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Randomized double-blind crossover trial of ultraviolet light–sanitized keyboards in a pediatric hospital

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The effectiveness of ultraviolet light disinfection of keyboards was assessed in the intensive care unit and emergency department of a pediatric hospital. Ultraviolet light disinfection was 67% effective (95% confidence interval, 46%-87%) in eliminating bacterial contamination as measured by quantitative bacterial culture.

Key Words: Health care–associated infection.

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Keyboards are potential reservoirs for bacteria in clinical settings.[1-5] Bacteria can persist for up to weeks on surfaces[6] and potentially can be transferred from surfaces to the bare or gloved hands of health care workers.[1,7,8] Although disinfectant wipes have proven effective in decreasing keyboard contamination in controlled settings,[9] this method requires consistent and thorough cleaning by health care staff, which is difficult to achieve in a busy hospital environment. To address this issue, we evaluated the effectiveness of ultraviolet (UV) light disinfection of keyboards in a clinical setting.

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METHODS

This study was a randomized, double-blind, crossover trial comparing keyboards with UV light irradiation with identical control keyboards not exposed to UV light irradiation. The study design was approved by the Seattle Children's Hospital's Institutional Review Board. The test keyboard was a UVKB50 Self-Sanitizing Keyboard (Vioguard LLC, Kirkland, WA). In this device, a motorized drawer retracts the keyboard after each use into a case, where it is exposed to two 25-W germicidal fluorescent lamps (253.7 nm output), which deliver a total dose of 120 mWs/cm^2. The keyboard retracts and cycles automatically after 10 minutes of inactivity or can be manually cycled by the user. During UV light exposure, the keyboard is contained within a light-tight enclosure with safety interlock switches that interrupt UV light emission if the enclosure door is opened. Each device has an indicator light, with green indicating that the keyboard has been disinfected and yellow indicating that the keyboard has been used since the last UV light cycle. The control keyboards had an identical appearance and operation to the intervention keyboards, but were not irradiated with UV light after being retracted into the case.

Test keyboards were installed at clinical workstations at 12 locations in the intensive care unit and at 12 locations in the emergency department (24 total) at Seattle Children's Hospital. At each location, a UV light keyboard and an inactive control were installed sequentially for 8 days each, with the order determined by coin flip. Keyboards were labeled as matched case–control pairs, and all users and study staff were blinded to the status of each keyboard during placement on the units and data collection. Based on pilot testing of new keyboards, an 8-day testing window was chosen to allow sufficient time for contamination to accumulate on the keyboards. Keyboards were thoroughly cleaned with quaternary ammonium-containing wipes for a minimum of 5 seconds before the beginning of each 8-day testing phase, and thrice-daily cleaning with quaternary ammonium-containing wipes was maintained in accordance with standard hospital cleaning protocol. The efficacy of cleaning between test phases was monitored to ensure that no previous contamination affected the results of subsequent phases.

Quantitative bacterial cultures targeting potential pathogens (including *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Acinetobacter* spp) and organisms associated with human flora (including *Enterobacteriaceae*) were performed. Existing keyboards were swabbed before being replaced by study keyboards, and study keyboards were swabbed on days 0 and 8 of each testing period. Study keyboards found in the open position were not run through a new disinfection cycle before sampling, to closely approximate the bacteria levels encountered by a clinical user. Specimens were collected with sterile cotton swabs moistened with 100 μL of sterile normal saline solution. The mouse pad, mouse buttons, and the "F," "M," "Enter," and "Space" keys of a single keyboard were sampled with a single swab.

After sampling, swabs were placed in a sterile collection tube to which 1 mL of saline was added. After vortexing, 0.1 mL of the sample was added to each of the following agar plates (Remel, Lenexa, KS): sheep's blood agar, MacConkey's agar, Spectra MRSA chromogenic agar, and bile esculin azide agar. An additional sheep's blood agar plate was inoculated with 0.05 mL for confirmation of quantitation and organism identification. Plates were incubated at 35°C overnight. Bacterial contamination of keyboards was defined as total detection of ≥10 colony-forming units (cfu) of any organism.

Observations were matched by hospital location (one control period and one case period each). Differences between the UV light–treated and control keyboards were assessed using McNemar's test and the paired *t* test with Stata version 11.0 (StataCorp, College Station, TX). A secondary analysis was conducted to exclude any pairs with days lost for servicing.

RESULTS

Primary analysis

At the end of the 8-day test period, bacterial contamination was detected on 8 of the 24 active UV light–treated keyboards (33%) and on all 24 of the control keyboards (P = .001, McNemar's test) (Table 1). The estimated effectiveness of the UV light treatment was 67% (95% confidence interval [CI], 46%-87%). No significant difference in effectiveness between the intensive care unit and the emergency department was identified. The average bacterial count on test day 8 was higher on the control units than on the active units (20-860 cfu vs 0-160 cfu; P = .003) (Table 1 and Fig 1). Contamination consisted primarily of gram-positive human flora (eg, coagulase-negative staphylococci, not identified at the species level) and gram-negative environmental flora (eg, gram-negative nonfermenters other than *P aeruginosa* or *Acinetobacter* spp); however, *S aureus* and *P aeruginosa* were isolated from 2 control keyboards from different locations.

