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Major Article

Comparative effectiveness of rapid-cycle ultraviolet decontamination to chemical decontamination on high-touch communication devices

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Key Words:
Contamination
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Background: This quantitative, comparative-descriptive study of inpatient units in a large military medical center was designed to compare the effectiveness of compact ultraviolet (UV-C) decontamination to standard chemical decontamination in reducing the microbial burden on Vocera (San Jose, CA) communication devices and to characterize changes in staff cleaning practices following UV-C device implementation.

Methods: Aerobic and anaerobic swabs were used to collect microbial samples from Vocera devices (n = 60) before and after chemical decontamination (first sampling) and before and after UV decontamination (second sampling). Cleaning behaviors were assessed by observation and oral inquiry during the baseline sampling and surveyed 8 weeks after UV-C device implementation. Outcomes included aerobic and anaerobic colony-forming units and prevalence of methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococci, or *Clostridium difficile*, as determined by standard microbiological methods.

Results: No differences were found between the two cleaning methods in their ability to reduce aerobic bacteria; however, UV-C was significantly more effective at reducing bacteria grown anaerobically ($P < .01$). This study elucidated an 8.3% prevalence of methicillin-resistant *Staphylococcus aureus* on Vocera devices in the inpatient environment. Initially, 42% of respondents reported deviations from manufacturer's cleaning guidelines, and 16.7% reported daily or more frequent cleaning of the Vocera devices.

Conclusions: After implementation, UV-C decontamination reduced average cleaning time by 43% and increased the rate of daily Vocera cleaning to 86.5%. Respondents reported an overall 98% user satisfaction with the UV-C device.

BACKGROUND

Frequently handled, non-critical medical devices and other high-touch surfaces have been shown to harbor pathogenic organisms in the clinical setting.[1-3] Many of these surfaces are often overlooked or disregarded during routine environmental decontamination.[4,5] These cleaning failures in turn have been linked to bacterial transmission and subsequent infection.[6] Although the popularity of hospital-assigned wireless communication devices (such as smartphones, pagers, and push-to-talk devices) has grown, little is understood regarding the cleaning practices or surface contamination risks for these devices. Wireless devices allowing real-time voice communications in the hospital setting have been reported to improve communication among staff and decrease the number of physician interruptions and delays.[7,8] The devices often operate through a large central call button and preset voice commands (caller can request receiver by name or key position). The high-touch and wearable nature of these devices leads to frequent exposure to pathogenic and opportunistic microorganisms from human and environmental contaminants. Moreover, their wearable design puts them in close proximity to vulnerable or infected patients throughout the day. After an episode of care, staff may continue to utilize a contaminated device throughout the day, propagating the spread of potentially infectious microorganisms throughout the environment of care. Several authors have likened these devices to a "Trojan horse" capable of harboring and transporting pathogens.[1]

Although it is nearly impossible to regulate environmental decontamination for every foreseeable hospital surface, the Centers for Disease Control and Prevention maintains that high-touch surfaces in patient care areas should be cleaned and/or disinfected more frequently than surfaces with minimal hand contact, which, at minimum, require cleaning on a regular basis, when soiling or spilling

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occurs, or when a patient is discharged.[9] Unfortunately, across various behavioral studies, staff have reported a gap in knowledge of environmental cleaning practices, knowledge of infection transmission processes, lack of guidance/modeling behavior, and lack of available resources.[10,11] To address that problem, various decontamination alternatives have been manufactured to reduce staff burden and minimize human error. One strategy that has demonstrated reliability and efficacy is the medical-grade germicidal energy of ultraviolet C (UV-C) irradiation technology. Although these devices have demonstrated the greatest clinical impact in terminal room decontamination,[12,13] smaller, rapid-cycle UV-C devices have also shown the potential to reduce the risk of infection in hospital settings.[1,10] For example, under controlled conditions, a rapid-cycle UV-C enclosed device reduced methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* on mobile handheld devices by up to >4 log and >1 log, respectively.[14] Many questions remain, however, including how advantageous these devices are compared to current chemical decontamination and whether cleaning behaviors can be meaningfully altered.

