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Brief reports

Evaluation of a low-intensity ultraviolet-C radiation device for decontamination of computer keyboards

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Computer keyboards are a potential source for dissemination of pathogenic microorganisms. We demonstrated that a low-intensity ultraviolet-C (UV-C) radiation device was effective in reducing methicillin-resistant *Staphylococcus aureus*, carbapenem-resistant *Escherichia coli*, and *Clostridium difficile* spores on steel carriers and significantly reduced bacterial counts on in-use keyboards.

Contaminated computer keyboards are a potential source for transmission of health care–associated pathogens and respiratory viruses in health care facilities.[1-4] Rutala et al[1] reported that keyboards in a health care setting were frequently contaminated with potential bacterial pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA), *Enterococcus* spp, and nonfermentative gram-negative bacilli. In the setting of a *Clostridium difficile* outbreak, 26% of computer keyboards in nursing and physician work areas were contaminated with *C difficile* spores.[2] Wiping with disinfectants or sterile water is effective for decontamination of keyboards.[1] Moreover, it has recently been reported that once daily cleaning of keyboards in an intensive care unit with 2% chlorhexidine and 70% isopropyl alcohol resulted in sustained reductions in bacterial contamination.[5] Although application of disinfectants may be effective for keyboard decontamination, there is a need for new approaches that can be automated and be applied after each use of the keyboard. In addition, because disinfectants, such as chlorhexidine, lack sporicidal activity, there is a need for approaches that eliminate *C difficile* spores.

Ultraviolet-C (UV-C) radiation is effective in killing a wide range of viral and bacterial pathogens, including *C difficile* spores.[6] However, high-intensity UV-C devices commonly used for room disinfection cannot be used when people are present. Here, we tested the effectiveness of a low-intensity UV-C device for disinfection of keyboards. We also tested the potential for inadvertent UV-C exposure of personnel because the device is intended to be used in the presence of health care personnel or patients.

METHODS

The UV Angel system (UV Angel, Livonia, MI) is a small (17.8 cm tall × 30.5 cm wide), portable device containing a single 8.9-cm-long cold cathode UV-C lamp that draws power (maximum 0.5 A) from a personal computer through a Universal Serial Bus port or is powered by an AC-DC Universal Serial Bus wall adapter. The device is intended to provide fully automated decontamination of keyboards, touchscreens, and other small medical equipment. For keyboard decontamination, the device is placed directly above the top center of the keyboard at a height of 4 in above the center keys and 9 in from the most peripheral keys on the keyboard. The bulb emits approximately 6,700 μW/cm^2 at the bulb surface that is directed downward toward the keyboard, resulting in approximately 11 μW/cm^2 irradiance delivered to the edges of the keyboard 9 in from the bulb, but with no detectable irradiance >6 in lateral to the keyboard or above the keyboard (personal communication, data provided by manufacturer). For comparison, a continuous mercury UV-C room disinfection device was reported to have a total output of

