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Mobile Technology Disinfection: Contaminated Devices Pose Threat to Patients

Mobile devices are ubiquitous in society and their infiltration of the healthcare environment poses new challenges for infection prevention and control. Numerous studies have documented that mobile handheld devices are frequently contaminated with healthcare-associated pathogens, but they are seldom cleaned and disinfected due to individuals being unsure of what kind of products and methods to use to decontaminate their electronics.

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Mobile devices are ubiquitous in society and their infiltration of the healthcare environment poses new challenges for infection prevention and control. Numerous studies have documented that mobile handheld devices are frequently contaminated with healthcare-associated pathogens, but they are seldom cleaned and disinfected due to individuals being unsure of what kind of products and methods to use to decontaminate their electronics.

Manning, et al. (2013) emphasize that "It is imperative that infection prevention and control programs be actively engaged in providing healthcare worker (HCW) guidance and education in how to mitigate the risk of bacterial contamination of their mobile health devices (MHDs). Programs also have an important role in working together with healthcare providers to establish and implement organizational MHD policies and procedures."

As Manning, et al. (2013) explain further, "Whereas there is no evidence of a direct link between environmental pathogens on small portable electronic devices and the rate of HAIs, cross contamination among patients may occur via the hands of HCWs after they have touched contaminated devices. Multiple investigators have shown that HCW mobile devices provide a known reservoir of pathogenic bacteria, with the potential to undermine infection control efforts aimed at reducing bacterial cross contamination. This potential could be amplified further as HCWs begin to carry additional personal electronic devices such as MHDs without concurrently providing appropriate protocols on decontamination, especially at the point of acute care. This is an important concern given the mounting descriptive evidence of the rapid adoption of MHDs in the healthcare arena. If the trend continues, MHDs could quickly surpass the use of mobile phones and PDAs."

Let's review what the literature reveals about mobile technology contamination.

Kotris, et al. (2017) sought to identify and investigate a difference between microorganisms present on intensive care unit (ICU) healthcare workers' (HCW, doctors, nurses or medical technicians) and medical students' mobile phones as well as to investigate a difference between the frequency and the way of cleaning mobile phones. Fifty swabs were collected from HCWs who work in the ICU and 60 swabs from medical students. Out of 110 processed mobile phones, mobile phones microorganisms were not detected on 25 (22.7 percent), 15 (25 percent) students' and 10 (20 percent) HCWs' mobile phones. No statistically significant difference was found between the number of isolated bacteria be-tween the HCW' and students' mobile phones, however, a statistically significant difference was found between both HCW and students and frequency of cleaning their mobile phones ($p<0.001$). A significant difference was also obtained with the way of cleaning mobile phones be-tween HCWs and students. The most common isolated microorganisms in both groups were coagulase-negative staphylococci (CoNS) and Staphylococcus aureus. Most HCWs cleaned their mobile phones at least once a week, 35 (52 percent), and most medical students several times per year, 20 (33.3 percent). HCWs cleaned their mobile phones with alcohol disinfectant in 26 (40 percent) and medical students with dry cloth in 20 (33.3 percent) cases.

Murgier, et al. (2016) took samples from 52 cell phones of hospital staff (surgeons, anesthetists, nurses, radiology operators, and external medical representatives) entering the operating room of a university hospital center orthopedic surgery department. Both sides of the phone were sampled, before and after decontamination with a pad imbibed with 0.25 percent disinfectant. A nasal sample was also taken to investigate the correlation between Staphylococcus aureus in the nasal cavities and on the cell phone. Before decontamination, the mean number of colony-forming units (CFU) was 258 per phone; after decontamination, it was 127. Forty-nine cell-phones bore CFUs before decontamination (94 percent), and 39 after (75 percent).

Kirkby and Biggs (2016) explain that cell phone use by both family and staff introduce unwanted bacteria into the NICU environment, there-by becoming a threat to this high-risk population. The phones of 18 NICU parents and staff were sampled for bacteria pre- and post-cleaning with disinfectant wipes; microbial surface contamination was evident on every phone tested before disinfecting.

