Comparison of ultraviolet C light and isopropyl alcohol for the disinfection of cellular phones in a paediatric intensive care unit setting

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Background. A considerable proportion of cellular phones (cell phones) used by healthcare workers (HCWs) have been shown to be contaminated with pathogenic micro-organisms, making these devices reservoirs to infect susceptible patients. Although many units have well-defined infection control protocols, methods for the decontamination of cell phones are scarce.
Objectives. To compare the efficacy of ultraviolet C (UVC) light with that of 70% isopropyl alcohol in disinfecting cell phones used by HCWs in a paediatric intensive care unit (ICU).
Methods. A randomised controlled study in a paediatric ICU setting was conducted. Cell phones of HCWs or other personnel entering the ICU were swabbed prior to and after decontamination with either the 70% isopropyl alcohol or UVC light method. The reduction ratio of colony-forming units (CFUs) before and after intervention was analysed using the Mann-Whitney *U*-test. In addition, the effectiveness of the disinfection methods was compared using the Wilcoxon signed-rank paired test.
Results. A total of 74 cell phones were acquired from HCWs working in the paediatric ICU. After excluding 5, 69 samples were therefore available for statistical analysis, with 34 samples subjected to disinfection using 70% isopropyl alcohol-based swabs and 35 samples treated with UVC light disinfection. Disinfection with 70% isopropyl alcohol (z=5.16; p<0.000001) and with UVC light (z=3.28; p<0.005) were individually statistically significantly effective in reducing CFUs. The CFU reduction ratio indicated that disinfection using a 70% isopropyl alcohol solution was 67% more effective than UVC light disinfection (Mann-Whitney *U*-test score 968; p<0.001).
Conclusion. Although both 70% isopropyl alcohol and UVC light disinfection effectively reduced CFUs following decontamination, 70% isopropyl alcohol was determined to be much more effective.

Keywords: cellular phones, UVC, 70% isoprophyl alcohol, infection, disinfection, ICU

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Cellular phones (henceforth, cell phones) have significantly transformed our lives, extending far beyond the realm of communication and producing numerous advantages for society. By the end of 2025, ~7.3 billion people worldwide will own a cell phone.[1] The use of cell phones in hospital settings improves communication and information accessibility, ultimately enhancing the quality of patient care. However, a considerable proportion of cell phones utilised by healthcare workers (HCWs) have been shown to be contaminated with pathogenic micro-organisms, with prevalence rates ranging from 72% to 96.2%.[2,3] This contamination increases susceptibility of patients to healthcare-associated infections (HAIs). HAIs are defined by the World Health Organization (WHO) as infections that occur in a patient while they are receiving care in a healthcare facility that were not present or had not developed at the time of admission.[4] The US Centers for Disease Control and Prevention offers a more exact characterisation of HAI as an infection that develops on the 3rd day or beyond after a person is admitted.[5] HAIs that arise in the intensive care unit (ICU) result in significantly elevated morbidity and mortality.[6]

Although many units have well-defined infection control protocols, methods for the decontamination of cell phones are scarce. Fabrics, paper towels and non-alcohol-based substances lack effectiveness in disinfecting cell phones. The predominant disinfection agent utilised was 70% isopropyl alcohol, which has consistently demonstrated a reduction in bacterial growth of ~90% in numerous trials.[7-12] Researchers have recently documented the use of ultraviolet C (UVC) radiation to decontaminate cell phones.[13] The advantages of UV light-based disinfection have been recognised for a considerable time. Nils Ryberg Finsen was an early pioneer in the use of UV radiation for the treatment of bacterial diseases. In 1903, Finsen was awarded the Nobel Prize in Medicine for the successful use of UV radiation for treatment of skin tuberculosis.[14,15] The UVC wavelength range of 250 - 270 nm is highly absorbed by the nucleic acids of micro-organisms, resulting in bactericidal effects. The UVC absorbed by the nucleic acid leads to the dimerisation of pyrimidine molecules, particularly thiamines. Once the micro-organism undergoes dimerisation, it ceases to multiply and/or remain viable.[16]

The objective of the present study was to compare the efficacy of UVC light with that of 70% isopropyl alcohol in disinfecting cell phones used by ICU HCWs.

