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ORIGINAL ARTICLE

Healthcare Workers' Mobile Phones as a Possible Vehicle of Nosocomial Pathogens and the Role of Different Disinfectants in their Decontamination

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ABSTRACT

Background: *As Mobile Phones (MPs) aren't cleaned routinely and have been touched during patient's examination, they may become contaminated with hospital pathogens.* ***Objectives:*** *Screen MPs of Health care workers (HCWs) for pathogens and verify the effect of disinfectants in their decontamination.* ***Methods:*** *A questionnaire was submitted by 160 HCWs in Tanta University Hospitals. Samples were taken from their MPs and subjected to pour plate counting before and after disinfection. Standard identification and antibiotic susceptibility of isolates were done.* ***Results:*** *Colony count was greater in MPs used while caring for patients or inside restroom, and was less in regularly cleaned MPs. All tested disinfectants reduced the colony count significantly. Pathogens were isolated from 84.38% of samples and 36.25% of them were Multi-Drug Resistant Organisms (MDROs).* ***Conclusion:*** *Using MPs at critical care areas and restroom may contribute to their contamination with pathogens. Regular disinfection of MPs can reduce this contamination.*

INTRODUCTION

The acquisition of transient bacteria by hand contact with contaminated fomites or surfaces is a critical source of Health care-associated infections (HCAIs), particularly for HCWs[1]. The raise in advanced technological applications of MPs is tempting to use this technology to provide good contact between health providers and patients[2]. Cross contamination may happen by the HCWs' hands after they have touched contaminated MPs[3]. The use of MPs has a special character among other fomites, as it is used close to many parts of human body such as the face, ears, nose, lips, and hands [4]. Continuous use of MPs by HCWs exposes them to an array of microorganisms, and the skin of palms provides the moisture plus the suitable temperature needed for survival of pathogens[5]. Additionally, the heat coming out from the device itself, in turn, create a perfect surface for growth of many organisms. Hence, they expressed MP being the ''Technological Petri Dish''[6].

Health care workers in critical areas as Intensive Care Units (ICUs) and Operating Rooms (ORs) where the chance of HCAIs is greatly increased are highly exposed to microorganisms, and their MPs may act as vehicles for spreading these microorganisms wherever they are taken along [7]. As these areas are main sites for HCAIs, this makes a great need for increasing the awareness about cross contamination by MPs as a vector and how to avoid such risk in these areas [8]. So, this study was designed to evaluate HCWs' mobile phones as a potential vehicle for spreading pathogens in hospital sittings and the reducing effect of different disinfectants on them.

METHODOLOGY

Sample size:

The sample size for this research was calculated at 5% significance level and 80% power of the study. It was estimated to be 160 samples. Using the following formula [9]

$$N = \frac{Z2*P*(1-P)}{d2}$$

Where, Z = 1.96 for 95% confidence level. p = Expected proportion of the factor under study and d = precision (Margin of error).

Study locality:

The present study was carried out at Medical Microbiology and Immunology Department, Faculty of Medicine, Tanta University, at the period from July 2019 to July 2020. Samples were taken in the ORs and ICUs of Tanta University Hospitals.

Target population:

Health Care Workers serving in the ORs and ICUs at Tanta University Hospitals were the target population. The researcher informed the participants about the aim of this work and received their consent. A face-to-face interview was conducted. The participant was asked to complete a questionnaire concerning usage of MPs

inside hospitals. Privacy was guaranteed, and the results were kept confidential.

Ethical approval for this research was provided by Ethics and Research Committee, Faculty of Medicine, Tanta University.

Collection and processing of samples:

Sample collection:

Sterile cotton swabs were used for samples collection. Each swab was first moisturized with sterile peptone water and then rotated all over the surface of the front and back of the tested MPs, covering the entire surface without removal of the protective case followed by applying the disinfectant. The selected disinfectant was used for 10 minutes, then another swab was obtained using the same manner. Samples were divided into three groups according to the used disinfectant; group A: for 70% ethyl alcohol, group B: for 70% isopropyl alcohol and group C: for 0.5% chlorhexidine, then transferred to Microbiology Laboratory and each swab was immersed in 10 ml peptone water.

Aerobic colony counting:

Aerobic Colony counting was done before and after the use of disinfectant on each MP tested in the present study using the Pour Plate Method [10]. This method was used to count the number of colonies when the sample is added to a molten agar medium (plate count agar) before its solidification [10]. The number of Colony Forming Units (CFU) for each sample subjected to pour plate method was counted and recorded as CFU/ml. The CFU/cm^2 was estimated by dividing the total count of the sample by the surface area of the tested MP.