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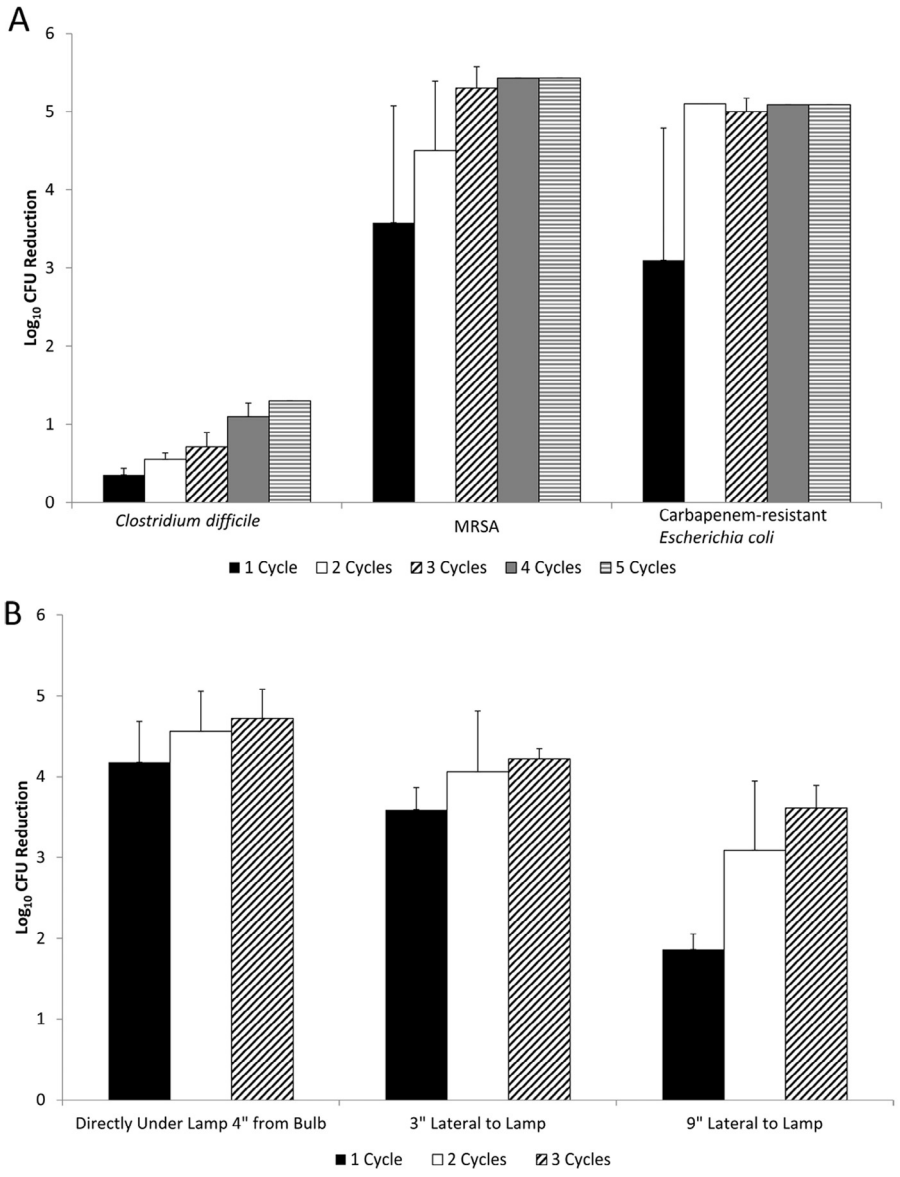

Fig 1. (A) Mean reduction (log_{10} CFU) in recovery of MRSA, New Delhi metallo-β-lactamase–producing, carbapenem-resistant *Escherichia coli*, and *Clostridium difficile* spores from steel carriers positioned on a computer keyboard directly below the UV Angel at a distance of 4 in from the ultraviolet-C decontamination device for 1, 2, 3, 4, or 5 six-minute cycles. (B) Mean reduction (log_{10} CFU) in recovery of MRSA from steel carriers positioned on a computer keyboard directly below the UV Angel ultraviolet-C decontamination device at a distance of 4 in from the bulb or 4 in below and 3 or 9 in lateral to the lamp for 1, 2, or 3 six-minute cycles. Error bars show SEM. *CFU*, colony forming units; *MRSA*, methicillin-resistant *Staphylococcus aureus*.

Table 1
Contamination of 25 in-use computer keyboards before versus after a single 6-minute cycle with the ultraviolet-C decontamination device

	Positive, n (%)			Mean CFU (range)		
Bacteria	Before	After	*P*	Before	After	*P* value
Total aerobic and facultative bacteria	22 (88)	18 (72)	.13	83.5 (1 to >200)	15.6 (1-53)	.0006
Gram-negative bacilli	1 (4)	0 (0)	.33	1 (1)	0 (0)	.33
Clostridium difficile	2 (8)	0 (0)	.16	—	—	—
Staphylococcus aureus	2 (8)	0 (0)	.16	156.5 (113 to >200)	0 (0)	.18
Enterococcus spp	15 (60)	5 (20)	.02	110.2 (2 to >200)	25.6 (6-50)	.0007
Any potential pathogen*	20 (80)	5 (20)	.0001	—	—	—

NOTE. *C difficile* cultures were qualitative.
CFU, colony forming units.
*Any potential pathogen included gram-negative bacilli, *C difficile*, *Enterococcus* spp, or *S aureus*.

1,200 W with a measured irradiance of approximately 1 mW/cm^2 at directly exposed sites in a hospital room.[7]

The device includes sensors that detect use of the keyboard and motion within the area of the keyboard and is programmed to begin a 6-minute decontamination cycle automatically 60 seconds after each use of the keyboard as long as no motion or computer activity has been detected. The cycle is automatically discontinued if motion or computer activity is detected. The number of cycles per day is determined based on use of the keyboard (>100 six-minute cycles can potentially be completed each day).

