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Major Article

Effect of automated ultraviolet C–emitting device on decontamination of hospital rooms with and without real-time observation of terminal room disinfection

Katie Penno MPH [a], Roman A. Jandarov PhD [b], Madhuri M. Sopirala MD, MPH [c,*]

[a] Public Health Program, University of Cincinnati College of Medicine, Cincinnati, OH
[b] Division of Biostatistics and Bioinformatics, Department of Environmental Health, University of Cincinnati College of Medicine, Cincinnati, OH
[c] Division of Infectious Diseases, Department of Internal Medicine, University of Cincinnati College of Medicine, Cincinnati, OH

Key Words:
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Background: We studied the effectiveness of an ultraviolet C (UV-C) emitter in clinical settings and compared it with observed terminal disinfection.

Methods: We cultured 22 hospital discharge rooms at a tertiary care academic medical center. Phase 1 (unobserved terminal disinfection) included cultures of 11 high-touch environmental surfaces (HTSs) after terminal room disinfection (AD) and after the use of a UV-C–emitting device (AUV). Phase 2 (observed terminal disinfection) included cultures before terminal room disinfection (BD), AD, and AUV. Zero-inflated Poisson regression compared mean colony forming units (CFU) between the groups. Two-sample proportion tests identified significance of the observed differences in proportions of thoroughly cleaned HTSs (CFU < 5). Significant *P* value was determined using the Bonferroni corrected threshold of $\alpha = .05/12 = .004$.

Results: We obtained 594 samples. Risk of overall contamination was 0.48 times lower in the AUV group than in the AD group ($P < .001$), with 1.04 $\log_{10}$ reduction. During phase 1, overall proportion of HTSs with <5 CFUs increased in AUV versus AD by 0.12 ($P = .001$). During phase 2, it increased in AD versus BD by 0.45 ($P < .001$), with no significant difference between AD and AUV ($P = .02$).

Conclusions: Use of UV-C with standard cleaning significantly reduced microbial burden and improved the thoroughness of terminal disinfection. We found no further benefit to UV-C use if standard terminal disinfection was observed.

BACKGROUND

Hospital environment has gained importance as one of the major factors in occurrence of hospital-acquired infections. Microorganisms can persist in the environment for several days to weeks.[1,2] Hospital transmission of microorganisms from prior inhabitants of a patient room to a new patient admitted to the same room via the environment is quite well known.[3-5] Hospital-acquired infections such as central line–associated bloodstream infections may occur because of persistent contamination of hospital rooms.[6] Monoclonal and polyclonal outbreaks also occur because of environmental transmission.[7-9]

Standard approaches to environmental cleaning may not be very effective in eliminating environmental contamination in hospital rooms.[2,10,11] Many adjuncts to standard methods of environmental cleaning have been described in the literature and are in market for use. One of these adjunct methods is use of ultraviolet (UV) radiation. Varieties of devices have shown efficacy in killing microorganisms in simulated experiments.[12-16] Ultraviolet C (UV-C) emitters are automated devices using UV-C (254 nm range) to decontaminate surfaces while measuring UV reflection from flat surfaces to calculate the time to deliver the programmed dose. A trained person operates the device via a remote control from outside a sealed patient's room.

To our knowledge, only 4 studies have compared the effectiveness of standard terminal disinfection alone with that when combined with UV-C disinfection in real hospital settings.[17-20] Two other studies evaluated the effectiveness of UV-C in a clinical setting

* Address correspondence to Madhuri M. Sopirala, MD, MPH, Division of Infectious Diseases, University of Cincinnati Medical Center, 231 Albert Sabin Way, MSB 6109, ML 0560, Cincinnati, OH 45267.
E-mail addresses: msopirala@gmail.com, madhuri.sopirala@uc.edu (M.M. Sopirala).

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but did not perform a comparative evaluation with standard disinfection.[15,21] Although there has been great emphasis on using expensive adjunct measures in the recent years, there have been no evaluations of the effectiveness of observed standard terminal cleaning compared with unobserved standard terminal cleaning with or without UV-C application except for one.[22] This study demonstrated that observation resulted in a significant improvement in housekeeper disinfection of nontoxigenic *Clostridium difficile* spores artificially inoculated onto surfaces but did not study UV-C application or compare it to observed disinfection.

The objective of our study was to evaluate the effectiveness of a UV-C emitter and observed terminal disinfection in real clinical settings. This is the first study to compare the difference of microbial counts after observed versus unobserved terminal disinfection using conventional methods and after UV-C disinfection in either scenario. Our study is also unique in that the vendor is unaware of the study and provided no assistance in any form, including free product.

METHODS

We performed this study from January-April 2016 at the University of Cincinnati Medical Center (699 beds), which is a tertiary care academic medical center. The study was determined to not be human subjects research by the institutional review board and was approved by the institutional biosafety committee.

