Mobile Phones used by Healthcare Workers: The Potential Role in Transmission of Healthcare Associated Infections

Amira M. Sultan[1*] and Mohammad A. Ahmed[2]

[1]*Department of Medical Microbiology and Immunology, Faculty of Medicine, Mansoura University, Al Gomhoria St., Mansoura, Egypt*
[2]*Department of Anaesthesia, Faculty of Medicine- Mansoura University, Mansoura, Egypt*

*Corresponding author

A B S T R A C T

To identify bacterial contamination of cellular phones used by healthcare workers (HCWs) and to investigate antibiotic resistance patterns of recovered isolates. In addition, we assessed the possible risk factors for contamination of mobile phones. Mobile phones were sampled from HCWs across inpatient, outpatient and intensive care wards in Mansoura Emergency Hospital. Isolated bacteria were identified and subjected to disk diffusion test to detect their antibiotic resistance patterns. Sampled mobile phones had a contamination rate of 90.4% (P= 0.00). *Staphylococcus epidermidis* was the commonest isolated organism (41.3%). Significant risk factors included the usage of mobile cover and lack of history of mobile phones disinfection by the HCWs. Bacterial isolates demonstrated the least antimicrobial resistance toward imipenem (11.9%) and amikacin (17.3%). Out of the isolated *Staphylococcus aureus*, 27.9% were methicillin resistant while 32.7% of the isolated Gram-negative bacteria were producers of extended spectrum β-lactamases. Besides, multidrug resistant isolates constituted 41.1% of the tested bacteria. We demonstrated that mobile phones may serve as a vehicle for transmission of healthcare associated infections. Therefore, education of HCWs and limitation of mobile phones usage in high-risk settings parallel to frequent disinfection of hands and mobile phones should be implemented.

Introduction

Healthcare associated infections (HAIs) represent a serious problem in different healthcare settings as they increase mortality, morbidity, hospital stay and medical cost. These infections are transmitted through hands of healthcare workers (HCWs), contaminated patient care items and other inanimate hospital objects (Schultz *et al.,* 2003; Singh *et al.,* 2010). Personal electronic devices as personal digital assistants and hand-held computers were found to play a significant role in transmission of HAIs (Bellamy *et al.,* 1998; Isaacs *et al.,* 1998).

Throughout the last decade, mobile phones have emerged as portable communication devices that became essential in modern life. Affordable and user-friendly operating

systems have made mobile phones accessible to a wide range of users all over the world. Many HCWs in different settings and locations currently use mobile phones for communication. Mobile phones frequently come in contact with the body surfaces of their users as face and hands. Furthermore, they commonly touch environmental surfaces present in healthcare settings. Therefore, mobile phones are potentially liable for contamination with various microorganisms (Pal *et al.,* 2015). Direct handling of mobile phones without proper disinfection can make them reservoir and vehicles of microorganisms associated with HAIs (França *et al.,* 2018). Implementation of proper disinfection of mobile phones was reported to be effective in limiting the spread of these pathogens (Arora *et al.,* 2009; Trivedi *et al.,* 2011).

Despite all the benefits provided by mobile phones, they might pose a health problem by harboring different microorganisms and thus contributing in the transmission of HAIs. Doctors and other HCWs working in high-risk areas as intensive care units (ICUs) are more exposed to pathogenic microorganisms. Thus, mobile phones used by those HCWs may act as a vehicle spreading pathogens to other locations (Kakote *et al.,* 2012). In addition, mobile phones used by HCWs can transmit resistant bacteria that are commonly present in healthcare settings environment to household and other community settings (Bhat *et al.,* 2011; Pal *et al.,* 2015).

Previous studies demonstrated that organisms recovered from mobile phones in the healthcare settings included *Staphylococcus epidermidis* (*S. epidermidis*), *Staphylococcus aureus (S. aureus), Pseudomonas aeruginosa (P. aeruginosa), Klebsiella pneumoniae (K. pneumoniae)* and *Escherichia coli (E. coli)* (Ulger *et al.,* 2009; Trivedi *et al.,* 2011). Multidrug resistant (MDR) bacteria were also

recovered from mobile phones (Ulger *et al.,* 2009; Tekerekoglu *et al.,* 2011).

