American Journal of Infection Control ■■ (2017) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Ultraviolet-C light as a means of disinfecting anesthesia workstations

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Key Words:
Operating room
Surgical site infection
Hand hygiene

Background: Anesthesia workstations (AWs) are a reservoir for pathogenic organisms potentially associated with surgical site infections. This study examined the effectiveness of the Tru-D SmartUVC device (Tru-D LLC, Nashville, TN) on bioburden reduction (BR) on AWs.

Methods: Strips of tissue inoculated with a known concentration of either *Staphylococcus aureus*, *Enterococcus faecalis*, or *Acinetobacter* sp were placed on 22 high-touch surfaces of an AW. Half of the AW surfaces received direct ultraviolet (UV) light exposure and half received indirect exposure. Two inoculated strips, in sterile tubes outside of the room, represented the control. Trials were conducted on AWs in an operating room and a small room. Strips were placed in a saline solution, vortexed, and plated on blood agar to assess BR by the number of colony forming units.

Results: All experimental trials, compared with controls, exhibited a BR >99%. There was a significantly greater reduction of *E faecalis* colony forming units in the operating room AW under direct exposure ($P = .019$) compared with indirect exposure. There was no significant difference in reduction when comparing AWs between rooms.

Conclusion: Regardless of room size and exposure type, automated UV-C treatment greatly influences BR on AW high-touch surfaces. Hospitals instituting an automated UV-C system as an infection prevention adjunct should consider utilizing it in operating rooms for BR as part of a horizontal infection prevention surgical site infection-reduction strategy.

Recent efforts to reduce surgical-site and catheter-associated infections have focused on anesthesia workstations (AWs), reservoirs for infectious organisms in operating rooms.[1,2] Loftus et al[3,4] demonstrated that AWs are an important source of pathogenic bacteria, and AW bioburden has been implicated in postoperative infection in up to 16% of patients undergoing surgery.

Ultraviolet-C (UV-C) light applied by the Tru-D SmartUVC (Tru-D LLC, Nashville, TN) has been described previously.[5] Surface disinfection by UV light was superior to chemical/mechanical methods, particularly in areas where chemical disinfectant is inadequately applied.[6] This study tests the efficacy of UV-C light for decontaminating complex surfaces of an AW.

METHODS

High-touch areas of a training AW, including surfaces that are directly and indirectly exposed to UV light during decontamination, were chosen for evaluation in a simulated operating room (Fig 1).

Decontamination with the Tru-D SmartUVC was performed using the "Vegetative Bacteria" setting, ensuring that the sensor with the lowest reflected light receives an exposure of 12,000 μWs/cm^2. Experiments were conducted in both small (12 ft × 18 ft 4 in/220 sq ft/20 m^2) and large rooms (21 ft × 29 ft/609 sq ft/56.6 m^2). The device was placed in approximately the middle of both rooms (135 cm and 254 cm from AWs in small and large rooms, respectively). Run times were approximately 20 minutes in the small room and 55 minutes in the large room, per the device's algorithm. Two decontamination runs were conducted in each room, for a total of 4 runs.

To assess organism killing in difficult-to-access areas of the AW, a method capable of delivering known quantities of organism to these areas was developed. Initially, 2 delivery substrates were evaluated: 0.25 cm^2 sterile Wypal squares (Kimberly-Clark Worldwide, Irving, TX) and 6 mm sterile disks (as used in disk diffusion).

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Conflicts of interest: None to report.

0196-6553/
http://dx.doi.org/10.1016/j.ajic.2017.02.016

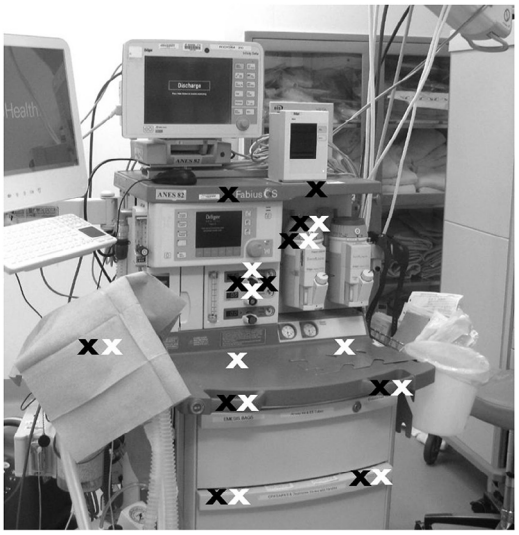

Fig 1. Example of the complex surfaces of an anesthesia machine and sites experimentally contaminated before ultraviolet-C (UVC) treatment and cultured after UVC treatment. White ×s represent sites directly exposed to UV light and black ×s represent indirectly exposed sites.