We established collaboration with our environmental services (EVSs) staff to identify discharge rooms that were about to undergo terminal disinfection process. We performed the study in 2 phases. In phase 1, we obtained environmental cultures from 11 high-touch surfaces (HTSs) from 11 rooms after standard terminal disinfection and after the use of a UV-C–light emitting device. In phase 2, we obtained environmental cultures from the same HTSs from 11 rooms before standard terminal disinfection (BD), after standard terminal disinfection (AV), and after the use of a UV-C–light emitting device (AUC). We also observed manual terminal disinfection during phase 2. We obtained all cultures in duplicate. The 11 HTSs that were cultured were bed rails, call button, phone, over bed table, patient chair, doorknobs, supply drawer pulls, light switches, faucet, toilet lever, and toilet seat. A single investigator (first author) performed all observations and cultures. The EVSs staff was aware of the presence of the observer, but there was no feedback provided before, during, or after the observation. We did not ensure that we observed a unique person cleaning the room with each observation because we did not provide feedback, but most encounters were with different staff members. We took precautions to ensure that no contamination was introduced before sampling had occurred by obtaining all samples as soon as the disinfectant was dry after manual disinfection and within 5 minutes after UV-C disinfection.

Automated UV-C–emitting device

We used the Intelligent Automated Syndicate UV-C system with Steritrak Web Based Reporting (The Syndicate, Skytron, LLC, Grand Rapids, MI), which emits light at the wavelength of 254 nm. It uses multipoint real-time UV dose monitoring with 12 sensors on each device. We programmed it to deliver 22,000 $\mu Ws/cm^2$ with each treatment. Average treatment time was 15 minutes per patient room. The hospital used 6 UV-C–emitting devices (3 sets of devices with 2 devices in each set) throughout the study period. The protocol involved using 1 set in a room, with strategic placement of the 2 devices by EVSs staff in the room and the bathroom. Their goal was to expose most surfaces to the light during the treatment period. The protocol also involved leaving the drawers and cabinets open before using the device.[23]

Microbiologic culture methods

We swabbed HTSs aseptically with E-swabs (Copan Diagnostics Inc., Murrieta, CA) using previously described methods,[24] using a consistent surface area (8×12 cm). This was the surface area of the smallest HTS in our study. We also used negative and positive controls with every sampling. We transferred the inoculated swabs to tryptic soy agar, incubated the agar at 37°C for 3 days, and determined the number of colony forming units (CFUs) on each plate. Plates with CFUs that were too numerous to count were represented as 250 CFUs. All positive and negative controls performed as expected. We took samples from different rooms on various floors, on random days of the week, on random times of day, with cleaning performed by a variety of environmental staff to ensure random sampling.

Statistical methods

We compared the mean CFU counts obtained from each room at each location BD, AD, and AUV decontamination. We performed the statistical analysis of significance of these comparisons using a zero-inflated Poisson regression. Although parametric *t* tests or nonparametric Wilcoxon-Mann-Whitney tests are widely used by researchers to compare the average values of a numerical outcome between groups, these tests may lose power to detect true significant differences in means or even be invalid when discrete counts are analyzed.[25,26] As an alternative, we used a zero-inflated Poisson regression to compare the differences between contamination levels in different groups (BD, AD, and AUV). In contrast with *t* tests or Wilcoxon-Mann-Whitney tests, zero-inflated Poisson regression assumes the data are discrete counts and allows for zero inflation in the data.[25] CFU counts after manual and UV disinfection were zero on some HTSs, as one would expect after cleaning.

Because we performed 12 comparisons (for each HTS and an overall comparison), instead of using a traditional significance threshold of .05, we used the Bonferroni-corrected threshold of $\alpha = .05/12 = .004166667$. This conservative statistical significance threshold will adjust for multiple comparisons and reduce the probability of detecting an insignificant difference between groups as significant by chance. In addition, we estimated the proportions of measurements with CFU counts <5 CFUs for each HTS and for the overall counts. We chose the threshold of 5 CFU as a marker of thoroughness based on published literature.[24,27,28] We performed 2-sample proportion tests to identify significance of the observed differences in proportions.

RESULTS

We sampled 594 high-touch environmental surfaces from 22 patient rooms during the study period. In phase 1 (unobserved terminal disinfection), mean CFUs decreased from 10.98 (95% confidence interval [CI], 3.57-18.39) in the AD group to 1.07 (95% CI, –0.88 to 3.02) in the AUV group. In phase 2 (observed terminal disinfection), mean CFUs decreased from 28.91 (95% CI, 18.26-39.55) in the BD group to 1.62 (95% CI, 0.52-2.72) in the AD group. It further decreased to 0.51 (95% CI, 0-0.15) in the AUV group (Table 1). The total number of CFUs detected on culture plates from all sampled environmental sites during the study decreased from 1,509 in the AD group to 137 after use of the UV-C device (1.04 $\log_{10}$ reduction) ($P = .00$).

Relative risk of contamination is significantly lower in the AUV group compared with the AD group for most of the HTSs (Table 1).