8-second cycle before again walking into and out of the room on a separate specified 1-m-wide path. For the floor sections where personnel walked before and after UV-C shoe treatment, Replicate Organism Detection and Counting (RODAC) plates with enterococcosel agar (Becton Dickinson, Franklin Lakes, NJ) and CHROMAgar (Becton Dickinson) selective for *Staphylococcus aureus* were applied to 3 separate locations. The plates were incubated for 48 hours. Colonies consistent with enterococci and *S. aureus* were subjected to identification and

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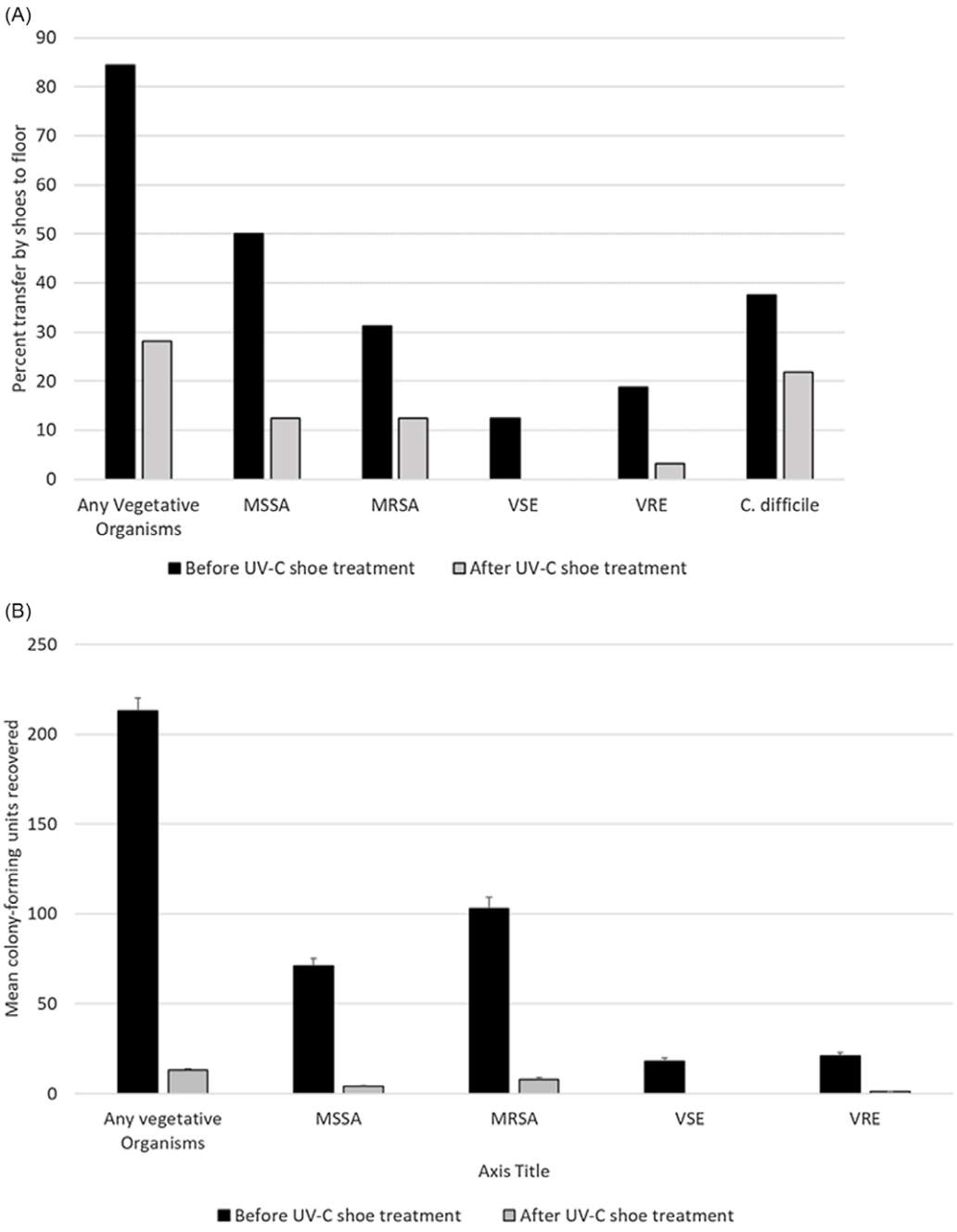

Fig. 1. Percentage of pathogen transfer from shoes of personnel to floors in patient rooms (A) and number of vegetative pathogens transferred (B) before versus after ultraviolet-C (UV-C) treatment of shoes. Note. MSSA, methicillin-susceptible *Staphylococcus aureus*; MRSA, methicillin-resistant *S. aureus*; VSE, vancomycin-susceptible enterococci; VRE, vancomycin-resistant enterococci. Error bars show standard deviation.

susceptibility testing using standard methods.[9] Total colony-forming units (CFU) of vancomycin-susceptible enterococci, vancomycin-resistant enterococci, methicillin-susceptible *S. aureus*, and methicillin-resistant *S. aureus* were counted.

