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Concise Communication

Efficacy of a far-ultraviolet-C light technology for continuous decontamination of air and surfaces

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Abstract

A wall-mounted, far-ultraviolet-C light technology reduced aerosolized bacteriophage MS2 by >3 $\log_{10}$ plaque-forming units within 30 minutes. Vegetative bacterial pathogens on steel disk carriers in the center of the room were reduced by >3 $\log_{10}$ after 45 minutes of exposure, but *Candida auris* and *Clostridioides difficile* spores were not.

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Ultraviolet C (UV-C) light is effective for inactivation of bacterial, fungal, and viral pathogens on surfaces and in air.[1,2] UV-C room decontamination devices are increasingly used as an adjunct to standard cleaning and disinfection in healthcare settings.[1] However, 254-nm UV-C light produced by conventional low-pressure mercury devices is hazardous, and the devices cannot be used in occupied areas.[1]

Far-UV-C light (200–230 nm) has been proposed as an alternative to 254-nm UV-C light that may provide similar efficacy while being safe in occupied areas.[3,4] Far-UV-C light is strongly absorbed by proteins and other biomolecules, resulting in minimal penetration into skin or eye tissues.[3,4] In animal models and some human-volunteer studies, 222-nm far-UV-C doses within threshold limit values proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) did not result in adverse effects to eyes or skin.[3–7] Here, we evaluated the effectiveness of commercial far-UV-C technology in reducing an aerosolized virus and several healthcare-associated pathogens on carriers.

Methods

Description of the far-UV-C technology and test room

The far-UV-C technology (Myna Life Technologies, Chesterfield, MO) uses krypton-chloride excimer lamps that emit a primary wavelength of 222 nm with filters to block emitted wavelengths >230 nm. Each device contains 3 lamps with a field of illumination of 60° per lamp. The number of devices required varies with room size; 2 devices are recommended for a typical patient room. The device includes proprietary sensors that detect the presence and location of people relative to the lamps. The device is programmed to automatically reduce or discontinue far-UV-C exposure by turning off 1 or more light modules as needed based on proximity of people to keep exposure below a threshold limit value of 160 mJ/cm^2 per 8 hours.[3–7] This feature is intended to provide maximal far-UV-C doses when people are not present versus in proximity to the devices.

Testing was conducted in a 23.5-m^3 room in the research building that was ventilated with ~4 air changes per hour. Two devices were positioned at opposite corners of one wall 2 m from the floor, angled toward the center of the room, with 1.6 m of space between the devices. A picture of the device and illustration of the test-room setup are included in the Supplementary Material (online). With all 6 lamps from the 2 devices operating, the calculated doses of UV-C delivered over 8 hours at 2 and 3 m from the lamps were 230 and 150 mJ/cm^2, respectively.

Reduction in aerosolized bacteriophage MS2

For each simulation, an Aerogen Solo (Aerogen, Galway, Ireland) nebulizer was used to release 1 mL aerosol containing 10^8 plaque-forming units (PFU) of bacteriophage MS2 over 3 minutes. Also, 99% of particles generated by the Aerogen Solo are ≤5 µm diameter.[8] Air samples were collected using National Institute for Occupational Safety and Health (NIOSH) 2-stage bioaerosol samplers (Tisch Environmental, Cleves, OH) over 5-minute periods at baseline (0–5 minutes after aerosol release) and 5–10, 10–15, 25–30, and 40–45 minutes after release. Bacteriophage MS2 was prepared and quantitatively cultured as previously described.[8] Each simulation was repeated in triplicate. Log_{10} reductions were calculated in comparison to control experiments run in the same room with the far-UV-C technology turned off.