Toward that aim, this study set out to compare the performance of rapid UV-C decontamination against standard manual chemical decontamination. An additional objective was to evaluate the feasibility of implementation in a real-world hospital setting and assess the reception of the UV-C device from the end user's perspective. Aerobic and anaerobic bacterial growth were characterized on a wireless communication device before and after chemical decontamination or, alternatively, 1-step UV-C irradiation. In addition, staff surveys were used to outline the feasibility of use and adoption of UV-C technology in a real-world setting.

METHODS

Participants and baseline sampling

This study was a quantitative, comparative study with descriptive elements. Sixty nursing staff (20 from 3 inpatient units) were invited to participate. The institutional review board determined that participants were exempt from written consent requirements for this study. Nursing staff were asked to provide their devices for baseline sampling. The devices used at the study site were Vocera Badges (Vocera Communications; San Jose, CA). Because bacteria grown aerobically (A) and anaerobically (AN) were required from the same device, either the front- or back-facing side was predesignated as the A or AN sampling surface by random assignment. Sterile transport swabs (BD BBL CultureSwabs with liquid Amies medium; Becton, Dickinson and Company, Franklin Lakes, NJ) or anaerobic specimen collectors (BD BBL Vacutainer anaerobic specimen collectors) were rubbed across the front- or back-facing device surface vigorously for 60 seconds in both vertical and horizontal zigzag patterns. Participants were then asked a series of questions regarding device cleaning practices and history of device cleaning. Routine cleaning and decontamination were then performed by the participants, and the research coordinator noted cleaning time (start/stop of wiping action) and cleaning method (eg, alcohol wipes, antiseptic wipes). A second series of microbiological samples was subsequently taken after chemical decontamination.

Laboratory procedures

Samples were collected and transported securely to the laboratory, where swabs were inoculated onto blood agar plates (BD BBL Trypticase soy agar with 5% sheep's blood). Plates were grown either aerobically or anaerobically at 37°C for 24-48 hours in the appropriate atmospheric conditions. Colonies were enumerated by the Protos 3 automated colony counter (Synbiosis; Frederick, MD) and reported as colony-forming units (CFUs). Heterogeneous colonies from aerobic culture were subsequently subcultured onto MRSA (Hardy Diagnostics; Santa Maria, CA) and VRE screening agar plates (Bio-Rad; Hercules, CA) and incubated aerobically at 37°C for 24 hours. Interpretation for presumptive positive colonies was made according to manufacturer guidelines, and organisms were confirmed using standard clinical microbiological methods. *Clostridium difficile* screening plates (Hardy Diagnostics) were sequentially inoculated by anaerobic swab, cultured parallel to blood agar plates, and incubated at 37°C anaerobically for 48 hours (BD GasPak EZ pouch systems). *C. difficile* evaluation was performed according to the manufacturer's interpretation guidelines.

UV-C intervention and implementation

One month following baseline sampling, a compact (width, 26"; depth 17.5"; height, 9") UV-C decontamination cabinet (ReadyDock; West Hartford, CT) was introduced on each participating unit. Twenty participants per unit were once again invited to provide their devices for microbial sampling. Rather than performing self-directed manual decontamination, participants were asked to place their device inside the ReadyDock UV-C cabinet for 30 seconds. This 1-step alternative required the user to pull open the drawer, place the device on a wire shelf within the device, close the drawer, and press the start button on the device touchscreen to the right of the drawer. The device displays a cycle timer followed by a cycle-complete message ("DISINFECTED"). It was recommended that hand hygiene be performed prior to device retrieval in order to prevent immediate re-inoculation of the device with possible hand contaminants. Following the entirety of the process, participants removed the device and provided it to the research team for sampling. Sampling was performed after the UV-C treatment, and the samples were then taken to the laboratory and processed as previously described. Following unit-wide demonstrations of the ReadyDock UV-C cabinet and instructions for its use, the cabinet was implemented on a long-term basis. The device was situated in the central nursing station and product literature was made available at all times.

The efficacy of the UV-C cabinet was tested in the lab prior to study use. Briefly, 100 μL of 0.17-McF turbidity suspensions of MRSA or *Clostridium difficile* were inoculated onto a device and air dried for 10 minutes. Samples were obtained from devices before and after decontamination by either 30 seconds of UV-C irradiation or 30 seconds of wiping with the chemical decontaminant CaviCide (Metrex; Orange, CA). Procedures were repeated at least 10 times for each bacteria. Figure 1 shows representative growth from samples before and after either chemical or UV-C decontamination. Each method demonstrated comparable efficacy in line with the manufacturer's advertised efficacy.

