CONCISE COMMUNICATION

Relative Resistance of the Emerging Fungal Pathogen *Candida auris* and Other *Candida* Species to Killing by Ultraviolet Light

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Mobile ultraviolet-C (UV-C) light room decontamination devices are frequently used as an adjunct to standard cleaning in healthcare facilities, but their efficacy in killing *Candida* species is not clear. In laboratory testing, the emerging multidrug-resistant *Candida auris* and 2 other *Candida* species were significantly less susceptible to killing by UV-C than methicillin-resistant *Staphylococcus aureus*.

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Candida auris is a globally emerging fungal pathogen that is often resistant to multiple antifungal agents.[1–3] The Centers for Disease Control and Prevention issued a clinical alert requesting reporting of *C. auris* isolates in June, 2016.[4] As of September 18, 2017, 153 cases of *C. auris* infection had been reported, and 143 patients were found to be colonized.[4] Most infections have occurred in healthcare facilities, and many are suspected to be due to exogenous acquisition.[1,2] In several outbreaks, *C. auris* has been recovered from environmental surfaces.[1,2] Therefore, it has been recommended that surfaces in rooms of patients infected or colonized with *C. auris* receive thorough daily and terminal disinfection with a hospital-grade disinfectant with activity against *Clostridium difficile* spores.[4]

Mobile ultraviolet-C (UV-C) light room decontamination devices are increasingly used as an adjunct to standard cleaning in healthcare facilities. These devices are effective in killing vegetative bacterial pathogens, and with sufficient exposure, they are effective against *Clostridium difficile* spores.[5,6] Although there is evidence that UV-C is effective against *C. albicans*,[7] no published studies have reported the efficacy of room decontamination devices against *Candida* species. Here, we tested the hypothesis that a UV-C room decontamination device would be as effective in killing *C. auris* and other *Candida* species as the vegetative pathogen methicillin-resistant *Staphylococcus aureus* (MRSA).

METHODS

We evaluated the efficacy of a room decontamination device that emits 254-nm UV-C light (Clorox Healthcare Optimum-UV System, Clorox, Oakland, CA) against *C. auris* (N = 4 strains), *C. albicans* (N = 3 strains), and *C. glabrata* (N = 3 strains) in comparison to MRSA (N = 3 strains) and *C. difficile* spores (N = 3 strains). The device has been described previously.[6] The 4 strains of *C. auris* included 3 multidrug-resistant clinical isolates including 2 from Germany (MRL 31102 and 31103) and 1 from the CBS-KNAW Fungal Biodiversity Centre (Utrecht, Netherlands; CBS #12373); 1 drug-susceptible *C. auris* isolate was also tested (MRL35364). The *C. albicans* strains were American Type Culture Collection (ATCC) strains SC5314, MBL32249, and MBL 32708. The *C. glabrata* strains were ATCC MBL31820, 34870, and 9542. The MRSA strains were 2 pulsed-field gel electrophoresis (PFGE) type USA300 strains and 1 USA800 strain. The *C. difficile* strains were VA 17, a restriction endonuclease analysis (REA) type BI strain, VA 11, an REA type J strain, and ATCC strain 43598. Spores were prepared and stored as previously described,[5] and MRSA and *C. difficile* were cultured on selective media as previously described.[5]

For each pathogen, 10-μL aliquots containing 10^6 $\log_{10}$ colony-forming units (CFU) in phosphate-buffered saline (PBS) with 5% fetal calf serum were spread to cover 10-, 20-, or 40-mm-diameter circular stainless-steel carriers and allowed to air dry for 30 minutes in a laminar flow hood. The different diameter carriers were used because we have previously demonstrated that spreading of an inoculum over a larger surface significantly enhanced killing of *C. difficile* spores and MRSA.[6] The carriers were placed perpendicular to the vertical lamps 5 feet from the device at a height of 4 feet and were exposed to a UV-C cycle of 10 minutes. Additional experiments were conducted with 1 strain of each of the pathogens on 20-mm-diameter disks at exposure times of 10, 20, and 30 minutes. Disks were processed as previously described, and log reductions in the pathogens were calculated in comparison to untreated control carriers.[6] For the *Candida* species, quantitative cultures were performed by plating specimens on Sabouraud dextrose agar (Becton Dickinson, Sparks, MD) and incubating at 37ºC for 72 hours. The experiments were performed in triplicate.

A 2-way analysis of variance was performed to compare the mean log reductions for the different pathogens. A post hoc Tukey HSD test was used to test pairwise differences between group means. Data were analyzed using R studio version 3.2.2 software (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Figure 1 shows the mean log reduction for the organisms with a 10-minute exposure time, stratified based on spreading of the inoculum to cover the different disk sizes. MRSA was reduced by ≥6.1 $\log_{10}$CFU after 10 minutes of UV-C exposure for each

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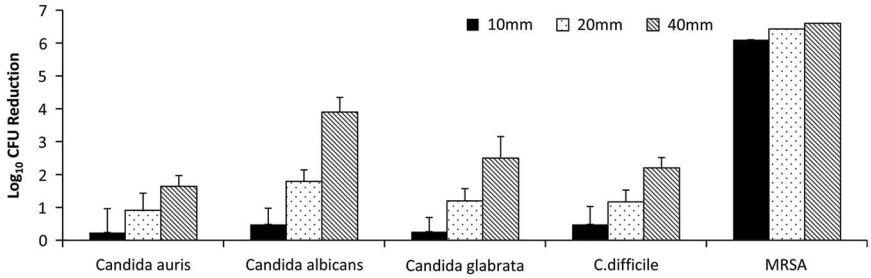

FIGURE 1. Reduction in *Candida auris* (N = 4 strains), *C. glabrata* (N = 3 strains), *C. albicans* (N = 3 strains), *Clostridium difficile* (N = 3 strains), and methicillin-resistant *Staphylococcus aureus* (MRSA) (N = 3 strains) after exposure to an ultraviolet-C room decontamination device at 5 feet from the device with an exposure time of 10 minutes. For each pathogen, 10-µL aliquots containing 10^6 $\log_{10}$ colony-forming units (CFU) were spread to cover 10-, 20-, or 40-mm-diameter stainless-steel carriers. Log reductions in the pathogens were calculated in comparison to untreated control carriers. Error bars show standard error.

