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Hospital Room Sterilization Using Far-Ultraviolet Radiation: A Pilot Evaluation of the Sterilray Device in an Active Hospital Setting

Environmental contamination of hospital rooms is well recognized as a reservoir for highly resistant nosocomial pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE), which can be transferred to patients through contact with healthcare providers and contaminated surfaces.[1-4] Numerous studies dedicated to environmental cleaning and disinfection have found promising results with several novel technologies, including vaporized hydrogen peroxide and ultraviolet overhead lighting or wands.[5,6] We conducted a pilot study of one such device, the Sterilray Disinfection Wand (Healthy Environment Innovations), a handheld ultraviolet (UV) room decontamination wand. The Sterilray device claims to generate UV radiation in the far-UV spectrum (185–230 nm), resulting in the rapid killing of contaminant bacteria.[7] The goal of this pilot was to collect preliminary data on the efficacy of this device in reducing surface contamination, particularly of common nosocomial pathogens, in an active hospital setting.

We conducted a pilot evaluation of the Sterilray device in the Johns Hopkins Hospital medical intensive care unit (MICU) during its move to the Sheikh Zayed Tower. We selected 5 rooms in the original MICU whose patients were colonized with MRSA, VRE, and/or multidrug-resistant *Acinetobacter baumannii* (MDR-AB) and initiated the pilot study immediately after the patients and beds were transferred out of the MICU. Two regions of each room, broadly defined as patient contact areas (ie, overbed desk and bedside table) and healthcare worker (HCW) contact areas (ie, in-room computer keyboard and mouse) were sampled in a composite manner using Becton Dickenson RODAC (BD BBL) nonselective agar plates before and after exposure to the Sterilray, in accordance with the manufacturer's guidelines. Additionally, premoistened double-headed CultureSwabs (Copan, BD BBL) were obtained from the same surfaces (before and after UV exposure) to culture on selective media.

Protective goggles and clothing were worn during use of the device. The device was used to administer 100 mJ of far-UV radiation (20-mW lamp output over 5 seconds) from a distance of approximately 10 cm from the target surfaces.

After samples were collected in the MICU, they were immediately delivered to the microbiology laboratory. The RODAC plates were immediately incubated at 37°C for 48 hours, and the CultureSwabs were plated onto 5% sheep blood agar (BD BBL), after which they were placed in brain-heart infusion broth (BD BBL), incubated overnight, and then subcultured onto MRSA Select (BioRAD), in accordance with Johns Hopkins University microbiology laboratory standard procedures. Positive broths were subcultured on selective media to ascertain correlation with the pathogens of interest (MRSA, VRE, and MDR-AB). RODAC plates were used to quantify the number of colonies recovered (colony-forming units [CFUs]). Sterilray effectiveness was measured as $\log_{10}$ reduction = $\log_{10}$ (pretreatment CFUs) − $\log_{10}$ (posttreatment CFUs).

This study was granted non–human subjects research status by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board.

Table 1 summarizes the results. On average, patient contact surfaces saw a 0.687 (95% confidence interval [CI], −0.020 to 1.353) $\log_{10}$ decrease in the number of CFUs, and HCW contact surfaces saw a 1.088 (95% CI, 0.970–1.206) $\log_{10}$ decrease in environmental CFUs. On average, for all surfaces all rooms saw a 0.865 (95% CI, 0.484–1.246) $\log_{10}$ decrease across all surfaces following the Sterilray treatment. However, room B produced anomalous results, with an increase in the number of CFUs posttreatment on the patient contact surface and an inability to measure CFUs on the pretreatment HCW surface sample because of the presence of fungi. If the data from that room are removed, a 0.933 (95% CI, 0.341–1.526) $\log_{10}$ decrease was observed on the patient contact surfaces, and a 1.088 (95% CI, 0.970–1.206) $\log_{10}$ decrease was observed on the HCW surfaces. Overall, excluding data from that room a 1.011 (95% CI, 0.742–1.280) $\log_{10}$ decrease in CFUs was observed across all surfaces treated with the Sterilray device. Subcultures on selective media were inconclusive, and correlations between pathogens of interest and reduction in bioburden could not be established.

The MICU's move presented a unique opportunity for us to evaluate the Sterilray device in situ with minimal risk to patients. This context introduced a number of limitations,

TABLE 1. Microbial Burden before and after Treatment with the Sterilray Disinfection Wand

Surface, room	Pretreatment CFUs	Posttreatment CFUs	Log_{10} reduction	Adjusted[a] log_{10} reduction
Table				
A	20	18	0.046	
B	3	6	−0.301	
C	13	1	1.114	
D	60	4	1.176	
E	50	2	1.400	
Mean	29.2	6.2	0.687	0.933
SE or 95% CI[b]	11.0	3.1	0.020–1.353	0.341–1.526
Keyboard				
A	18	4	1.255[c]	
B	NA	4	NA	
C	50	5	1.000	
D	100	8	1.097	
E	10	0	1.000[c]	
Mean	44.5	4.2	1.088	1.088
SE or 95% CI[b]	20.5	1.3	0.970–1.206	0.970–1.206
All surfaces				
Mean	36	5.3	0.865	1.011
SE or 95% CI[b]	10.5	1.6	0.484–1.246	0.742–1.280

NOTE. Log_{10} reduction in colony-forming units (CFUs) was calculated with this formula: log_{10} reduction = log_{10} (pretreatment CFUs) − log_{10} (posttreatment CFUs). CI, confidence interval; NA, not applicable; SE, standard error.

