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The Effect of Ultraviolet Light on *Clostridium difficile* Spore Recovery Versus Bleach Alone

In 2014, 101,074 cases of hospital-acquired *Clostridium difficile* infections were reported to the National Healthcare Safety Network (NHSN) by acute-care hospitals.[1] Environmental contamination is a risk factor for hospital-onset *C. difficile*.[2] Ways to decrease environmental contamination include frequent hand hygiene and adequate environmental cleaning with sporicidal agents[3]; however, both methods are subject to human error. *Clostridium difficile* spores can persist in hospital environments for up to 5 months.[4] In multiple studies, an additional step of no-touch disinfection using ultraviolet light at 254 nanometers (UV-C) has eradicated *C. difficile* spores in hospital environments.[5,6]

Our aim was to evaluate the effectiveness of manual cleaning and subsequent UV-C treatment on inpatient hospital room surfaces of patients with confirmed *C. difficile* infections (CDIs). We measured colony-forming units (CFUs) of *C. difficile* on high-touch surfaces.

The Surfacide system (Waukesha, WI) produces UV-C light and is composed of 3 towers that work together or individually. The towers are placed around the bed in a triangle to focus on high-touch surfaces and to minimize shadowing. This system utilizes a laser to measure the space and calculate the required disinfection cycle time using a prespecified algorithm while rotating 360°. The system is equipped with a motion sensor to trigger a machine shut down to protect patients and staff. At our 308-bed comprehensive cancer center, we have trained staff to operate the emitters.

Our study focused on patient rooms of occupants with confirmed CDI via positive toxin B gene (*tcdB*) polymerase chain reaction (PCR) testing results. These patients are placed in enteric contact isolation, which mandates daily room cleaning with bleach and daily bathroom UV-C disinfection, but the latter does not necessarily occur immediately after manual cleaning. One emitter is used in the bathroom with the door closed, while the patient may be present in the room. Upon discharge, the bathroom and room are terminally cleaned with bleach and are immediately disinfected with UV-C. One emitter typically runs for 10 minutes in a bathroom, then the 3 emitters run for 45 minutes in the patient room.

After bleach cleaning, prior to UV-C disinfection, 2–3 high-touch surfaces were sampled by vigorously swabbing the right side of each high-touch surface with a urethane sponge (4 cm × 3.5 cm) moistened with neutralizing buffer (World Bioproducts EZ-10NB PUR). After UV-C disinfection, the same site was sampled, but on the left side of each high-touch surface. The 9 sample sites included over-bed table, toilet seat, computer keyboard, bathroom doorknob, bathroom faucet handles, bed side rails, bedside commode, recliner chair table, and call light (Table 1). Each swab was placed in a sterile bag, and 9.9 mL of 0.1% peptone buffer was added to each bag in the lab. The sponge was mechanically stomached to release recovered microorganisms into the buffer. Samples were dilution plated onto liver veal agar plates and incubated anaerobically at 37°C for 2 days. Sample cutoffs are reported as <10 CFUs as the lower limit of detection, meaning 9 to 0 colonies on the plate. Results are not reported between 0 and 9 CFUs due to addition of buffer, which releases organisms from swabs and dilutes the sample. Descriptive statistics for surfaces sampled prior to UV-C implementation were calculated using a dichotomous outcome of 10 CFUs. An overall comparison of UV-C treatment by ≥10 CFUs and <10 CFUs was assessed using the Fisher exact test. All statistical procedures were performed in SAS version 9.3 software (SAS Institute, Cary, NC). Values were considered significant at $P < .05$.

Over 4 months, 476 sites were cultured: 186 were in bathrooms and 290 were in the patient rooms. Overall, prior to UV-C treatment, 32 of 238 (13%) were positive after bleach cleaning for *C. difficile* at ≥10 CFU. In the bathrooms, 5 of 88 high-touch surfaces (6%) were *C. difficile* positive; in the patient rooms, 27 of 118 high-touch surfaces (23%) were *C. difficile* positive, respectively. The toilet seat and the over-bed table were the 2 most commonly positive sites (Table 1).

Among all sites, after UV-C treatment, only 1 of 238 high-touch surfaces (0.4%) was positive: 1 computer keyboard had 10 CFUs. We observed a statistically significant decrease in the

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TABLE 1. *Clostridium difficile* Culture Results: Effectiveness of Manual Cleaning Versus UV-C

	Post Bleach CFUs		Post UV-C CFUs	
Site	≥10 CFUs	<10 CFUs	≥10 CFUs	<10 CFUs
Over-bed table	13	41	0	54
Toilet seat	9	65	0	74
Computer keyboard	3	19	1	43
Bathroom doorknob	2	20	0	22
Faucet handles	2	39	0	41
Bed side rails	1	3	0	4
Bedside commode	1	11	0	12
Recliner chair table	1	6	0	7
Call light	0	2	0	2

NOTE. CFU, colony-forming units; UV-C, ultraviolet light at 254 nanometers.

detection of CFU following UV-C treatment (odds ratio [OR], 0.027; 95% confidence interval [CI], 0.0006–0.1664; $P < .0001$). The hospital-onset *C. difficile* cases decreased to 11.4 per 10,000 patient days from 12.9 for the same period the prior year (during which UV-C had not yet been utilized).

In rooms of patients with confirmed CDI, UV-C treatment significantly reduced the amount of *C. difficile* spores present on the surfaces tested. Manual bleach cleaning alone resulted in residual spores in 13% of high-touch-surface cultures. These cultures were obtained as part of daily routine cleaning without the knowledge of Environmental Services workers. The performance of our cleaning staff is regularly evaluated by VeriClean blacklight audits, another objective evaluation tool demonstrating areas potentially missed by the cleaning staff. The average pass rate was 90.8% during the study period. Data recently published by Wong et al[7] are consistent with our findings; they reported that 5 of 22 rooms (22%) were positive for *C. difficile* after terminal cleaning.[7] The hospital-onset *C. difficile* rate decreased as well, even without 100% compliance of UV-C treatment of discharge enteric contact isolation rooms.

In patient rooms of those with confirmed CDI, adding UV-C treatment to daily bathroom and terminal discharge cleaning reduces the amount of *C. difficile* spores present on frequently contaminated surfaces. UV-C disinfection represents an additional measure for room cleaning to avoid inadvertent transfer of *C. difficile* spores to hands or other surfaces.

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Resolution of Carbapenemase-Producing *Klebsiella pneumoniae* Outbreak in a Tertiary Cancer Center; the Role of Active Surveillance

Carbapenem-resistant *Enterobacteriaceae* (CRE) are a source of healthcare-associated infections with high attributable mortality.[1] Carbapenemase-producing CRE (CP-CRE) (eg, KPC, OXA-48, NDM, IMP or VIM) are more commonly acquired

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