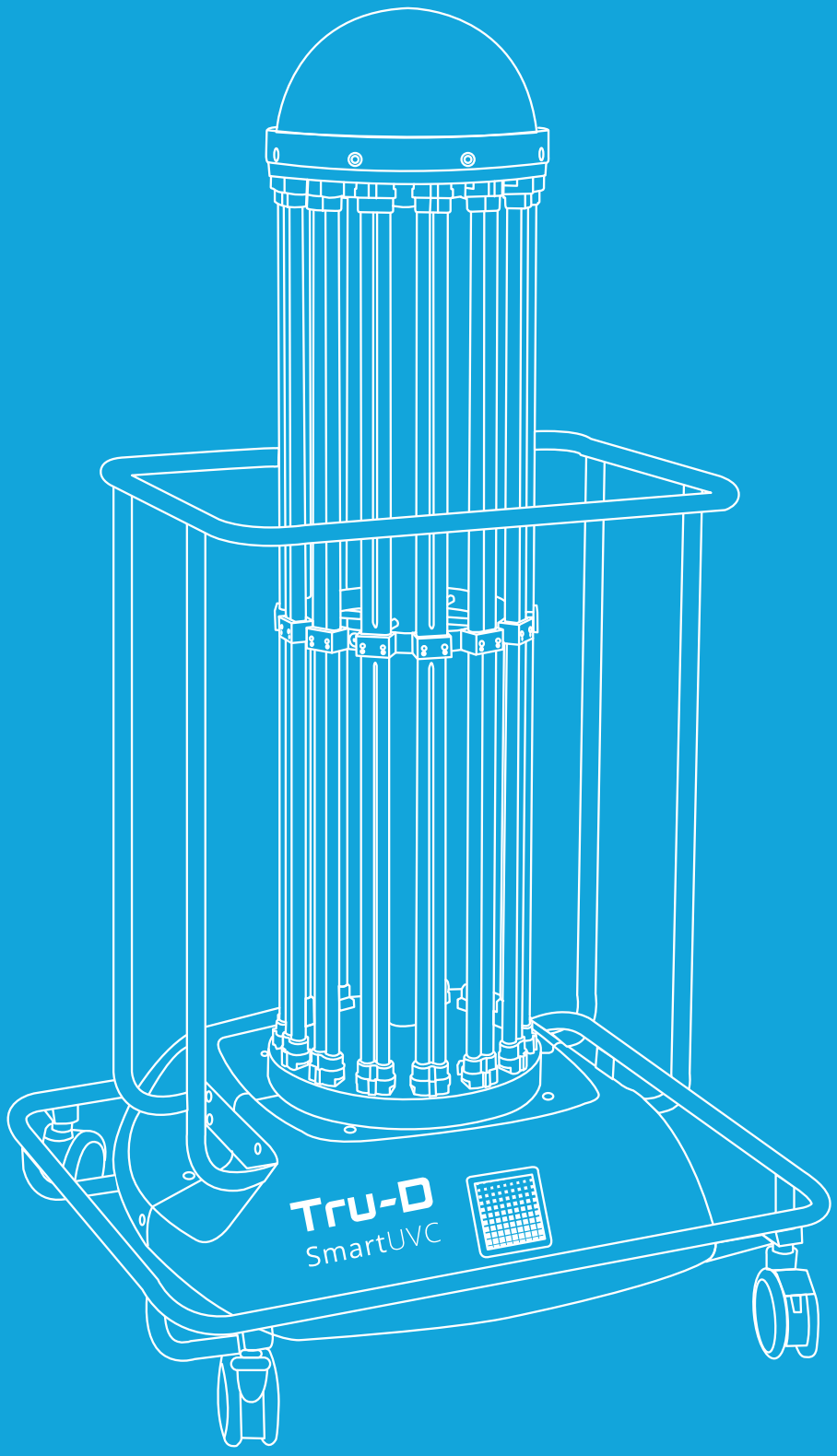

CASE STUDY

RAPID HOSPITAL ROOM DECONTAMINATION USING ULTRAVIOLET (UV) LIGHT WITH A NANOSTRUCTURED UV-REFLECTIVE WALL COATING

CONCISE COMMUNICATION

Rapid Hospital Room Decontamination Using Ultraviolet (UV) Light with a Nanostructured UV-Reflective Wall Coating

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We tested the ability of an ultraviolet C (UV-C)–reflective wall coating to reduce the time necessary to decontaminate a room using a UV-C-emitting device (Tru-D SmartUVC). The reflective wall coating provided the following time reductions for decontamination: for methicillin-resistant *Staphylococcus aureus*, from 25 minutes 13 seconds to 5 minutes 3 seconds ($P < .05$), and for *Clostridium difficile* spores, from 43 minutes 42 seconds to 9 minutes 24 seconds ($P < .05$).