Identification of isolates:

All samples were cultured on nutrient agar, blood agar, MacConkey's agar and Sabouraud's dextrose agar plates and incubated at 37°C for 24 hours and then the isolates in the primary plates were identified by their colonial morphology, microscopic examination, subculture on different differential and indicator medias and using the appropriate biochemical reactions per guidelines [11,12].

Antibiotic sensitivity testing:

Antimicrobial susceptibility of the isolated pathogens was done by modified Kirby Bauer disc diffusion method , CLSI, 2020 [13] using the following antibiotics discs on Mueller Hinton agar plates: Penicillin, Ampicillin, Oxacillin, Piperacillin, Amoxicillin clavulanic acid, Ampicillin sulbactam, Piperacillin tazobactam, Aztreonam, Cefoxitin, Ceftazidime, Cefotaxime, Ceftriaxone, Cefepime, Linezolid, Sulfamethoxazole/ trimethoprim, Erythromycin, Rifampin, Clindamycin, Tetracycline, Imipenem, Meropenem, Amikacin, Gentamicin, Ciprofloxacin and Colistin. Vancomycin susceptibility was detected using E-test. Modified Double Disc Synergy Test was performed for detection of Extended Spectrum Beta Lactamase (ESBL) [14].

Quality assurance:

- The questionnaire was tested for validity and reliability via a pilot study done before starting data collection. It included 10% of the sample size (16 HCWs). The internal consistency reliability was calculated via Cronbach's Alpha (a). The result showed highly reliable internal consistency as Cronbach's Alpha (a) equals 0.832 [15].
- Before sample taking, researcher's hands were cleaned by alcohol-based hand rub and disposable gloves were worn to prevent cross contamination.
- All culture media and antibiotic susceptibility material were stored, prepared and pre sterilized if needed according to manufacturer's instructions. Control Strains ATCC-25923 and ATCC-25922 were used as control strains to check quality of culture media and Antibiotic disks.

Statistical analysis:

Statistical presentation and analysis of the present study was performed using the mean, standard deviation, student t-test, Paired t-test, Chi-square, Linear Correlation Coefficient and Analysis of variance [ANOVA] tests by SPSS V20[16].

RESULTS

Participants' MPs in this study were evaluated for their surface' colony count before and after applying certain disinfectant agent. The results are shown in table (1) as follow:

- **In group A** (tested with 70% ethyl alcohol spray), the mean colony count before using was 130.68 ± 76.97 CFU/ml, and reduced after disinfection to become 0.98 ± 2.01 CFU/ml. The mean CFU/cm^2 before disinfection was 5.22 ± 3.08 CFU/ cm^2. There was a statistically significant reduction in the colony count after using 70% ethyl alcohol (P value <0.001).
- **In group B** (tested by 70% isopropyl alcohol wipes), the mean colony count before using disinfection was 124.25 ± 70.66 CFU/ml, and reduced after disinfection to become 0.77 ± 1.95 CFU/ml. The mean CFU/cm^2 before disinfection 4.97 ± 2.82 CFU/ cm^2. There was a statistically significant reduction in the colony count after using 70% isopropyl alcohol (P value <0.001).
- **In group C** (tested by 0.5% chlorhexidine wipes), the mean colony count before using disinfection was 130.44 ± 78.99 CFU/ml, and reduced after disinfection to become 1.09 ± 1.85 CFU/ml. The mean of CFU/cm^2 before disinfection was 5.21 ± 3.16 CFU/ cm^2. There was a statistically significant reduction in the colony count after using 0.5% chlorhexidine (P value <0.001).
- There was no statistically significant difference between the three groups.

