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Major Article

Shining a light on the pathogenicity of health care providers' mobile phones: Use of a novel ultraviolet-C wave disinfection device

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Background: Mobile phones are known to carry pathogenic bacteria and viruses on their surfaces, posing a risk to healthcare providers (HCPs) and hospital infection prevention efforts. We utilize an Ultraviolet-C (UV-C) device to provide an effective method for mobile phone disinfection and survey HCPs about infection risk.
Methods: Environmental swabs were used to culture HCPs' personal mobile phone surfaces. Four cultures were obtained per phone: before and after the UV-C device's 30-second disinfecting cycle, at the beginning and end of a 12-hour shift. Surveys were administered to participants pre- and poststudy.
Results: Total bacterial colony forming units were reduced by 90.5% (P = .006) after one UV-C disinfection cycle, and by 99.9% (P = .004) after 2 cycles. Total pathogenic bacterial colony forming units were decreased by 98.2% (P = .038) after one and >99.99% (P = .037) after 2 disinfection cycles. All survey respondents were willing to use the UV-C device daily to weekly, finding it convenient and beneficial.
Discussion: This novel UV-C disinfecting device is effective in reducing pathogenic bacteria on mobile phones. HCPs would frequently use a phone disinfecting device to reduce infection risk.
Conclusions: In light of the ongoing coronavirus (COVID-19) pandemic, a standardized approach to phone disinfection may be valuable in preventing healthcare-associated infections.

BACKGROUND

As we aspire to reduce the spread of infection in hospital systems, mobile phones are increasingly recognized as fomites and potential contributors to healthcare-associated infections (HAIs). Previous studies have shown the presence of multiple bacteria associated with HAIs on healthcare providers' (HCPs) mobile phones.[1-4] Ten percent of phones have also been shown to carry viral pathogens such as influenza and respiratory syncytial virus.[5] More importantly, the pathogens found on mobile phones are similar to those found on hands.[3] Therefore, the cleanliness of mobile phones may be an important contributor to hand hygiene and the prevention of HAIs. In previous studies only 13%-37% of HCPs claim to clean their phones regularly.[2,5] Germicidal wipes for handheld devices are currently available but are inconsistently used, can damage electronic screen, and are not renewable. Although studies have recognized the colonization of pathogens on mobile phones and the need for disinfection, they do not offer a more efficacious solution.[1-4,6]

Our study presents a novel and safe method of ultraviolet-c light (UV-C) mobile phone disinfection. UV-C is already commonly used and has demonstrated efficacy in the hospital setting for disinfecting of patient rooms, pharmacy cleanrooms, and operating rooms.[7-9] UV-C light technology kills or inactivates methicillin-resistant *Staphylococcus aureus* (MRSA), *Clostridioides difficile* (*C. diff*) spores, and norovirus at the same effectiveness as hydrogen peroxide wipes.[10,11] Marra et al also showed a statistically significant reduction of *C. diff* and vancomycin-resistant *Enterococcus* (VRE) infection rates with UV light technology.[12] When used on keyboards and computer mice, UV-C light led to a >99% reduction in bacteria, including those responsible for HAIs.[13] By implementing a UV-C mobile phone cleaning device in a hospital unit, we attempted to decrease the burden of overall bacteria and pathogens identified on HCPs' mobile phones.

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We aim to decrease the risk of HAIs presented by mobile phones in a safe and effective manner without using valuable resources such as germicidal wipes or cleaning solutions. We hypothesize that this UV-C technology can be effective when used for mobile phones.

METHODS

We performed a prospective investigational study evaluating the use of a novel disinfection protocol for personal mobile communication devices in a healthcare setting. This study was reviewed and approved by the Children's Hospital Los Angeles institutional review board.

We utilized a new UV-C device (PhoneSoap Med + Version 1, Provo, UT),[14] to provide a more effective and convenient tool for the disinfection of mobile phones. The device is a hands-free box with 16 UV-C bulbs that encase the phone and uses a 30-second cleaning cycle. Step-by-step instructions are displayed on the box (Supplemental Fig 1).[15]

We evaluated both pediatric residents and nurses working a 12-hour shift on a pediatric medical/surgical unit. Exclusion criteria included nonclinical staff, attending physicians, and physician subspecialists as their shift times were less regulated. Environmental swabs were used to obtain bacterial cultures of the HCPs' personal mobile phone surfaces. The mobile phones were labeled by number to ensure anonymity from the HCPs. Swabs were obtained at 4 time points. Two swabs were collected per phone prior to a nursing or resident shift: before (premorning disinfection) and after (postmorning disinfection) the 30-second disinfection cycle. After being handled throughout a 12-hour shift by HCPs during the course of patient care, the mobile phones were again swabbed twice: before (prenight disinfection) and after (postnight disinfection) using the UV-C device.