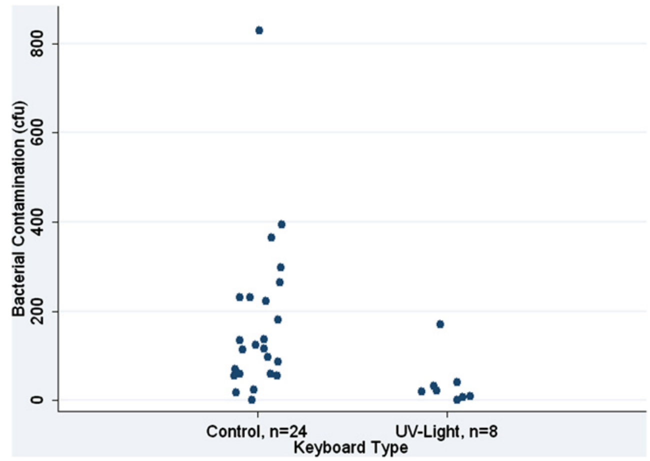

Fig 1. Quantity of bacteria (in cfu) detected on UV light–treated and control keyboards.

Among the 8 active UV light–treated keyboards with bacteria isolated, 5 were found closed and had been subjected to a disinfection cycle before sampling. The other 3 keyboards were open (ie, the keyboard drawer was extended out from the disinfection unit), one with a green "disinfected" indicator light and two with a yellow "disinfection needed" light. Maximum bacteria levels were 160 cfu on the closed units, 10 cfu on the open unit with the green indicator light, and 60 cfu on the open units with the yellow indicator light.

Secondary analysis

During the study period, 9 keyboard units were removed for servicing on a total of 10 occasions for up to 1 day each. A secondary analysis was performed, restricted to only those 15 locations with an uninterrupted 8-day test period in both study arms. After 8 days of use, bacteria were detected on 5 of the 15 UV light–treated keyboards (33%) and on all 15 of the control keyboards (P = .006, McNemar's test). The overall effectiveness of decontamination in the secondary analysis was 67%

Table 1. Bacteria isolation and quantitation for study keyboards

	Existing keyboards, n = 24*	UV light–treated keyboards, n = 24	Control keyboards, n = 24
Units with bacteria isolated, n (%)	23 (96)	8 (33)	24 (100)†
Bacterial load, cfu, mean ± SD	153 ± 369	14 ± 34	171 ± 182†
Specific pathogens			
Units with bacteria isolated, n (%)			
S aureus	1 (4)	0 (0)	2 (8)
P aeruginosa	0 (0)	0 (0)	1 (4)
Bacterial load, cfu			
S aureus	30 (n = 1)	-	20, 220 (n = 2)
P aeruginosa	-	-	110 (n = 1)

*Results for existing keyboards removed before the randomized trial.
†$P < .01$ for comparison between UV light–treated and control keyboards.

(95% CI, 40%-94%). The mean bacterial count was 56 cfu on the UV light–treated keyboards and 181 cfu on the control keyboards ($P = .009$, paired t test).

DISCUSSION

Our results demonstrate that UV light can effectively reduce bacterial contamination on keyboards in a clinical setting. Two-thirds of the keyboards subjected to active UV light decontamination had no detectable bacteria after 8 days of use in a clinical setting.

The consistent contamination found on the control keyboards reflects the difficulty of maintaining regular and thorough keyboard cleaning by hospital staff, particularly at busy workstations with multiple users. The passive nature of the automated cleaning, occurring as often as every use, likely contributed to the effectiveness observed in this study. Although UV light treatment was effective overall, bacteria was detected immediately after disinfection on 5 units. We suspect that this might be due to interference with the UV light by dirt or proteinaceous matter on the keyboard, underscoring the importance of regular physical cleaning even when antiseptic technology is in use.

The present study is limited by our small sample size obtained from a single pediatric institution. Further studies are needed to define the direct clinical impact or cost-effectiveness of this intervention. However, our conclusions are strengthened by the use of identical control keyboards, and our crossover design matched by each specific computer controlled for any differences in usage that might have accounted for the reduced contamination on the test keyboards. Furthermore, deployment and sampling of the keyboards in an active clinical unit enabled accurate assessment of the true effectiveness of the technology in its intended environment. Overall, passive UV light disinfection effectively reduced bacterial contamination on keyboards without the compliance challenges and limitations inherent in routine manual cleaning.

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