Although mobile phones are routinely used, they are usually not adequately cleaned by HCWs. Moreover, improper implementation of hand hygiene by HCWs could increase the risk of mobile phones contamination. Guidelines for limitation of mobile phone usage, particularly in high-risk areas, and regular disinfection of phones are lacking in many healthcare settings. Besides, many health professionals are even unaware of the risk carried by these phones (Pal *et al.,* 2015).

Studies that evaluated the role of mobile phones in development of HAIs in our locality are scarce. Therefore, we carried out this study to identify bacterial contamination of cellular phones used by HCWs and to investigate antibiotic resistance patterns of recovered isolates. Besides, the possible risk factors for contamination of mobile phones were evaluated.

Materials and Methods

Setting

A hospital-based study was performed in Mansoura Emergency Hospital in collaboration with Medical Microbiology and Immunology Department, Mansoura Faculty of Medicine, Mansoura- Egypt. The study protocol was reviewed and approved by the Institutional Review Board. An informed consent was taken, after full explanation of the study, from all participating HCWs.

Sample collection

Mobile phones were sampled from randomly participating HCWs across inpatient wards, outpatient clinics and ICUs in Mansoura Emergency Hospital during the months of June and July, 2018. Participating HCWs

included doctors, nurses and other HCWs as technicians and therapists. Data of participating HCWs were collected as profession, location and gender. In addition, other possible risk factors for mobile phones contamination were recorded such as the type of mobile phone (touch-screen or keypad), use of mobile cover, site of mobile placement and previous history of mobile phone disinfection by HCWs. All participants were excluded from further enrollment in the study to ensure that each phone was submitted for one time only. Samples were collected in aseptic way by sterile cotton swabs. In order to sample each mobile phone, a sterile swab was moistened with sterile saline and rolled over all surfaces of the phone including screen, sides and mobile cover if present.

Culture and identification

All collected swabs were immediately cultured onto blood agar plates. Cultured plates were aerobically incubated for 24 hours at 37 °C. Following Gram-staining of isolated organisms, Gram-negative bacteria were subcultured on MacConkey agar plates for further identification. Identification of isolated bacteria was performed according to standard protocols by colonial morphology, Gram-staining, different biochemical reactions and analytical profile indices (API) strips.

Antimicrobial susceptibility testing

All recovered isolates were subjected to disk diffusion test in order to identify their antibiotic sensitivity profiles. Disk diffusion test was conducted using Mueller-Hinton agar (MHA) plates and a panel of ten antibiotic disks (Oxoid, UK). The test procedure and interpretation of results were carried out along with the guidelines of clinical and laboratory standard institute (CLSI) (CLSI, 2018). E-test strips (bioMerieux, France) on MHA plates

were used to determine vancomycin minimum inhibitory concentration as per manufacturer's guidelines. The CLSI breakpoints for resistance were used for results interpretation (CLSI, 2018). Bacterial isolates showing resistance to three or more antimicrobial classes were counted as MDR isolates (Vergnano *et al.,* 2011; Seliem and Sultan, 2018).

Detection of methicillin resistant *staphylococcus aureus*

Identified *S. aureus* isolates were subjected to cefoxitin disk diffusion test in order to detect methicillin resistance. Following the CLSI guidelines, the cefoxitin disk diffusion test was conducted by standard procedure using MHA plates and 30 μg-cefoxitin disks (Oxoid, UK). After incubation of the inoculated plate at 35 °C for 24 hours, the inhibitory zone diameter was measured. Isolates with a diameter of ≤ 21 mm were reported as methicillin resistant *S. aureus* (MRSA) (CLSI, 2018).

Detection of extended spectrum β-lactamases production

Gram-negative bacilli that demonstrated resistance to cefotaxime or ceftazidime were further tested for the production of extended spectrum β-lactamases (ESBL). Detection of ESBL production was conducted by disk diffusion clavulanate inhibition test using both ceftazidime and cefotaxime alone and in combination with clavulanate as per the guidelines of CLSI (CLSI, 2018).

A standard disk diffusion test was conducted by using MHA plates, single and combined antibiotic disks (Oxoid, UK). Briefly, one disk of ceftazidime (30 μg)and a second disk of ceftazidime-clavulanate (30/10 μg) were placed onto the inoculated MHA at a distance of 2 cm. Similarly, one disk of cefotaxime (30

μg) and another disk of cefotaxime-clavulanate (30/10 μg) were placed onto the same MHA plate. Following that, plates were incubated at 35 °C for 18 hours. A confirmed ESBL producing strain was reported when there is ≥ 5-mm increase in the inhibition zone diameter for either antimicrobial agent combined with clavulanate versus the inhibition zone diameter of the antimicrobial agent alone (CLSI, 2018).