Prior to obtaining swabs and placing each cell phone in the UV-C device for disinfection, study coordinators disinfected their hands with alcohol-based hand sanitizer and donned gloves. The entirety of the front screen of the mobile phone was swabbed at each time point. Cultures were immediately labelled with the date and the pre-/post-disinfection cycle timing of the swab and were transported to a reference environmental microbiology laboratory. The mean bacterial colony forming units (CFU) count was calculated for each time period when cultures were obtained. Analysis was done for both total bacterial counts and pathogenic bacterial counts. No susceptibility testing was done to differentiate MRSA or other resistant organisms.

For statistical analysis, total bacterial count and pathogenic bacterial count were analyzed separately. The designation of a bacteria as "pathogenic" was agreed upon by 2 infectious disease experts (MAS, JMB). Comparisons were made based on 2 complete data points. For assessment of statistical reductions or increases in bacterial load, SPSS statistical analysis software (version 26) was utilized to run paired t-test analyses. A 2-sided P value of .05 is considered statistically significant.

In addition, paper questionnaires were administered at the beginning and end of the study day to elucidate attitudes towards mobile phone contamination and effectiveness of the novel UV-C device. A pre-study survey assessed HCPs' perception of the risk of contaminated cell phones, current cleaning practices, and knowledge of UV-C light as a disinfecting mechanism. A poststudy survey was also administered to determine the HCPs' assessment of using the UV-C device and its ease and effectiveness for future use. SPSS statistical analysis software (version 26) was utilized to run frequency tables for the survey. Participants were verbally consented to participate, given the surveys, and handed an information sheet regarding the study. In compliance with IRB guidelines no names or signatures were collected.

RESULTS

We enrolled 21 nurses and 9 pediatric residents actively engaged in patient care on a contained pediatric medical/surgical unit. Thirty mobile phones were tested with a total of 4 bacterial cultures each. One participant did not return for the second postshift test, preventing the last 2 cultures of the protocol from being collected. This participant was still included to calculate the effectiveness of 1 disinfection cycle in the morning. This resulted in a total of 118 cultures collected during the study day.

Decrease in total bacterial counts after UV-C disinfection

Prior to the shift (morning), after one 30-second disinfection cycle, there was a 90.5% (P = .006) reduction in the total bacterial CFU isolated from the mobile phones (Fig 1A). The mean pre- and postdisinfection CFU for total bacteria were 245,893 (standard deviation [SD] 437,155) and 23,364 (SD 111,899), respectively. After the 12-hour shift (night), cultures were again obtained and the mean pre- and postdisinfection CFU were 838 (SD 1,712) and 277 (SD 1,158), respectively for a 67% reduction (P = .160). Over the entire 24-hour shift with 2 cycles of disinfection the total bacterial load decreased by 99.9% (P = .004). High

