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Review Article

Bacterial contamination of mobile phones among health care workers: a meta-analysis study

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Abstract

Background

Mobile phones (MPs) are becoming commonplace in both community and hospital settings. There are studies that show that phones can be considered fomites in potential, ones that give organisms an environment conducive to their development, such as constant heat and moisture.

Aim

The present study aimed to do a meta-analysis to investigate the bacterial contamination of MPs among health care workers (HCWs).

Materials and methods

Using MEDLINE database (*http://www.pubmed.com*), we conducted a systematic literature search to identify relevant studies published within the past 20 years (from 2000 up to 2020). Appropriate articles were accessed in full text to determine eligibility and extract data by two reviewers.

Results

A total of 18 articles were eligible to this study. Overall, 2300 HCWs were included in all studies. By forest plot test, 78% of HCWs' MPs were found to be contaminated by various types of organisms. The difference between HCWs and non-HCWs is not statistically significant regarding bacterial colonization of MPs. The prevalence of MP colonization by specific bacteria among HCWs was estimated. Coagulase-negative staphylococci were the most prevalent organism found in 50% of the tested HCWs, followed by *Escherichia coli* 12%, *Staphylococcus aureus* 11%, *Klebsiella* 10%, *Enterobacter* 10%, *Proteus* 8%, *Pseudomonas* 7%, *Streptococci* 7%, aerobic spores 5%, *Enterobacter faecalis* 2%, and *Sphingomonas* 2%.

Conclusion

MP contamination with different organisms is extremely common among HCWs, and resistance of these isolates to various antibiotics has also been detectable. The high level of contamination indicates that the MPs of these professionals may be serving as a reservoir and vehicle in the transmission of pathogenic agents both of hospital origin and community.

Keywords: Bacterial contamination, health care workers, meta-analysis, mobile phones

Introduction

Mobile phones (MPs) are ubiquitous in society and their widespread use among health care environment poses new challenges for infection control programs. Within hospital settings, health care workers (HCWs) and medical students are using their phones in the clinical environment and practice, including during physical contacts with patients. The quality, efficiency, and rapidity of communication among HCWs can be improved by using the MPs [1–4]. It has been proved that many medical conditions have been controlled after the innovation of mobile communications [3,5]. These include asthma [6] and diabetes [7], with increased rate of vaccination among travelers through reminder by short message services [8]. However, one of the most common concerns regarding heavy

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use of MPs is that they can act as a vehicle for transmitting pathogenic bacteria and other microorganisms [9,10]. A previous study reported that more than 90% of cell phones of HCWs were contaminated with microorganisms, and more than 14% of them carried pathogenic bacteria that commonly caused nosocomial infections [8,11], such as methicillin-resistant *Staphylococcus aureus*, *Acinetobacter* species, vancomycin-resistant enterococci, *Pseudomonas* species, and coliforms. These contaminated devices can serve as a reservoir of bacteria known to cause nosocomial infection, so may play a role in their transmission to patients through hands of HCWs [4,12,13]. Many authors have studied MP contamination among HCWs and in their community.

The present study aimed to do a meta-analysis to investigate the potential role of mobile communication devices in the dissemination of organisms and the effective preventive measures.

Materials and methods

Search for relevant studies

Using MEDLINE database (*http://www.pubmed.com*), we conducted a systematic literature search to identify relevant studies published within the past 20 years (from 2000 up to 2020). Appropriate articles were accessed in full text to determine eligibility and extract data by two reviewers. Studies were stratified by organisms and prevention measures.

The electronic searches were supplemented by scanning the reference lists from retrieved articles to identify additional studies that may have been missed during the initial search. It was decided to include only those studies that were published in English or translated to English language, studies that mentioned the numbers of HCWs, studies that mentioned the numbers of contaminated MPs, and studies that may have included controls. Articles should include age-matched and sex-matched HCWs and controls. Excluded articles were those articles that missed one or more of the aforementioned inclusion criteria, duplicated studies or those outdated by subsequent ones, and studies that provided insufficient data.

Study selection and data abstraction

From each relevant article, we abstracted the following information: type of the study (meta-analysis or randomized control trials , prospective, retrospective, and systematic review), number of HCWs included, number of control, number of contaminated MPs, and type of organisms cultured.