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Surface disinfection of noncritical surfaces and equipment is normally performed by manually applying a liquid disinfectant to surfaces or objects with a cloth, disposable wipe, or mop. Effective environmental disinfection in healthcare facilities is essential for reducing environment-mediated infection transmission via contaminated hands of healthcare personnel or environmental surfaces. Recent studies have identified substantial opportunities in hospitals to improve the cleaning and disinfection of hospital room surfaces.[1] For example, of 20,646 standardized environmental surfaces (14 types of objects), only 9,910 (48%) were cleaned at terminal room cleaning according to institutional cleaning policies.[1] Epidemiologic studies have shown that patients admitted to rooms previously occupied by individuals infected or colonized with methicillin-resistant *Staphylococcus aureus* (MRSA),[2] vancomycin-resistant *Enterococcus* (VRE),[2,3] or *Clostridium difficile*[4] are at significant risk of acquiring these organisms. These data have led to efforts to improve surface disinfection practices and the development of room decontamination units that avoid the problems associated with manual disinfection.[5]

We investigated a room decontamination unit that uses ultraviolet C (UV-C) energy (254 nm). The unit is fully automated and is activated by a handheld remote, and the room ventilation does not need to be modified. It measures UV-C reflected from walls, ceilings, floors, and items in the room and calculates the time required to deliver the programmed lethal dose for pathogens.[6] Following decontamination, it will power down, and an audible alarm will notify the operator. The goal of this study was to assess the time required for a UV-C room decontamination unit to kill important healthcare-associated pathogens (ie, MRSA and *C. difficile*) in a room with standard white paint–coated walls versus walls coated with an agent specifically formulated to be reflective of UV-C wavelengths.

METHODS

A single UV-C device was investigated (Tru-D SmartUVC; Lumalier); it can be set to deliver a minimum reflected dose of 22,000 μWs/cm^2 for *C. difficile* spores and 12,000 μWs/cm^2 for vegetative bacteria. All testing (with the exception of 3 cycles in a nonreflective room) was done in a single patient hospital room (117-ft^2 room plus 13 ft^2 for the bathroom). The cycle time to achieve microbial killing was determined in this room before and after the room was coated with an agent designed to maximize the UV-C reflectivity. The coating (Lumacept) is formulated using nanoscale inorganic oxides whose crystal structures are transparent to UV-C. It also contains polymer binders and functional additives with chemical structures that are minimally absorbent of UV-C. Standard paint is 3%–7% UV reflective, while the special coating is 65% UV reflective at 254 nm. The coating is white in appearance and can be applied with a brush or roller in the same way as any common interior latex paint. The cost to coat the walls of the room and bathroom used in this study (approximately 12.1 m^2) was estimated to be less than $300.

Testing was performed using Formica sheets (approximately 3 in. × 3 in.), with a template of a Rodac plate (approximately 25 cm^2; Becton Dickinson) drawn on each sheet. MRSA was grown on sheep blood agar. The *C. difficile* spore preparation was stored in Dulbecco's modified Eagle medium (HyClone), and serial dilutions were made with trypticase soy broth (Remel). A 10-μL inoculum containing approximately 10^4–10^5 organisms/Rodac template of the 2 test organisms was spread separately on the Formica sheet by use of a sterile glass hockey loop. The test organisms were *C. difficile* spores (BI strain) and a clinical isolate of MRSA (USA300 strain). After our templates were inoculated, the Formica sheets were left to dry for a minimum of 10 minutes at room temperature and were then placed in 10 locations throughout the patient room (ie, the far side of the bedside table, facing the wall; the top of the bed; the closet door; the top of the toilet seat; the back of the chair; the floor [right side of the bed]; the foot of the bed, facing the door; the side of the sink, facing the bedside table; the back of the computer, facing the wall; and the bathroom wall, above the toilet). The room was then vacated, and the UV-C device was remotely activated. The room decontamination times were recorded for all cycles. Following cycle completion, Rodac plates containing DE neutralizing agar (Becton Dickinson) were used to culture each Formica template. These plates were then incubated aerobically at 37°C for 48 hours for MRSA and

TABLE 1. Ultraviolet C (UV-C) Decontamination (Mean Log_{10} Reduction) of Formica Surfaces in a Patient Room That Were Experimentally Contaminated with Methicillin-Resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* Spores with and without a Reflective Coating on Walls