Table 1: Relationship between disinfectants and colony count

CFU counts			Disinfection by									ANOVA	
			Group A 70% Ethyl alcohol			Group B 70% Isopropyl alcohol			Group C 0.5% Chlorhexidine			F	P-value
Before	**/ml**	**Range**	23	-	345	17	-	300	15	-	340	0.134	0.875
		Mean ±SD	130.68	±	76.971	124.25	±	70.659	130.44	±	78.986		
	/cm²	**Range**	0.92	-	13.8	0.68	-	12	0.6	-	13.6		
		Mean ±SD	5.22	±	3.08	4.97	±	2.82	5.21	±	3.16		
After	**/ml**	**Range**	0	-	10	0	-	10	0	-	6	0.375	0.688
		Mean ±SD	0.982	±	2.014	0.77	±	1.953	1.093	±	1.849		
	/cm²	**Range**	0	-	0.4	0	-	0.4	0	-	0.24		
		Mean ±SD	0.04	±	0.08	0.03	±	0.07	0.04	±	0.07		
Differences/ml		**Mean ±SD**	129.7	±	75.935	123.48	±	69.517	129.35	±	78.085		
Paired Test		**P-value**	<0.001**			<0.001**			<0.001**				

ANOVA test was used for comparison among different times in the same group in quantitative data, paired Student T-test was used to compare between related sample. P-value ≤ 0.05 is significant and < 0.01 is highly significant.

In table (2), correlations between colony count and participants' answers as regard using MPs in hospitals show that the mean colony count (CFU/ml) was significantly higher in MPs of HCWs who use it while caring for patients (P value =0.024) and in MPs of HCWs who use it inside the restrooms (P value = 0.016). The mean CFU/ml was significantly lower in MPs of HCWs who regularly clean their MPs (P value = 0.035).

Table 2: Correlations between colony count on mobile phones and answers of HCWs as regard using their mobile phone in hospitals.

Responses obtained from participants		N	CFU/ml Before disinfection Mean	±	SD	T-Test or ANOVA T or F	P-value
Do you use mobile phone	**No**	0	0	±	0	-	-
at the hospital?	**Yes**	160	128.163	±	74.772		
Do you use it in critical care	**No**	10	131.1	±	81.649	0.128	0.898
areas like ICUs and ORs?	**Yes**	150	127.967	±	74.584		
Do you answer/ make calls	**No**	31	101.129	±	55.353		
while caring for patients?	**Yes**	129	134.659	±	77.507	-2.271	0.024*
Do you answer/make calls while	**No**	160	128.163	±	74.772	-	-
doing an invasive procedure?	**Yes**	0	0	±	0		
Would you share your phone	**No**	35	133.543	±	79.371	0.48	0.632
with a colleague if asked for?	**Yes**	125	126.656	±	73.696		
Do you use the same	**No**	10	168.2	±	85.629	1.76	0.08
phone at home?	**Yes**	150	125.493	±	73.542		
Does a family member	**No**	43	120.791	±	75.434	-0.755	0.451
use your phone?	**Yes**	117	130.872	±	74.669		
Do you use your	**No**	103	117.651	±	67.256	-2.427	0.016*
phone inside the restroom?	**Yes**	57	147.158	±	84.051		
Do you think your mobile	**No**	28	149.964	±	85.748	1.709	0.089
phone may carry pathogens?	**Yes**	132	123.538	±	71.745		
Do you regularly clean	**No**	109	136.67	±	81.811		
your mobile phone?	**Yes**	51	109.98	±	53.169	2.127	0.035*

ANOVA test was used for comparison among different times in the same group in quantitative data, Unpaired Student T-test was used to compare between two groups in quantitative data. P-value ≤ 0.05 is significant and < 0.01 is highly significant.

In this study, 84.38% of tested MPs were contaminated with pathogens. As regard types of isolated pathogens, table (3) shows that, the 160 MPs tested from ORs gave growth of 320 organisms. The majority of isolated microorganisms were Coagulase Negative *Staphylococci (CoNS)* (28.4%), then followed by *Staphylococcus aureus (Staph. aureus)* (23%). The least isolated pathogens were *Salmonella spp*. (0.6%) and Fungal isolation accounted for only 1.9%. There was no statistically significant variance between types of isolated pathogens from phones of HCWs from ORs and from ICUs.