Kordecka, et al. (2016) aimed to analyze the relationship between the number of Candida genera/species isolated from samples collected from the surfaces of mobile phones and the hands of personnel. Out of 175, 131 (74.9 percent) were colonized. Candida glabrata, C. albicans and C.krusei were isolated more frequently from the hand as well as phone surface. The average number of Candida colonies was higher in samples collected from hand surfaces than mobile phone surfaces. Only 19.4 percent of participants reported cleaning the surface of their phones.

Cavari, et al. (2016) swabbed both sides of 50 HCW mobile phones; 10 percent of sampled phones were contaminated with viral pathogens tested for. Ninety-one percent of sampled individuals reported using their mobile phone within the workplace, and 37 percent said they used their phone at least every hour. Eighty-nine participants were aware that mobile phones could be a source of contamination, yet only 13 disinfect their cell phone regularly.

Morvai and Szabó (2015) performed a systematic review on the potential role of mobile communication devices in the dissemination of path-ogens and found that only 8 percent of healthcare workers routinely cleaned their mobile communication devices resulting in a high rate of contamination (40-100%). Coagulase-negative Staphylococci and Staphylococcus aureus were the most commonly identified bacteria and most of them were methicillin resistant (10 percent to 95.3 percent). This review identified effective interventions to reduce bacterial contamination risks including staff education, hand hygiene and regular decontamination of mobile communication devices.

Shakir, et al. (2015) sought to document the frequency of bacterial contamination on the cell phones of orthopedic surgeons in the operating room and to determine whether a standardized disinfecting protocol decreased the rate of bacterial contamination and the amount of organic material. Orthopedic attending and resident cell phones were swabbed on the front and back with adenosine triphosphate bioluminescence to quantify organic material contamination and culture swabs to evaluate bacterial contamination. Adenosine triphosphate was quantified with use of relative light units, and one photon of light was emitted for each molecule of adenosine triphosphate. Thresholds of 250 and 500 relative light units were used. The phones were cleaned with a cleaning wipe and were retested. One week later, a final set of studies was obtained. Of fifty-three cell phones enrolled in the study, 44 cell phones (83 percent) had pathogenic bacteria at initial testing, four (8 percent) had pathogenic bacteria after disinfection, and 40 (75 percent) had pathogenic bacteria one week later. The mean result at initial testing was 3488 ± 2998 relative light units, which reduced after disinfection to 200 ± 123 relative light units, indicating a cleaned surface, but increased one week later to 1825 ± 1699 relative light units, indicating a poorly cleaned surface.

Heyba, et al. (2015) studied the prevalence of microbiological contamination of mobile phones that belong to clinicians in intensive care units (ICUs), pediatric intensive care units (PICUs), and neonatal care units (NCUs). Out of 213 mobile phones, 157 (73.7 percent) were colonized. Co-agulase-negative staphylococci followed by Micrococcus were predominantly isolated from the mobile phones; methicillin-resistant Staphylococ-cus aureus (MRSA) and Gram-negative bacteria were identified in 1.4 percent and 7 percent of the mobile phones, respectively. Sixty-eight clinicians (33.5 percent) reported that they disinfected their mobile phones, with the majority disinfecting their mobile phones only when they get dirty.

Koroglu, et al. (2015) screened 205 mobile phones/devices; 76 devices belonged to HCWs and 129 devices belonged to the non-HCW group. By rubbing swabs to front screen, back, keypad, and metallic surfaces of devices, 444 samples were collected. Of 205 mobile phones/devices, 143 (97.9 percent) of the devices were positive for microbial contamination. The significant difference in this analysis was attributable to the screen size of mobile phones larger than 5 inches, as microbial contamination rates increased significantly as phone size increased.