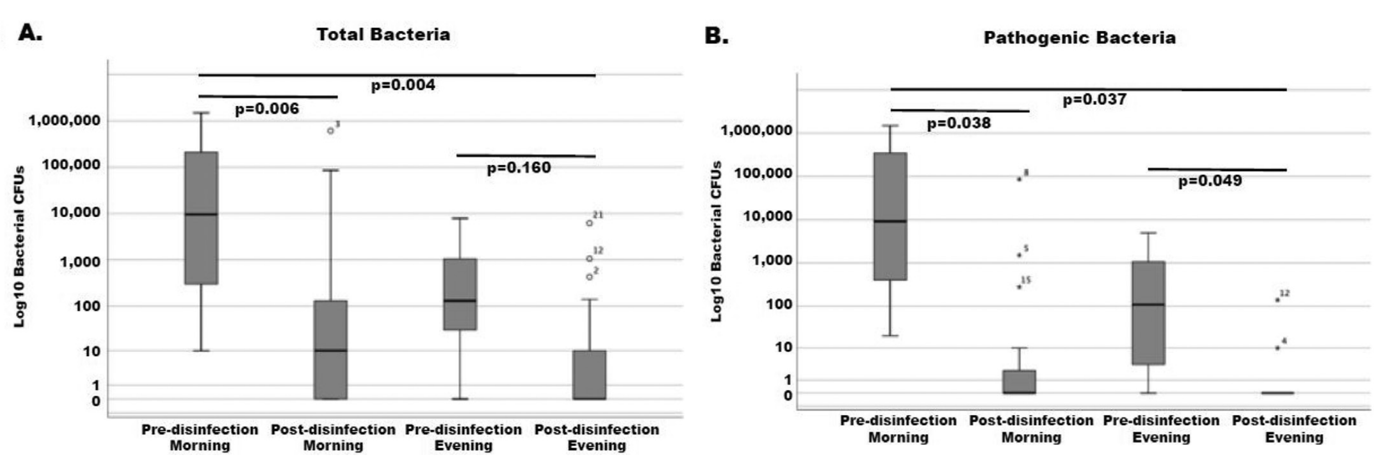

Fig 1. (A) Reduction in total bacterial CFU. Box and whiskers plot depiction of *total* bacterial CFU at 4 culture time points (before shift morning pre- and postdisinfecting and after shift night pre- and postdisinfecting) displayed in logarithmic scale. Thirty second UV-C disinfection cycles were done between both sets of pre- and postlabels. (B) Reduction in Pathogenic Bacterial CFU. Box and whiskers plot depiction of *pathogenic* bacterial CFU at the same 4 culture time points displayed in logarithmic scale. Thirty second UV-C disinfection cycles were done between both sets of pre- and postlabels.

standard deviations and postdisinfection CFU counts were observed secondary to 2 major outliers (Supplemental Fig 2). With removal of the outliers, the morning CFU dropped from 192,028 (SD 400,159) to 176 (SD 391) CFU after one disinfection cycle for a >99.99% decrease in bacterial load after 1 cycle ($P = .017$).

Decrease in pathogenic bacterial counts after UV-C disinfection

At the beginning of the shift, 66% of phones grew pathogenic bacteria. After one 30-second morning disinfection cycle, there was a 98.2% reduction ($P = .038$) in pathogenic bacterial load (Fig 1B). The mean morning pre- and postdisinfection CFU for pathogenic bacteria were 274,341 (SD 497,241) and 5,171 (SD 20,832), respectively. By the end of shift, 84% of the night predisinfection phones grew pathogenic bacteria. Comparing the postshift (night) results, bacterial CFUs pre- and postdisinfection with the UV device demonstrated a 99.9% reduction in pathogenic bacteria from 718.8 CFU (SD 1,320) to 9.38 CFU (SD 35) ($P = .049$). Over the entire 24-hour shift with 2 cycles of disinfection the pathogenic bacterial load decreased by 99.99% ($P = .037$).

Excluding the outliers, there was a 496% increase in bacterial load after a 12-hour shift. Including the outliers, statistically there was a decrease in CFU after the completion of the shift by 96.4% ($P = .143$) from 23,364 CFU to 838 CFU prenight disinfection. This decrease is unlikely to be a true representative of bacterial load present on mobile phones without any interval cleaning considering the continued exposures throughout a HCP's shift. Thus, the data excluding outliers may be more accurate. Given that in the outliers, the same species of bacteria were observed in both the pre- and postdisinfection time points, we did not feel that they could be considered contaminant and fully excluded from our analysis; therefore, we present both sets of data.

We found that 30% of phones had 3 or more different types of bacteria present. The most common species were *Bacillus spp* and *Coryneform bacillus.* The most common pathogenic species were coagulase-negative *Staphylococcus, Acinetobacter, and S. aureus* (Table 1).

Healthcare provider perception

All 29 providers filled out a prestudy survey (Supplemental Table 1) and a poststudy survey (Fig 2). We found 30.1% of respondents cleaned their mobile phones daily, and 37.8% cleaned their phones once a week or even less frequently. Most HCPs (96.4%) were concerned that their mobile device was a significant risk factor in the transmission of bacterial pathogens. We discovered that 75.4% of surveyed HCPs use their mobile phones inside patients' rooms, and 44.8% of HCPs use their device in a patient's room even when the patient is under contact/droplet isolation precautions. Furthermore, 89.7% of HCPs expressed that physicians and nurses should take active measures to disinfect their phone during their shift. Of the respondents, 69% reported prior knowledge of using UV light as a disinfection technique. After using the device, our postsurvey showed that 100% of surveyed HCPs endorsed that the UV-C device was easy to use, that they were interested in using the device, and that the hospital would benefit from mobile phone disinfection.