Statistical analysis

The SPSS statistical package software for windows version 22 (SSPS Inc, Pennsylvania, USA) was used to carry out the statistical analysis of our data. Differences between two categorical variables were assessed by using the Chi square test. In order to identify statistically significant differences between three variables, the one-way analysis of variance (ANOVA) was performed. P value < 0.05 was considered indicative of significant difference.

Results and Discussion

The present study included the mobile phones belonging to a total number of 146 HCWs from different locations in Mansoura Emergency Hospital; 55 HCWs (37.7%) from inpatient wards, 51 (34.9%) from outpatient clinics and 40 (27.4%) from ICUs. Out of 146 study participants, 41 (28.1%) were doctors, 90 (61.6%) were nurses and 15 (10.3%) were other HCWs as demonstrated in Table 1.

During our study, bacterial growth was detected from 132 mobile phones with a contamination rate of 90.4% while 14 mobile phones (9.6 %) revealed negative cultures which was statistically significant (P= 0.00). Single type of bacteria was recovered from 71 (48.6%) mobile phones while two types of bacterial growth were isolated from 46 (31.5%) mobile phones. A number of 15 (10.3%) mobile phones were contaminated with three types of bacteria as demonstrated in Figure 1.

Out of the sampled 146 mobile phones, 86 (58.9%) grew *S. epidermidis,* 44 (30.1%) methicillin sensitive *S. aureus* (MSSA), 21 (14.4%) *E. coli,* 17 (11.6%) MRSA, 17 (11.6%) *K. pneumoniae,* 11 (7.5%) *P. aeruginosa,* 6 (4.1%) *Acinetobacter baumannii (A. baumannii)* and 6 (4.1%) *Bacillus anthracoid* as demonstrated in Table 2.

A total number of 208 bacterial isolates were recovered from the contaminated mobile phones. Of the recovered 208 isolates, 116 (55.8%) were established nosocomial pathogens. Isolated bacteria included 153 (73.6%) Gram-positive and 55 (26.4%) Gram-negative bacteria. The most commonly isolated organism was *S. epidermidis* as constituted 41.3% (86/208) of the total isolates. Out of the 61 recovered *S. aureus* isolates, 44 (72.1%) were methicillin sensitive and 17 (27.9%) were methicillin resistant.

Mobile phones belonged to doctors had the least contamination rate (87.8%), while phones belonged to nurses and other HCWs had contamination rates of 91.1% and 93.3% respectively. There was no significant association between the profession of HCWs and contamination rate of mobile phones as demonstrated in Table 3.

The mobile phones screened in the outpatient clinics had the highest contamination rate (98.0%) followed by inpatient wards (89.1%) and ICUs (82.5%). The rate of contamination of mobile phones was not significantly related to the type of clinical setting as shown in Table 4.

Table.1 Distribution of mobile phones in relation to location and profession of healthcare workers

Location	Profession of healthcare workers			Total
	Doctors	**Nurses**	**Other HCWs**	
Inpatient wards	10 (24.4)	39 (43.3)	6 (40.0)	55 (37.7)
Outpatient clinics	18 (43.9)	29 (32.2)	4 (26.7)	51 (34.9)
Intensive care units	13 (31.7)	22 (24.4)	5 (33.3)	40 (27.4)
Total	41 (100)	90 (100)	15 (100)	146 (100)

HCWs: Healthcare workers
Values are expressed as No (%)

Table.2 Types of bacterial isolates recovered from mobile phones

Bacterial isolates	Mobile phones No= 146 (%)
Gram-positive bacteria	
Staphylococcus epidermidis	86 (58.9%)
MSSA	44 (30.1%)
MRSA	17 (11.6%)
Bacillus anthracoid	6 (4.1%)
Gram-negative bacteria	
Escherichia coli	21 (14.4%)
Klebsiella pneumoniae	17 (11.6%)
Pseudomonas aeruginosa	11 (7.5%)
Acinetobacter baumannii	6 (4.1%)

MSSA: Methicillin sensitive Staphylococcus aureus
MRSA: Methicillin resistant Staphylococcus aureus