Morioka, et al. (2015) sought to clarify the contamination and cleaning of touch panels used in everyday life and the awareness of persons in charge and users of devices about contamination. Samples from touch panels were cultured to detect viable bacteria (n=132), Staphylococcus aureus (n=66) and Escherichia coli (n=64). A questionnaire survey was conducted on persons in charge and users of the devices on the day of sampling. Viable bacterial cells were detected in more than 90 percent of the automatic teller machines (ATMs) at banks, the ticket machines at stations, and the copy machines at convenience stores. S. aureus and E. coli were detected in more than one-half of such devices examined. The detection rate of viable bacterial cells in smartphones was 57.5 percent and was lower than those in other devices. More than 65 percent of the ATMs, ticket machines, and copy machines were cleaned once or twice a day. More than one-half of the users of smartphones or button-type mobile phones did not clean their devices. Those who did not aware about the contamination of touch panels were 46.6 percent of the persons in charge and 38.2 percent of the users.

Ulger, et al. (2015) reviewed 39 studies published between 2005 and 2013 on the relationship between mobile phones and bacterial cross-contamination. Of these, 19 (48.7 percent) identified coagulase-negative staphylococci (CoNS), and 26 (66.7 percent) identified Staphylococcus aureus; frequency of growth varied. The use of MPs by healthcare workers increases the risk of repetitive cyclic contamination between the hands and face, and differences in personal hygiene and behaviors can further contribute to the risks, as mobile phones are rarely cleaned after handling.

Pal, et al. (2015) sampled the mobile phones and dominant hands of 386 participants were sampled from four groups: hospital doctors and staff (132), college faculty and staff (54), medical students (100) and control group (100). Informed consent and questionnaire was duly signed by all the participants. 316 mobile phones (81.8 percent) and 309 hand swab samples (80 percent) showed growth of bacterial pathogens. The most predominant isolates were Coagulase-negative Staphylococcus, Staphylococcus aureus, Acinetobacter species, Escherichia coli, Klebsiella pneumoniae, Pseudomonas species and Enterococcus species.

Chao, et al. (2015) screened 226 staff members (146 doctors and 80 medical students) between January 2013 and March 2014. This study found a high level of bacterial contamination (n = 168/226, 74 percent) on the mobile phones of staff members in a tertiary hospital, with similar organisms isolated from the staff member's dominant hand and mobile phones. While most of the isolated organisms were normal skin flora, a small percentage were potentially pathogenic (n = 12/226, 5 percent). Being a junior medical staff was found to be a risk factor for heavy microbial growth. Only 31 percent (70/226) of participants reported cleaning their phones routinely, and only 21 percent (47/226) reported using alcohol containing wipes on their phones.

Egert, et al. (2015) sampled 60 touchscreens of smartphones provided by randomly chosen students of a university. The average bacterial load of uncleaned touchscreens was 1.37 ± 0.33 CFU/cm(2). Touchscreens wiped with commercially available microfiber cloths or alcohol-impregnated lens wipes contained significantly less bacteria than uncleaned touchscreens, i.e., 0.22 ± 0.10 CFU/cm(2) and 0.06 ± 0.02 CFU/cm(2), respectively. Out of 111 bacterial isolates, 56 isolates (50 percent) were identified to genus level and 27 (24 percent) to species level. The vast majority of the identified bacteria were typical human skin, mouth, lung and intestinal commensals, mostly affiliated with the genera Staphylococcus and Micrococcus. Five out of 10 identified species were opportunistic pathogens.

Mark, et al. (2014) swabbed 50 mobile phones of members of the multidisciplinary team working in a surgical unit. Sixty percent of phones sampled had some form of contaminant isolated from their phone. Thirty-one (62 percent) of phones had only three colonies or less isolated on medium. No pathogenic or drug resistant strains of bacteria were identified. A total of 88 percent of individuals sampled by questionnaire used their phone within the workplace of which 55 percent used it for clinical purposes. Sixty-three percent expected there to be some form of contaminant on their phone with only 37 percent admitting to cleaning it regularly. Seventy-five percent of people did not view a ban on phones as a practical solution was they found to be an infection risk.

Nwankwo, et al. (2014) collected 112 swab samples from the mobile phones of HCWs and found that the rate of bacterial contamination of mobile phones was 94.6

percent, and that Staphylococcus epidermidis (42.9 percent) was the most frequently isolated bacteria followed by Bacillus spp. (32.1 percent), Staphylococcus aureus (25 percent), Pseudomonas Aeruginosa (19.6 percent), Escherichia coli (14.3 percent), Streptococcus spp. (14.3 percent), Proteus spp. (12.5 percent), Klebsiella spp. (7.1 percent), and Acinetobacter spp. (5.3 percent).