We examined the efficacy of the device against 1 strain each of MRSA (a clinical isolate with pulsed-field gel electrophoresis type USA300), carbapenem-resistant *Escherichia coli* (New Delhi metallo-β-lactamase-1 [NDM-1]–producing strain), and *C difficile* spores (VA-17, an epidemic North American pulsed-field gel electrophoresis type 1 strain) on steel carriers with and without organic load using a modification of the American Society for Testing and Materials standard quantitative carrier disk test method (ASTM E-2197-02).[8] The device was placed with the bulb directed downward 4 in above the top center of a computer keyboard. Ten μL aliquots of the organisms spread on 22-mm steel carriers were air dried and affixed to a computer key directly below the UV-C bulb. After 1-6 six-minute cycles of UV-C, the treated carriers and unexposed controls were neutralized with 1 mL of Dey-Engley neutralizer (Remel Products, Lenexa, KS). Serially diluted specimens were plated onto prereduced *C difficile* Brucella agar,[9] CHROMAgar (BD Diagnostic Systems, Hunt Valley, MD) containing 6 μg/mL cefoxitin, or MacConkey agar (Becton Dickinson) to quantify *C difficile* spores, MRSA, and *E coli*, respectively. Log_{10} colony forming unit (CFU) reductions were calculated by comparing the log_{10} CFU recovered from carriers after decontamination versus untreated controls. For MRSA, additional experiments were conducted with the carriers positioned 3 and 9 in lateral to the lamp. Experiments were performed in triplicate.

To assess real-world efficacy of the device, we cultured 25 in-use keyboards before and after 1 cycle of decontamination. One half of the surface area of each keyboard was cultured using a sterile BBL CultureSwab (BD Diagnostic Systems) premoistened with Dey-Engley neutralizer before use of the device, and the other half was cultured after decontamination. Swabs were plated on ChromAgar, MacConkey agar, and trypticase soy agar containing 5% sheep blood (BD Diagnostic Systems) to quantify *S aureus*, facultative and aerobic gram-negative bacilli, and total aerobic colony counts, respectively. The swabs were then submersed in *C difficile* Brucella broth and cultured for *C difficile* as previously described.[9] To assess the potential for inadvertent UV-C exposure of personnel, we used UV-C indicator strips (Clorox, Oakland, CA) and radiometric readings (International Light Technologies, Peabody, MA) inside and 6 or 12 in outside the direct field of exposure.

RESULTS

As shown in Figure 1A, on steel disk carriers positioned on a key directly below the device, recovery of MRSA and NDM-1 *E coli* was reduced by >3 logs with a single 6-minute cycle, and further reduction was achieved with additional cycles. In contrast, 4 cycles of exposure (24 minutes total) were required to achieve >1 log reduction in *C difficile* spores. For MRSA, similar reductions were achieved when the carriers were placed on a key directly below the lamp versus 3 in lateral to the lamp. The reduction in MRSA was significantly reduced on carriers placed 9 in lateral to the lamp versus on the central key with 1 or 2 cycles of exposure, but not with 3 cycles (Fig 1B). Based on indicator strips and radiometric readings, there was no detectable UV-C penetration at 6 or 12 in distance lateral or anterior to the keyboard, above the bulb, or anterior to the bulb.

As shown in Table 1, the UV-C device significantly reduced total aerobic bacterial counts on in-use keyboards. In addition, there was a significant reduction in recovery of potential pathogens after use of the device.

DISCUSSION

We found that a low-intensity UV-C radiation device was very effective in reducing MRSA and NDM-1–producing *E coli* on steel carriers positioned on keyboard keys. On in-use keyboards, the device significantly reduced total bacterial counts and potential pathogens after a single 6-minute cycle. These findings suggest that the device could provide a useful means to achieve effective and automated decontamination of keyboards after each use in health care settings.

The device was less effective against *C difficile* spores, requiring 4 or 5 cycles of exposure to achieve a >1 log reduction. However, it is plausible that the device could be effective in reducing *C difficile* spore contamination in real-world settings. The number of spores present on keyboards is typically low,[2] and it is anticipated that numerous cycles of UV-C will be delivered to keyboards that are used frequently. Moreover, the 2 keyboards with *C difficile* contamination in our study had negative cultures after 1 cycle of UV-C.

Because the device is intended to be used while personnel are in the same room, the potential for exposure of personnel to UV-C is a concern. Using UV-C indicator strips and a radiometric sensor, we did not find evidence that UV-C penetrated outside of the area immediately over the keyboard. In addition, the device consistently aborted UV-C cycles when movement into the area of the keyboard was detected. One potential strategy to further reduce the risk for UV-C exposure might be to retract the keyboard to a shielded area for decontamination; a similar design of an alternative UV-C device has been shown to be effective for keyboard decontamination.[10]

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