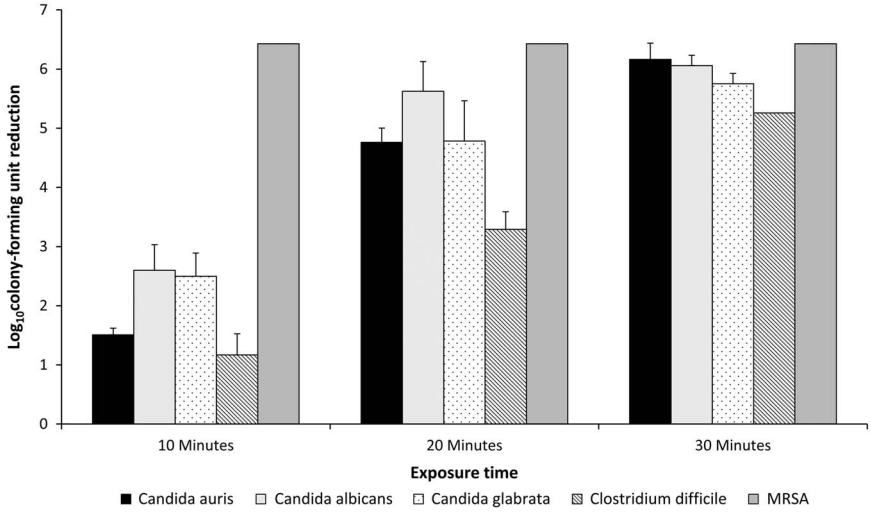

FIGURE 2. Effect of increasing time of exposure to an ultraviolet-C room decontamination device on reduction in 1 strain each of *Candida auris*, *C. glabrata*, *C. albicans, Clostridium difficile*, and methicillin-resistant *Staphylococcus aureus* (MRSA). The inoculum was spread to cover a 20-mm-diameter steel disk, and the disk was placed 5 feet from the device. Error bars show standard error.

disk size. The reduction in MRSA was significantly greater than the reduction in each of the *Candida* species and *C. difficile* spores ($P < .001$). For *C. difficile* spores and the *Candida* species, spreading the same inoculum over increasing disk sizes resulted in significantly increased log reductions for the 40 mm versus 10-mm-diameter disks ($P < .01$). There were no significant differences in reductions of the different *Candida* species with the exception of *C. albicans* which had a greater log reduction on the 40-mm disks ($P < .05$) but not on the 10- or 20-mm disks.

As shown in Figure 2, for each of the *Candida* species and for *C. difficile* spores, increasing the cycle time to 20 or 30 minutes resulted in significantly greater reductions in recovery ($P < .001$), whereas MRSA was reduced by > 6 logs at each exposure time. At the 10-minute exposure time, *C. auris* was reduced less than *C. glabrata* and *C. albicans* ($P \leq .04$). However, the reductions of *C. auris* and the other *Candida* species were similar after the 20- and 30-minute exposures ($P > .05$).

DISCUSSION

The emerging pathogen *Candida auris* has frequently been recovered from hospital surfaces during outbreaks.[1,2] In previous studies, non-*albicans Candida* species, including *C. lusitaniae*, *C. parapsilosis*, and *C. glabrata*, have also been recovered from the hospital environment.[8] These findings suggest that the environment may be an underappreciated source for transmission of *Candida* species. Thus, there is a need to identify effective methods to reduce *Candida* species environmental contamination. In the current study, we found that a UV-C room decontamination device was significantly less effective against *Candida* species than against MRSA. These findings have important implications for control of *C. auris* and other *Candida* species.

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For patients with *C. auris* colonization or infection, thorough daily and terminal cleaning and disinfection of room surfaces with a sporicidal disinfectant has been recommended.[4] Both mechanical removal due to wiping and sporicidal and hydrogen peroxide-based disinfectants are very effective in reducing *Candida* species on surfaces.[9,10] Thus, UV-C devices could be useful as an adjunct to standard cleaning and disinfection to provide disinfection of any surfaces that are missed or inadequately covered by manual disinfection. Given the relative resistance of *Candida* species to UV-C killing, standard cleaning should continue to be emphasized. In addition, our results suggest that longer cycle times may be beneficial, as has been recommended for some devices in *C. difficile* infection rooms.[5]

The microbiologic basis for reduced susceptibility of *Candida* species to UV-C is unclear. *Candida* organisms are larger in size than bacteria and might require a larger UV-C dose to penetrate to the nucleus. The fact that spreading of an inoculum enhanced killing suggests that outer layers of yeast cells may protect underlying cells from UV-C, as has been observed for *C. difficile* spores and MRSA.[6] There are also significant differences in the cell walls of *Candida* species versus bacteria. *Candida* cell walls contain unique components such as chitin and mannoprotein that could confer increased resistance to UV-C.

Our study has some limitations. We studied only 4 *C. auris* strains. However, killing by UV-C was similar for each strain. We studied efficacy in a laboratory setting. The carriers were placed 5 feet from the device; thus, our results may underestimate the efficacy of UV-C at closer proximity. Further studies are needed to evaluate efficacy of UV-C devices in patient rooms.

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