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Research Article

Microbiological colonization of healthcare workers' mobile phones in a tertiary-level Italian intensive care unit

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ABSTRACT

Background: Careful hand hygiene of healthcare workers is recommended to reduce transmission of pathogenic microorganisms to patients. Mobile phones are commonly used during work shifts and may act as vehicles of pathogens.
Objective: To assess the colonizsation rate of intensive care unit healthcare workers' mobile phones before and after work shifts.
Methods: Prospective observational study conducted in an academic, tertiary-level intensive care unit. Healthcare workers (including doctors, nurses and healthcare assistants) had their mobile phones sampled for microbiology before and after work shifts. Samples were taken with a swab in a standardizsed modality.
Results: Fifty healthcare workers participated in the study (91% of the department staff). One hundred swabs were taken from 50 mobile phones. Forty-three healthcare workers (86%) reported a habitual use of their phones during the work shift. All phones (100%) were positive for bacteria. The most frequently isolated bacteria were Coagulase Negative Staphylococci, *Bacillus* sp. and Methicillin-resistant Staphylococcus aureus (97%, 56%, 17%, respectively). No patient admitted to the intensive care unit during the study period was positive for bacteria found on healthcare workers' mobile phones. No difference in bacteria types and burden was found between the beginning and the end of work shifts.
Conclusion: Healthcare workers' mobile phones are colonized even before the work shift and irrespective of the patients' microbiological flora.

Implications for clinical practice

- All intensive care unit healthcare workers' mobile phones are colonized by microorganisms, included potential pathogenic ones.
- The microbiological colonization of intensive care unit healthcare workers' mobile phones doesn't depend on the inpatients' microbiological flora.
- The healthcare workers' mobile phones colonization doesn't significantly change from the beginning to the end of the work shift.

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Introduction

Mobile phones have become indispensable in our society, and they are used extensively in hospital settings (Heyba et al., 2015; Kotris et al., 2017). The use of mobile phones can improve the quality of health care, allowing faster communication especially in emergency situations (Kotris et al., 2017; Ulger et al., 2009). However, in spite of all the potential benefits, mobile phones may also play an important role in microorganism transmission (Ulger et al., 2009), since healthcare workers (HCWs) commonly handle their phones irrespective of the cleanliness of their hands and rarely disinfect them (Heyba et al., 2015; Juyal et al., 2015). For this reason, mobile phones may become potential reservoirs of several microorganisms (Christensen and Brüggemann, 2014; Elkholy and Ewees, 2010; Kotris et al., 2017; Smibert et al., 2018).

Different kinds of microorganisms can be isolated from the surface of mobile phones (Heyba et al., 2015; Kotris et al., 2017; Michelow et al., 2004). In some cases, those microorganisms belong to the normal skin flora, but isolation of pathogens causing nosocomial infections has also been reported (Jayalakshmi et al., 2008; Magill et al., 2014; Revelas, 2012). Nosocomial infections are continuously increasing and they affect morbidity, mortality and hospital-associated costs (Goldblatt et al., 2007; Selim and Abaza, 2015; Ulger et al., 2015). Due to the high number of invasive devices (e.g. intravascular catheters, urinary catheters and tracheal tubes) which can facilitate the entry of pathogens (Heyba et al., 2015; Kotris et al., 2017), ICU patients are at very high risk of nosocomial infections, caused by microorganisms which can be transmitted also from mobile phones (Brady et al., 2007, 2009).

While the debate on the effect of electromagnetic interference from mobile phones on medical equipment has ended, the potential role of mobile phones in infections transmission remains a matter of intense discussion (Heyba et al., 2015). Several studies have described the contamination of HCWs' mobile phones, reporting a level of contamination and type of bacteria that change in different clinical and geographical settings (Russotto et al., 2015). However, few of these studies have been conducted in the ICU and none in the Italian critical care reality. These studies reported that the most common microorganisms isolated on HCWs' mobile phones in ICU were CoNS (Coagulase Negative Staphylococci) (62.9%–97%) but also other "difficult" bacteria causing hospital acquired infections (HAI), mainly Methicillin-resistant Staphylococcus aureus (MRSA) (1.4%–14%), *Acinetobacter* spp. (2.8%) and *Pseudomonas* spp. (0.9%) (Heyba et al., 2015; Kotris et al., 2017; Michelow et al., 2004).