Reduction in healthcare-associated pathogens on carriers

We tested the efficacy of the technology against bacteriophage MS2 and several healthcare-associated pathogens using a modification of the American Society for Testing and Materials (ASTM) standard

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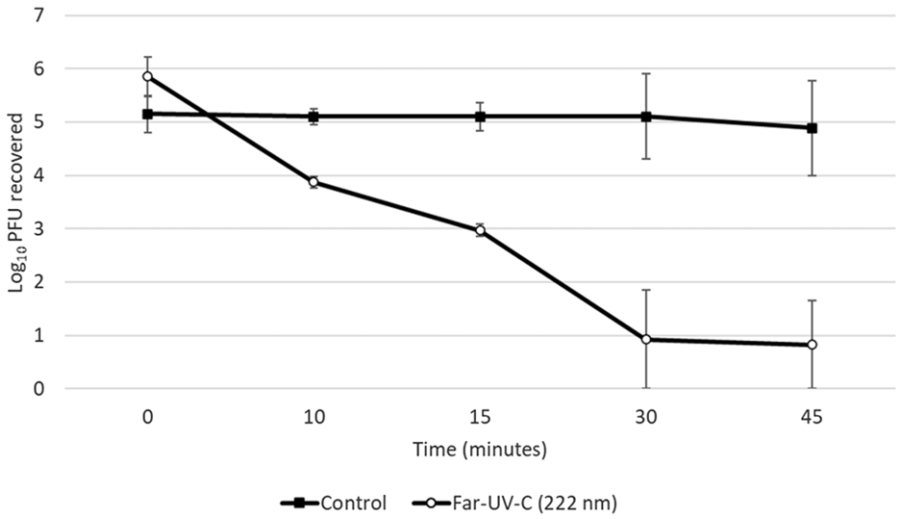

Figure 1. Reduction in aerosolized bacteriophage MS2 over 45 minutes in a test room with and without exposure to far-ultraviolet-C light. Note. PFU, plaque-forming units. Error bars show standard error.

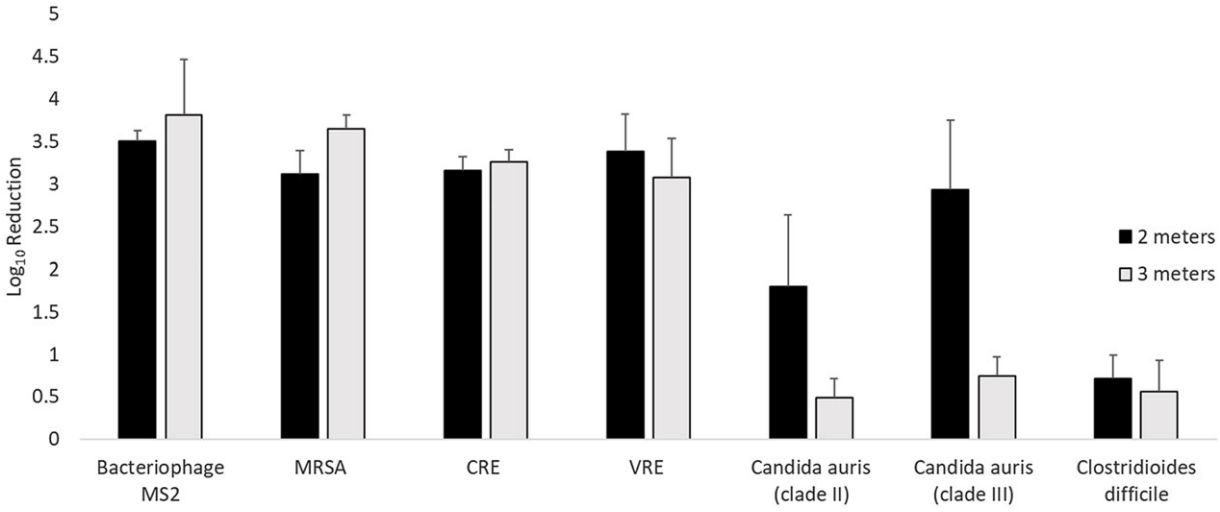

Figure 2. Reduction in organisms on steel disk carriers after 45 minutes of exposure to far-ultraviolet-C light. Note. CRE, carbapenem-resistant *Escherichia coli*; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus faecium*. Error bars show standard error. Log_{10} reductions were calculated in comparison to untreated controls.