Methods

Ethical considerations

Ethics clearance was granted by the Walter Sisulu University Faculty of Health Sciences Research Ethics and Biosafety Committee (ref. no. HREC 108/2020). Approval was also obtained from the Eastern Cape

Department of Health Research Committee (ref. no. EC_202012_002) and Frere Hospital.

Design, setting and population

This study was a randomised controlled trial designed to compare the effectiveness of 70% isopropyl alcohol-based swabs and UVC light for disinfecting cell phones. The study was carried out in the paediatric ICU at Frere Hospital, a tertiary medical facility in East London, South Africa. A sample size of 37 was calculated using the population size, confidence interval (95%), and a 5% margin of error.[17] To verify the internal validity of the study, 74 cell phones were randomly assigned to two groups: 37 phones were to be decontaminated with 70% isopropyl alcohol-based swabs, and 37 phones were placed in the UVC light disinfectant group. The principal investigator was not involved in the randomisation procedure. Each phone was swabbed before and after intervention to determine the spectrum of organisms present on the phone.

Inclusion and exclusion criteria

The study only included the cell phones of HCWs who entered the paediatric ICU during the designated study period of 1 month.

Cell phones belonging to HCWs who declined participation in the study or had entered the ICU in an emergency situation, or whose cell phones had already been swabbed, were excluded from the study. Additionally, cell phones with a white plastic exterior were excluded because of concerns that UVC light could cause discoloration of the cover.[18]

Experiment

Cell phones were obtained from HCWs at the entrance to the ICU before routine hand disinfection, to prevent the disinfectant solution from inadvertently falling onto the phone and distorting the results. The following other measures were also taken to prevent distortion of the results. Between each sampling/specimen collection and decontamination process, the principal researcher's hands were disinfected with the Barrs Steriscrub antiseptic skin solution (chlorhexidine gluconate 4% m/v) (Barrs Pharmaceutical Industries (Pty) Ltd, South Africa) and water. New sterile gloves were also donned between each step. Before sampling, the swab was pre-moistened with sterile 0.9% normal saline to increase pathogen yield. After sampling, all swabs were mixed with 1 mL of saline solution, making it easier to plate and improve the yield.

The HCW randomly picked a non-transparent envelope from a container. A card in the envelope assigned the phone to either the 70% isopropyl alcohol group or the UVC light group.

As a control, all the cell phones were swabbed prior to decontamination. The cotton swab was run rotationally over the ventral surface (front screen) of the phone. The swab was then diluted in 1 mL of saline and sent to the laboratory for processing. Thereafter, the phones were decontaminated using one of the two methods. In the first group, the investigator cleaned all surfaces of the phone and the cover with a sterile 70% isopropyl-alcohol swab (Alpha Clin, South Africa). After 120 seconds to allow the isopropyl alcohol to dry, a pre-moistened cotton swab was again run rotationally over the front screen of the phone. In the second group, the phone was decontaminated using a UVC light device. A second-generation UVC ultraviolet sterilisation box (Shenzhen Lemons Slmm Technology Co. Ltd, China) with a wave band of 253.7 nm was used. The research assistant opened the UVC device, and the researcher placed the phone inside. The assistant then closed the box and switched it on. After 5 minutes, the device was opened carefully, ensuring that the assistant did not touch the phone or the interior of the UVC device. The phone was removed by the investigator and the pre-moistened cotton swab was run rotationally over the front surface.

After sampling, all samples were transferred to the microbiology unit of the East London branch of the National Health Laboratory Service, where 0.25 mL of the solution from each specimen was plated on blood agar, MacConkey agar, and chocolate plates. The agar plates were incubated at 37°C. Following a 48-hour incubation period, the agar plates were examined, and colony-forming units (CFUs) were manually counted. If detected, organisms were further identified in all pre-disinfectant samples. If colonies were Gram-negative bacteria, the organism was identified, and antibiotic resistance for extended-spectrum beta-lactamases (ESBLs) was determined using the API 10 S system (bioMérieux, France). If colonies of Gram-positive organisms were detected, any *Staphylococcus* species was further identified using biochemical techniques, including the Staphaurex Latex Agglutination Test (Remel, UK).