After UV-C decontamination had been implemented on each participating unit for at least 2 months, users were anonymously surveyed for satisfaction with the device and whether they would recommend it for hospital-wide implementation (yes/no). Users were additionally asked to rate the ease of use and time required to use the UV-C technology (very poor, poor, neutral, good, or very good). Finally, users were asked about the frequency of device use (never, weekly, daily, 2-3 times/day, 4-5 times/day, other).

Statistical analysis

Wilcoxon rank-sum tests were used to evaluate differences in CFU levels before and after decontamination with standard cleaning or UV-C decontamination. Cases where no CFUs were found before cleaning were excluded from the analysis of percent removal (3 anaerobic swabs prior to standard cleaning and 2 anaerobic swabs prior to UV-C decontamination). A Fisher exact test was used to test whether rates of CFU counts > 1 differed between cleaning groups.

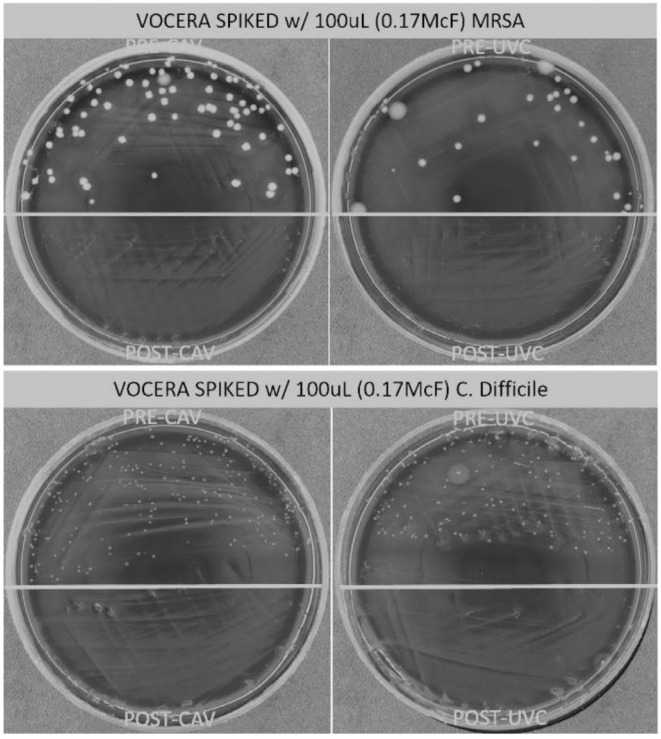

Fig 1. Representative colony formation before and after chemical and ultraviolet C decontamination. Top halves indicate pre-decontamination colony-forming units (CFUs) after 24-h incubation on blood agar media. Bacteria were recovered from devices experimentally inoculated with 100 μL of 0.17-McF turbidity methicillin-resistant *Staphylococcus aureus* (MRSA) (top) or Clostridium difficile (bottom). The efficacy of either decontamination method was comparable (100% decontamination for MRSA; >99.99999% decontamination for *C. difficile*).

A significance level of .05 was used for all analyses, which were conducted using SAS 9.4 software (SAS Institute; Cary, NC).

RESULTS

Findings suggested that both chemical and UV-C decontamination performed well and dramatically reduced the number of bacteria on the devices. Chemical cleaning achieved a 98% reduction in aerobic bacteria and a 96% reduction in obligate/facultative bacteria grown anaerobically. In comparison, UV-C decontamination achieved a 97% reduction in aerobic bacteria and a 100% reduction in bacteria grown anaerobically. Table 1 presents the mean number of CFUs for both aerobic bacteria and bacteria grown anaerobically before and after chemical and UV-C decontamination.