Objective

The objective of this study was to assess the colonization rate of HCWs' mobile phones before and after work shifts in an Italian general ICU. Our hypothesis was that bacterial load on mobile phones could change and increase during the work shift.

Methods

Study design, hospital and participants

This is an observational prospective study conducted in the general ICU (12 beds) of Foundation IRCCS Ca' Granda Ospedale Maggiore Policlinico, an academic tertiary-level hospital in Milan, Italy. We studied all mobile phones of doctors, nurses and healthcare assistants. All participants gave their written informed consent and were blinded to the sampling date. The sampling period lasted 6 days between September and October 2017.

Two swabs were taken from every mobile phone, one at the beginning and one at the end of the work shift. Following the same modality including the four angles, front, back, audio and battery charger jack, the same researcher took the swab. During the procedure, the researcher wore disposable gloves and "E-Swab COPAN" swabs were used.

Before the sampling a short questionnaire was administered to all participants in order to investigate the habits on the use of their mobile phones during the working activity.

The swabs results from mobile phones were compared with the swabs results from patients' routine microbiological control. The baseline of patients' contamination was assessed with oral, pharyngeal and anal swabs taken at the ICU admission and during the ICU stay (weekly infection surveillance).

Laboratory methods

Each Swab was cultured on Brain Heart Infusion Agar plus 5% Sheep Blood (BHI + SB) (BioMerieux) and incubated aerobically at 35 ± 2 °C for 48 h. Colony growth was assessed by semiquantitative method at 24 and 48 h and identification was performed using Gram stain, catalase and oxidase reaction. Bacterial load was classified in 4 categories: absent, rare, mild, moderate and high. A slide coagulase test differentiated staphylococcal isolates into Staphylococcus aureus and CoNS. Oxacillin sensitivity of staphylococci were investigated by Cefoxitin disk diffusion method according to clinical laboratory standards (CLSI) criteria. Gram-negative strains were identified by Vitek 2 (BioMerieux).

Statistical analysis

Categorical variables are presented as absolute and relative frequencies. Mc-Nemar's chi square test and Stuart-Maxwell marginal homogeneity test (an extension of Mc-Nemar test for comparing variable with more than two categories) were used to estimate the effect of the work shift on qualitative and semiquantitative HCWs' mobile phone colonization, respectively. Fisher's exact test was used to test the difference between groups. All tests were two-sided. Risk difference and 95% confidence interval is reported. Stata 13.1 was used for analyses (StataCorp, College Station, TX, USA).

Results

One hundred swabs on 50 mobile phones were taken during the sampling period, belonging to 28 (56%) nurses, 16 (32%) doctors and 6 (12%) healthcare assistants. Twenty-four HCWs (48%) were male and 26 (52%) female. Overall, the study involved 90.9% of the people working in our ICU (93.3% of the nurses, 94.1% of the doctors and 75% of the healthcare assistants).

Forty-three HCWs (86%) admitted to use their mobile phones during the work shift: 38 (88.4%) of them kept the mobile phone in their pocket and 5 (11.6%) in their bag. Among HCWs who used their mobile phones, 36 (83.7%) reported to use it for mobile applications (87.5% of the doctors) or as a calculator (60.7% of the nurses). All mobile phones were touchscreen. Thirty HCWs (60%) admitted not to wash their hands after using their mobile phones. Twenty HCWs (40%) reported to wash their hands after the use of the mobile phone: 2 doctors (12.5% of doctors), 14 nurses (50% of nurses) and 4 healthcare assistants (66.7% of healthcare assistants). Nineteen HCWs (38%) reported occasional cleaning of their mobile phones with alcoholic solution after working activity: 3 doctors (18.7% of the doctors), 13 nurses (46.4% of the nurses) and 3 healthcare assistants (50% of the healthcare assistants).