Table 3: Types of isolated nosocomial pathogens from tested mobile phones

Isolated pathogens	Place						Chi-Square	
	ORs		ICUs		Total			
	n= 133		n= 187		n= 320			
	No.	%	No.	%	No.	%	X^2	P - value
Coagulase Negative *Staphylococci*								
-Novobiocin sensitive	32	24	45	24.1	77	24	1.043	0.307
-Novobiocin resistant	7	5.3	7	3.7	14	4.4	1.023	0.312
Staphylococcus aureus	29	21.8	45	24.1	74	23	0.168	0.682
Enterococci	10	7.5	20	10.7	30	9.4	0.274	0.601
Streptococcus pyogens	4	3	1	0.5	5	1.6	2.326	0.127
Klebsiella spp.	16	12	18	9.6	34	10.6	1.683	0.195
Escherichia coli	7	5.3	17	9.1	24	7.5	0.837	0.36
Proteus spp.	3	2.3	2	1.1	5	1.6	1.115	0.291
Enterobacter spp.	2	1.5	3	1.6	5	1.6	0.014	0.907
Salmonella spp	1	0.8	1	0.5	2	0.6	0.135	0.713
Pseudomonas spp.	13	9.7	13	6.9	26	8.2	2.07	0.15
Acinetobacter spp.	7	5.3	11	5.9	18	5.6	1.352	0.245
Candida spp.	2	1.5	4	2.2	6	1.9	0.046	0.83

Chi-squared ($\chi 2$) test was used to determine differences between groups, a P <0.05 was considered significant. - *: P <0.05, **: P <0.0

As regard the antibiotic resistance profiles, from total of 320 isolated organisms, 116 (36.25%) were MDROs. The results in table (4) show the frequency of MDROs isolation from MPs. Isolated Methicillin Resistant *Staphylococci* (*MRSA)*, Vancomycin Resistant *Enterococci* (*VRE)*, ESBL producing E. *coli* and Multidrug Resistant (MDR) *Acinetobacter* were significantly greater in MPs from ICUs workers compared to the MPs of ORs workers (P values = 0.0289, 0.0047, 0.0097 and 0.0339 respectively).

Table 4: Multidrug Resistant Organisms (MDROs) on mobile phone surfaces

Isolated MDR organisms	Numbers of isolates from:			% of MDROs among the same genus isolated	Chi-Square	
	ORs	ICUs	Total		X^2	p- value
MRSA	5	16	21	28.4	4.773	0.0289*
Methicillin Resistant Coagulase Negative Staphylococci (MR-CoNS)	11	12	23	25.27	0.001	1.000
VRE	0	8	8	26.6	8.000	0.0047**
ESBL producing *klebsiella*	7	13	20	58.8	1.800	0.1797
ESBL producing E. *coli*	2	13	15	62.5	6.696	0.0097**
MDR *Proteus*	0	2	2	40	2.000	0.1573
MDR *Enterobacter*	1	2	3	60	0.333	0.5637
MDR *Salmonella*	1	0	1	50	1.000	0.3173
MDR *Pseudomonas*	4	11	15	57.7	3.267	0.0707
MDR *Acinetobacter*	1	7	8	44.4	4.500	0.0339*

Chi-squared ($\chi 2$) test was used to determine differences between groups, a P<0.05 was considered significant. - *: P <0.05, **: P <0.01

DISCUSSION

Contamination of surfaces and equipment are well-documented sources of HCAIs[17]. The isolation of pathogens from fomites indicates that they can be vehicles for disease transmission. In the light of this, there is need therefore for thorough disinfection and conscientious contact control procedures to decrease the risk of spreading these pathogens [18].

Upon studying colony count present on MP surface in this work, it was founded that the mean CFU/ml before disinfection was 130.68 ± 76.97, 124.25 ± 70.65 and 130.44 ± 78.98 in groups A, B and C respectively. This count is less than the count detected by the same method (pour plate) in a study done by Selim and Abaza [19] in Alexandria, Egypt, in which the mean bacterial count was found to be 357.10 CFU/ml.

Regarding the effect of disinfectants, in group A; the mean colony count was reduced after ethyl alcohol use to become 0.98 ± 2.01 CFU/ml. Supporting this results, Habyarimana *et al.* [20] reported high growth in cultured samples before disinfection, while cultures after treatment with 70% ethyl alcohol revealed no growth. Also, Rozario *et al.*[21] observed that using 70% ethanol significantly reduced microbial count on the MP surfaces.

In group B; the mean colony count was reduced after isopropyl alcohol use to become 0.77 ± 1.95 CFU/ml. Amala and Ejikema [22] supported these findings, MPs included in the study (which showed heavy bacterial growth) were wiped with 70% isopropanol, and samples taken after 10 minutes of applying alcohol yielded no growth. In contrast, a study by Gashaw *et al.*[23] showed lower efficacy of isopropyl alcohol (47.8%). Although their result was low compared to others, they suggested that decontamination will have an important value in reducing bacterial count if used on a regular basis [23].