Ustun and Cihangiroglu (2012) sampled 183 mobile phones of healthcare personnel and found that 94 (51.4 percent) from nurses, 32 (17.5 percent) from laboratory workers, and 57 (31.1 percent) from healthcare staff. In total, 179 (97.8 percent) culture-positive specimens were isolated from the 183 mobile phones, including 17 (9.5 percent) MRSA and 20 (11.2 percent) ESBL-producing Escherichia coli. Forty-four (24.6 percent) of the 179 specimens were isolated from mobile phones of ICU workers, including two MRSA and nine ESBL-producing E. coli. A signifi-cant ($p = 0.02$) difference was detected in the isolation of ESBL-producing E. coli between ICU workers and non-ICU workers.

Sadat-Ali, et al. (2010) swabbed the screen, dialing pad and the sides of 288 healthcare personnel (HCP)'s mobile phones and cultured them. The researchers found that 109 (43.6 percent) HCP carried infective organisms on their devices which could potentially cause infection. Forty (51.3 percent) of 78 physicians' phones were positive for bacteria compared with 41.8 percent of the nurses' phones. Thirty-one (12.4 percent) HCP indicated that they had cleaned their phones on occasion with alcohol swabs available in the hospital, and six (19.4 percent) of their devices had bacterial colonies, whereas, of the 219 HCP who never cleaned their phones, 103 (41.2 percent) of the devices had bacterial colonies and 68 of 103 grew pathologic bacteria. This study found that 43.6 percent of HCPs carried bacteria on their phones. Other studies such as Brady, et al. (2006) found that 96.2 percent of staff's phones had bacterial contamination, and 14.3 percent were organisms that could potentially cause nosocomial infection; however, Goldblatt et al. (2007) found that the prevalence of microorganisms on mobile phones in U.S. hospitals was 45.5 percent, with a higher incidence of physicians' phones having nosocomial bacteria than the nursing staff -- 60 percent and 20 percent, respectively.

In the study by Sadat-Ali, et al. (2010), the majority of the organisms cultured could cause HAIs, reflecting similar findings by a number of re-searchers: Ulger et al. (2009) cultured bacteria from cell phones and hands of HCP and found that Staphylococcus aureus strains isolated from 52 percent of phones and those cultured from hands of 37.7 percent were methicillin resistant. Their study indicates that regular handwashing could limit the transmission of bacteria from the hand to the phone. Sekimoto, et al. (2008) reported that teaching hospitals are better equipped than nonteaching institutions in controlling HAI. Sadat-Ali, et al. (2010) note that "Even though the use of cell phones may help in patient care because of better communication, the constant use has added another risk to patients in the form of HAI. We believe that new strategies have to be found in encouraging regular disinfection of cell phones of HCP, which could reduce the type and bacterial counts on cell phones, thereby reducing HAI."

In their review, Brady, et al. (2009) state, "Innovation in mobile communication technology has provided novel approaches to the delivery of healthcare and improvements in the speed and quality of routine medical communication. Bacterial contamination of mobile communication devices (MCDs) could be an important issue affecting the implementation of effective infection control measures and might have an impact on efforts to reduce cross-contamination. This review examines recent studies reporting bacterial contamination of MCDs, most demonstrating that 9 percent to 25 percent of MCDs are contaminated with pathogenic bacteria. Recommendations to reduce contamination risks include staff education, strict hand hygiene measures, guidelines on device cleaning and consideration of the restrictions regarding use of mobile phone tech-nology in certain high risk areas, for example, operating theatres, intensive care units and burns units. Further work is required to evaluate the benefit of such interventions on MCD contamination and to determine whether a link exists between contamination and subsequent patient infection."

