Does Coating All Room Surfaces with an Ultraviolet C Light–Nanoreflective Coating Improve Decontamination Compared with Coating Only the Walls?

Over the past decade, substantial scientific evidence has accumulated indicating that contamination of environmental surfaces in hospital rooms plays an important role in the transmission of several key healthcare-associated pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* species (VRE), *Clostridium difficile*, *Acinetobacter* species, and norovirus.[1-5] All of these pathogens have been demonstrated to persist in the environment for hours to days (and in some cases months), to frequently contaminate the surface environment and medical equipment in the rooms of colonized or infected patients, to transiently colonize the hands of healthcare personnel (HCP), to be associated with person-to-person transmission via the hands of HCP, and to cause outbreaks in which environmental transmission was deemed to play a role. Furthermore, hospitalization in a room in which the previous patient had been colonized or infected with MRSA, VRE, *C. difficile*, multidrug-resistant *Acinetobacter* species, or multidrug-resistant *Pseudomonas* has been shown to be a risk factor for colonization or infection with the same pathogen for the next patient admitted to the room.[4,5]

To decrease the frequency and level of contamination of environmental surfaces and medical equipment in hospital rooms, routine and terminal disinfection with a germicide has been recommended. Unfortunately, routine and terminal cleaning of room surfaces by environmental service personnel and medical equipment by nursing staff is frequently inadequate. Multiple studies have demonstrated that less than 50% of hospital room surfaces are adequately cleaned and disinfected when disinfectants are used.[5] The implementation of enhanced education, checklists, and methods to measure the effectiveness of room cleaning (eg, use of fluorescent dye) with immediate feedback to environmental service personnel has been found to improve cleaning and lead to a reduction in healthcare-associated infections.[6]

"No-touch" methods (eg, ultraviolet C light [UV-C], hydrogen peroxide vapor) have been developed to improve terminal room disinfection.[7] These methods demonstrate reliable biocidal activity against healthcare-associated pathogens and provide decontamination of room surfaces and equipment. A major concern with the routine use of these devices is the time required for decontamination: for UV-C light, 15–25 minutes (vegetative bacteria) and ~50 minutes (*C. difficile*); and for hydrogen peroxide systems, ~2.0–2.5 hours. We[8] and others[9,10] have demonstrated previously the effectiveness of a portable UV-C device for decontamination of hospital room surfaces. Furthermore, we have demonstrated that the use of a nanostructured UV-reflective wall coating substantially decreased (80% reduction) the time necessary to achieve more than 4-$\log_{10}$ kill of vegetative bacterial (~5 minutes) and more than 2.5-$\log_{10}$ inactivation of *C. difficile* spores (~10 minutes).[11] Here, we report whether coating other room surfaces (eg, floors, ceilings) would further reduce the time needed to achieve adequate room decontamination.

We studied a UV-C device (Tru-D SmartUVC; Lumalier) in 2 similar patient rooms.[10] All testing was done in a single patient hospital room (117 ft^2 plus 13 ft^2 for the bathroom), with results compared to a control room (136 ft^2 plus 13 ft^2 for the bathroom). The cycle time to achieve microbial killing was determined in this room before and after various areas of the room (ie, wall, ceiling, floor) were coated with an agent (Lumacept) designed to maximize UV-C reflectivity.[11] Testing was performed using Formica sheets (~3 in. × 3 in.), with a template of a Rodac plate (~25 cm^2; Becton Dickinson) drawn on the sheet. The Formica sheets were placed 1–6 ft (median, 2.5 ft) from the UV-C device. MRSA and *C. difficile* were used to test the effectiveness of room disinfection, as described in detail elsewhere.[11]