Table.3 Relationship between the profession of healthcare workers and contamination rate of mobile phones

Profession	Doctors	Nurses	Other HCWs	P value
Rate of contamination (%)	87.8% (36/41)	91.1% (82/90)	93.3% (14/15)	0.89

HCWs: Healthcare workers

Table.4 Relationship between the type of clinical setting and contamination rate of mobile phones

Type of clinical setting	Inpatient wards	Outpatient clinics	Intensive care units	P value
Rate of contamination (%)	89.1% (49/55)	98.0% (50/51)	82.5% (33/40)	0.69

Table.5 Risk factors associated with contamination of mobile phones

Risk factor	Total number of mobile phones	Number of contaminated mobile phones	Rate of contamination (%)	P value
Gender				
Male	87	79	90.8%	0.93
Female	59	53	89.8%	
Use of mobile cover				
Covered phones	108	102	94.4%	0.048*
Uncovered phones	38	30	78.9%	
Site of mobile placement				
Clothing (pocket)	119	110	92.4%	0.62
Bag	27	22	81.5%	
History of mobile phone disinfection				
Absent	128	124	96.9%	0.025*
Present	18	8	44.4%	

*Statistically significant

Table.6 Resistance patterns of isolated bacteria from mobile phones

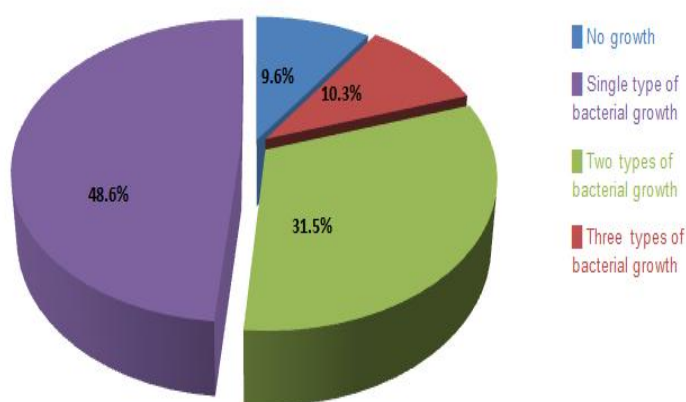| Antibiotic	Resistance of Gram-positive bacteria No= 147	Resistance of Gram-negative bacteria No= 55	Total resistance No= 202
Ampicillin	111 (75.5)	54 (98.2)	165 (81.7)
Amoxicillin/ clavulanic acid	48 (32.7)	21 (38.2)	69 (34.2)
Cefotaxime	61 (41.5)	40 (72.7)	101 (50.0)
Ceftazidime	61 (41.5)	40 (72.7)	101 (50.0)
Ciprofloxacin	59 (40.1)	18 (32.7)	77 (38.1)
Gentamicin	50 (34.0)	19 (34.5)	69 (34.2)
Amikacin	26 (17.7)	9 (16.4)	35 (17.3)
Imipenem	17 (11.6)	7 (12.7)	24 (11.9)
Cotrimoxazole	76 (51.7)	45 (81.8)	121 (59.9)
Vancomycin	0 (0.0)	NT	-

Values are expressed as No (%), NT: not tested
Isolates of *Bacillus anthracoid* were not tested

Table.7 Extended spectrum β-lactamases production by isolated Gram-negative bacteria

Gram-negative bacterial isolates	Total number	ESBL producers No (%)
Escherichia coli	21	9 (42.9)
Klebsiella pneumoniae	17	5 (29.4)
Pseudomonas aeruginosa	11	3 (27.3)
Acinetobacter baumannii	6	1 (16.7)
Total	55	18 (32.7)

ESBL: Extended spectrum β-lactamases

Figure 1: Results of bacterial culture of samples collected from mobile phones.

In our study, we investigated the possible risk factors for mobile phones contamination (Table 5). Both male and female HCWs had nearly the same rate of contamination of mobile phones. Covered mobile phones had a significantly higher contamination rate than the uncovered phones (P= 0.048). Out of 146 HCWs participated in our study, 119 (81.5%) used to place their mobile phones in the pockets of their attires. Mobile phones that were placed in the pockets had a higher contamination rate (92.4%) than those kept in bags (81.5%). However, the difference in contamination rate between both groups was not significant.

