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Are mobile phones of health care workers portals of pathogenic organisms causing hospital acquired infections in intensive care units? A mini systematic review

DOI:<http://dx.doi.org/10.4314/njp.v47i3.3>

Accepted: 17th April 2020

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Abstract: *Background:* Health care workers at the bedside of critically ill babies freely carry their mobile phones in between procedures and handling patients. Concerns are rising as this may contribute to nosocomial infections with pathogenic bacteria.

Aim: To determine if mobile phones of health care workers in Intensive care units carry potentially pathogenic bacteria leading to hospital acquired infections.

Design: Systematic review.

Data sources: Electronic databases (Medline via ovid, CINAHL, Web of science) and hand searching of references and citations were done to identify studies. Screening and inclusion criteria were used to identify studies with a cross-sectional or cohort design. The search was limited to journal articles published between 2008-2015 and to English language. Quality assessment was done using the National Institute of Health tool for observational studies. Data was extracted on to excel sheets and analysed using SPSS version 22.

Results: Six studies with a cohort (1) or cross-sectional design (5)

involving 1, 131 health care workers were reviewed. The overall quality of the studies was fair, and a narrative synthesis was done.

The colonization rate of the mobile phones ranged between 46.3 % and a 100% with 13-50% carrying potentially pathogenic multidrug resistant microorganisms. Methicillin resistant staphylococcus aureus, Vancomycin resistant enterococci, acinobacter and coagulase negative staphylococci were reported across all studies and were recognized as leading causes of morbidity and mortality in the ICU.

Conclusion: Mobile phones Of HCW are portals of potentially pathogenic microorganisms, which could result in morbidity and mortality. Although no causal relationship could be established, strong associations have been reported. Guidelines by hospital infection control committees are needed on restriction, care and routine cleaning of mobile phones as well as further research.

Key words: Health care worker, Intensive care unit, Hospital Acquired Infections, mobile phones

Introduction

Hospital acquired infections (HAI) are a leading cause of morbidity and mortality globally especially in intensive care units.¹ They affect more than 25% of admitted patients in low and middle-income countries.² In 2002, the Centre for Disease Control reported about 1.7 million HAI's in US hospitals leading to about 99,000 deaths.³ The source is often cross-infection from health-care workers, patients, general surfaces and devices such as mobile phones (MP)

Mobile communication devices have become an indispensable accessory of professional and social life. The MP enables fast communication, use of applications,

and spread of medical information. As such, health care workers (HCW) handle it several times a day with the risk of transferring multi drug resistant microorganisms from patients, equipment and surfaces onto their hands and phones.

Hand hygiene with alcohol rub greatly reduces bacterial load on hands and phones, but mobile phones are more cumbersome to clean and HCW may not make the effort to clean them.⁴ Aronson⁵ was the first to report the infection potential of phones in 1977, and Borer⁶ in 2005 published a report on the risks of infection associated with mobile phones in intensive care units (ICU). Since then several reports have been written using different

methodologies, diverse sampling and analysis methods and in different settings. It is however, difficult to draw conclusions and establish clear guidelines from these individual studies. This systematic review aims to review newer studies done since the review published by Brady⁷ in order to synthesize their findings and draw conclusions and recommendations towards preventing HAI's.

Objective

To identify and report common findings of studies done between 2008-2015 investigating the role of mobile phones of ICU health workers as portals of pathogenic organisms and the risk of hospital acquired infections.

Selection criteria

The review protocol is attached as Appendix 1.

Study design: Observational studies with a cohort or cross-sectional design were identified.

Participants: Health care workers who used MP and worked in intensive care units such as neonatal, paediatric or adult intensive care units, dialysis units, burns units and operating rooms.

Intervention: The intervention was the use of a MP at work. This could be either a smart touch screen phone or a keypad phone.

Comparator: There was no comparator.

Outcome

The outcome measures were detection of potentially pathogenic microorganisms causing HAI, morbidity and mortality. A secondary outcome measure was the proportion of HCW that clean their phones at least weekly.