Statistical analysis

The data were recorded on an Excel spreadsheet, version 16.8 (Microsoft, USA), and analysed using the Statistical Package for the Social Sciences, version 27 (IBM, USA). CFU counts were compared on blood agar plates in both the UVC light and 70% isopropyl alcohol groups before and after disinfection.

The Wilcoxon signed-rank paired test was used to evaluate the efficacy of both the decontamination techniques. The CFU reduction ratio was compared using the Mann-Whitney *U*-test, a non-parametric test employed because of the violation of the assumption of normality. The threshold for significance was set at 5%.

The reduction in bacterial growth was calculated for both groups using the following formula:

$$\frac{\text{Total bacterial count prior to decontamination} - \text{total bacterial count after decontamination}}{\text{Total bacterial count (before intervention)}}$$

A statistical comparative effect size using the *U*-value from the Mann-Whitney test was performed between the 70% isopropyl alcohol group and the UVC light group using rank correlation. The total percentage reduction in CFUs for both groups was individually calculated as follows:

$$\frac{\text{Sum of total CFUs prior to decontamination} - \text{sum of total CFUs after decontamination} \times 100}{\text{Sum of total CFUs before decontamination}}$$

Results

A total of 74 cell phones were acquired from a group consisting of 30 medical doctors, 27 professional nurses, 9 allied health personnel (physiotherapists, dieticians, radiographers and pharmacists), 6 auxiliary staff (porters, clerks and cleaning staff), and 2 nursing students. Four samples (3 from the isopropyl alcohol group and 1 from the UVC light group) were removed because no CFUs were detected in the pre-disinfection culture. Furthermore, 1 sample from the UVC light group experienced leakage following disinfection and was eliminated from the comparison. A total of 69 samples were therefore available for statistical analysis, with 34 samples subjected to disinfection using 70% isopropyl alcohol-based swabs and 35 samples treated with UVC light disinfection.

A total of 155 organisms were cultured from swabs in the pre-disinfectant group. The predominant organisms identified were coagulase-negative staphylococci (CNS) (91.9%), *Bacillus* species (41.9%), *Micrococcus* species (32.4%) and *Corynebacterium* species

(23.0%). The complete distribution of pathogens detected on cell phones before disinfection is shown in Fig. 1. The comparison of CFUs before disinfection between the 70% isopropyl alcohol group (μ=24.5) and the UVC light group (μ=24) revealed no significant difference (Mann-Whitney *U*-test score 591; p=0.996). After disinfection, there was a 93.1% reduction in the 70% isopropyl alcohol group (1 610 to 110 CFUs per 0.25 mL). In the UVC light group, there was a total CFU reduction of 58.9% (1 575 to 648 CFUs per 0.25 mL). The post-disinfection analysis conducted using the Wilcoxon signed-rank paired test with a two-tailed approach revealed that both the group treated with 70% isopropyl alcohol (z=5.16; p<0.000001) and the UVC light group (z=3.28; p<0.005) exhibited statistically significant reductions in the growth of organisms. The CFU reduction ratio indicated that disinfection using a 70% isopropyl alcohol solution was 67% more effective than UVC light disinfection (Mann-Whitney *U*-test score 968; p<0.001) (Table 1).

Discussion

The WHO has launched the Clean Care is Safer Care global effort in response to the increasing prevalence of HAIs worldwide.[19] The objective of this campaign is to apply a range of measures to decrease HAIs on a global scale, regardless of the level of development of healthcare systems and the availability of resources. A large focus of this campaign is to advocate for proper hand hygiene. However, hands are not the only source of HAIs. As indispensable as cell phones are in modern medicine, nearly 100% of HCWs' cell phones have shown growth of bacterial pathogens.[20]

