Journal of Hospital Infection 105 (2020) 200–204

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

The effectiveness of germicidal wipes and ultraviolet irradiation in reducing bacterial loads on electronic tablet devices used to obtain patient information in orthopaedic clinics: evaluation of tablet cleaning methods

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A R T I C L E I N F O

Article history:
Received 29 February 2020
Accepted 7 April 2020
Available online 11 April 2020

Keywords:
Tablet
Bacteria
Orthopaedics
Ultraviolet radiation
Infection control
Disinfection

S U M M A R Y

Background: Electronic tablet devices are commonly used in outpatient clinics to obtain patient information for both clinical and research purposes. These devices are often colonized with bacteria; there are many cleaning methods to reduce this bacterial load.
Aim: The primary purpose of this study was to evaluate whether regular cleaning with either germicidal wipes or ultraviolet (UV) irradiation leads to lower bacterial levels compared with irregular cleaning.
Methods: A randomized blinded trial was conducted of tablet cleaning strategies between each patient encounter in orthopaedic clinics. The cleaning method was randomized to either germicidal wipes, UV irradiation, or cleaning only when the tablet was visibly soiled. Research assistants (blinded to the treatment) obtained bacterial cultures from the tablets at the beginning and end of each clinic day.
Findings: Using germicidal wipes between each patient encounter vs no routine cleaning resulted in a marked decrease in the amount of bacterial contamination (risk ratio (RR) = 0.17 (0.04–0.67)). Similarly, using UV irradiation between each patient encounter led to significantly lower bacterial contamination rates (RR = 0.29 (95% confidence interval (CI) = 0.09–0.95)) compared with no routine cleaning. The majority of bacteria identified were normal skin flora. No meticillin-resistant *Staphylococcus aureus* was identified and only sparse colonies of meticillin-sensitive *S. aureus*.
Conclusion: Electronic tablets used in orthopaedic trauma clinics are colonized with bacteria if no routine cleaning is performed. Routine use of either UV irradiation or germicidal wipes

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https://doi.org/10.1016/j.jhin.2020.04.014

significantly decreases this bacterial burden. Providers should implement routine cleaning of tablets between each patient encounter to minimize exposure to potential pathogens.

Introduction

Tablets and other electronic devices are increasingly used in the hospital and outpatient settings to facilitate patient care and to collect patient-reported data both for clinical purposes and research [1]. Multiple studies have shown the contamination of various apparel and devices in the hospital setting. According to a 2015 systematic review of 115 papers, surfaces such as stethoscopes, mobile phones, pagers, computers, white coats, ties, and other items were commonly contaminated with bacterial pathogens [2], while other studies have shown both fungal and viral contamination [3–5]. Several disinfection/cleaning methods have been suggested to combat this problem, including different brands of germicidal wipes, each with different levels of harshness and efficacy against certain pathogens [6,7].

The use of germicidal wipes to clean electronic tablet devices is discouraged by some manufacturers. For example, the online user manual for Apple iPad devices recommends that a 'soft, lint-free cloth' should be used to clean the device, while harsh cleaning products (as well as allowing moisture into any openings on the iPad) should be avoided [8]. A study by Albrecht *et al.* has shown that cleaning in the way Apple recommends does not effectively reduce bacterial levels [9]. Despite the recommendation against using germicidal wipes, it has been our experience that germicidal wipes can be used without significantly degrading the screen or usability of our tablet devices. One alternative to using germicidal wipes is the use of ultraviolet (UV) irradiation. UV irradiation has been used extensively in the healthcare setting to reduce the bacterial, fungal, and viral loads in patient rooms, the operating room, and on electronic devices such as cell phones [10–14] via the inactivation of microbes at the molecular level [15].

Beyond the need to reduce bacterial contamination, the routine cleaning of tablet devices also has implications for clinic flow. Many common disinfecting wipes require that they be applied to the device which is then allowed to dry for 2–4 min in order to effectively remove pathogens [16,17]. Conversely, the use of UV irradiation requires specialized equipment and only one device can be sanitized at a time. It has been our experience that rigorous cleaning protocols are difficult to maintain during a busy clinic setting. Medical assistants have a significant workload related to rooming patients, obtaining vital signs, helping with intake paperwork, cleaning rooms, removing sutures, and other clinical work. We observed that routine cleaning of tablet devices in our clinics was not always performed, despite hospital policies requiring routine cleaning between patients.