Methods of review

Search Strategy

A comprehensive literature search was done in April 2016 on electronic databases: Medline via Ovid, CINAHL and Web of science. These databases are recognised for publishing medical and nursing research. Free text and thesaurus terms and Mesh headings used included *cell phone OR mobile phone, nosocomial infection OR, Hospital-acquired infection OR cross infection; Intensive care unit, operating room; morbidity or mortality and health care personnel*. These were combined using Boolean words AND/OR, truncations * \$ or wild cards? #. Subject headings were exploded and free text searching was also done. See Appendix 2

Google scholar and star plus were used for scoping search and to follow citations to articles. Reference lists of identified studies were reviewed to identify any unlisted studies. Letters to editors, meeting abstracts and conference proceedings were also used. Authors could however not be contacted, unpublished data, on-going and in press studies and hand searching of important journals such as journal of infection control could not be

done due to time constrains. The search was limited to articles published or at least with an abstract in English language only. This is because this is a mini review that requires few final articles because of time limitations. A time limit was applied to 2008-2015 to identify articles since the last review by Brady et al.⁷

The studies that met the search criteria were identified and searches saved on the various electronic databases for retrieval later. Citation searches as well as manual searches of retrieved references were also done. Mendeley was used to save citations for easy referencing and to retrieve the PDF files when required. The retrieved PDFs were stored in a folder on Google drive. Systematic review management software such as review manager, Eppi reviewer or distiller SR could also be used. The author reviewed the available abstracts, those that met the inclusion criteria were further selected and the full articles retrieved. Table 1 shows the inclusion and exclusion criteria.

Table 1: Inclusion and Exclusion criteria

Selection criteria	Inclusion	Exclusion
Study design	Cohort or cross-sectional	Systematic reviews, case control studies and randomized controlled trials
Population	Health care workers in ICUs Adults.	Non-healthcare workers Patients Veterinary Healthcare workers
Intervention	Mobile phone	Other mobile communication devices such as pagers, I pads, personal digital assistants, PC keyboards and fixed telephones.
Comparator	None	None
Outcome	Hospital acquired infections Morbidity or Mortality	Studies using other outcomes
Language	English Language	All non-English articles.

Ideally, screening, determining eligibility and inclusion should be done by two or more independent reviewers to avoid or reduce bias. All involved reviewers should confirm the obtained data and if differences arise, they should be resolved by consensus. Should there still be differences, a third reviewer should be involved. This could not be done in this review due to the limited time available and the assignment requires one person to do the review. All excluded studies that appear to meet the inclusion criteria but on further investigation did not, will be presented in a table with reasons for exclusion in the Appendix 3.

Quality Assessment

The reviewer used the quality assessment tool for observational cohort studies and cross-sectional studies for systematic reviews developed by the National Institute of Health.⁸ Fourteen criteria were assessed and answered with either a yes, no, not applicable, not reported or can-

not determine option. This checklist is presented on Table 3.

Data Extraction

In this mini review, the reviewer extracted the data using a pre-determined form based on a previous study with some adaptation on Excel sheet. The form was designed based on the study design, the population characteristic and setting, exposure to mobile phones (intervention), outcome and results. A total of 5 cross-sectional and 1 cohort studies were extracted in which the current exposure to use of mobile phones was established amongst health care workers in intensive care units and subsequently outcomes were identified within the time of follow up. See Appendix 4 for Data Extraction sheet. Ideally a second reviewer should crosscheck the data extracted, but this could not be done because of the limited time.

Assessing bias

Cross-sectional studies have the advantages of providing prevalence of risk factors and disease in a defined population, being relatively easy to carry out, and therefore can be useful when planning health services. Repeated studies can also monitor changes over time. However, they are prone to sampling, recall and non-response bias.⁹

Risk of sampling and selection bias were evaluated both at study level and at outcome level by identifying the justification for the sample size used, the selection of participants from the same or different populations and the response rate. The use of blinding between those collecting samples and those processing was also assessed as observer bias can be introduced. The potential for these biases will be evaluated during synthesis.

Assessment of heterogeneity

Assessment was done for clinical and methodological heterogeneity. Comparing the distribution of the study participants and study setting assessed clinical heterogeneity. Methodological heterogeneity was assessed by the mobile phone sampling method, laboratory method of analysis, blinding of outcome assessment, and loss to follow up. Statistical heterogeneity was difficult to assess because a number of the studies did not have comparable statistics. However if this had been possible,

forest plots would have been generated and a Chi² test I² statistic done. If the P value is less than 0.10 and I² exceeds 50%-75% and visual inspection of forest plot is indicative, then heterogeneity would be moderate to high and reasons would have been evaluated.

Data synthesis

The demographic characteristics and results of the studies are presented in Table 4. Across the included studies the most common bacterial isolates were presented as percentages of microorganisms found. Many of the studies did not use inferential statistics and the groups and subgroups lacked similarity to allow a statistical meta-analysis. As such, this review did not conduct a meta-analysis of the studies identified rather a narrative synthesis of the data was done. Sub group and sensitivity analyses were not done. Graphs were generated on SPSS version 22.