Table 1
Pathogenic bacteria found on medical staff mobile phones prior to 30 second UV-C disinfection cycles before and after shift

	Predisinfection morning (before shift) N = 29 (%)	Predisinfection night (end of shift) N = 29 (%)
Staphylococcus aureus	3 (10)	3 (10)
Enterococcus faecalis	2 (7)	2 (7)
Pseudomonas spp.	2 (7)	1 (3)
Acinetobacter spp.	4 (14)	2 (7)
Coagulase-negative *Staphylococcus* spp.	12 (41)	18 (62)
Bacillus cereus	0 (0)	2 (7)

DISCUSSION

Ultraviolet light presents a renewable, effective, and easy-to-use disinfection method that has the potential to conserve hospital resources and decrease the healthcare-associated transmission of bacteria and viruses. Our HCPs' mobile phones were found to have a significant bacterial burden with over 250,000 CFU of pathogenic bacteria on average. Our protocol utilizing UV-C disinfection demonstrated high effectiveness with a significant decrease in both total and pathogenic polymicrobial bacterial load. Pathogenic bacteria were found on the majority of phones in high concentrations, which could potentially impact HAI rates such as central line associated

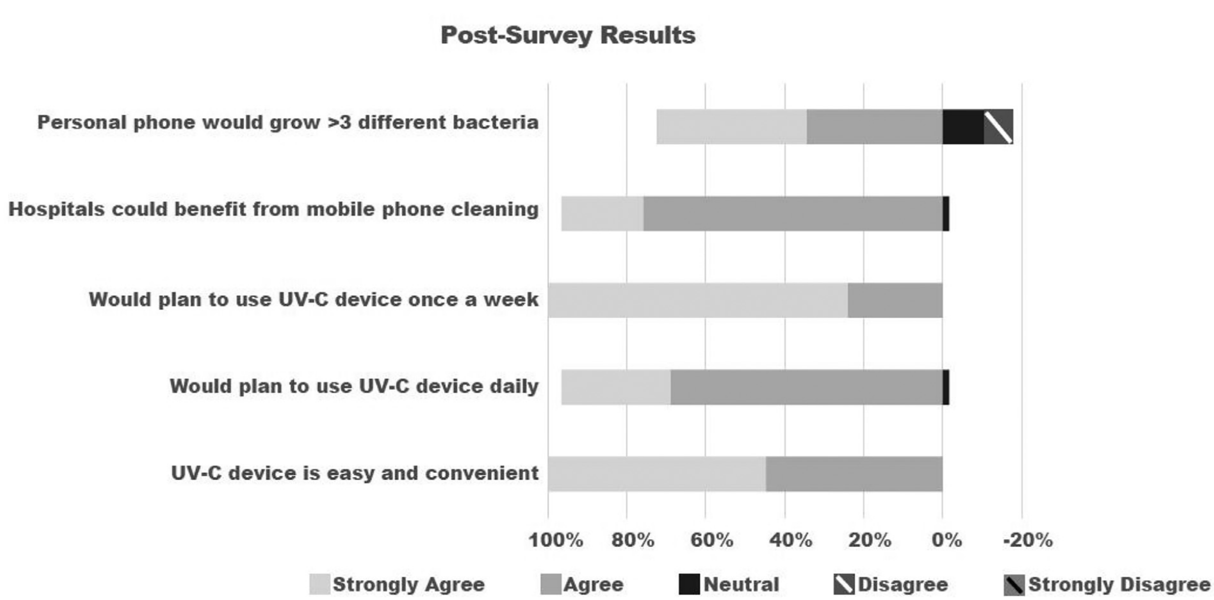

Fig. 2. Poststudy survey results from 29 participants regarding healthcare provider opinions of UV-C device for the disinfection of mobile phones.

bloodstream infections, ventilator associated pneumonias, and wound infections. All of our surveyed HCPs found the device easy and convenient to use and endorsed the need to implement ultraviolet light disinfection for mobile phones in hospitals.

Our study showed the presence of a significant bacterial load on phones with important pathogens. This is consistent with previous studies, which have found that 60%-96% of phones demonstrated evidence of bacterial contamination with 21%-38% growing 3 or more different species.[1,2] Mobile phones present a potential risk for the transmission of HAIs in the operating room and the intensive care unit with the phones demonstrating a high frequency of MRSA and gram negative bacteria.[3,4] Despite the risks posed by mobile phones, it is impractical to limit or ban their use in hospitals. The majority of providers would not support such measures, and previous attempts in United Kingdom hospitals have failed due to the widespread use of mobile phones by providers for key communication.[2,6] Currently, mobile phone wipes are available for cleaning, but they are not proven to be true disinfectants and are a nonrenewable resource and subject to shortages. Therefore, an effective and easy-to-use disinfection method for mobile phones such as UV-C light provides value and potentially helps reduce HAIs.