To our knowledge, there are no studies directly evaluating the presence of bacteria on tablet devices used in outpatient clinics to gather patient-related information, for either clinical or research purposes. The primary goal of this study was to evaluate the effectiveness of rigorous cleaning with either germicidal wipes or UV radiation compared with no routine cleaning. Further, we wished to evaluate the levels of bacteria present on tablet devices used to collect patient reported data, and to evaluate whether there was a difference in the reduction of bacteria seen when comparing germicidal wipes with UV irradiation. Finally, we wished to evaluate which cleaning method was associated with the largest reduction in meticillin-sensitive *Staphylococcus aureus* (MSSA) and meticillin-resistant *S. aureus* (MRSA).

Methods

We performed a randomized blinded study comparing three cleaning strategies. For each clinic day, the cleaning method was randomized to either routine cleaning with germicidal wipes between each patient encounter, UV irradiation between each patient encounter, or no routine cleaning. This study was conducted in the outpatient orthopaedic trauma clinic at a large urban hospital and did not require review from an institutional review board.

The clinics of two different attending physicians were utilized. The type of treatment day was randomized across 12 total days. Block randomization was used to ensure that each attending surgeon had the same number of days of each cleaning strategy. This method ensured that each physician had two clinic days with routine cleaning, two clinic days with germicidal wipe use, and two clinic days with UV irradiation use. This specific type of randomization was used to try to avoid any potential confounding based on clinical volume or practice pattern differences between providers. The average number of patients seen per day over the course of the study was 41. The tablets utilized for all clinics were iPad Air devices (Apple, CA, USA) protected with Otterbox Defender cases (Otterbox, CO, USA) and had a surface area of 27 $\times$ 19 $\times$ 1.5 cm.

General study procedures are outlined as follows. At the start of each clinic day a research assistant sampled each tablet that was to be used for the day. The entire surface area of the tablet was swabbed. Samples were collected using Becton Dickinson Liquid Amies Elution Swabs, and sampling was performed on sterile drapes using sterile gloves. Details of the microbiological analysis can be found in the Supplementary Data. This research assistant then left the clinic area and a second research assistant arrived to randomize the cleaning strategy for the day. Per usual clinic flow, the medical assistant roomed patients and provided one of three tablet devices to enter patient-reported outcome measurements (PROMs) prior to their clinical encounter. Following the clinical encounter, the tablets were then collected and cleaned (or not) based on the strategy assigned for the day. The second research assistant was present throughout the day to ensure that the randomized cleaning protocol was followed. At the conclusion of clinic, the cleaning supplies or irradiation device was stored away, and the first research assistant returned to the clinic area. Each of the three tablets were then sampled in the same manner as the morning measurement. This first research assistant remained blinded to the treatment strategy for the day.

The detailed procedures for specific randomized treatments are outlined as follows. On days randomized to germicidal

