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Major Article

Evaluation of an ultraviolet C light–emitting device for disinfection of electronic devices

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Background: A tabletop-type ultraviolet C (UVC) light–emitting disinfecting device was evaluated for microbiologic effectiveness, safety, usability, and end-user satisfaction.

Methods: Three different inoculums of methicillin-resistant *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Acinetobacter calcoaceticus-baumannii* complex strains suspended in both saline and trypticase soy broth were applied onto stainless steel carriers and electronic device surfaces in triplicate and cultured for growth after UVC disinfection. Assessments of functionality and usability were performed by biomedical and human factors engineers. End-user feedback was captured using a standardized in-use survey.

Results: The 54 stainless steel carriers displayed growth at inoculums as low as 10^2 colony forming units (CFU) when a quartz dish supplied by the manufacturer was used during UVC exposure. Without the quartz dish, 54 electronic device surfaces displayed no growth for inoculums from 10^2-10^4 CFU for all organisms suspended in saline, but lower kill rates (95.7%-100%) for organisms in broth. Several minor safety and usability issues were identified prior to clinical evaluation. In-use evaluation revealed keen user endorsement; however, suboptimal sensitivity of the machine's input sensors during sequential object insertion precluded implementation.

Conclusions: Optimization of some safety and functionality parameters would improve a conceptually popular and microbiologically effective tabletop UVC disinfecting device.

The use of personal electronic devices is increasingly prevalent in modern health care environments among medical professionals, patients, and visitors alike. Unfortunately, devices such as cell phones and laptops have been found to serve as reservoirs for bacterial colonization.[1,2] This is of particular concern in the hospital setting, where the contamination of portable equipment has been implicated in the transmission of pathogens.[3] Ultraviolet C (UVC) light disinfection technology has been demonstrated in recent years to be an effective method for the disinfection of environmental surfaces.[4] The microbiologic effectiveness and user heuristics of the Aluvis (Angelini Pharma, Gaithersburg, MD), a tabletop-style UVC-emitting appliance, was assessed for the disinfection of personal electronic devices.

MATERIALS AND METHODS

Background

Vancouver General Hospital is a 728-bed, tertiary care academic teaching hospital in Vancouver, British Columbia, Canada. Between December 2015 and March 2016, the Aluvis UVC system was evaluated for its microbiologic efficacy, safety, usability, and customer satisfaction. The Aluvis is a 34-kg tabletop-type UVC-emitting appliance developed in 2015 for the disinfection of mobile handheld devices. It operates via a roller-based conveyor system with 5 American Air & Water (Hilton Head Island, SC) UVC low-pressure mercury lamps embedded within the rollers (which also comprise the conveyor system) and 5 additional UVC lamps overhead. The total UVC

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dose delivered by the lamps is >175 mJ/cm^2. The device has input and output openings on opposite sides from each other, both of which are covered by UV-blocking curtains. The disinfection cycle time is 35 seconds.

Preparation of organisms

An in-house strain of methicillin-resistant *Staphylococcus aureus* and ATCC (Manassas, VA) strains of *Pseudomonas aeruginosa* (ATCC 27853) and *Acinetobacter calcoaceticus-baumannii* complex (ATCC BAA-1605) were subcultured overnight on blood agar plates (BAPs). A 0.5 McFarland standard solution, approximating a concentration of 1.5×10^8 colony forming units (CFU)/mL, was prepared for each organism in normal saline. Each solution was then diluted to attain concentrations from 10^7-10^2 CFU/mL, in both saline and trypticase soy broth (TSB) media. The accuracy of the dilutions was verified by counting the number of colonies present in 100-μL aliquots of the 10^4, 10^3, and 10^2 dilutions after 18-24 hours of incubation in CO_2 on BAPs.

Laboratory carrier studies

For each organism, 10 μL of the 10^6, 10^5, and 10^4 CFU/mL solutions of either saline or TSB were inoculated in triplicate onto sterile stainless steel washers, as per methodology described elsewhere.[4] These suspensions were allowed to dry and then immediately processed (approximately 30 minutes postinoculation) to minimize changes in viability caused by inactivation from drying. Once dry, they were placed onto a quartz dish provided by the manufacturer, which had undergone disinfection with alcohol wipes and passage through the Aluvis twice. The dish surface was also swabbed and cultured in TSB prior to washer placement to confirm complete dish disinfection. The washers on the dish were passed through the Aluvis once and then placed into TSB. Positive and negative control washers were also inoculated and cultured in the same manner. Turbid broth specimens were subcultured to BAPs for identification. Identification of microorganisms was confirmed using either standard biochemical reactions or matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) (database version 3.1.66; Bruker Daltonics, Billerica, MA). For each concentration, the number of broths displaying growth was determined.