All swabs (100%) were positive for at least one isolated bacteria. More than one bacterial species were isolated on 36 (72%) mobile

phones at the beginning of the work shift and on 33 (66%) phones at the end of the work shift. CoNS, *Bacillus* spp. and MRSA were the most frequent colonizing microorganisms (98% and 96%, 58% and 54%, 16% and 18% of the mobile phones before and after the work shift, respectively) (Fig. 1). Microorganisms were similar at the beginning and at the end of the work shifts (Table 1). The same result was verified for the HCWs who reported keeping the mobile phone in their uniform pocket compared to the HCWs who kept it in their bag ($p = 0.58$).

Comparing the swabs results at the beginning and at the end of the work shift, 19 (38%) mobile phones changed bacterial colonization for at least one microorganism. Eight (18.6%) mobile phones acquired a new microorganism during the work shift, namely 3 phones acquired MRSA, 3 acquired *Bacillus* spp., 1 acquired *Acinetobacter* spp. and 1 acquired molds (Table 1).

We did not found any difference in the bacterial burden from the beginning to the end of the work shift. Semiquantitative analysis for clinically relevant microorganism are reported in Table 2.

No patients in the ICU during the 6 days when swabs were performed were positive for bacteria found on HCWs' mobile phones.

Discussion

In this study, all (100%) HCWs' mobile phones were contaminated but only a few of them with potentially pathogenic microorganisms. This frequency is higher than that one reported in previous studies conducted in Egypt (Elkholy and Ewees, 2010), in Kuwait (Heyba et al., 2015) and in Croatia (Kotris et al., 2017), who reported a rate of mobile phones contamination of 96.5%, 73.7%, 77.3%, respectively. Taken together, these findings confirm that contaminated objects such as mobile phones could serve as reservoirs of bacteria with potentially relevant clinical consequences. During every phone call, mobile phones come into close contact with contaminated human body areas such as mouth, nose and ears (Michelow et al., 2004). Indeed, a study conducted in Taiwan shows that the 94.3% of the HCWs with contaminated mobile phones were colonized by the same bacteria in their nares or hands. In particular, *Staphylococcus aureus* was the most commonly isolated pathogen in the nares (19.9%) (Chang et al., 2017).

In our study, colonization of the mobile phones was not influenced by the place where the phones were kept, in fact there was no difference between the HCWs who kept their mobile phones in their uniform pocket, which is washed every day but it is in close contact with the patients, and those who kept them in their bags (hand bags or rucksacks), which are far from the patients but are seldom cleaned. This means that it is more important how the mobile phone is handled than where it is kept.

Interestingly we found a higher incidence of MRSA contamination compared to previous studies (Heyba et al., 2015; Kotris et al., 2017) because *S. aureus*, which is a coagulase-positive pathogen, can cause infections of the skin and other organs in immune-competent patients. CoNS are the most frequently isolated bacteria as reported in the literature: indeed, one study reported CoNS represent the 94% of isolated microorganisms, followed by *Sarcina* (8%) and Bacillus (4%), while MRSA were not found (Kotris et al., 2017). Another study showed a high percentage of CoNS (70,4%), followed by Bacillus (8,4%), *Acinetobacter* spp. (2,8%), MRSA (1,4%), *Pseudomonas* spp. (0,9%) and *E. coli* (0,5%)(Heyba et al., 2015).