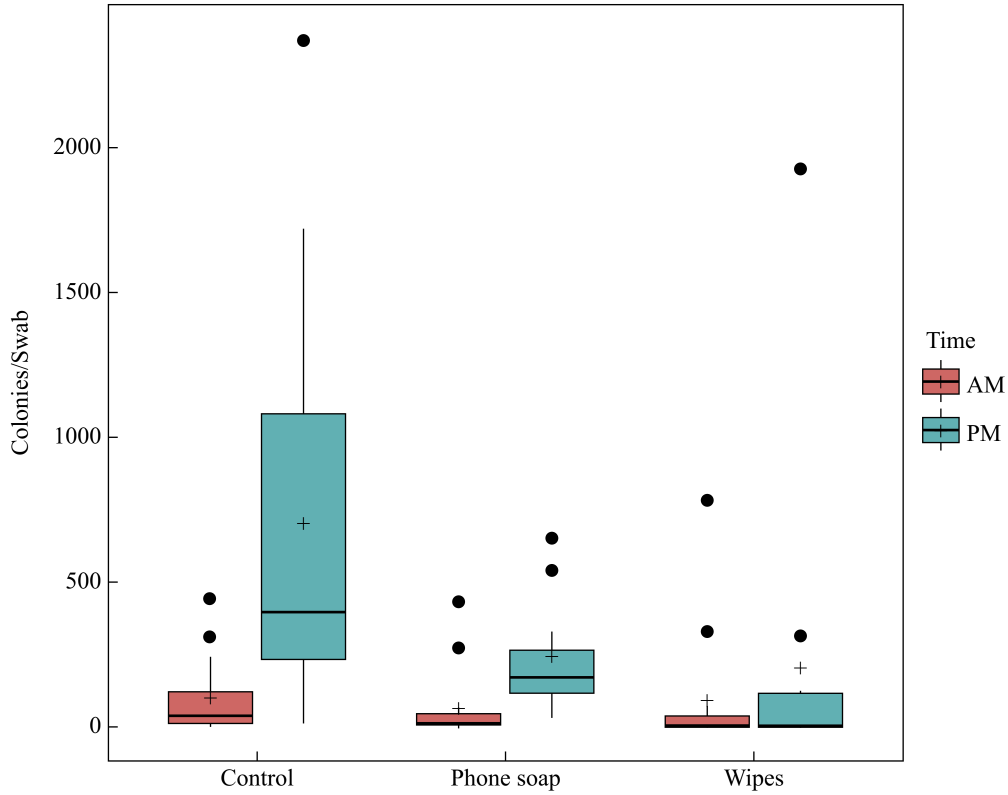

Figure 1. Comparison of treatment groups and sample times. Box plots of overall colonies per swab by treatment group and timing are shown. Means are designated with a '+' symbol.

wipes, the tablet devices were first cleaned following the morning bacterial sampling and then again after every patient encounter. After each patient use, quaternary ammonium and isopropyl alcohol germicidal wipes (Super Sani Cloth Germicidal Disposable Wipe, PDI Healthcare, 55% isopropyl alcohol, 0.5% quaternary ammonium chlorides) were used across all surfaces of the tablet, which was then allowed to dry fully as per the manufacturer recommendations [17]. On days randomized to UV irradiation, the tablet was irradiated following the morning bacterial sampling and again following each patient encounter. A UV irradiation device designed for the medical setting was used (PhoneSoap, Lindon, UT, USA). Each exposure was over the course of 30 s in a contained box designed to fit a large tablet (external dimensions about 40 cm long $\times$ 30 cm high $\times$ 12 cm wide) and involved a peak UV-C irradiance of 3275 $\mu W/cm^2$ from a mercury bulb source. On days randomized to no routine cleaning, the tablet device was only cleaned by the medical assistant if it was visibly soiled.

A power analysis was performed to determine sample size. Quaternary ammonium and isopropyl alcohol germicidal wipes and the UV irradiation device used both have a reported pathogen reduction rate of over 99% when used under ideal conditions. To increase sample size and account for imperfect product use, we aimed to demonstrate a bacterial reduction of 50%. Sample sizes of 11 bacterial cultures in each treatment group were thus required to achieve 80% power with a type I error of 0.05. Power analysis was based on the least likely to be found organism, and thus calculated assuming a 1.745 ± 0.695 log cfu *S. aureus*/MRSA count, ascertained from pilot data on bacterial levels on hospital iPads [18].

After study completion, the mean, median, and spread of bacterial count per swab by study group and time (baseline or end of day) were reported using boxplots. SAS 9.4 (SAS Institute, Cary, NC, USA) and R (Version 3.6.2) were used for statistical analysis. Of primary interest were the pairwise comparisons of the control group and two treatment groups with respect to bacterial levels at the end of the day. Given that the bacterial counts were right skewed, negative binomial regression with a log link was used. Poisson regression was not used due to the presence of overdispersion. The model included a linear effect for morning bacteria count (assumed independent of study group by design), two dummy variables for the three study groups, two dummy variables adjusting for the three iPads, and end-of-day bacterial count as the response. Adjustment for iPad was used to account for potential correlation within iPads; fixed effects were used in lieu of random effects due to the small number of iPads. Individual observations were assessed using Cook's Distance and the deviance residuals were assessed for fit. All testing was two-tailed and *P*-values less than 0.05 were considered statistically significant.