Results

Description of studies

Study selection

The search identified 90 papers and reports. The PRISMA diagram¹⁵ in Figure 1 shows the process of identification, screening, eligibility and inclusion. Duplicates of the same article obtained from different databases searched were identified and removed. Other articles were excluded either because of study design, a different population of interest, or use of other mobile communication devices such as pagers, I pads etc, or they had different study outcomes.

Study Design

Six studies, one cohort¹⁰ and 5 cross-sectional¹¹⁻¹⁵ from different journals met the inclusion criteria. The studies were published between 2009 and 2015 and conducted over 6 weeks to 6 months. They all involved health care workers in intensive care units of teaching hospitals that gave oral consent for participation. The mobile phones and hands of HCW were sampled in 3 studies while only mobile phones were sampled in the other 3 studies although one of them compared a keypad phone and a touch screen phone.

Fig 1: PRISMA Flow Diagram

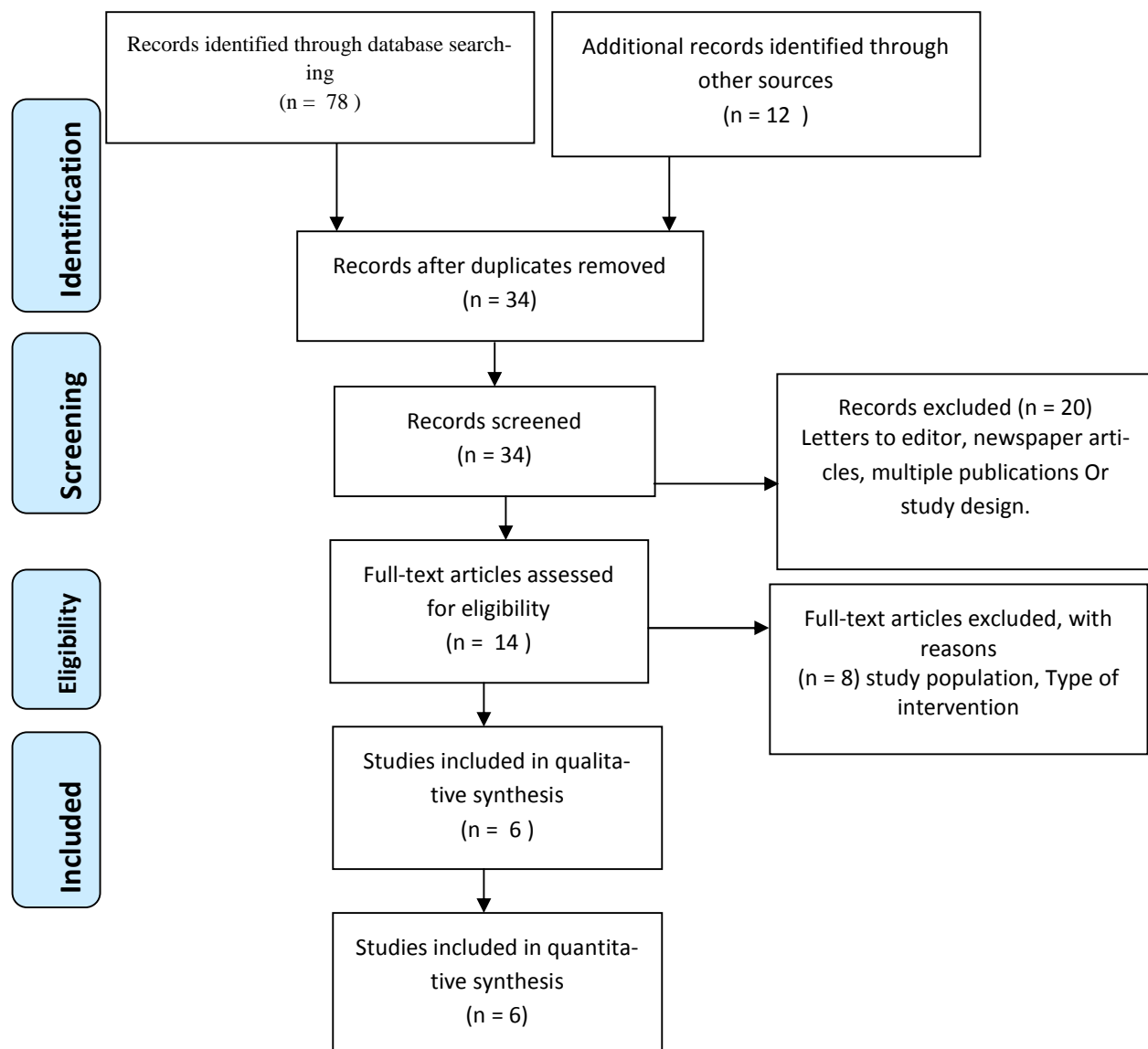


Table 2: study selection

Study/ duration	Study design	Population	Intervention	Comparator	Outcome
Shekar <i>et al.</i>	Cohort	Doctors Nurses Medical students Public	MP and dominant hand of HCW	MP and dominant hand of Public	HAI Isolated organisms
Sadat <i>et al.</i>	Cross-sectional	Doctors Nurses	MP of HCW	None	HAI Isolated organisms
Heba <i>et al.</i>	Cross-sectional	Doctors Nurses Lab technicians Other HCW	MP of HCW	None	HAI Isolated organisms
Ulger <i>et al.</i>	Cross-sectional	Senior Doctors Resident doctors 79 Nurses Other HCW	MP and hand of HCW	None	HAI Isolated organisms
Pallavi <i>et al.</i>	Cross-sectional	Senior doctors Resident doctors Nurses	Key pad MP of HCW	Touch screen MP of HCW	HAI Isolated organisms
Sepehri <i>et al.</i>	Cross-sectional	Doctors Nurses Nurse aids Medical students	MP and dominant hand of HCW	None	HAI Isolated organisms

Quality Assessment

Using the quality assessment tool for observational cohort studies and cross-sectional studies for systematic reviews developed by the National Institute of Health⁸ fourteen criteria were assessed.

All studies had a clear objective, a defined population with recruitment among similar populations and follow up rates greater than 80%. The diagnostic methods for bacterial isolation were also similar across studies and involved swabbing or direct plating of the mobile phones or hands on to blood agar, eosin methylene blue