In our study, UV-C light was effective in nearly eliminating the total and pathogenic bacterial load found on phones. UV light's role in the medical field is rapidly expanding with its main use residing in the nursing home setting and in operating room sterilization.[16] UV light has high efficacy on a wide range of pathogenic bacteria with successful elimination of pathogens such as MRSA, VRE and *C. diff*.[10-12] UV light has been shown to be as effective or potentially more effective compared to accelerated hydrogen peroxide for surfaces and neutral detergent for floors in decontamination after patient use.[17-19]

Furthermore, in light of the need for renewable methods for disinfection with the novel coronavirus disease (COVID-19) pandemic, UV-C light has been shown to be effective in disinfecting viral aerosols, specifically coronavirus.[20] Another study found that UV-C light reduces infectivity of severe acute respiratory syndrome-coronavirus-1 (SARS-CoV-1) in plasma.[21] The use of a UV-C device can present an easy-to-use and effective disinfection method which has the potential to prevent the spread of SARS-CoV-2 via fomites such as mobile phones within a medical/surgical hospital unit. The potential benefits of implementing mobile phone UV-C disinfecting devices which do not consume valuable resources such as germicidal wipes in a pandemic may be far reaching. This may also further mitigate transmission if usage is standardized as providers are leaving the hospital to their families.

Our HCPs reported high rates of using phones during rounds and in patient rooms including combined/droplet isolation rooms which could contribute to the rates of pathogenic bacteria found. The majority of them felt that doctors and nurses should clean their phones upon entering and leaving the hospital. Despite this belief, HCPs identified a clear lack of standard mobile phone disinfection practices with many individuals failing to disinfect their mobile devices weekly. Respondents identified the UV-C device's ease of use and their willingness to use it daily to weekly. This is more frequent than current phone disinfection practices at our institution. Consistent with prior studies, our respondents agree that mobile phones are a high risk for potential infection transmission.[2,5] This was further supported by their responses anticipating multiple different bacterial colonies and even possible resistant bacteria on their phones. We believe that implementing the use of this device in conjunction with ongoing hand hygiene efforts could change practices. This subsequently could have lasting effects on reducing HAIs and potentially protect HCPs and their families.

Limitations to this study include a small sample size; however, our sample size was large enough to power our study to demonstrate significant changes in bacterial loads. Another limitation includes a lack of a direct comparison to a more standard method of mobile device disinfecting—germicidal wipes, which were infrequently used to clean personal mobile phone devices in our institution. This study was also done at a single academic pediatric hospital. Different mobile phone bacterial colonization patterns may be seen at adult hospitals or in different healthcare settings. Finally, this study did not further characterize the bacteria as MRSA or resistant gram-negative organisms, which would shed further light on the potential clinical significance of our results. Studies are underway to show that the decrease in bacterial burden translates to clinically significant reductions in infection rates. Future areas for investigation include assessing the effectiveness of UV-C disinfection devices on SARS-CoV-2 and other potential pandemic pathogens and the utility of widespread implementation of UV-C disinfection devices in a hospital system. We anticipate this is an opportunity to renew discussion of fomite decontaminating techniques and environmental hygiene beyond mobile phones in the clinical setting as UV-C and other novel disinfection methods arise.

CONCLUSIONS

This novel UV-C cleaning device is effective in reducing both total and pathogenic bacteria on mobile phones by over 90%-99%. HCPs would frequently use a phone disinfecting device to reduce infection risk and found it convenient and beneficial. In light of the COVID-19 pandemic, a standardized approach to phone disinfection would be valuable in preventing HAIs and protecting HCPs themselves.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.ajic.2020.05.040.