Statistical analysis

Statistical analysis was done using the jamovi project (2019) (jamovi, version 1.0, Computer Software; retrieved from *https://www.jamovi.org*) and the JASP software, version 0.11.1 (University of Amsterdam, 2013–2019).

Assessment of heterogeneity: studies included in meta-analysis were tested for heterogeneity of the estimates using the following tests:

(1) Cochran Q χ^2 test: a statistically significant test ($P < 0.1$) that denotes the heterogeneity among the studies.
(2) I^2 index, which is interpreted as follows:

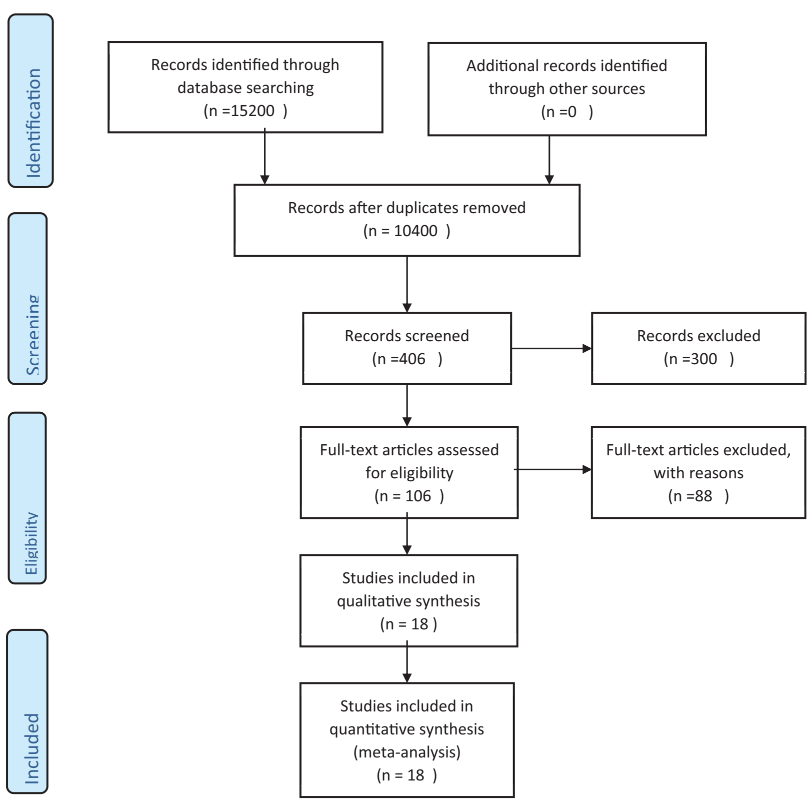

Diagram 1: PRISMA diagram [14–17].

(a) I^2 = 0–40%: unimportant heterogeneity.
(b) I^2 = 30–60%: moderate heterogeneity.
(c) I^2 = 50–90%: substantial heterogeneity.
(d) I^2 = 75–100%: considerable heterogeneity.

Assessment of publication bias: publication bias was assessed by the following:

(1) Examination of funnel plots of the estimated effect size on the horizontal axis versus a measure of study size (SE for the effect size) on the vertical axis. In the presence of publication bias, the plots are asymmetrical.
(2) Begg and Mazumdar rank correlation test for asymmetry of funnel plot.
(3) Egger regression test for asymmetry of funnel plot.

Pooling of estimates: binary outcomes were expressed as proportion and 95% confidence interval (95% CI). Comparison of binary outcomes was done by estimation of the log odds ratio with the 95% CI. Estimates from included studies were pooled using restricted maximum-likelihood random-effects model.