	MRSA		*C. difficile* spores	
	With coating (inoculum, 4.75 log_{10})	Without coating (inoculum, 4.69 log_{10})	With coating (inoculum, 4.45 log_{10})	Without coating (inoculum, 4.19 log_{10})
Cycle time	5m3s (3m28s–6m39s)	25m13s (9m10s–41m16s)	9m24s (5m49s–12m59s)	43m42s (29m14s–58m9s)
Line of sight				
Direct	4.70 (4.36–5.04) [$n = 42$]	4.71 (4.53–4.89) [$n = 36$]	3.29 (1.92–4.66) [$n = 39$]	3.41 (2.33–4.49) [$n = 33$]
Indirect	4.45 (3.67–5.22) [$n = 28$]	4.27 (3.37–5.17) [$n = 24$]	2.43 (1.65–3.20) [$n = 31$]	2.01 (1.28–2.75) [$n = 27$]
All	4.60 (4.00–5.20) [$n = 70$]	4.53 (3.81–5.25) [$n = 60$]	2.91 (1.49–4.33) [$n = 70$]	2.78 (1.12–4.44) [$n = 60$]

NOTE. The patient room comprised 130 ft^2. Data in parentheses are 95% confidence intervals, which were used to determine that there was no significant difference ($P > .05$) when comparing cycle times with and without the reflective coating or when comparing direct UV-C to indirect UV-C. Sites were evaluated as receiving direct (laser point visible on site) or indirect (laser point not visible on site) UV-C by following the path of the laser. *n* values indicate the number of samples.

anaerobically (Anaeropack; Mitsubishi Gas Chemical) at 37°C for 48 hours for *C. difficile*. After incubation, colony-forming units (CFUs) of the test organisms on each plate were quantified. The *C. difficile* culture was treated by heat at 56°C for 10 minutes, and the presence and resistance of *C. difficile* spores (not vegetative bacteria) was verified by exposing the stock preparation to dilute hydrochloric acid, as specified in the AOAC International sporicidal activity test.[7] The suspension was then stained to confirm the presence of spores (more than 90% spores).

RESULTS

In our unoccupied patient room, the effectiveness of UV-C radiation with respect to reduction of MRSA on surfaces was a 4.53-log_{10} reduction without the reflective coating and a 4.60-log_{10} reduction with the reflective coating ($P > .05$), while the cycle time was 5 minutes 3 seconds with the reflective coating and 25 minutes 13 seconds without the reflective coating ($P < .05$; Table 1). For C. *difficile* spores, there was a 2.78-log_{10} reduction without the reflective coating and a 2.91-log_{10} reduction with the reflective coating ($P > .05$), but the cycle time with the reflective coating was 9 minutes 24 seconds, compared with 43 minutes 42 seconds without the reflective coating ($P < .05$).

DISCUSSION

Several studies have shown the ability of the tested device to deliver lethal UV-C doses to epidemiologically important microorganisms,[8-10] with pathogens reduced by 2.5 log_{10} to more than 4 log_{10} under high contamination levels that exceed those normally found in healthcare facilities. For example, studies have shown that, although the frequency of contamination by these pathogens (eg, *C. difficile* and MRSA) is high (10% to more than 50%), the microbial load is generally low (less than 10 CFUs per Rodac plate or sample), which suggests that the clinical efficacy of UV-C could be significant.

All room decontamination technologies have advantages and disadvantages.[5] A major disadvantage of both UV and hydrogen peroxide systems is that they can be used only for terminal disinfection (ie, they cannot be used for daily disinfection) because the room must be emptied of people. The main advantage of both technologies is their ability to achieve a reduction in healthcare pathogens. A major disadvantage of hydrogen peroxide systems—and to a lesser extent UV-C—is the time required for decontamination. The UV-C system offers faster decontamination (15–50 minutes, compared with 2–5 hours for hydrogen peroxide systems) before the development of this UV-C-reflective coating, but with this innovation cycle times were 5–10 minutes, which would significantly reduce (by approximately 80%) the room's downtime before another patient could be admitted.

In summary, UV technology offers a potential option for room decontamination in healthcare settings. MRSA, VRE, multidrug-resistant *Acinetobacter*, and *C. difficile* spores comprise a growing reservoir of epidemiologically important pathogens that have an environmental mode of transmission. The UV-C technology (and other effective room decontamination technologies) can effectively reduce environmental contamination and potentially mitigate infection risks, and it should be considered when the environmental mode of transmission is important (eg, after patients under contact precautions are discharged) and enhanced interventions are not effective. Use of the nanostructured UV-C-reflective coating allows room decontamination to be completed in 5–10 minutes with UV-C, which could be easily integrated into healthcare practices in which the occupancy is high and fast patient room turnaround time is critical.

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Potential conflicts of interest. B.M.T. reports being a coinventor of the patent-pending reflective coating and a co-owner of Twilight Labs, which makes the reflective coating. All other authors report no conflicts of interest relevant to this article. All authors submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and the conflicts that the editors consider relevant to this article are disclosed here.

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