In this study, we asked individuals if we could sample the device and recorded the last time the device was cleaned. We found that 46% of the respondents were either unaware of the last time the device was cleaned or specifically confirmed that the devices had not been cleaned that day. We then asked the individuals to clean the devices according to their normal practice and observed the performance of this task. We found that staff used 5 different cleaning products, and 42% of the staff used a solution explicitly prohibited for cleaning the device used in this study (per the manufacturer, devices should be cleaned with alcohol or alcohol-based wipes only). We also found that the time spent cleaning the devices varied from 15 seconds to 2 minutes (average, 52.5 seconds of wipe time). During the course of the study, 5 instances of MRSA contamination were confirmed across 120 sampling events (4.2%); however, no instances of VRE or *Clostridium difficile* contamination were detected. In laboratory tests performed with clinical specimens, applying antiseptic for 30 seconds or UV-C irradiation effectively eliminated all pathogens tested (Fig 1). As displayed in Table 1, CFU levels prior to cleaning did not differ between the standard cleaning and UV-C decontamination groups ($P = .170$ for aerobic samples; $P = .817$ for anaerobic samples). After cleaning, CFU levels did not differ between groups for aerobic samples, but CFUs for bacteria grown anaerobically were significantly lower for the UV-C decontamination compared to standard cleaning (median = 0 vs median = 1; $P = .011$). No CFUs were found in 60% of plates incubated anaerobically after UV-C decontamination compared to 42% after standard cleaning, but the standard cleaning group was more than twice as likely to have anaerobic CFUs > 1 after cleaning than the UV-C decontamination group (47% vs 22%; $P = .006$). Due to the preprogrammed, 30-second UV-C cycle time of the device, UV-C decontamination also reduced the time expenditure of users from 53 seconds (average, baseline phase) to 30 seconds (43%).

Finally, after 8 weeks of uninterrupted availability of the UV-C devices, 2 of the 3 study-participating units provided user feedback (Fig 2). During this study, 1 unit significantly scaled down use of the device due to factors unrelated to the study and were thus excluded from the 8-week UV-C implementation phase; consequently, user feedback was not collected from this unit. Staff consistently reported being satisfied with the device (98%). There was a significant rise in the number of staff reporting daily or more frequent cleaning of the device (86%), with some users reporting use up to 4 or 5 times a day (Fig 3). Additionally, the majority of staff (90%) stated that they recommended expanding UV-C technology to other areas of the hospital, that the UV-C device was easy to use (100%), and that the 30-second cleaning cycle was either good or very good (96%).

DISCUSSION

To date, research regarding hands-free communication devices has focused on how these devices have been received by staff and their correlation with workflow efficiency. This study introduces a unique investigation of the capacity of such devices to act as a reservoir for infectious agents. We demonstrated that hands-free hospital communication devices pose a risk of harboring and transmitting infectious microorganisms in a hospital setting. Currently, the frequency and duration of cleaning are not specified for a majority of non-critical medical devices within the Centers for Disease Control and Prevention guidelines that recommend “routine” cleaning.[9] The isolation and identification of MRSA in several instances illustrate the risk of the communication devices in the chain of infection, a risk that is likely exacerbated by the infrequent and inconsistent decontamination practices characterized by staff currently. Additionally, it is known that many bactericides (eg, chlorinated hydrocarbons, quaternary ammonium, hydrogen peroxide) do not completely eliminate bacteria, particularly high-stress-surviving pathogens or in cases where biofilm or organic matter build-up are abundant.[15-17]

One unique aspect of our study was the evaluation of both aerobic and anaerobically grown bacteria, a distinction that is commonly overlooked when focusing mainly on frequent hospital pathogens. Evaluating the efficacy of decontamination strategies in a clinical setting is often treated as a one-size-fits-all exercise, despite the established differences between aerobic and anaerobic microorganisms. For example, not only do these bacterial categories differ regarding optimal growth conditions (temperature, oxygen, acidity), but they also have been shown to respond differently to common antiseptics.[15] In this study, although both methods of decontamination were performed similarly, we found that the frequency of cleaning improved with the UV-C device, potentially decreasing the risk for these devices to harbor and potentially serve as vectors for health care–acquired infections.