After collection of the RODAC cultures, sterile gauze premoistened with Dey-Engley neutralizing broth (Difco, Franklin Lakes, NJ) was used to wipe 1-m × 10-cm sections of the floor that had been contacted by shoes before or after UV-C shoe treatment. The gauze samples were cultured for *C. difficile* by broth enrichment.[5]

Efficacy of multiple UV-C treatments in reducing MRSA and C. difficile on shoe soles

To assess the impact of repeated UV-C treatments on shoe contamination, shoe soles were contaminated with 6 $\log_{10}$ CFU of a clinical isolate of MRSA and a ribotype 027 toxigenic strain of *C. difficile* (American Type Culture Collection no. 43598). The soles were treated with 6 consecutive 8-s cycles of with the UV-C device. After 1, 3, and 6 cycles, CultureSwabs (Becton Dickinson) were used to sample inoculation sites. Log_{10} reductions in MRSA and *C. difficile* spores were calculated.

Data analysis

The primary outcome was the frequency and burden of contamination of the floor with 1 or more vegetative pathogens. The McNemar χ^2 test was used to compare the frequency of contamination with 1 or more vegetative pathogens and with *C. difficile* spores before versus after shoe treatment with UV-C. The Wilcoxon signed-rank test was used to compare the mean

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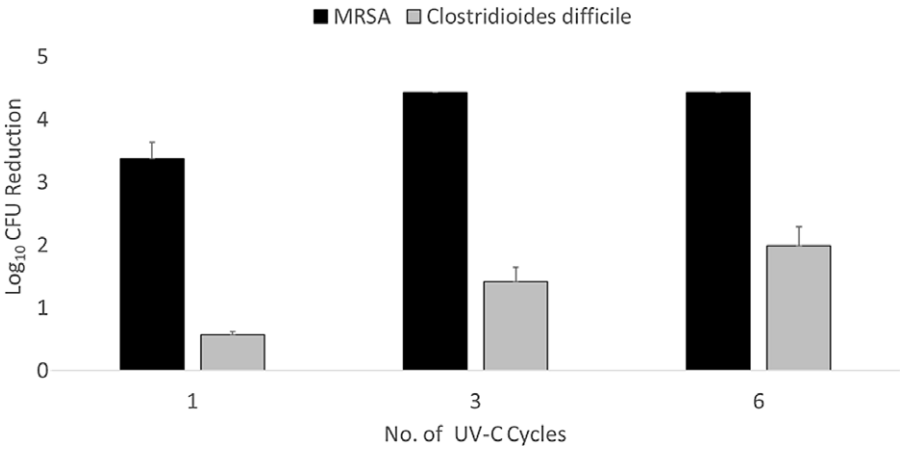

Fig. 2. Log_{10} colony-forming unit (CFU) reduction in methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridioides difficile* spores on inoculated shoe soles after one, three, or six 8-s treatments with an ultraviolet-C light.

CFU of a composite of the vegetative pathogens recovered from floors before versus after UV-C shoe treatment. Data were analyzed using R version 3.5.0 software (R Foundation for Statistical Computing, Vienna, Austria).

Results

Figure 1A shows the percentage transfer of pathogens from shoes to floors before versus after UV-C treatment of shoes. UV-C treatment significantly reduced transfer of a composite of the vegetative pathogens to floors [27 (84%) of 32 vs 9 (28%) of 32; $P < .001$]. However, UV-C treatment did not significantly reduce transfer of *C. difficile* [12 (38%) of 32 versus 7 (22%) of 32; $P = .58$]. As shown in Figure 1B, UV-C treatment resulted in a significant reduction in the mean number of vegetative pathogens transferred ($P < .001$).

Figure 2 shows the log_{10} CFU reductions in MRSA and *C. difficile* on inoculated shoe soles after 1, 3, and 6 cycles of UV-C treatment. After a single cycle, MRSA was reduced by >3 log_{10}, whereas the mean reduction in *C. difficile* spores was only 0.57 log_{10}. After 6 cycles of UV-C, the mean CFU reduction in *C. difficile* spores was 2.0 log_{10}.

Discussion

Several studies have demonstrated that the shoes of healthcare personnel are often contaminated with healthcare-associated pathogens.[5–7,10] Our results build upon those findings by demonstrating that personnel walking into patient rooms frequently transfer healthcare-associated pathogens from their shoes to the floor. In addition, we demonstrated that an 8-s treatment of shoes with a UV-C decontamination device significantly reduced the frequency of transfer of vegetative pathogens but not *C. difficile*. These findings suggest that the UV-C device could potentially be used to reduce transfer of pathogens into rooms of patients.

The finding that a single 8-s UV-C cycle did not significantly reduce transfer of *C. difficile* from shoes is not surprising given the relative resistance of *C. difficile* spores to UV-C.[1,5,8] Using the same device, Rashid et al[8] found that a single UV-C cycle resulted in only a 0.42±0.54 log_{10} reduction in *C. difficile* spores. However, we demonstrated that a 2 log_{10} reduction in *C. difficile* spores was achieved on inoculated shoe soles after six 8-s cycles. In practice, the shoes of personnel may receive repeated UV-C treatments that might be effective in reducing transfer of spores.

Our study had several limitations. The study was conducted in a single facility with a small number of personnel who entered the test room only once with and once without UV-C shoe decontamination. Only 3 gram-positive bacterial pathogens were studied. Studies are needed to evaluate efficacy against additional pathogens and during repeated room entries and to determine whether the use of this device will reduce acquisition of healthcare-associated pathogens. Finally, we did not compare the UV-C device with other potential methods to reduce transfer of pathogens into patient rooms on shoes (eg, shoe covers).

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2022.242.

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Conflicts of interest. C.J.D. has received research grants from Clorox, Pfizer, PDI, and Ecolab. All other authors report no conflicts of interest relevant to this article.

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