With the above in mind, we conducted the first randomised controlled study to compare the efficacy of 70% isopropyl alcohol and UVC light in disinfecting cell phones belonging to HCWs in an ICU environment. The study revealed that use of 70% isopropyl alcohol (p<0.000001) and UVC light (p<0.005) for disinfection purposes individually statistically significantly suppressed bacterial growth on cell phones. Moreover, disinfection using a solution containing 70% isopropyl alcohol was superior to UVC light disinfection (p<0.001). The 93.1% reduction in CFUs achieved by using 70% isopropyl alcohol as a disinfectant aligns with previous research that reported reductions in bacterial growth of >80%.[7,8,11,12,21,22] Although UVC light disinfection resulted in a CFU decrease of only 58.9%, this was still greater than the reduction achieved by other decontamination approaches.[21,23] A study conducted on dental HCWs in India also observed a decrease in CFU levels.[24] The study observed a reduction in the CFU load of 79.9% and 71% for disinfection using isopropyl alcohol and UVC light, respectively. There was no significant difference in the statistical analysis between UVC light and 70% isopropyl alcohol (p=0.884 and p=0.183, respectively). Given the limited sample size of 15 cell phones per group, these findings may not accurately represent the entire population. The UVC lamp used may have also varied, and the duration of exposure to UVC light was three times longer than in our study. Our study found that the majority of cell