agar or Mcconkey agar for aerobic and anaerobic cultures. Disk and double disk diffusion methods were used to identify resistant microorganisms. However a weakness identified in five of the studies^{1,10-14} was failure to justify how they arrived at their sample size. Two (33%) of the studies^{10,13} blinded the research team as they had separate teams for collection and processing of samples. Five studies^{1,10-12,14} did not report if they received any funding or not. Overall, the quality of the included studies was rated as fair as shown on Table 3.

Table 3: Quality assessment tool for observational cohort and cross-sectional studies

Criteria	Studies					
	Shekar	Sadat	Heba	Ulger	Sepehri	Pallavi
1. Was the research question or objective in this paper clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the study population clearly specified and defined?	Yes	Yes	Yes	Yes	Yes	Yes
3. Was the participation rate of eligible persons at least 50%?	Yes	Yes	Yes	Yes	Yes	Yes
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Yes	Yes	Yes	Yes	Yes	Yes
5. Was a sample size justification, power description, or variance and effect estimates provided?	No	No	Yes	No	No	No
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Yes	Yes	Yes	Yes	Yes	Yes
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	Yes	Yes	Yes	Yes	Yes	Yes
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	N/A	N/A	N/A	N/A	N/A	N/A
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Yes	Yes	Yes	Yes	Yes	Yes
10. Was the exposure(s) assessed more than once over time?	N/A	N/A	N/A	N/A	N/A	N/A
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Yes	Yes	Yes	Yes	Yes	Yes
12. Were the outcome assessors blinded to the exposure status of participants?	NR	NR	NR	NR	NR	Yes
13. Was loss to follow-up after baseline 20% or less?	Yes	Yes	Yes	Yes	Yes	Yes
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	N/A	N/A	N/A	N/A	N/A	N/A

Quality Rating (Good, Fair, or Poor) (see guidance)

Rater #1 initials: MM Fair

Rater #2 initials:

Additional Comments (If POOR, please state why):

N/A- Not applicable

NR-Not reported

Participants

A total of 1,131 HCW of diverse ages including doctors, nurses, nurse assistants and lab technologists that worked in ICUs, of teaching hospitals across different countries were involved.

Intervention

About 98-100% of the HCW reported using their mobile

phones for different functions while at work.

Comparator

The cohort study sampled mobile phones and the hands of 100 people from the community to compare findings with those amongst health care workers. They reported that the HCW hands and phones were twice as contaminated as those of the public and HCW carried multi-resistant organisms.