In the present study, 12.3% of participating HCWs (18/146) mentioned that they frequently disinfected their mobile phones with alcohol wipes. Mobile phones that belonged to this group of HCWs had a significantly lower rate of contamination (44.4%) with P value of 0.025. The remaining 128 HCWs (87.7%) declared that they never disinfected their mobile phones as they were not aware of the associated risk for contamination. The type of mobile phone, whether touch-screen or keypad, was not assessed as a risk factor for contamination as all of the participating HCWs in this study used touch-screen phones.

The highest resistance of isolated organisms was demonstrated against ampicillin (81.7%) followed by cotrimoxazole (59.9%), cefotaxime (50.0%), ceftazidime (50.0%), ciprofloxacin (38.1%), amoxicillin/ clavulanic acid (34.2%), gentamicin (34.2%), amikacin

(17.3%) and imipenem (11.9%). All tested Gram-positive isolates were sensitive to vancomycin. Multidrug resistance was found in 41.1% of the tested isolates (83/202). Resistance patterns of Gram-positive and Gram-negative bacterial isolates were demonstrated in Table 6.

In the present study, ESBL production was identified in 18 out of 55 (32.7%) isolated Gram-negative bacteria. *Escherichia coli* presented the highest ESBL production as 42.9% of the recovered isolates were ESBL producers, followed by *K. pneumoniae* (29.4%), *P. aeruginosa* (27.3%) and *A. baumannii* (16.7%) as shown in Table 7.

Mobile phones, unlike fixed ones, are frequently used at patients care areas, thus, they can serve as a vehicle for transmission of HAIs into susceptible patients. Moreover, mobile phones are often used by HCWs outside and inside the hospital, and therefore, they can transfer external microbes into the healthcare setting environment (Jeske *et al.,* 2007; Elkholy and Ewess, 2010).

During the present study, 146 mobile phones owned by HCWs of various professions and locations were sampled. Of the screened mobile phones, 132 (90.4%) were contaminated with different numbers of bacteria. In concordance with our results, Badr *et al.,* (2012) and Ulger *et al.,* (2009)reported that 93.7% and 94.5% of mobile phones were contaminated respectively. The rate of contamination of mobile phones in our study was higher than those reported by Trivedi *et al.,* (2011) (46.6%) and Panchal *et al.,* (2012) (65%). However, Daka *et al.,* (2015) and Tagoe *et al.,* (2011) reported that 97.4% and 100% of mobile phones were contaminated respectively. Reported differences in the rate of mobile phones contamination could be attributed to the variations among HCWs including the degree of awareness towards the contamination risk posed by mobile phones, routine disinfection of phones, implementation of hand hygiene policy and frequency of handling mobile phones when providing medical care to the patients.

Out of the screened mobile phones, 48.6% showed single bacterial growth, 31.5% grew two types of bacteria and 10.3% grew three types of bacteria. Similar pattern of microbial contamination was previously reported (Pal *et al.,* 2015; Daka *et al.,* 2015). On the other hand, Rekha and Borkotoki reported that all positive cultures of mobile phones showed single microbial growth (Rekha and Borkotoki, 2017). Gram-positive bacteria constituted the majority of total isolates recovered from mobile phones which was consistent with previous studies (Al-Abdalall, 2010; Roy *et al.,* 2013; Pal *et al.,* 2015; Daka *et al.,* 2015). The commonest recovered isolate was *S. epidermidis* that presented 41.3% of total isolates. Similar findings were reported in Egypt (Al-Mudares *et al.,* 2012), India (Pal *et al.,* 2015), Ethiopia (Daka *et al.,* 2015) and Brazil (França *et al.,* 2018). The predominance of *S. epidermidis* in the current study indicated that normal skin commensals could simply transfer to objects that might come in direct contact with the skin of HCWs. Even more, it is possibly that frequent and repetitive direct contact between the skin and mobile phones favors the transfer of these bacteria to the mobile phones (Goel and Goel, 2009). Although *S. epidermidis is* ordinarily non-pathogenic, it may cause HAIs in immunologically susceptible patients (Rekha and Borkotoki, 2017).