Table 1: Prevalence of mobile phone colonization by specific bacteria among health care workers

Bacteria	Study	Proportion	95% CI	Cochran Q (*P*)	I^2
Aerobic spores	Heyba *et al*. [23]	0.02	0.00-0.04		
	Kumar *et al*. [25]	0.09	0.04-0.15		
	Pooled (RE)	0.05	−0.02-0.13	0.011	84.4%
CoNS	Heyba *et al*. [23]	0.54	0.47-0.61		
	Kumar *et al*. [25]	0.49	0.40-0.59		
	Nwankwo *et al*. [27]	0.40	0.31-0.49		
	Ustun and Cihangiroglu [31]	0.55	0.47-0.62		
	Pooled (RE)	0.50	0.43-0.56	0.050	62.5%
Escherichia coli	Nwankwo *et al*. [27]	0.13	0.07-0.19		
	Ustun and Cihangiroglu [31]	0.11	0.06-0.15		
	Pooled (RE)	0.12	0.08-0.15	0.569	0.0%
Enterobacter	Heyba *et al*. [23]	0.02	0.00-0.04		
	Kumar *et al*. [25]	0.07	0.02-0.11		
	Nwankwo *et al*. [27]	0.30	0.21-0.38		
	Ustun and Cihangiroglu [31]	0.03	0.00-0.05		
	Pooled (RE)	0.10	−0.02-0.22	<0.001	98.2%
Enterobacter faecalis	Heyba *et al*. [23]	0.02	0.00-0.04		
	Kumar *et al*. [25]	0.02	−0.01-0.04		
	Pooled (RE)	0.02	0.01-0.04	0.784	0.0%
Klebsiella	Nwankwo *et al*. [27]	0.11	0.05-0.16		
	Ustun and Cihangiroglu [31]	0.09	0.05-0.13		
	Pooled (RE)	0.10	0.07-0.13	0.689	0.0%
Proteus	Nwankwo *et al*. [27]	0.11	0.05-0.16		
	Ustun and Cihangiroglu [31]	0.07	0.03-0.11		
	Pooled (RE)	0.08	0.05-0.12	0.287	11.7%
Pseudomonas	Heyba *et al*. [23]	0.03	0.01-0.05		
	Kumar *et al*. [25]	0.03	−0.00-0.06		
	Nwankwo *et al*. [27]	0.19	0.12-0.26		
	Ustun and Cihangiroglu [31]	0.05	0.02-0.09		
	Pooled (RE)	0.07	0.00-0.14	<0.001	93.8%
Sphingomonas	Heyba *et al*. [23]	0.02	0.00-0.04		
	Kumar *et al*. [25]	0.03	0.00-0.06		
	Pooled (RE)	0.02	0.01-0.04	0.791	0.0%
Staphylococcus aureus	Heyba *et al*. [23]	0.07	0.04-0.10		
	Kumar *et al*. [25]	0.11	0.05-0.17		
	Nwankwo *et al*. [27]	0.24	0.16-0.31		
	Ustun and Cihangiroglu [31]	0.05	0.02-0.09		
	Pooled (RE)	0.11	0.04-0.19	<0.001	91.0%
Streptococci	Nwankwo *et al*. [27]	0.13	0.07-0.19		
	Ustun and Cihangiroglu [31]	0.02	0.00-0.04		
	Pooled (RE)	0.07	−0.03-0.18	<0.001	90.9%

Prevalence of mobile phone colonization by specific bacteria among health care workers (HCWs) was estimated. CoNS was the most prevalent organisms found in 50% of tested HCWs, followed by *Escherichia coli* 12%, *Staphylococcus aureus* 11%, *Klebsiella* 10%, *Enterobacter* 10%, *Pseudomonas* 7%, aerobic spores 5%, *Enterobacter faecalis* 2%, *Proteus* 8%, *Sphingomonas* 2%, and *Streptococci* 7%. CoNS, coagulase-negative staphylococci; I^2, I-squared statistic; RE, random effects model.