In our control patient room, the effectiveness of UV-C radiation without any reflective surface coatings was as follows: MRSA, more than 4-$\log_{10}$ overall reduction in ~23 minutes; and *C. difficile*, more than 2.75-$\log_{10}$ overall reduction in ~43 minutes (Table 1). Microbial inactivation was better for both MRSA and *C. difficile* when the pathogens were placed in direct line of sight of the UV-C unit, both in the noncoated room and when walls were coated ($P < .05$). When walls were covered with the UV-C-reflective coating, similar levels of inactivation were achieved with significantly shorter UV-C exposure times for both MRSA (from 23.12 to 4.53 minutes; $P < .05$) and *C. difficile* (from 42.82 to 8.22 minutes; $P < .05$). Coating additional room surfaces (ie, ceilings, floor) with a UV-C-reflective coating did not meaningfully improve microbial inactivation or decrease the time to achieve the reported microbial kill. The time for microbial inactivation of MRSA with coated walls, floors, and ceiling was superior to that achieved for coating only some surfaces (ie, walls; walls and floor; walls and ceilings), but the actual difference in time, although statistically significant, was at most 1 minute. Similarly, the inactivation time for *C. difficile* was not significantly improved by coating surfaces other than the walls, although paradoxically coating the walls and ceilings was significantly better than coating the walls, floors, and ceilings. Our findings may be explained, in part, by the fact that the Tru-D sensors that measure the light reflected back to the device are aimed to best observe reflected light from the walls (ie, not aimed at floors or ceiling). Similarly, the small variation in cycle time might be explained by alteration in the placement of the Tru-D device in the room, which might affect the reflected light received by the sensors.

In conclusion, covering the walls of a patient room with a UV-C-reflective coating substantially decreases the time to achieve microbial inactivation. This eliminates one of the

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major disadvantages of the current no-touch technologies, increased turnover time of the room. As previously reported, the cost to coat the walls of the room and bathroom used in this study (~12.1 m^2) was estimated to be less than $300. 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. Our study demonstrates that coating the wall with a UV-C-reflective coating would allow effective decontamination of a room within 5–10 minutes, which would significantly reduce (by ~80%) the room's downtime before another patient could be admitted. Covering additional surfaces with a UV-C-reflective coating does not appear to further reduce the time necessary to decontaminate the room when using a sensor-based UV-C device.

TABLE 1. Effectiveness (Log_{10} Reduction) of Coating Different Room Surfaces with an Ultraviolet C Light–Nanoreflective Coating

	Control (no coating)			Coated walls			Coated walls and floors			Coated walls and ceilings			Coated walls, floors, and ceilings		
Pathogen, outcome	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
MRSA															
CFU reduction	4.12 (3.98–4.25)	4.46 (4.34–4.58)	3.70 (3.50–3.89)	4.21 (4.09–4.32)	4.50 (4.40–4.61)	3.83 (3.63–4.03)	3.95 (3.80–4.11)	4.27 (4.06–4.48)	3.64 (3.49–3.78)	4.02 (3.86–4.18)	4.40 (4.25–4.54)	3.64 (3.46–3.82)	3.80 (3.65–3.95)	4.12 (3.92–4.33)	3.47 (3.33–3.61)
Time, minutes	23.12 (19.40–26.84)			4.53 (3.99–5.08)			4.51 (3.89–5.14)			4.08 (3.80–4.37)			3.55 (3.42–3.67)		
C. difficile															
CFU reduction	2.75 (2.59–2.91)	3.48 (3.33–3.62)	2.09 (1.97–2.21)	2.67 (2.53–2.82)	3.08 (2.90–3.26)	2.12 (1.98–2.26)	2.68 (2.48–2.88)	3.08 (2.85–3.30)	2.09 (1.93–2.25)	2.32 (2.14–2.51)	2.76 (2.56–2.95)	1.89 (1.68–2.09)	1.94 (1.78–2.09)	2.37 (2.18–2.56)	1.51 (1.47–1.55)
Time, minutes	42.82 (39.04–46.60)			8.22 (7.07–9.34)			8.12 (6.72–9.51)			7.51 (6.73–8.29)			9.17 (8.59–9.76)		

NOTE. Data in parentheses are 95% confidence intervals. Reductions are expressed as log_{10}. CFU, colony forming unit; MRSA, methicillin-resistant *Staphylococcus aureus*.

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