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Concise Communication

Evaluation of a mobile disinfection cabinet using ultraviolet-C light and aerosolized hydrogen peroxide for disinfection of medical equipment

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Abstract

In laboratory testing, a mobile enclosed disinfection cabinet using ultraviolet-C light and aerosolized hydrogen peroxide was effective for disinfection of hard and soft surfaces. The addition of aerosolized hydrogen peroxide to ultraviolet-C light resulted in improved disinfection of soft surfaces and *Clostridioides difficile* spores.

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Ultraviolet-C (UV-C) light room decontamination devices and enclosed chambers are increasingly used as an adjunct to manual cleaning and disinfection in hospitals.[1] Enclosed UV-C light chambers provide an advantage for decontamination of small items because close proximity allows for relatively short cycle times.[2] However, the efficacy of UV-C enclosures can be suboptimal if treated items have irregular surfaces that result in shadowed areas or if soft, permeable items such as N-95 respirators do not allow full penetration of UV-C light into sites where organisms have been absorbed.[3] One potential approach to address these limitations could be to apply UV-C light in combination with other disinfection modalities. Here, we evaluated the effectiveness of a commercial disinfection cabinet that uses UV-C light in combination with aerosolized hydrogen peroxide for decontamination of hard and soft items used in healthcare settings.

Methods

Test organisms

The test organisms included a clinical isolate of pulsed-field gel electrophoresis type USA800 methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus faecium* (VRE) strain C68, bacteriophage MS2, and *Clostridioides difficile* American type culture collection strain 43598. *C. difficile* spores and bacteriophage MS2 were prepared and quantitatively cultured as previously described.[3,4]

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Description of the mobile disinfection cabinet

The PURitALL 3030L high-level disinfection cabinet is a mobile wheeled unit intended for disinfection of noncritical medical devices, packaged supplies, personal protective equipment (PPE), and personal items, including electronics. The unit has 2 doors, one for loading items and the other for unloading processed items. The doors lock automatically prior to cycle startup. The outer dimensions of the device are 182 cm (height), 76 cm (width), and 76 cm (depth); the dimensions of the inner disinfection chamber are 142 cm (height), 68 cm (width) and 68 cm (depth). The cabinet has plastic racks used to hold or hang items in a manner that maximizes exposure to UV-C light. The Supplementary Material (online) includes pictures of the device.

The device provides a single cycle time of ~15 minutes incorporating 254 nm UV-C light and aerosolized 3%–7% hydrogen peroxide. For the tests performed, the concentration of hydrogen peroxide was 6%. Additional features intended to enhance antimicrobial activity of the device include heat to a peak temperature of 35–50°C and high surface air flow to facilitate even distribution of the aerosolized hydrogen peroxide and to dry items after cycle completion. Hydrogen peroxide is converted to water and oxygen prior to cycle completion. According to the manufacturer, the door can be opened safely immediately after cycle completion. According to the manufacturer, the 15-minute cycle time was chosen based on efficacy testing.

Efficacy of the disinfection cabinet against the test organisms on real-world items

Testing was performed using a modification of the American Society for Testing and Materials (ASTM) standard quantitative disk-carrier test method (ASTM E 2197).[5] The inoculum in 5% fetal calf serum was spread on the test items to cover ~1 cm^2 and allowed to air dry. The inoculated items included a stethoscope

Table 1. Log_{10} Colony-Forming Unit or Plaque-Forming Unit Reductions in the Test Organisms on Inoculated Items Processed in the Disinfection Cabinet With and Without Aerosolized Hydrogen Peroxide (H_2O_2)

Test Organism	H_2O_2 Inclusion	Cell Phone	Surgical Mask Inside/Outside	Stethoscope	Blood Pressure Cuff Inside/Outside
MRSA	With H_2O_2	≥6.0	≥6.0/≥6.0	≥6.00	≥6.0/≥6.0
	Without H_2O_2	≥6.0	≥6.0/≥6.0	≥6.00	≥6.0/≥6.0
VRE	With H_2O_2	≥6.0	≥6.0/≥6.0	≥6.00	≥6.0/≥6.0
	Without H_2O_2	≥6.0	≥6.0/≥6.0	≥6.00	5.0 (1.0)/4.9 (.2)
Bacteriophage MS2	With H_2O_2	≥6.0	≥6.0/≥6.0	≥6.00	≥6.0/≥6.0
	Without H_2O_2	≥6.0	≥6.0/≥6.0	≥6.00	≥6.0/≥6.0
Clostridioides difficile	With H_2O_2	≥6.0	≥6.0/≥6.0	≥6.00	≥6.0/≥6.0
	Without H_2O_2	2.0 (.3)	0.6 (0.4)/1.3 (.3)	0.89 (.2)	2.9 (.2)/2.8 (.7)

Note. MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus*; PAPR, powered air-purifying respirator.