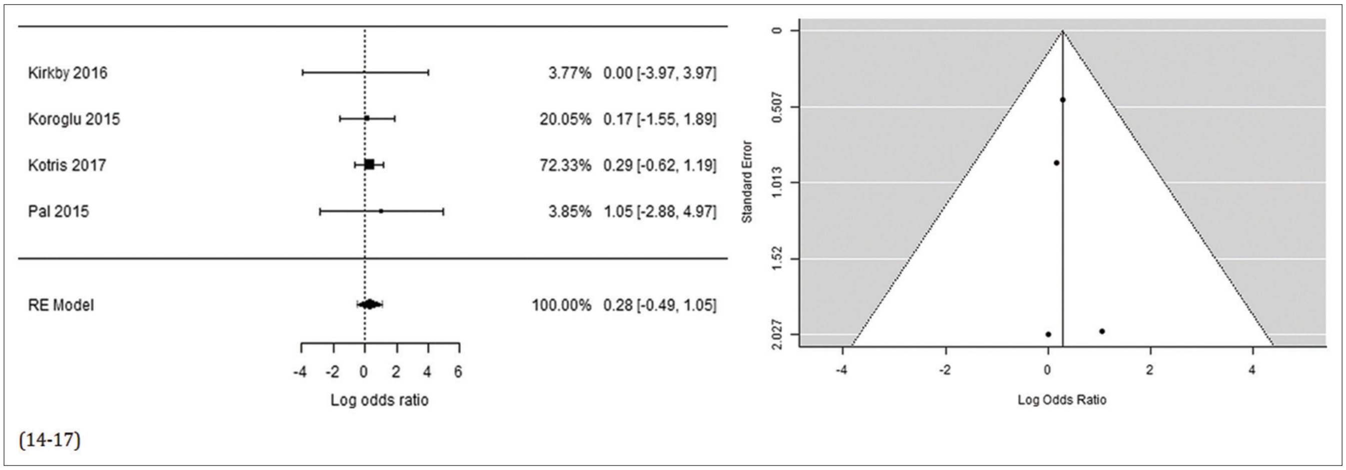

Figure 1: (a) Forest plot for difference between health care workers (HCWs) and non-HCWs as regards bacterial colonization of mobile phones. There is no heterogeneity across included studies (I^2, 0%; Cochran *Q* test' $P = 0.980$). Difference between HCWs and non-HCWs is not statistically significant (random-effects log odds ratio, 0.28; 95% confidence interval, −0.49 to 1.05). (b) Funnel plot for difference between HCWs and non-non-HCWs as regards bacterial colonization of mobile phones. There is no evidence of publication bias (rank correlation test for funnel plot asymmetry $P = 1.000$; regression test for funnel plot asymmetry $P = 0.907$) [14–17].