Results

Both the use of germicidal wipes and UV irradiation were associated with a statistically significant reduction in overall bacterial load at the end of the clinic day compared with no routine cleaning (Figure 1 and Supplementary Data). The mean number of colony counts following days of cleaning with germicidal wipes was 215, compared with 233 on days utilizing UV

Table I
Statistical results: comparisons of cleaning method effectiveness in bacterial reduction

Comparison	Rate ratio	95% Confidence interval	*P*
UV radiation vs control	0.29	0.09–0.95	0.04
Germicidal wipes vs control	0.17	0.04–0.67	0.01
Germicidal wipes versus UV radiation	0.60	0.16–2.18	0.44

Rate ratios (numerator of the ratio is the first treatment listed in each row) were calculated for treatment comparison ($N = 36$). Regression coefficients representing the pairwise comparison between study groups for end-of-day bacterial counts after adjusting for baseline bacterial counts are presented as rate ratios along with 95% confidence intervals. UV, ultraviolet.

Table II
Statistical results – comparisons of cleaning method effectiveness in bacterial reduction (modified)

Comparison	Rate ratio	95% Confidence interval	*P*
UV radiation vs control	0.31	0.10–0.90	0.03
Germicidal wipes vs control	0.07	0.02–0.22	<0.0001
Germicidal wipes vs radiation	0.22	0.07–0.71	0.01

Rate ratios by treatment comparison excluding one high-influence observation from the germicidal wipe group were calculated ($N = 35$). UV, ultraviolet.

irradiation and 713 on days with no routine cleaning. The routine use of germicidal wipes compared with no routine cleaning was associated with a rate ratio of 0.17 (confidence interval (CI) 0.04–0.67, P=0.01) (Table I). The routine use of UV irradiation compared with no routine cleaning was associated with a rate ratio of 0.29 (CI 0.09–0.95, P=0.04) (Table I).

During the primary analysis there was no statistically significant difference comparing germicidal wipes to UV irradiation, which had a rate ratio of 0.60 (CI 0.16–2.18, P=0.44). However, as indicated by Cook's Distance, one observation (1920 colonies/swab in germicidal wipes) had a substantial influence on the model, and thus a second analysis was performed excluding this observation. In this new model, both germicidal wipes and UV irradiation still remained effective compared with no routine cleaning (Table II). However, a significant reduction in bacterial contamination was now seen when comparing germicidal wipes with UV irradiation, with a rate ratio of 0.22 (CI 0.07–0.71, P=0.01) (Table II).

Both analyses showed that without routine cleaning, there were substantial numbers of bacteria present on tablet devices at the end of clinic days (mean colony count of 713, standard deviation ± 742.5). No MRSA was isolated at the end of the clinic day. MSSA was encountered on only four iPads over the course of the trial (out of 36 total iPad samples), with an average of 15 colony counts.

Discussion

The use of tablet devices in outpatient clinics to gather data directly from patients, for both clinical and research purposes, is becoming commonplace [1]. Other studies have shown that electronic devices used in the clinical setting can become easily colonized with bacteria unless they are routinely cleaned after each patient encounter [2]. To our knowledge, this is the first study to evaluate the bacterial contamination of tablet devices in orthopaedic clinics.

We found an extensive burden of bacteria on tablet devices not routinely cleaned between each patient encounter. This presents a higher risk of exposure to those patients who receive tablets by the end of a clinic day. Routine use of germicidal wipes and UV irradiation, conversely, both substantially reduced the bacterial load present on the tablets. Germicidal wipes were associated with a 69.86% decrease in bacteria compared with no routine cleaning, and UV irradiation was associated with a 67.29% decrease in bacteria compared with no routine cleaning. While we were unable to evaluate the transfer of potentially pathologic organisms from patient to patient, it is clear that routine cleaning of tablet devices between each patient encounter considerably reduces the exposure to potentially harmful bacteria – similar to the routine use of hand hygiene.