Outcome

Most of the studies considered relationships between gender, age, type of healthcare worker, duration of ownership of cell phone and the type of telephone used with

bacterial colonization; however no significant relationship was found in majority of studies. Some studies^{1,12} however, reported that doctor's phones were more contaminated compared to nurses $P < 0.04$ and keypad phones had higher colonies of bacteria compared to touch phones¹³ F statistics 14.13 $P < 0.001$. Table 4 describes the main findings from studies.

Table 4: Main findings across studies					
Study/Design/year	Country/setting	Sample size	Phone colonization (%)	Main Findings N (%)	HCW clean phone once a week (%)
Shekar <i>et al.</i> Cohort 2015	India TH	386	316 (82.0)	Total isolates 664 CONS 255(39.5) MSSA 186(28.0) MSRA 16(2.5) Acinobacter 82 (12.3)	3.0
Sadat <i>et al.</i> Cross-sectional 2010	Saudi Arabia TH	288	109 (43.6)	Total isolates 109 MSSA 36 (33.1) MRSA8 (7.30) E Coli 14(12.8) Acinobacter 10 (9.1)	12.4
Heba <i>et al.</i> Cross-sectional 2014	Egypt TH	40	40 (100)	Total Isolates 307 MRSA 21 (52.5) CONS 20 (50.0) Bacillus SPP. 17 (42.5) Diphtheroids 12 (30.0) MSSA 7 (17.5)	74.0
Ulger <i>et al.</i> Cross-sectional 2012	Turkey TH	200	190 (95)	Total Isolates 307 Staph aureus 50 (16.3) {MSSA (48%) MRSA (52.0%)} CONS 181 (59) Strept. Spp. 12(3.9) Moulds 20(6.5)	10.5
Pallavi <i>et al.</i> Cross-sectional 2013	United Kingdom TH	67	52 (77)	Total isolates Not stated MRSA or VRE 9(13%) Others	N/A
Sepehri <i>et al.</i> Cross-sectional 2009	Iran 3TH	150	150(100)	Total isolates 159 Staph epidermidis 37 (77.1) Staph aureus 6(12.5) Klebsiella pneumonie 1(2.1) Yeasts 5(10.4)	N/A

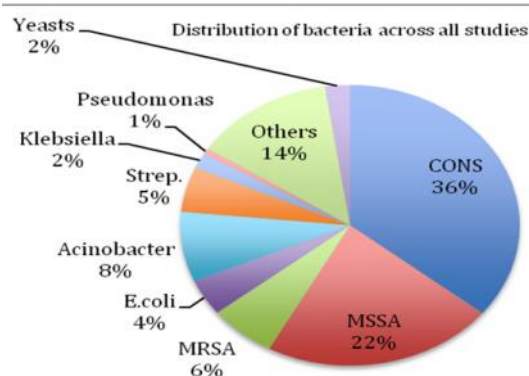
TH- Teaching Hospital, CONS- Coagulase negative staph aureus, MSSA- Methicillin sensitive staphylococcus aureus, MRSA- Methicillin resistant staphylococcus aureus, VRE- vancomycin resistant enterococci. N/A not available

The colonization rate of the mobile phones ranged between 46.3% to 100%. In about 83% of the studies that had isolates, multiple microorganisms were grown while 17% isolated a single organism. Between 13-50% of the mobile phones of HCW carried potentially pathogenic microorganisms with a large number of these being multidrug resistant. Methicillin resistant staphylococcus aureus (MRSA), Vancomycin resistant enterococci (VRE), acinobacter and coagulase negative staphylococci (CONS) were reported across all studies and were recognized as leading causes of morbidity and mortality in the ICU. One study¹⁰ reported that keypad phones had a higher probability of growing multidrug resistant organisms compared to touch screens. $P < 0.01$.

Some studies^{10,12, 14} sampled both the mobile phones and hands of HCW hands, and the microbial yield and distribution amongst HCW were not too different and considered statistical insignificant $P < 0.49$. About 67% of the

studies enquired if HCW cleaned their phones at least once a week and those that responded in the affirmative ranged from 3-74.0%. Despite these claims, when their phones were swabbed 41-72% of them cultured microorganisms many of which were pathogenic

Fig 2: The distribution of bacterial isolates across all studies



Discussion

The primary objective of this review was to determine and synthesize findings from various studies on contamination of HCWs mobile phones with potentially pathogenic organisms causing HAIs leading to increased morbidity and mortality. All included studies isolated several microorganisms from phones of HCW in ICUs. Some were considered as skin commensals getting on to phones via handling, while a significant number were potentially pathogenic organisms.