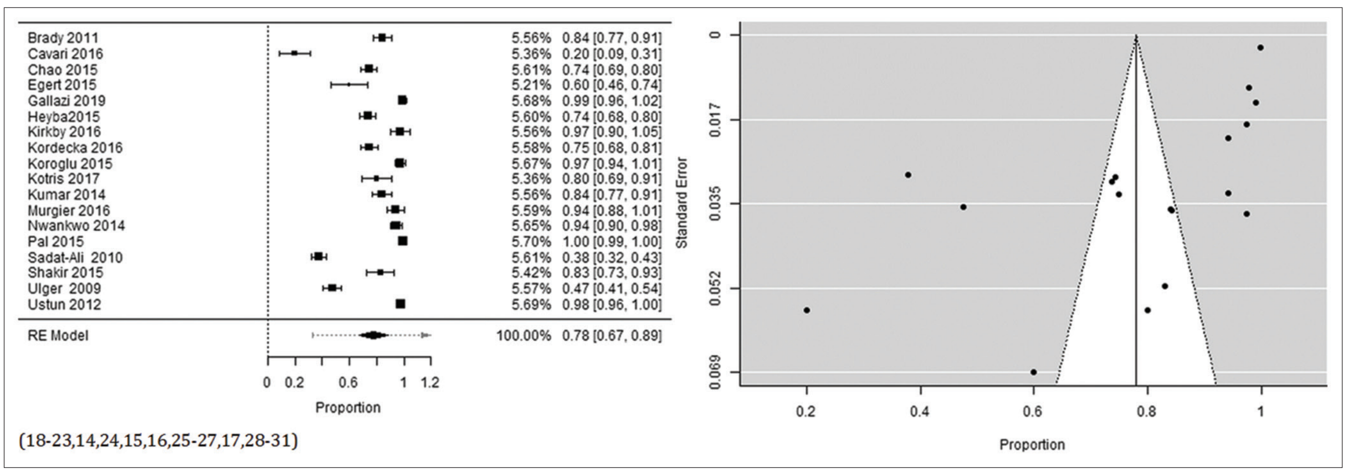

Figure 2: (a) Forest plot for prevalence of bacterial colonization of mobile phones of health care workers (HCWs). There is considerable heterogeneity across included studies (I^2, 99.4%; Cochran *Q* test; $P < 0.001$). Random effects proportion of HCWs with colonized cellular phones is 0.78 (95% CI, 0.67–0.89). (b) Funnel plot for prevalence of bacterial colonization of mobile phones of HCWs. There is possibility of publication bias (rank correlation test for funnel plot asymmetry; $P = 0.131$; regression test for funnel plot asymmetry; $P = 0.009$) [18-23,14,24,15,16,25-27,17,28-31].

Results

Study identification and eligibility

Our search identified 15 200 potentially relevant studies in MEDLINE. Records after duplicate removal were 10 400 articles. Of them, there were 406 potentially eligible studies. We excluded 300 of the 406 studies because they missed one or more of the aforementioned inclusion criteria or were outdated by other more recent ones. Thus, 106 studies remained for possible inclusion and were retrieved in full text version. After reviewing the full article, 88 studies were excluded for the following reasons: some of them were essay studies, whereas others did not mention the organisms or number of contaminated devices. This process left 18 original articles which fulfilled the inclusion criteria, and only four of them contained control group; thus, were included them and used for further analyses (Diagram 1).

Analysis of included articles

Among the 18 included articles, there were no randomized control studies. Only prospective studies were found and used for further analysis (Table 1, Figs. 1a, b, 2a, b, 3a–d).

Discussion

Nowadays, the usage of MPs has increased dramatically worldwide and considered as one of the indispensable accessories. This device has been considered as one of the most important factor that threatens human health, for example, transmitting organisms from one person to another, despite the potential benefits of mobile in facilitating communications [2,14]. This is especially important in health care centers because the constant handling of MPs by HCWs facilitates gathering different types of nosocomial organisms