In our primary analysis we found no difference in the effectiveness of germicidal wipes compared with UV irradiation. However, careful evaluation of the data revealed that there was a single outlier in the germicidal wipe group that had a significant impact on the statistical analysis. When this outlier event was ignored, there did appear to be a significant difference. Our *pre hoc* power analysis did not consider making this comparison; the difference in bacterial reduction rates for wipes compared with UV irradiation is as little as 1000^{th} of a percent, and thus the sample size required to detect this difference would have been unrealistic to implement. Thus, whether the difference shown in our study is a real effect, or even clinically important if it is real, is unknown.

While our study identified a significant burden of skin flora on tablet devices not routinely cleaned between patient encounters, we did not identify a significant amount of either MSSA or MRSA. We found a low level of MSSA contamination, an average of 15 colony counts on only 11% of all samples taken over the course of the trial. No MRSA was found on any tablet device. Other specific bacterial species were not evaluated, but the microbiology team anecdotally noted that beyond the trace amounts of MSSA, the other bacterial colonies appeared consistent with normal skin flora.

This study has a number of limitations. The protocol used represents an ideal scenario with a research assistant ensuring strict adherence to the protocol is followed. However, in actual clinical practice, with less stringent compliance with cleaning protocols, either or both treatments may turn out to be less effective than we have shown in this idealized study. In addition, as mentioned above, while this study was powered to evaluate the effectiveness of either germicidal wipes or UV irradiation in reducing MRSA levels, it was not powered to detect a difference between the two cleaning methods. Despite these limitations, it was clear that UV cleaning was fast and easy for staff to use, taking about 30 s to complete and not requiring drying time as germicidal wipes did. The UV device, however, by nature of its method, did not remove fingerprints and other visual smudging that resulted from normal use. While the device used in this study had a peak irradiance of 3275 $\mu W/cm^2$, a newer model performs at 9600 $\mu W/cm^2$. Other devices on the market, each varying in design and size, can range in peak irradiance levels from 2750 μW/cm^2 at a 12.5 mm distance to 5,500,000 μW/cm^2 at a 1-m distance, and utilize either mercury or pulsed xenon bulbs [12,19,20]. Higher doses of UV radiation are likely to be more effective in reducing the bacterial burden on electronic devices. Further study into the specific advantages and disadvantages of germicidal wipes and UV irradiation, including comparing different devices, is warranted. Future epidemiological studies of potential viral and fungal loads on hospital tablets and mobile devices are also warranted, especially those comparing UV irradiation and germicidal wipes, to address the paucity of research pertaining both to these specific pathogens as well as those taking place in outpatient settings.

As noted in this study, tablet devices used in the clinical setting to gather patient data can easily become contaminated with skin flora, and thus also have the potential to become contaminated with pathologic organisms such as MSSA. Our study demonstrates that the routine use of either germicidal wipes or UV irradiation between each patient encounter substantially and significantly reduces the bacteria present on tablet devices. Based on these findings, we recommend that clinics adopt cleaning policies to ensure that tablet devices are adequately treated prior to any patient encounter.

Acknowledgements

The authors are grateful to the Massachusetts Host-Microbiome Center for their help in processing, growing and quantifying the bacterial samples in this study. The statistical analysis for this work was conducted with support from Harvard Catalyst/The Harvard Clinical and Translational Science Center (National Center for Advancing Translational Sciences, National Institutes of Health Award UL 1TR002541) and financial contributions from Harvard University and its affiliated academic healthcare centres. The content is solely the responsibility of the authors and does not necessarily represent the official views of Harvard Catalyst, Harvard University and its affiliated academic healthcare centers, or the National Institutes of Health.

Conflicts of interest statement

All authors report no conflicts of interests relevant to this article.

Funding sources

The cost of microbiological analysis for this work was supported by PhoneSoap LLC but the study design, execution, and this paper are solely the work of the Principal Investigator and the study team.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2020.04.014.

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