Staphylococcus aureus, a well-known nosocomial pathogen, was the second most commonly isolated organism in the present study. Methicillin resistance was detected among 27.9% of the recovered *S. aureus* isolates. Our findings were higher than those reported by Roy *et al.,* (2013) (13.63%), Tambe and Pai (2012) (16.9%) and Pal *et al.,*

(2015) (21.05%). However, other studies reported higher incidence of MRSA reaching up to 52% (Trivedi *et al.,* 2011) and 83% (Tambekar *et al.,* 2008) of total *S. aureus* isolates. In agreement with our results, Tambekar and his colleagues isolated *K. pneumoniae* and *P. aeruginosa* from mobile phones of HCWs (Tambekar *et al.,* 2008).

In the current study, mobile phones owned by doctors were the least contaminated which could be explained by their higher awareness, medical knowledge and better implementation of hand hygiene. In agreement with our results, other reports showed that mobile phones owned by doctors had the lowest contamination rate followed by other professions (Tambe and Pai, 2012; Pal *et al.,* 2015;Rekha and Borkotoki, 2017). The mobile phones screened in the outpatient clinics had the highest contamination rate (98.0%) which could be attributed to the demanding busy working environment in the outpatient clinics and deficient time available for hand hygiene and disinfection of mobile phones.

Covered mobile phones were more contaminated than uncovered phones with a statistically significant difference (P= 0.048). This could be explained by gaps and cracks present between the mobile phones and their covers that work as niches for contaminating bacteria. In addition, cleaning and disinfection of covered mobile phones might be more challenging and less effective because of these gaps. Out of 146 HCWs participated in the present study, 87.7% were unaware of the role played by phones as a potential source of bacteria inside the healthcare settings, and therefore, they never decontaminated their mobile phones. In line with our results, Daka and his colleagues reported that 94.7% of the participating HCWs never cleaned their mobile phones (Daka *et al.,* 2015).

In the present study, all tested Gram-positive isolates were sensitive to vancomycin. Besides, isolated bacteria demonstrated the least resistance to imipenem (11.9%) and amikacin (17.3%). Contrary to our findings, Akinyemi and his collaegues reported that fluoroquinolones were the most effective against the recovered isolates from mobile phones (Akinyemi *et al.,* 2009).Variable antibiotic sensitivity patterns were reported in other studies (Trivedi *et al.,* 2011; Pal *et al.,* 2015). These variations may be explained by different geographical regions, the prevalence of resistant strains in healthcare and community settings, implementation of antibiotic policy and execution of infection control measures to limit the spread of resistance genes. Recovered *E. coli* isolates demonstrated the maximum ESBL production followed by *K. pneumoniae*. In agreement with our findings, Tekerekoglu and his colleagues reported that ESBL producing *E. coli* and *K. pneumoniae* were recovered from HCWs mobile phones (Tekerekoglu *et al.,* 2011).

We demonstrated that mobile phones used by HCWs represent a potential threat, since 90.4% of screened mobile phones revealed bacterial contamination and 55.8% of the isolated bacteria were established nosocomial pathogens. Besides, *S. epidermidis,* which is a potential nosocomial pathogen, constituted 41.3% of total isolates. These findings highlighted the potential role of mobile phones in transmitting HAIs. Thus, HCWs should be aware that their personal mobile phones could both harbor and disseminate harmful bacteria inside and outside the healthcare setting environment.

The results of this study and similar reports could be used to educate HCWs about the possible health hazards carried by mobile phones to their patients as well as family members at home. Furthermore, these data

could be used to provide the knowledge required to establish efficient prevention strategies. Such strategies might include limitation of mobile phones in ICUs and other high-risk areas, routine disinfection of mobile phones by alcoholic wipes or other disinfectants and routine performance of hand hygiene in particularly after handling the mobile phones and before touching the patient.

In conclusion, our study revealed that 90.4% of the cellular phones handled by HCWs were bacterially contaminated and thus may serve as a vehicle for transmission of HAIs. Isolated bacteria included both established and potential nosocomial pathogens. Methicillin resistant *S. aureus* constituted 27.9% *of* the total *S. aureus* isolates while 32.7% of the isolated Gram-negative bacteria were ESBL producers. Besides, MDR isolates constituted 41.1% of the tested bacteria. Most of the participating HCWs, however, were unaware of the mobile phones-associated contamination risk. In order to reduce the role of mobile phones in transmitting HAIs, HCWs should be educated about the potential threat played by mobile phones along with limitation of their usage especially in high risk areas. Moreover, good practice including frequent disinfection of hands and mobile phones should be emphasized. Furthermore, study of effective and suitable disinfection methods for mobile phones should be considered.

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