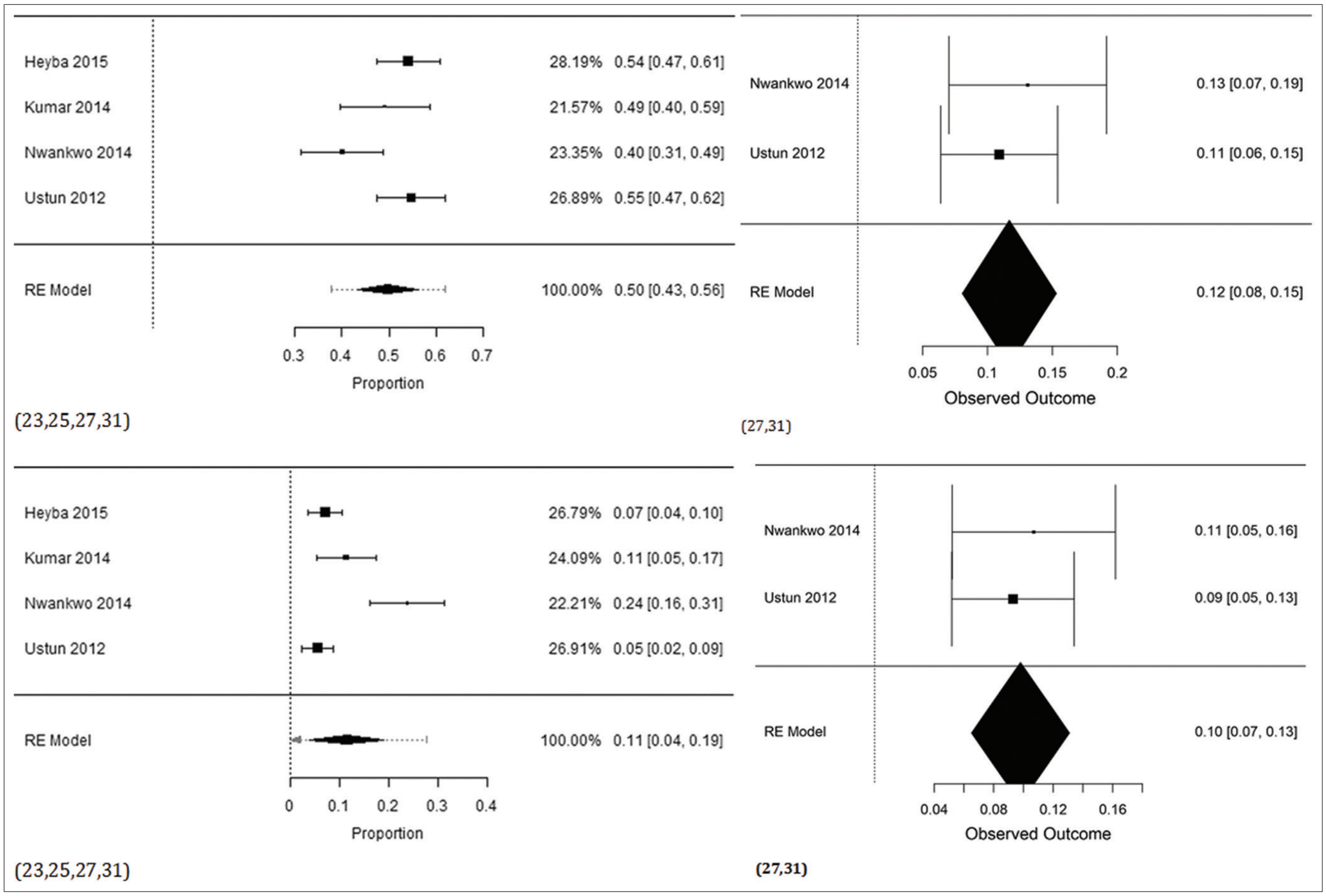

Figure 3: (a) Forest plot for proportion of health care workers (HCWs) with CoNS-colonized mobile phones. There is considerable heterogeneity across included studies (I^2, 62.5%; Cochran *Q* test; $P = 0.050$). Random effects (RE) proportion of HCW with CoNS-colonized mobile phones is 0.50 (95% CI, 0.43–0.56) [23,25,27,31]. (b) Forest plot for proportion of HCWs with *Escherichia coli*-colonized mobile phones. Random effects (RE) proportion of HCWs with *E. coli*-colonized mobile phones is 0.12 (95% CI, 0.08–0.15). There is no heterogeneity across included studies (I^2, 0.0%; Cochran *Q* test; $P = 0.569$) [27,31]. (c) Forest plot for proportion of HCWs with *Staphylococcus aureus*-colonized mobile phones. There is considerable heterogeneity across included studies (I^2, 91.0%; Cochran *Q* test; $P < 0.001$). RE proportion of HCWs with *S. aureus*-colonized cellular phones is 0.11 (95% CI, 0.04–0.19) [23,25,27,31]. (d) Forest plot for proportion of HCWs with *Klebsiella*-colonized mobile phones. RE proportion of HCWs with *Klebsiella*-colonized mobile phones is 0.10 (95% CI, 0.07–0.13). There is no heterogeneity across included studies (I^2, 0.0%; Cochran *Q* test; $P = 0.689$). [27,31].

that can be a source for transmission of these infections [15]. Furthermore, colonization of pathogenic organisms on phones may lead to the rise of antibiotic resistance. Despite the highest hygienic standards in hospital wards, bacterial transmission to the patients by the contaminated hands of HCWs commonly occurs [16].

In this meta-analysis, we aimed to investigate the potential hazards of infection transmission by using MPs among HCWs in health care settings.

A total of 18 articles were eligible to this study, and 2300 HCWs were included in all studies. Overall, 78% of HCWs' MPs were found to be contaminated by various types of organisms (Fig. 2a and b). This was in accordance with Murgier *et al*. [26], who took samples from 52 MPs of hospital staff entering the operating room of a university hospital center orthopedic surgery department. They found 94% of their MPs were contaminated. Moreover, Morvai and Szabó [32] in their systematic review on the potential role of MPs in the dissemination of pathogens found a high rate of contamination (40–100%). Shakir *et al*. [29] sought to document the frequency of bacterial contamination on the MPs of orthopedic surgeons in the operating room. Of 53 MPs enrolled in their study, 83% had pathogenic bacteria. Heyba *et al*. [23] studied the prevalence of microbiological contamination of MPs that belong to clinicians in ICUs, pediatric ICU, and neonatal intensive care units (NICUs). Of 213 MPs, 73.7% were colonized. Moreover, Pal *et al*. [17] stated that the MPs and hands of HCWs showed a high contamination rate (81.8 and 80%, respectively) with bacteria and also with nosocomial pathogens.