References

1. Brady RR, Wasson A, Stirling I, McAllister C, Damani NN. Is your phone bugged? The incidence of bacteria known to cause nosocomial infection on healthcare workers' mobile phones. *J Hosp Infect*. 2006;62:123–125.
2. Mark D, Leonard C, Breen H, Graydon R, O'Gorman C, Kirk S. Mobile phones in clinical practice: reducing the risk of bacterial contamination. *Int J Clin Pract*. 2014;68:1060–1064.
3. Ulger F, Esen S, Dilek A, Yanik K, Gunaydin M, Leblebicioglu H. Are we aware how contaminated our mobile phones with nosocomial pathogens? *Ann Clin Microbiol Antimicrob*. 2009;8:7.
4. Ulger F, Dilek A, Esen S, Sunbul M, Leblebicioglu H. Are healthcare workers' mobile phones a potential source of nosocomial infections? Review of the literature. *J Infect Dev Ctries*. 2015;9:1046–1053.
5. Cavari Y, Kaplan O, Zander A, Hazan G, Shemer-Avni Y, Borer A. Healthcare workers mobile phone usage: a potential risk for viral contamination. Surveillance pilot study. *Infect Dis (Lond)*. 2016;48:432–435.
6. Brady RR, Hunt AC, Visvanathan A, et al. Mobile phone technology and hospitalized patients: a cross-sectional surveillance study of bacterial colonization, and patient opinions and behaviours. *Clin Microbiol Infec*. 2011;17:830–835.
7. El Haddad L, Ghantoji SS, Stibich M, et al. Evaluation of a pulsed xenon ultraviolet disinfection system to decrease bacterial contamination in operating rooms. *BMC Infect Dis*. 2017;17:672.
8. Simmons S, Dale C, Holt J, Passey DG, Stibich M. Environmental effectiveness of pulsed-xenon light in the operating room. *Am J Infect Control*. 2018;46:1003–1008.
9. Casini B, Tuvo B, Cristina ML, et al. Evaluation of an ultraviolet C (UVC) light-emitting device for disinfection of high touch surfaces in hospital critical areas. *Int J Environ Res Public Health*. 2019;16:3572.
10. Nerandzic MM, Cadnum JL, Eckart KE, Donskey CJ. Evaluation of a hand-held far-ultraviolet radiation device for decontamination of Clostridium difficile and other healthcare-associated pathogens. *BMC Infect Dis*. 2012;12:120.
11. Wallace RL, Ouellette M, Jean J. Effect of UV-C light or hydrogen peroxide wipes on the inactivation of methicillin-resistant Staphylococcus aureus, clostridium difficile spores and norovirus surrogate. *J Appl Microbiol*. 2019;127:586–597.
12. Marra AR, Schweizer ML, Edmond MB. No-touch disinfection methods to decrease multidrug-resistant organism infections: a systematic review and meta-analysis. *Infect Control Hosp Epidemiol*. 2018;39:20–31.
13. Gostine A, Gostine D, Donohue C, Carlstrom L. Evaluating the effectiveness of ultraviolet-C lamps for reducing keyboard contamination in the intensive care unit: a longitudinal analysis. *Am J Infect Control*. 2016;44:1089–1094.

14. PhoneSoap Med+. *PhoneSoap|Healthcare*. 2018. Published Accessed March 2020. Available at: https://www.pro.phonesoap.com/medplus.
15. MedGadget. *Phonesoap Med cleans smartphones, tablets, stethoscopes with UV*. Available at: https://www.medgadget.com/2018/03/phonesoap-med-cleans-smartphones-tablets-stethoscopes-ultraviolet-light.html. Accessed March 5, 2020.
16. Kovach CR, Taneli Y, Neiman T, Dyer EM, Arzaga AJ, Kelber ST. Evaluation of an ultraviolet room disinfection protocol to decrease nursing home microbial burden, infection and hospitalization rates. *BMC Infect Dis*. 2017;17:186.
17. Rutala WA, Gergen MF, Tande BM, Weber DJ. Rapid hospital room decontamination using ultraviolet (UV) light with a nanostructured UV-reflective wall coating. *Infect Control Hosp Epidemiol*. 2013;34:527–529.
18. Rutala WA, Gergen MF, Tande BM, Weber DJ. Room decontamination using an ultraviolet-C device with short ultraviolet exposure time. *Infect Control Hosp Epidemiol*. 2014;35:1070–1072.
19. Wong T, Woznow T, Petrie M, et al. Postdischarge decontamination of MRSA, VRE, and clostridium difficile isolation rooms using 2 commercially available automated ultraviolet-C-emitting devices. *Am J Infect Control*. 2016;44:416–420.
20. Walker CM, Ko G. Effect of ultraviolet germicidal irradiation on viral aerosols. *Environ Sci Technol*. 2007;41:5460–5465.
21. Eickmann M, Gravemann U, Handke W, et al. Inactivation of three emerging viruses - severe acute respiratory syndrome coronavirus, Crimean-Congo haemorrhagic fever virus and Nipah virus - in platelet concentrates by ultraviolet C light and in plasma by methylene blue plus visible light. *Vox Sang*. 2020;115:146–151.