Toward the goal of eradicating the risk of bacterial transmission and infection in the clinic, emerging tools such as UV-C decontamination

Table 1
Bacterial reduction achieved by chemical decontamination and ultraviolet decontamination

	Standard chemical decontamination, median (IQR)(n = 60)	UV-C decontamination, median (IQR)(n = 60)	*P* value
Pre-decontamination, CFUs			
Aerobic bacteria	23 (9-43)	29 (16-54)	.170
Bacteria grown anaerobically	16 (7-33)	15 (6-34)	.817
MRSA	1	3	—
Post-decontamination, CFUs			
Aerobic bacteria	1 (0-3)	1 (0-3)	.320
Bacteria grown anaerobically	1 (0-3)	0 (0-1)	.011
MRSA	1	0	—
Percent removal, %			
Aerobic bacteria	98 (84-100)	97 (88-100)	.537
Bacteria grown anaerobically	96 (86-100)	100 (91-100)	.073

NOTE: Five cases of bacteria grown anaerobically that yielded 0 CFU before cleaning were excluded from the percent removal analysis (3 standard cleaning and 2 UV-C irradiation).
CFUs, colony-forming unit; *IQR*, interquartile range; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *UV-C*, ultraviolet C.

devices are continually being optimized. Although their effectiveness has been established in previous literature,[12,13] staff-centered, rapid-cycle UV-C decontamination has not been investigated as an alternative to chemical decontamination. This study is among the first to characterize changes in infection prevention practices after ultraviolet implementation in a real-world hospital setting. Although future studies should focus on long-term UV-C usage patterns and a broader spectrum of infection prevention practices, this study reports promising evidence that UV-C decontamination technology can efficiently reduce bacterial burden in the environment of care and that staff may be more willing to adhere to frequent cleaning guidelines when facilitated by rapid, easy to use solutions. Other advantages of UV-C technology include reduction of the respiratory irritant and potentially corrosive effects of chemical disinfectants[18] and the elimination of human variables introduced by manual application. Finally, as we learn more about the potential of nosocomial pathogens to form biofilm and polymicrobial communities that may impart resistance to chemical disinfectants,[19,20] including alcohol-based disinfectants,[21] it will remain important to persistently challenge standard decontamination practices.

Some limitations of our study include the use of mechanical swabbing for sample collection, which may have reduced the frequency of positive cultures compared to impression-based sampling. Another limitation is the potential bias of self-reported behaviors provided by staff for our evaluation of cleaning behaviors. Additionally, the single-site nature of this study limits the generalizability of our findings at this time. In future studies, it will also remain important to characterize anaerobic bacteria more definitively to better understand the underlying mechanisms of susceptibility and resistance to decontamination strategies.

CONCLUSIONS

The findings from this study highlight the need for clear guidance on both the method and frequency of cleaning high-touch surfaces to minimize the potential for bacterial contamination and mitigate their potential as vectors for health care–associated infections. Due to the potential accumulation of pathogenic microorganisms on the device, routine cleaning could mitigate the risk of bacterial transmission. Moreover, minimizing the effort required for staff to integrate routine cleaning of communication devices would likely increase compliance with task performance. Given the high percentage of staff who were either unaware of the cleanliness of the device or knowingly wore devices that had not been cleaned, we recommend continued education to health care providers regarding the contamination risks of high-touch surfaces and the urgency of routine cleaning to reduce health care–associated infections. As facilities continue to adopt various UV-C decontamination devices (primarily as an adjunct to terminal room cleaning) it is important that facilities also remain vigilant