However, Manning *et al*. [4] stated that there is no evidence of a direct link between environmental pathogens on MPs and the rate of hospital acquired infection. Similarly, Kumar *et al*. [25] noted that no risk has been reported for the transmission of pathogens to patients through noncritical items such as MPs which do not contact mucous membranes and/or nonintact skin. However, they mentioned that several studies have also reported antibiotic-resistant hospital strains, such as *Staphylococcus epidermidis*, *S. aureus*, *Enterococcus*, and *Pseudomonas* species, which are common health care-associated pathogens. They added that educating HCWs and patients about infection control and stressing individual responsibility of infection control is an important aspect of controlling nosocomial infections. Contaminated MPs may act as fomites because most people carry MPs along with them to places such as hospitals, toilets, and kitchens where microorganisms thrive. This study indicates that unreported antibiotic-resistant bacterial contaminants of MPs of patients may be a matter of great concern.

For that, Manning *et al.* [4] emphasized that 'it is imperative that infection prevention and control programs be actively engaged in providing HCWs guidance and education in how to mitigate the risk of bacterial contamination of their MPs. Programs also have an important role in working together with health care providers to establish and implement organizational MPs policies and procedures.'

In their review, Brady *et al.* [18] stated, innovation in mobile communication technology has provided novel approaches to the delivery of health care and improvements in the speed and quality of routine medical communication. Bacterial contamination of MPs could be an important issue affecting the implementation of effective infection control measures and might affect the efforts to reduce cross-contamination. This review examines the recent studies reporting bacterial contamination of MPs, most demonstrating that 9–25% of MPs are contaminated with pathogenic bacteria.

In this review, we found that only four studies included a control arm. Analysis of the forest plot for difference between HCWs and non-HCWs regarding bacterial colonization of mobiles phones showed no heterogeneity across included studies (I^2, 0%; Cochran Q test; $P = 0.980$). Difference between HCWs and non-HCWs is not statistically significant (random-effects log odds ratio, 0.28; 95% CI, −0.49 to 1.05) (Fig. 1a and b). This collaborates with the results of other studies. Kotris *et al*. [16] found no statistically significant difference between the number of isolated bacteria between the HCWs and students' MPs. Moreover, Kirkby and Biggs [14] explained that the use of MPs by both family and staff introduces unwanted bacteria into the NICU environment, thereby becoming a threat to this high-risk population. The phones of 18 NICU parents and staff were sampled for bacteria before and after cleaning with disinfectant wipes. Microbial surface contamination was evident on every phone tested before disinfecting, which means no statistically significant difference was found between parents of patients (control) and HCWs.

The prevalence of MP colonization by specific bacteria among HCWs was estimated. Coagulase-negative staphylococci (CoNS) were the most prevalent organisms found in 50% of tested HCWs, followed by *Escherichia coli* (12%), *S. aureus* (11%), *Klebsiella* (10%), *Enterobacter* (10%), *Proteus* (8%), *Pseudomonas* (7%), *Streptococci* (7%), aerobic spores (5%), *Enterobacter faecalis* (2%), and *Sphingomonas* (2%) (Table 1 and Fig. 3a–d).

This results were in accordance with, Kotris *et al.* [16] who stated that, the most common isolated microorganisms in his study were CoNS and *S. aureus*. Morvai and Szabó [32], also stated that, CoNS and *S. aureus* were the most commonly identified bacteria and most of them were methicillin resistant (10–95.3%). Heyba *et al.* [23] found that, CoNS followed by *Micrococcus* were predominantly isolated from the MPs; methicillin-resistant *S. aureus* and Gram-negative bacteria were identified in 1.4 and 7% of the MPs, respectively. Ulger *et al.* [30] showed in their systematic review that, 19 (48.7%) identified CoNS, and 26 (66.7%) identified *S. aureus*. Pal *et al.* [17] found that, the most predominant isolates were CoNS, *S. aureus*, *Acinetobacter* species, *E. coli*, *Klebsiella* pneumoniae, *Pseudomonas* species and *Enterococcus* species.