(diaphragm inoculated), cell phone, and inside and outside surfaces of a surgical mask and blood pressure cuff. The items were distributed in multiple locations throughout the chamber. The surgical mask and blood pressure cuff were hung from a rack in a manner that maximized UV-C light exposure. After completion of a 15-minute cycle, the inoculum sites were sampled with rayon swabs moistened with Dey-Engley neutralizer and processed as previously described.[3,4] To assess how much benefit the aerosolized hydrogen peroxide added to UV-C alone, experiments were run both with and without hydrogen peroxide (ie, water was substituted for hydrogen peroxide).

For bacteriophage MS2, additional experiments were conducted with items routinely used in our facility during care of patients with coronavirus disease 2019 (COVID-19), including powered air-purifying respirator (PAPR) helmet and face shield, goggles, and face shield. The experiments were conducted both with and without hydrogen peroxide.

Log_{10} reductions were calculated by subtracting viable organisms recovered from treated versus untreated control items inoculated using the same method. All experiments were performed in triplicate. A 3 log_{10} or greater reduction in the test organisms in comparison to untreated controls was considered effective.[3,4]

Results

Table 1 shows the reductions in the test organisms with and without the inclusion of aerosolized hydrogen peroxide in the disinfection cycle. With aerosolized hydrogen peroxide, ≥6 log_{10} reductions were achieved for all organisms on all the inoculated items. In the absence of aerosolized hydrogen peroxide, the disinfection cabinet achieved ≥6 log_{10} reductions of MRSA and bacteriophage MS2 on all inoculated items; however, VRE was reduced by ≤5 log_{10} CFU on the inside and outside surfaces of the blood pressure cuff, and *C. difficile* spores were reduced by ≤2.9 log_{10} CFU on all surfaces. For items used during care of COVID-19 patients, ≥6 log_{10} reductions of bacteriophage MS2 were achieved on all items with and without aerosolized hydrogen peroxide. There was no evidence of damage or discoloration to any of the test items after up to 6 cycles of disinfection.

Discussion

A mobile disinfection cabinet using 254-nm UV-C light and aerosolized hydrogen peroxide was very effective for disinfection of hard and soft surfaces. Without the aerosolized hydrogen peroxide, the technology did not consistently reduce vegetative organisms on soft items and did not achieve ≥3 log_{10} reductions in *C. difficile* spores. These findings suggest that the addition of relatively low concentrations of aerosolized hydrogen peroxide to enclosed UV-C light cabinets may result in a substantial benefit for disinfection of soft surfaces and spore-forming organisms. The technology could potentially be used to disinfect noncritical devices, PPE if shortages occur, the external packaging of sterile supply items from patient rooms that otherwise might be discarded,[6] and shared toys or physical therapy equipment.[7]

The disinfection cabinet was very effective in reducing the nonenveloped virus bacteriophage MS2, including on items routinely used in the care of COVID-19 patients. Cleaning of items such as PAPR helmets and face shields between users may be suboptimal, and items such as face shields or goggles may be damaged by some disinfectants. In simulations of patient care interactions while wearing respiratory protection, contamination of items such as face shields occurred frequently.[8] Thus, mobile disinfection cabinets could potentially be useful in the care of COVID-19 patients.

Our study had several limitations. We did not test the effectiveness of the technology in reducing contamination on in-use items including packaged items. We did not evaluate whether heat to 35–50°C and high surface air flow provided a benefit in organism reduction, and we did not evaluate the efficacy of aerosolized hydrogen peroxide without UV-C. We did not evaluate the effectiveness of the technology against *Candida* spp. However, UV-C alone can be effective against *Candida* spp, including *Candida auris*.[9,10] We did not evaluate disinfection of lumened devices or tubing; the manufacturer is currently developing the next generation of the technology intended for endoscope disinfection. We did not evaluate the efficacy of the technology for disinfection of N95 respirators. In previous studies, UV-C light has provided suboptimal decontamination of some N95 respirators due to inadequate penetration to reach absorbed viral particles.[4,5] It is plausible that the addition of aerosolized hydrogen peroxide could substantially improve N95 respirator decontamination. Finally, the device has not currently been cleared by the US Food and Drug Administration for high-level disinfection.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2023.211

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