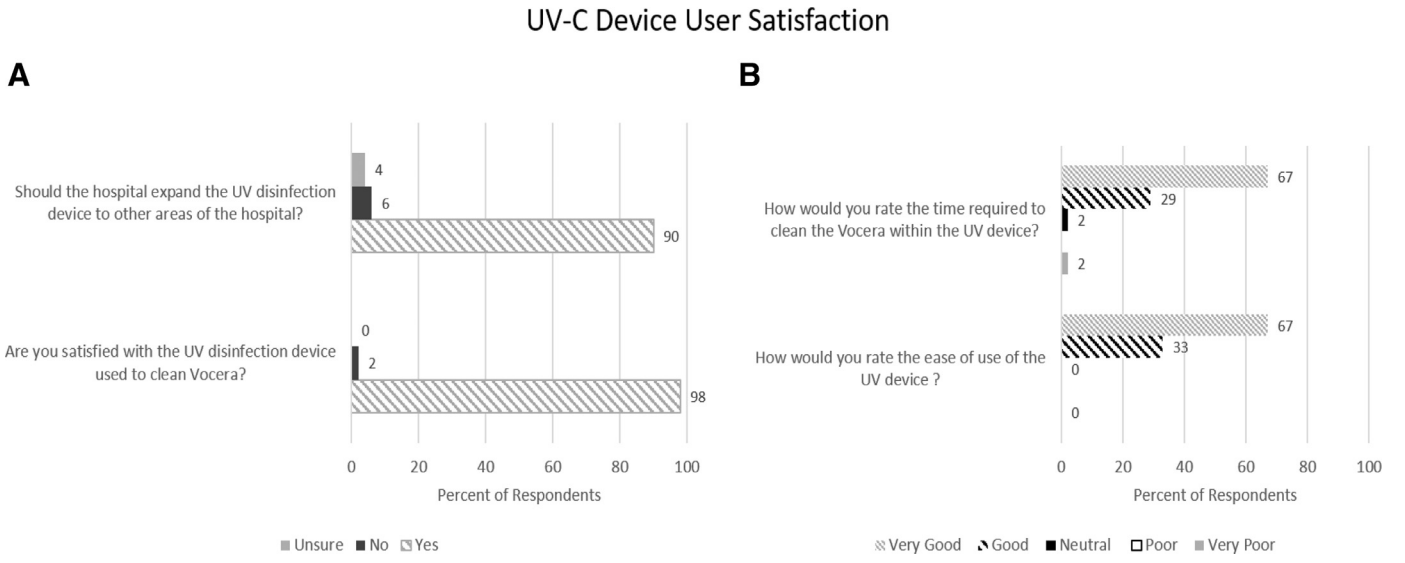

Fig 2. Ultraviolet C device feedback after 8-wk implementation. Survey questions administered to staff (n = 51) are shown with (A) percent reported categorically (yes, no, or unsure) and (B) percent reported on a Likert-type scale (very poor, poor, neutral, good, or very good).

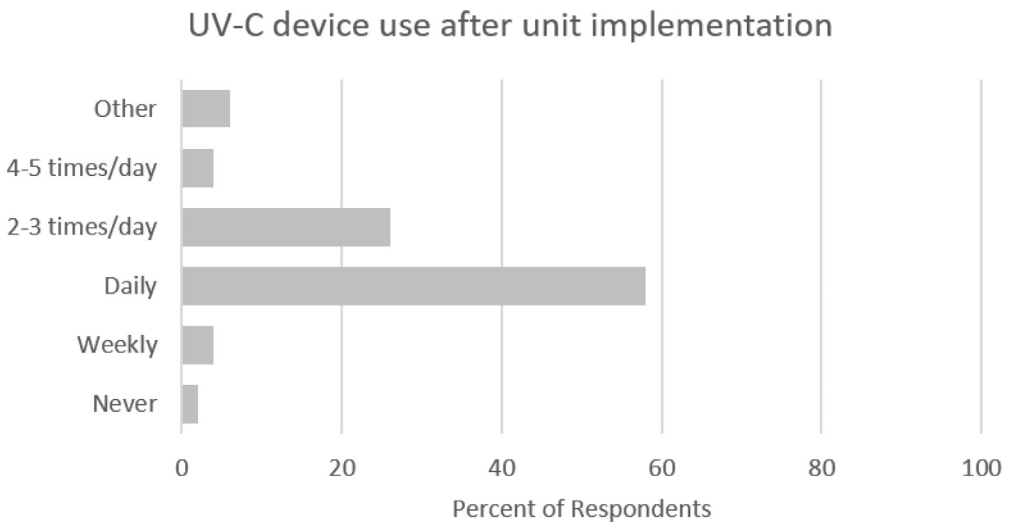

Fig 3. Ultraviolet C device use after 8-wk implementation. Graph shows survey choices provided during feedback collection (n = 50) and the percent reported in each category.

in addressing high-touch surfaces. Our findings suggest that these smaller UV-C decontamination devices are an efficient and well-received alternative to traditional chemical cleaning. We would suggest that high-touch electronic devices used within the health care environment are the ideal items to be disinfected utilizing UV-C technology, as staff may be reluctant to use liquid chemical cleaners on these devices.

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