quantitative disk carrier test method (ASTM E 2197-02).[9] The healthcare-associated pathogens included a clinical carbapenem-resistant *Escherichia coli* (CRE) strain, a clinical methicillin-resistant *Staphylococcus aureus* (MRSA) strain, vancomycin-resistant *Enterococcus* strain C68, a clinical ribotype 027 *Clostridioides difficile* strain, and *Candida auris* strains Antibiotic Resistance Bank (AR)-0381 (clade II; East Asia origin) and AR-0383 (clade III; Africa origin). *C. auris* AR-0383 forms aggregates and exhibits reduced susceptibility to 254-nm UV-C light in comparison to AR-0381.[10]

Testing was conducted in the room previously described with an exposure time of 45 minutes. We used 5% fetal calf serum as a soil load. The 10-µL inoculum of the test organisms was spread to cover the 20-mm steel disks. The disks were oriented horizontally 0.8 m high in the center of the room at 2 m or 3 m from the lamps. Experiments were completed in triplicate. For *C. difficile* spores, additional experiments were conducted with exposure times of 3 and 5 hours. For MRSA, additional experiments were conducted with the disks placed at the side of the room or on the floor at 2 or 3 m from the nearest lamp. Log_{10} reductions were calculated in comparison to untreated controls. Disks were processed as previously described.[10] A 3-log_{10} or greater reduction in the test organisms in comparison to untreated controls was considered effective.[10]

Results

As shown in Figure 1, ~5 log_{10} PFU of bacteriophage MS2 was recovered from air at baseline and at all time points from control samples. The far-UV-C exposure resulted in a >3 log_{10} PFU reduction in bacteriophage MS2 after 30 minutes.

As shown in Figure 2, bacteriophage MS2, MRSA, CRE, and VRE were reduced by >3 log_{10} PFU or CFU on disks positioned in the center of the room 2 or 3 m from the lamps. The *C. auris* strains and *C. difficile* spores were not reduced by >3 log_{10} CFU at either distance. For MRSA, a >2 log_{10} CFU reduction was achieved in 45 minutes when disks were positioned on the floor or at the sides of the room. For *C. difficile* spores, a 1.3 log_{10} CFU reduction was achieved by increasing the exposure time to 5 hours.

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Discussion

Technologies that provide safe and continuous decontamination of surfaces and air while people are present could be an important advance for prevention of healthcare-associated infections. We demonstrated that a wall-mounted far-UV-C light technology that is purported to be safe in occupied spaces was effective in reducing aerosolized bacteriophage MS2 by >3 $\log_{10}$ PFU within 30 minutes. The technology also reduced vegetative bacteria and bacteriophage MS2 on carriers by >3 $\log_{10}$ within 45 minutes. The technology was less effective against *C. auris* and *C. difficile*, but greater efficacy might be achieved with longer exposure times in real-world settings.

Although recent studies suggest that far-UV-C light may be safe in occupied spaces, only a few studies included human volunteers.[3–7] Studies are needed to evaluate the long-term safety of far-UV-C light in real-world settings. Such evaluations will be essential prior to considering routine implementation of far-UV-C light in occupied areas.

Our study had several limitations. The results demonstrate the optimal performance of the technology because we tested the dose that would be delivered in an unoccupied room. According to the manufacturer, in the presence of a person 2 m from the device, the far-UV-C dose would be reduced such that 65.5 minutes would be required to achieve the dose delivered in an unoccupied room over 45 minutes. We did not measure the far-UV dosage delivered or assess the impact of disk orientation or shadowing. We did not assess ozone production by the technology. However, ozone generation by far-UV-C technologies is generally modest, with limited potential for accumulation above recommended exposure limits in well-ventilated spaces.[3] Finally, we did not examine efficacy in a real-world setting.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/ice.2023.159

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