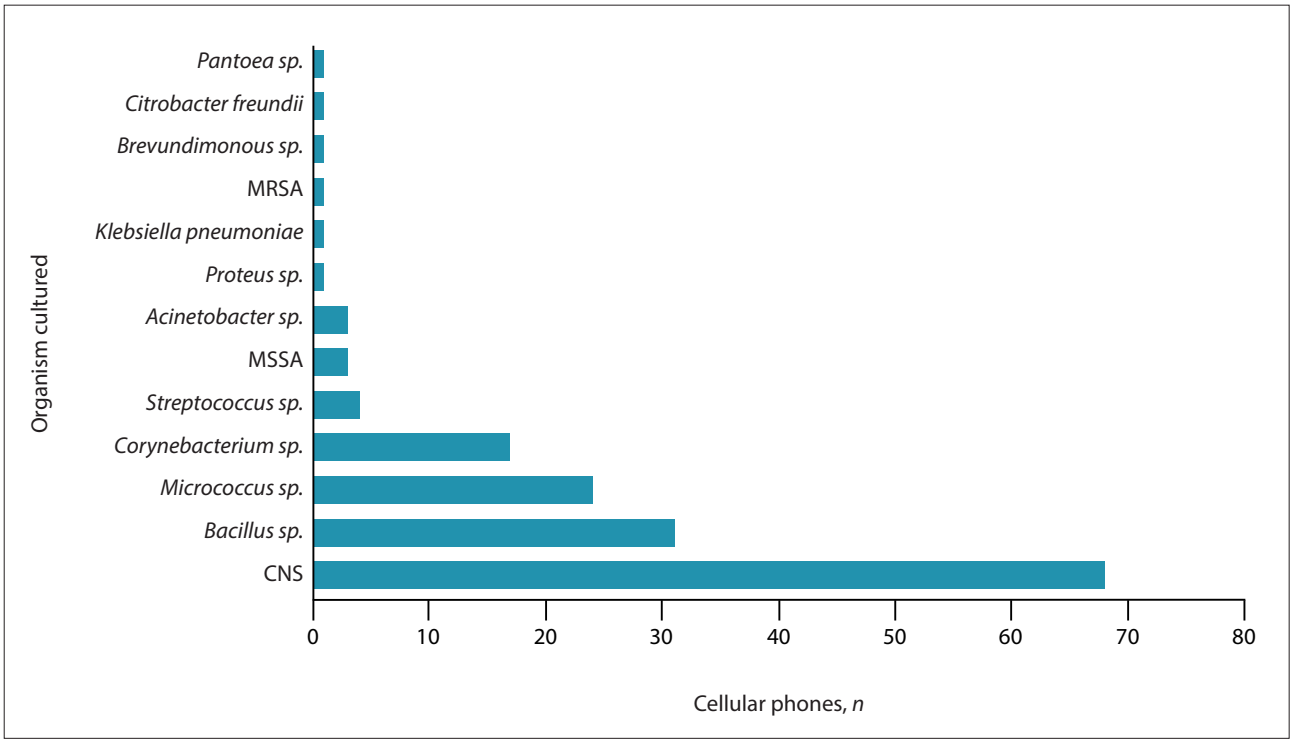

Fig. 1. Distribution of organisms identified on cell phones prior to disinfection. (MRSA = methicillin-resistant Staphylococcus aureus*; MSSA = methicillin-sensitive* S. aureus*; CNS = coagulase-negative* Staphylococcus.*)*

Table 1. Comparison of disinfection between the isopropyl alcohol group and the UVC light group

Clinical outcomes	Isopropyl alcohol (n=34), median (IQR)	UVC light (n=35), median (IQR)	p-value	Effect size
Before disinfection (CFUs/mL)*	24.5 (6.25 - 41.75)	24 (7 - 50)	0.996	0.01
After disinfection (CFUs/mL)*	0 (0 - 3)	10 (4.5 - 22)	<0.001	0.67
Change (CFU reduction ratio)	1 (0.7 - 1)	0.48 (0.08 - 0.82)	<0.001	0.63

UVC = ultraviolet C; IQR = interquartile range; CFU = colony-forming unit.
*In 0.25 mL.

phones used by HCWs (94.6%) harboured an organism. This finding is consistent with those of earlier studies that reported contamination rates ranging from 92.5% to 96.2%.[3,23,25,26] In the pre-disinfectant group, 155 organisms were detected from the cultured colonies, with Gram-positive organisms being the most prevalent. Similar to other reports,[27,28] the organism that was most commonly cultured before disinfection was CNS, with a frequency of 91.9%. Although CNS are typically considered contaminants, they have been identified as a major cause of HAIs, particularly in immunocompromised patients such as premature neonates, individuals with oncological diseases, and those who have undergone solid organ transplants.[29] The organism attaches and establishes colonies through biofilms on indwelling catheters,[29] and between 50% and 70% of catheter-related infections have been specifically linked to CNS, particularly *Staphylococcus epidermidis*.[30] Therefore, the significant proportion of this organism that enters the paediatric ICU cannot be disregarded. In our cohort, only three cell phones grew methicillin-sensitive *Staphylococcus aureus*, whereas one cell phone grew methicillin-resistant *S. aureus* (MRSA). MRSA and *Klebsiella pneumoniae* are commonly identified as the causative agents of HAIs.[31,32] Despite the small numbers of these organisms found in this study (one MRSA and one non-ESBL-producing *K. pneumoniae*), these two species can cause outbreaks that are difficult to control and can potentially be deadly for patients in the paediatric ICU.[33,34] It is possible that the low numbers can be attributed to heightened awareness of hand hygiene due to the emergence of COVID-19, along with the regular cleaning of cell phones during the study period.

Our study has certain limitations. Statistical comparisons were based exclusively on CFUs in the blood agar media. However, other studies have employed different culture media, potentially leading to conflicting comparisons. The study was conducted during the COVID-19 pandemic period, and our figures may have been influenced by HCWs' greater awareness and regular decontamination of cell phones.

Conclusion

Cell phones, which are rarely decontaminated, have become an extension of the hands of HCWs. The findings of this study demonstrate noteworthy presence of micro-organisms on cell phones of HCWs in a paediatric ICU environment. Although both 70% isopropyl alcohol and UVC light disinfection effectively reduced CFUs following decontamination, 70% isopropyl alcohol was determined to be much more effective. Based on these findings, we recommend implementing a decontamination procedure for cell phones in every ICU.

Data availability. The datasets generated and analysed during the present study are available from the corresponding author (LT) on reasonable request.

Declaration. The research for this study was conducted in partial fulfilment of the requirements for LT's MMed (Paediatrics) degree at Walter Sisulu University.

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Author contributions. LT: conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, writing – original draft. JJ: writing – original draft, resources, writing – review and editing. HL: supervision.

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Conflicts of interest. None.

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