Bacteria strongly associated with HAIs such as MRSA, *acinetobacter spp.*, *pseudomonas spp.* and *klebsiella spp.* were frequently reported^{1,10-14} Although, none of the studies could establish a causal relationship between the isolated organisms and increased mortality, some of the identified pathogenic organisms were multi drug resistant and known causes of invasive HAIs leading to prolonged hospital stay and even death.^{5,6} Virjens³ reported that HAIs resulted in additional stay of 9.9 days and cost of 4900 euro per patient.

The most common gram-positive bacteria identified were CONS, MSSA, MRSA, *Staphylococcus aureus* and *streptococcus Spp.* *Staphylococcus aureus* is known to cause skin sepsis, bone infections and pneumonia in immune competent persons while CONS could cause sepsis, and urinary tract infection in immune-compromised patients such as newborns and patients on dialysis. On the other hand, the most common gram-negative organisms included *acinetobacter spp.* *E. coli*, *klebsiella* and *pseudomonas aeruginosa*. These are known to cause meningitis, wound dehiscence and pneumonia especially in ICU patients.

The secondary outcome revealed that a significant number of HCW did not clean their phones at least once a week and even among those that claim they do, 41-72% of their devices grew microorganisms many of which were pathogenic. This raises questions about levels of hand hygiene, cleaning technique, solutions used, frequency and the risk of cross infection. HCW phones could be reservoirs for microorganism that cause HAI because they provide the ideal breeding ground by providing the warm temperature and humidity needed for survival.

In a review by Brady,⁷ 9-25% of Mobile communication devices were contaminated with *pathogenic bacteria*. Several studies^{1,6,10-14} have reported variable rates of contamination between 16-100%. Importantly, three of the studies evaluated hands and phones of HCWs and found that the flora are not too different. This highlights the significance of hand hygiene in preventing cross infection.

A study¹³ focussed on the type of mobile phone used and found that keypad phones were more likely to harbour pathogenic organisms compared to touch screens. Similar findings were reported in other studies and may not be unrelated to access to cleaning surface.^{18,19}

Discussions and recommendations from the studies ranged across various subjects such as staff education in

infection control, strict hand hygiene before and after the use of phones and restriction on use of mobile phones in critical areas.^{1,4,10,14} Others discussed on the need for adequate decontamination of phones to reduce cross infection.¹¹⁻¹³ Studies^{1,10-12} have consistently reported high numbers of HCW who do not clean their phones and studies reporting the usefulness of decontamination outweighed those that did not. Cleaning with chlorhexidine and 70% isopropyl alcohol wipes is reported as most efficacious.¹⁶ Other recommendations included the development of guidelines for HCW on how to reduce the risk of contamination of their mobile phones. Authors pointed out that unfortunately manufactures have failed to provide guidelines on how to decontaminate phones as they have done for other health care products.¹⁷

Strengths and weaknesses of the review

The studies reviewed were of mixed quality and rated of fair quality. They were homogenous in terms of design and clinical characteristics. Statistical heterogeneity was difficult to assess because a number of the studies did not have comparable statistics as such a Meta analysis could not be done. However the findings across all studies were similar and thus can be generalized because they involved screening of mobile phones and or hands of health care workers from different settings using variable sample sizes and having a common outcome.

This review made maximum use of available resources within the limits allowed, however many more studies could have been included if it was not a mini-review and the literature search extended to more data bases and less limited in terms of language, grey literature and years. Additionally, two or more reviewers should have been used to identify, screen and include studies to reduce bias. Furthermore, the quality assessment of studies ideally should be by independent reviewers and differences arising would have been resolved by consensus.

Implications for practice

Mobile phones have become indispensable, but clearly, there is sufficient evidence to point to them as portals of potentially pathogenic organisms in hospitals. The resultant risk could be to the patient, HCW or beyond. Guidelines by hospital infection control committees are needed on restriction, care and routine cleaning of mobile phones. They should be limited to emergency calls only and periodic surveillance should be done. There is a need to reinforce hand hygiene practice, provide chlorhexidine- isopropyl wipes for routine cleaning of phones and staff education to reduce cross infection.

Implications for research

There is a need for more research that could provide a causal relationship by using molecular tests to determine similarities between isolated organisms on HCW phones and those from patients with HAI.

Further research could be done on the use of antibacterial phone covers such as those made of metals or using

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