Ulger, et al. (2009) sought to determine the contamination rate of the healthcare workers' mobile phones and hands in operating room and ICU. Microorganisms from HCWs' hands could be transferred to the surfaces of the mobile phones during their use. Two-hundred HCWs were screened; samples from the hands of 200 participants and 200 mobile phones were cultured. In total, 94.5% of phones demonstrated evidence of bacterial contamination with different types of bacteria. The gram negative strains were isolated from mobile phones of 31.3 percent and the ceftazidime resistant strains from the hands were 39.5 percent. S. aureus strains isolated from mobile phones of 52% and those strains isolated from hands of 37.7 percent were methicillin resistant. Distributions of the isolated microorganisms from mobile phones were similar to hands isolates. Some mobile phones were contaminated with nosocomial important pathogens.

Patients' devices are no less contaminated than healthcare personnel's phones. In their study, Kumar, et al. (2014) found that 89 (83.9%) out of 106 patient mobile phones were found to be contaminated with bacteria. Fifty-two (49.0%) coagulase-negative Staphylococcus, 12 (11.3%) Staphylococcus aureus, 7 (6.6%) Enterobacter cloacae, 3 (2.83%) Pseudomonas stutzeri, 3 (2.83%) Sphingomonas paucimobilis, 2 (1.8%) Enterococcus faecalis and 10 (9.4%) aerobic spore bearers were isolated. All the isolated bacteria were found to be resistant to various antibiotics.

Kumar, et al. (2014) note that "No risk has been reported for the transmission of pathogens to patients through non-critical items such as mobile phones which do not contact mucous membranes and/or non-intact skin. However, isolated organisms such as coagulase-negative staph-ylococci have emerged as a major pathogen in implant users and severely debilitated patients in hospitals; S. aureus is a known pathogen, P. stutzeri is an opportunistic pathogen and S. paucimobilis were reported to cause nosocomial infection. Since E. faecalis and E. cloacae are part of human intestinal microbial flora, isolation of E. faecalis and E. cloacae from mobile phones may indicate that such mobile phones may be contaminated with intestinal flora. Several studies have also reported antibiotic resistant hospital strains such as Staphylococcus epidermidis, S. aureus, Enterococcus, and Pseudomonas species, etc. which are common healthcare-associated pathogens." They add, "Educating patients about infection control and stressing individual responsibility of infection control is an important aspect of controlling nosocomial infections. Contaminated mobile phones may act as fomites because most people carry mobile phones along with them to places such as hospitals, toilets and kitchens where microorganisms thrive. This study indicates that unreported antibiotic resistant bacterial contaminants of mobile phones of patients may be a matter of great concern. Hence, it is recommended that all patients admitted in hospitals be educated about guidelines of using mobile phones, regular disinfection of their mobile phones, hand hygiene and be advised not to share mobile phones with other people so that role of contaminated mobile phones in the spread of nosocomial infections can be prevented to some extent."

Brady, et al. (2011) examined the demographics and characteristics of mobile phone utilization by inpatients and phone surface microbial contamination. One hundred and two out of 145 (70.3%) inpatients who completed a questionnaire detailing their opinions and utilization of mobile phones, also provided their mobile phones for bacteriological analysis and comparative bacteriological swabs from their nasal cavities; 92.4% of patients support utilization of mobile phones by inpatients; indeed, 24.5% of patients stated that mobile phones were vital to their inpatient stay. Patients in younger age categories were more likely to possess a mobile phone both inside and outside hospital ($p < 0.01$) but there was no gender association. Eighty-six out of 102 (84.3%) patients' mobile phone swabs were positive for microbial contamination. Twelve (11.8%) phones grew bacteria known to cause nosocomial infection. Seven (6.9%) phones and 32 (31.4%) nasal swabs demonstrated Staphylococcus aureus contamination. MSSA/MRSA contamination of phones was associated with concomitant nasal colonization. Patient utilization of mobile phones in the clinical setting is popular and common; however, we recommend that patients are educated by clear guidelines and advice on inpatient mobile phone etiquette, power charging safety, regular cleaning of phones and hand hygiene, and advised not to share phones or related equipment with other inpatients in order to prevent transmission of bacteria.