CoNS are involved in the infectious processes in immune-compromised patients or patients using catheters (Kramer et al., 2006; Martins and Cunha, 2007). Relatively innocuous CoNS such as *S. haemolyticus*, which is a frequent colonizer of human skin second in frequency only to *S. epidermidis*, have been regarded by many studies as an important nosocomial microorganism with a tendency to develop multiple resistances (Mazzariol et al., 2012).

The most common Gram-negative bacteria isolated from our mobile phones is *Acinetobacter* spp. as reported in several articles. *Acinetobacter* spp. and *P. aeruginosa*, with other pathogens have been proven to remain viable for months on inanimate surfaces (Kramer et al., 2006) and they represent a potential risk of circulating multi-drug resistant strains.

To the best of our knowledge, this is the first study comparing colonization of HCWs' mobile phones in ICU before and after work shifts. All mobile phones had bacteria on their surface both at the beginning and at the end of the shift. Notably, we found not only normal cutaneous bacteria but also nosocomial pathogenic ones.

In our sample, we observed qualitative and quantitative changes in the microbiological flora (especially "environmental" microorganisms) from the beginning to the end of the shift, but the relative frequency of isolation of each bacterial species was not significantly different between these time points. When focusing on clinically relevant (potentially pathogenic) bacteria, we

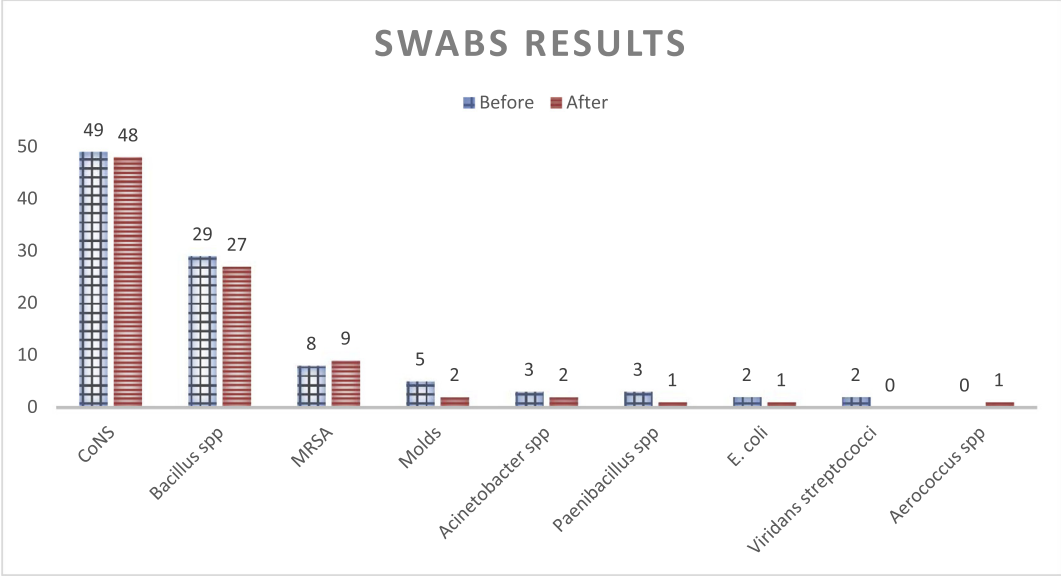

Fig. 1. Swabs results at the beginning and at the end of the work shift.

Table 1
Qualitative microbiology results at the beginning and at the end of the work shift.