In their study, Kumar *et al.* [25] found that 83.9% out of 106 patient MPs were found to be contaminated with bacteria. 49.0% CoNS, 11.3% *S. aureus*, 6.6% *Enterobacter cloacae*, 2.83% *Pseudomonas stutzeri*, 2.83% *Sphingomonas paucimobilis*, 1.8% *E. faecalis*, and 9.4% aerobic spore were isolated. All the isolated bacteria were found to be resistant to various antibiotics.

Other studies showed different categorization of bacteria. As Nwankwo *et al.* [27] who found that the rate of bacterial contamination of MPs was 94.6%, and that *S. epidermidis* was the most frequently isolated bacteria 42.9% followed by *Bacillus* species 32%, *S. aureus* 25%, *Pseudomonas aeruginosa* 19.6%, *E. coli* 14.3%, *Streptococcus* spp. 14.3%, *Proteus* spp. 12.5%, *Klebsiella* spp. 7%, and *Acinetobacter* spp. 5.3%.

Ustun and Cihangiroglu [31], stated that, the most common pathogen was 11.2% ESBL-producing *E. coli* and 9.5% methicillin-resistant *S. aureus*.

In the study by Sadat-Ali *et al.* [28], and Ulger *et al.* [30] cultured bacteria from MPs found that most common pathogen was, *S. aureus* strains isolated from 52% of phones and those cultured .

However, Chao Foong *et al.* [20] screened 226 staff members (146 doctors and 80 medical students) between January 2013 and March 2014, found that, most of the isolated organisms were normal skin flora, a small percentage were potentially pathogenic 5%. Also, Egert *et al.* [21] sampled 60 touch screens of smart phones. 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. Astonishelly Mark *et al.* [33] swabed 50 MPs 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 percent of phones had only three colonies or less isolated on medium. No pathogenic or drug resistant strains of bacteria were identified.

From this study we stated that, multiple investigators have shown that HCWs MPs 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 MPs without concurrently providing appropriate protocols on decontamination, especially at the point of acute care.

Solutions to the challenge of contaminated MPs; Mathew *et al.* [34] acknowledge the conundrum inherent in cleaning MPs: 'Wipes moistened with alcohol or bleach are effective in reducing levels of pathogenic bacterial load on MPs, and wipes moistened with saline or water may be similarly effective because of mechanical removal. However, several studies have demonstrated that most health care personnel do not regularly clean their phones. Moreover, device manufacturers discourage wiping of MPs 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 health care industry a number of enclosed ultraviolet-C radiation devices designed to decontaminate fomites such as MPs without damaging the integrity of touch screens or other components. For example, Mathew *et al.* [34] demonstrated that an enclosed ultraviolet-C radiation device was effective in rapidly reducing methicillin-resistant *S. aureus*, and with longer exposure times, *Clostridium difficile* spores, on glass slides and reducing contamination on in-use mobile handheld devices.

Application of the following elements: a waterproof/resistant, nonporous, hard or soft case for the MPs – disinfection of the MPs before and after patient/family interface with an approved disinfectant as per facility policy for noncritical items. Set alarm on the MPs to remind user to disinfect regularly in addition to the before and after patient/family interface disinfection (e.g. daily, hourly). Hand hygiene as per facility policy for patient interaction and after disinfecting the MPs.

The limitations of our study were absence of randomized control studies and most of the study have no control group. So, we recommend multicenter prospective randomized double blind controlled trials comprising larger numbers of HCWs compared with non-HCWs.

Conclusion

Mobiles contamination with different pathogens is extremely common among health care staffs, and resistant of these isolates to various antibiotics is also detectable. The high level of contamination indicates that the mobile device of these professionals may be serving as a reservoir and vehicle in the transmission of pathogenic agents both of hospital origin as community. To ensure that there is a reduction in the potential of the risks that these microorganisms can offer, it is necessary to the implementation of correct methods of disinfection of hands and own MP.

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Conflicts of interest

There are no conflicts of interest.

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