[a] The sample from room B grew *Aspergillus flavus*; therefore, mean values and 95% CIs for log_{10} change in the number of CFUs are provided in raw form and adjusted to exclude this sample.

[b] Data for pre- and posttreatment CFUs are SEs, and data for log_{10} reduction are 95% CIs.

[c] Because log_{10} (0) is undefined, a value of 1 was substituted for posttreatment colony counts, where necessary, to generate a conservative estimate of the log_{10} change in colony counts.

including a small sample size (low number of rooms that met inclusion criteria) and a lack of a standard cleaning group as a control. Even with these limitations, our results suggest that the Sterilray device may be effective for clinical room decontamination. The roughly 1 log_{10} (or 90%) reduction in environmental contamination, while significantly lower than what has been reported in laboratory-based and standardized culture-based studies,[8,9] is similar to the findings of a group at the Medical University of South Carolina investigating another novel device against their standard terminal cleaning procedures; both of their study groups also saw 90% reductions in bioburden.[5] This study's limited sample size and the unblinded nature of the protocol may have inadvertently introduced operator-derived bias, although standard protocols were developed and strictly followed. The device itself, despite its weight and size, remained quite portable, and the wand-based method was relatively easy to use by a single user. We experienced no technical or logistical problems with this device. Our results, although promising, require confirmation in larger clinical studies in situ to better quantify the sustained efficacy of this methodology compared with current disinfection and cleaning standards and its potential impact on outcomes. The Sterilray Disinfection Wand may warrant consideration alongside other new devices as a primary, secondary, or complementary technique for room decontamination. Its portability, ease of use, and battery-powered autonomy make this kind of technology an interesting consideration where these qualities are valuable—including in smaller clinics, where larger, more expensive solutions may not be feasible, and in temporary care facilities, such as those that are set up during humanitarian emergencies or natural disasters.

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Reliability Testing for Portable Adenosine Triphosphate Bioluminometers

Measurement of adenosine triphosphate (ATP) using portable bioluminometers has been adapted from the food manufacturing sector, and it has been suggested that it could be used as an indicator of surface soiling or cleanliness in hospital settings.[1] Some healthcare authorities are considering the use of portable ATP bioluminometers as a tool for standard setting for surface cleanliness to improve cleaning standards.[2] Central to this approach is the use of a commonly accepted level of detected ATP—expressed as relative light units (RLUs)—that may be used as a surrogate for underlying soiling, including the presence of pathogenic microorganisms.[3]

It has been demonstrated that improvements can be made to cleaning processes with fluorescent markers through a simpler approach that provides a qualitative efficiency measurement of the cleaning process.[4] Measurement of surface hygiene using ATP bioluminometers is thought to provide a more quantitative surrogate of surface cleanliness.[5]

A proposed ATP/RLU standard for acceptable cleanliness has been revised from 500 RLUs, originally suggested by Griffith et al,[1] to 250 RLUs by Lewis et al[6] and most recently to 100 RLUs by Mulvey et al.[7] However, a close examination of the references reveals that different brands of ATP bioluminometers were used to establish the data in each reference—a substantial problem given that each unit reads on a different relative scale.[8] Even with a single branded unit variable results are observed without a clear explanation.[9] There also is debate over the validity of using ATP measurement as an analogue for surface soils and the presence of pathogenic microorganisms.[10]

Our aim was to validate the reliability of measurement of 3 commonly available brands of portable ATP bioluminometers. Two of the brands selected (Hygiena and 3M) feature prominently in the published literature, and the third brand (Kikkoman) provided a different approach to luciferase presentation (a powder rather than a preprepared liquid).

Our method was selected to minimize confounding variables, such as brand-to-brand differences in RLU scaling, swab absorption, cell lysis mechanism and efficiency, liberation of cellular ATP, and variations in cellular ATP during bacterial cycles. To achieve this, the method used an ATP source of known purity (Sigma-Aldrich). The ATP was diluted across multiple dilution series, which enabled testing of the 3 devices across the full dynamic range of detection for each device, from the lower limit of detection to response tapering. We included multiple 10-fold dilution series as well as multiple narrower-range dilution series. A calibrated micropipette (Thermo Scientific) was used to apply the diluted ATP directly onto the swabs for each of the portable ATP bioluminometers, following an earlier method.[11]

At each dilution point, each brand was tested in triplicate or more frequently. The swabs for each brand were from multiple batches, stored in accordance with the manufacturers' recommendations, and used within the use-by dates. High-performance liquid chromatography (HPLC; Shimadzu) was used to validate accuracy, precision, specificity, and linearity and as a quantitative control for ATP.

Materials used in our experiments included 667 ATP swabs in 153 separately measured dilution series (3M: 246 swabs in 57 runs; Kikkoman: 222 swabs in 49 runs; Hygiena: 199 swabs