Microorganism	Before	After	Risk difference (95% CI)	P value*	Delta*
Muco-cutaneous					
CoNS, N (%)	49 (98%)	48 (96%)	0.02 (−0.04 to 0.08)	0.32	0
MRSA, N (%)	8 (16%)	9 (18%)	−0.02 (−0.13 to 0.09)	0.65	3 (6%)
Viridans streptococci, N (%)	2 (4%)	0 (0%)	0.04 (−0.03 to 0.11)	0.16	0
Environmental					
Bacillus spp., N (%)	29 (58%)	27 (54%)	0.04 (−0.09 to 0.17)	0.48	3 (6%)
Molds, N (%)	5 (10%)	2 (4%)	0.06 (−0.05 to 0.17)	0.18	1 (2%)
Acinetobacter spp., N (%)	3 (6%)	2 (4%)	0.02 (−0.07 to 0.11)	0.56	1 (2%)
Paenibacillus spp., N (%)	3 (6%)	1 (2%)	0.04 (−0.03 to 0.11)	0.16	0
Aerococcus spp., N (%)	0 (0%)	1 (2%)	−0.02 (−0.08 to 0.04)	0.32	0
Intestinal					
E. coli, N (%)	2 (4%)	1 (2%)	0.02 (−0.04 to 0.08)	0.32	0

N = number of mobile phones with that specific microorganism.
Delta = number of mobile phones that acquired a specific microorganism.
* P value from McNemar's chi square test.

Table 2
Semi-quantitative microbiology results for clinically relevant (potentially pathogen) microorganism.

			END OF WORK SHIFT				
			Absent	Rare	Mild	Moderate	High
MRSA (N) (p = 0.34)	BEGIN OF WORK SHIFT	Absent	39	1	0	0	2
		Rare	2	3	0	0	0
		Mild	0	0	0	0	0
		Moderate	0	0	0	0	0
		High	0	0	0	1	2
Acinetobacter (N) (p = 0.61)		Absent	46	0	0	0	1
		Rare	0	0	0	0	0
		Mild	0	0	0	0	0
		Moderate	1	0	0	0	0
		High	1	0	0	0	1
Molds (N) (p = 0.37)		Absent	44	0	1	0	0
		Rare	0	0	0	0	0
		Mild	3	0	0	0	0
		Moderate	0	0	0	0	0
		High	1	0	0	0	1

N = number of mobile phones.

found that only 3 mobile phones acquired MRSA, 1 mobile phone acquired molds, 1 mobile phone acquired *Acinetobacter* spp. and no mobile phone acquired *E. coli*.

Another important finding was that during the 6 days sampling period no patient hospitalized in our ICU was colonized by the same microorganism found on HCWs' mobile phones. This result could be explained by the fact that some pathogenies found at the sampling could be acquired from other ICU patients or from outside during the previous days and so we can suppose that the contamination of mobile phones happens during the working activity progressively.

Limitations

This study has some limitations which need to be acknowledged. First, it is a single centre observational study conducted on a relatively limited sample size, which can affect the generalizability of our findings. Second, some results may be affected by the reliability of the answers of the operators reported in the questionnaire: for example, some of them may have not remembered cleaning their phones or washing their hands. Third, we did not search the species and test the antibiotic resistance of CoNS and *Acinetobacter* spp. Fourth, although the HCWs were not aware of the study protocol, their behaviour about hand washing or mobile phone cleaning might be influenced by the enrollment in itself. Fifth, the questionnaire could have been more detailed of HCWs' habits during work activity.

Conclusion

This study shows that all ICU HCWs' mobile phones are colonized by microorganisms, included potential pathogenic ones, even before the work shift and irrespective of the microbiological patients' flora. The HCWs' work shift did not significantly change the colonization of mobile phones.

Since the use of mobile phones has not yet been regulated during hospital working shift, more research is needed to assess the impact of mobile phones contamination and of hygiene practices on hospital-acquired infections.

Authors contributions

AGA, MP, EB, IA and GG designed the study, coordinated and drafted the manuscript. EB and FB made the data collection. Microbiological analysis was conducted by AGR while data analysis was conducted by MP and AGA. GG, TM, AP and DL gave expert content to the manuscript. All authors read and approved the final manuscript.

Ethical statement

All participants (medical, nursing and healthcare assistants staff) agreed and gave their written informed consent. Since the study did not concern the patients, the Ethic Committee was not deemed necessary according to the local regulation.

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Conflict of interest

None of the authors discloses potential conflicts of interest.

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