Solutions to the Challenge of Contaminated Mobile Devices

Mathew, et al. (2016) acknowledge the conundrum inherent in cleaning mobile technology devices: "Wipes moistened with alcohol or bleach are effective in reducing levels of pathogenic bacterial load on mobile health devices (MHDs), and wipes moistened with saline or water may be similarly effective because of mechanical removal. However, several studies have demonstrated that most healthcare personnel do not regularly clean their phones. Moreover, device manufacturers discourage wiping of MHDs with disinfectants or abrasive materials of any kind because they may negatively affect screen quality."

Technology presents the problem, but it also provides a potential solution. The marketplace now offers the healthcare industry a number of enclosed ultraviolet-C (UV-C) radiation devices designed to decontaminate fomites such as phones without damaging the integrity of touchscreens or other components. For example, Mathew, et al. (2016) demonstrated that an enclosed ultraviolet-C radiation device was effective in rapidly reducing methicillin-resistant Staphylococcus aureus, and with longer exposure times, Clostridium difficile spores, on glass slides and reducing contamination on in-use mobile handheld devices.

Mathew, et al. (2016) describe a device consisting of an enclosed box with a conveyer belt that delivers UV-C radiation in close proximity to MHDs. The researchers examined the efficacy of this device against three strains each of MRSA and Clostridium difficile spores on glass slides with and without organic load. C difficile strains included American Type Culture Collection strain 43593, VA 17 (a restriction endonuclease analysis type BI strain), and VA 11 (a restriction endonuclease analysis type J strain). MRSA strains included two clinical isolates with pulsed-field gel electrophoresis types USA300 and USA800, and one American Type Culture Collection strain (43300).

To assess real-world efficacy of the device, the researchers cultured 50 MHDs of healthcare staff before and after decontamination with the device at the standard setting. Mathew, et al. (2016) report, "We found that an enclosed UV-C device designed for decontamination of MHDs was effective in rapidly reducing MRSA, and to a lesser degree, C difficile spores, in a laboratory testing. At slower conveyer speeds, C difficile spores were reduced by ≥4.6 log, even in the presence of organic material. Consistent with previous studies, 2, 3, 4, 5 and 6 we found that 14 percent of MHDs being used by health care personnel were contaminated with low levels of

≥1 health care–associated pathogen. The UV-C device was effective in significantly reducing contamination on the MHDs. Our results suggest that the UV-C device may provide a useful no-touch option for rapid and effective disinfection of MHDs."

The marketplace has a number of UV-based devices such as the one described above that can help address surface contamination. Other solutions include a bundle of interventions, as proposed by Manning, et al. (2013) who say that in the absence of specific tablet and phone disinfection guidelines, it is advisable for healthcare facilities to apply what is known about the contamination of other nonmedical mobile communication devices to create a "common sense" bundle to guide wireless media tablet infection prevention practices. As Manning, et al. (2013) explain, "New technologies will always be a part of clinical medicine, and there will always be the risk of new equipment popping up without IP's knowledge of its presence. Therefore, it is imperative that the IPs develop methods to be situationally aware of what technology is presenting within their care areas. For example, the IP should become a member of committees charged with the assessment and adoption of new technologies for the healthcare facility. Furthermore, the IP should campaign for said committee evaluating all equipment that would be alien to the facility, such as a nursing or medical school presence within a facility that uses MHD's during clinical rotations."

Manning, et al. (2013) add that the infection prevention department should strive to educate healthcare workers on the safe use of mobile devices and push reminders for compliance with their self-described iPBundle, which they say is "a common sense approach to the safe use of the MHD from both an infection prevention standpoint and the need to preserve the functionality of this valuable patient education tool and clinical documentation, communication, and decision support tool." The iPbundle includes the following elements:
- A waterproof/resistant, nonporous, hard or soft case for the MHD
- Disinfection of the MHD before and after patient/family interface with an approved disinfectant as per facility policy for noncritical items.
- Set alarm on the MHD to remind user to disinfect regularly in addition to the before and after patient/family interface disinfection (for ex-ample, daily, hourly)

- Hand hygiene as per facility policy for patient interaction and after disinfecting the MHD

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