Three organisms (*Enterococcus faecalis* [ATCC 29212], *Acinetobacter baumannii* [ATCC 19606], and *Staphylococcus aureus* [ATCC 43300]), which are commonly implicated in postsurgical infections, were used in all experiments. The 0.5 MacFarland suspensions (10^8 CFU/mL) of organism were made in 0.9% sterile saline from overnight growth of the bacteria incubated for 18-24 hours at 37°C in ambient air on 5% sheep blood agar plates. Both Wypall wipes and 6-mm sterile disks were inoculated with 10^6 CFU, allowed to dry, and then held for approximately 1 hour. These squares/disks were then placed in 2 mL sterile saline and vortexed to release organism. Colony counts were obtained by pipetting 10 μL resulting solution onto 5% sheep blood agar plates, struck for isolation, and incubated for 18-24 hours at 37°C in ambient air. Colony counts were calculated the following day. This experimental method generated quantifiable growth using the 0.25 cm^2 Wypall squares. However, no viable organism was recovered using the 6-mm disk method (data not shown). Therefore, Wypall squares were selected for further experimentation.

Using the method above, Wypall squares were inoculated and allowed to dry. Next, squares were immediately placed in 13 defined locations; 9 locations were tested in duplicate for a total of 22 data points. For each organism tested, 2 no-exposure control squares were included in the analysis. These squares were handled exactly like the test squares except that once drying was complete, the squares were placed in sterile conical tubes and held outside of the exposed room for the duration of the Tru-D SmartUVC run. On run completion, the control squares were processed for colony counts exactly as the test squares. Log reduction calculations were based on the difference between the test and control squares using the following equation:

$$TruD\ Percent\ Killing = \frac{Average\frac{CFU}{ml}(TruD\ group)}{Average\frac{CFU}{ml}(Control\ group)} \times 100$$

RESULTS

Following the application of the UVC device, all organisms, on all 13 AW locations, in both large and small operating rooms, demonstrated a 2 $\log_{10}$ CFU reduction in bioburden compared with untreated controls. This reduction was observed for all organisms regardless of position or room size (Table 1). Details of CFU growth by site, exposure, and room size may be found in the Supplementary Appendix.

Table 1
Bioburden reduction: UVC exposure versus control

Room	Species	Exposure	$\log_{10}$ CFU reduction	*P* value
Small	*Enterococcus faecalis*	Direct	2.85	.410
		Indirect	2.44	
	Acinetobacter baumannii	Direct	4	.341
		Indirect	> 4	
	Staphylococcus aureus	Direct	3.67	.112
		Indirect	2.45	
Large	*Enterococcus faecalis*	Direct	> 4	.019
		Indirect	2	
	Acinetobacter baumannii	Direct	> 4	.208
		Indirect	2.64	
	Staphylococcus aureus	Direct	4	.147
		Indirect	2.57	

DISCUSSION

Several studies have demonstrated the efficacy of UVC device decontamination of flat hospital surfaces. However, none of these studies evaluated the efficacy of UVC decontamination of complex surfaces. We developed a novel method for assessing UV light decontamination of complex hospital surfaces that will facilitate future evaluations of UVC decontamination performance.

No difference was observed between UV light decontamination of directly and indirectly exposed surfaces, with the exception of *E faecalis* in the large room (Table 1). No difference in decontamination effectiveness was seen between large and small room experiments. Importantly, our study included high-touch surfaces such as knobs, drawer handles, and dials that are difficult to clean manually. Our findings suggest that UV light could be an important supplement to manual cleaning of equipment such as AWs, adding to the body of literature on novel deployment strategies for UV-light decontamination.

There are several limitations to this study. First, the true burden of organisms on an AW surface is unknown, as is the necessary bioburden reduction for halting cross-transmission to patients. Second, the model derived for this study employed a porous Wypall wipe that does not perfectly represent the surface of the anesthesia instruments being assessed. However, we believe that the porous nature of the wipes would likely have a protective effect for bacterial viability and would thus underestimate the influence of UVC killing. Thus, we believe our findings of significant reduction in organism burden can be extrapolated to make conclusions about the effectiveness of UVC sanitization of AW surfaces. The porous nature of the carrier should also be considered when comparing these results with those of other studies testing UV decontamination on nonporous carriers or surfaces. Finally, the *A baumannii* and *E faecalis* control carriers produced too many colonies to count and, given our limited access to the simulation center, we were only able to complete a single repeat run of the *E faecalis*, from which we produced a 1:10 dilution while plating. As a result, although the *E faecalis* control colony forming unit counts were accurate, *A baumannii* control colony forming unit counts were estimated.

This study demonstrates that UV light significantly reduces bioburden of 3 organisms commonly implicated in surgical infections. Importantly, our findings show that UV-C technology effectively decontaminates surfaces that are not readily cleaned with manual techniques. Using the methods developed here, a similar study may

be performed on a larger scale. Further studies are required to assess whether reductions in bioburden on AWs influence surgical site infections.

Acknowledgments

This project is dedicated in memoriam to Dr. Gene Peterson, MD, PhD, a steadfast, dedicated physician and a champion for patient safety.

APPENDIX. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ajic.2016.01.025.

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