Portable electronic device studies

For each organism, 100 μL of 10^6, 10^5, and 10^4 CFU/mL solutions of the organisms of interest suspended in saline or TSB was inoculated in triplicate onto 2.54 cm^2 areas of the back surface of a calculator and the touchscreen and plastic cover of a personal digital assistant. Positive controls consisted of inoculated 2.54 cm^2 areas in triplicate that did not undergo disinfection. Negative controls consisted of noninoculated areas of the same size in triplicate subjected to UVC disinfection.

After UVC disinfection, sterile swabs premoistened with saline were used to swab each 2.54×2.54 cm^2 area in 3 different directions. Each swab was subsequently twirled for 15 seconds in 2 mL of saline to release organisms. After mixing, 100-μL aliquots of the saline solutions were transferred to TSB and BAPs, ensuring even inoculation across the BAP by using an inoculating loop. Broth and plates were then incubated for 18-24 hours at 37°C in CO_2. Turbid broth specimens were subcultured to BAP for identification. Plates with bacterial growth were counted to obtain the number of surviving viable bacteria. Devices with the positive and negative control squares were cultured in the same manner.

The percent kill of the organisms of interest at each concentration of both saline and broth was calculated by dividing the average of the numbers of surviving colonies postdisinfection on BAPs by the average of the triplicate colony counts from the original inoculums. The broth cultures, potentially more sensitive indicators of growth, were used as correlates to the BAPs to confirm the presence or absence of growth. Growth in any of the triplicate sets for a particular concentration was counted as positive.

Biomedical and human factors engineering assessment

Prior to microbiologic testing and in-use evaluation, a functional review to ensure device safety was performed by a biomedical engineer to ensure it met Canadian standards requirements. At the same time, a preliminary assessment to identify quality and safety issues that might contribute to human error during device operation was performed by a human factors engineer. For the latter, a set of usability heuristics with an applied severity ranking were used in the preliminary evaluation.[5,6] Subsequent in-use evaluation on the bone marrow transplant unit used a standardized user survey to capture health care worker feedback. The company provided the user manual and a poster detailing instructions for use in the clinical setting.

RESULTS

Laboratory carrier studies

In all experiments, the quartz dish itself exhibited no growth. All the positive stainless steel disk controls grew, whereas the negative controls did not. Stainless steel carriers placed on the quartz dish displayed growth postdisinfection at inoculums as low as 10^2 CFU in both saline and broth suspensions for methicillin-resistant *S aureus* and *A calcoaceticus-baumannii* complex. Carriers inoculated with *P aeruginosa* displayed growth at 10^4 CFU inoculum in saline and 10^3 and 10^4 CFU inoculums in broth (Table 1).

Portable electronic device studies

All of the positive controls grew, and the negative controls did not. The electronic devices displayed no growth postdisinfection for inoculums from 10^2-10^5 CFU for all organisms suspended in saline. The effectiveness of microbial killing was decreased for all 3 or-

Table 1
UVC results for stainless steel carriers using the quartz tray

Organism	Inoculum (CFU)	Growth in broth post-UVC disinfection
MRSA		
Saline	1.1×10^2	Growth
	1.1×10^3	No growth
	1.1×10^4	Growth
Broth	1.7×10^2	Growth
	1.7×10^3	Growth
	1.7×10^4	Growth
Pseudomonas aeruginosa		
Saline	1.2×10^2	No growth
	1.2×10^3	No growth
	1.2×10^4	Growth
Broth	2.9×10^2	No growth
	2.9×10^3	Growth
	2.9×10^4	Growth
Acinetobacter calcoaceticus-baumannii		
Saline	6.0×10^1	No growth
	6.0×10^2	Growth
	6.0×10^3	No growth
Broth	1.7×10^2	Growth
	1.7×10^3	Growth
	1.7×10^4	No growth

CFU, colony forming units; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *UVC*, ultraviolet C.