In group C; the mean colony count was reduced after chlorhexidine use to become 1.09 ± 1.85 CFU/ml. Similar result was obtained by Koscova *et al.* [4], who detected that chlorhexidine significantly reduced bacteria on MP surfaces (ranging from 36.8 to 100%). Also, Muniz *et al.*[24] found that chlorhexidine gel eliminated all bacteria without observed damage to the glass of MPs.

In the present study, 70% ethanol, 70% isopropanol and 0.5% chlorhexidine were compared and there was no statistically significant difference as regard their efficacy in reduction of bacterial load on MPs. The use of 70% alcohol is an easy and safe mode of sanitization, while the advantage of chlorhexidine is in its residual activity that make an extended effect of decontamination [25].

In the current study, the mean CFU/cm^2 was 5.22 ± 3.08, 4.97 ± 2.82 and 5.21 ± 3.16 in groups A, B and C respectively, breaching the acceptable levels of contamination. Greater than 2.5 CFU/cm^2 on environmental surfaces is considered unacceptable in hospital sittings [26]. In consistency with the current result, Misgana *et al.*[27] found that 62% of the contaminated MPs showed growth of >5 CFU/cm^2. The explanations for getting a high colony count from MPs of HCWs may be because HCWs have direct interaction with patients. Noncompliance of infection prevention strategies may also be related to this finding [27].

Correlations have been done between responses of HCWs to the questionnaire and the colony count on their MPs. In the current work, 35.62% of HCWs used their MPs in restrooms, and the colony count on their MPs was statistically higher than that present on those not used there (P value 0.016). Similar result was obtained by Bakry *et al.* [28] in Zagazig, Egypt, who found a statistically related association between the culture results and the use of phones inside restrooms. Also, Rozario *et al.* [21] recorded a strong statistical association between culture results and using MP in the restrooms, which surely concerns the hygiene issue and bacterial transmission opportunity.

The current study showed a statistically lower colony count on MPs of HCWs who regularly clean it (P value 0.035). This result is parallel to the results of Bodena *et al.* [29] and Simmonds *et al.* [30] who observed that the mean CFUs on devices that were never cleaned was significantly greater than mean CFUs on phones with regular cleaning. Also, Simmonds *et al.*[30] detected significantly higher colony count on MPs of HCWs than control phones cleaned daily.

Regarding microbial isolation from MP surface, it was found that 84.38% of tested MPs were contaminated with pathogenic microorganisms. Several Studies performed by Selim and Abaza [19], Habyarimana *et al.* [20], Hikmah and Anuar [31], and Simmonds *et al.* [30], all reported higher level of contamination as they found that nearly all MPs tested had been prone to single or polymicrobial contamination. Contaminated phones were 100%, 100%, 100% and 98.2% of tested mobile phones respectively. Sharma, A. [32] recorded a lower contamination rate (71.2%). Moreover, Bakry *et al.* [28] observed lower rate (46.3%) in Egypt. Arora *et al.* [33] reported a much less contamination rate, where out of 160 tested MPs of HCWs, only 40.62% were harbouring pathogens. The observed variation might be due to the difference in adherence to infection control measures inside hospitals, frequency of cleaning MPs, hand washing practice, and the personal behaviour of HCWs [27,29,31].

In the current study, out of 320 isolated organisms, gram-positive bacteria were most frequently isolated from MP surfaces, particularly *CoNS* (28.4%) followed by *Staph. aureus* (23%). This high frequency of isolation may be due to the constant contact of MPs with the skin, which is an important habitat of

Staphylococci [20]. This result is consistent with those recorded by many authors in which they noted that *CoNS* had the highest rate of isolation from MPs in their studies [29,30,34].

For gram-negative isolates, *Klebsiella* spp. accounted for the third most isolated organism in the current study (10.6%). This rate is less than the results reported by Tiwari *et al.* [35] and Hikmah and Anuar [31], where the isolated *klebsiella* accounted for 15.25% and 17.2% respectively. The present result is higher than the result by Bodena *et al.* [29], as *klebsiella* contributed for 6.9% of total isolates from MPs. The fourth most isolated bacteria in the current study was *Pseudomonas* spp. (8.2%), which is higher than Hikmah and Anuar [31] as their result was 2.4%.

In the current work, out of 320 isolated organisms, 116 (36.25%) were MDROs. This is higher than the reported percentage by Gashaw *et al.* [23] where MDROs represented 18% of the isolated bacteria, and less than the result of Bodena *et al.* [29] as most of isolated organisms (69.9%) were MDROs. This variation of antimicrobial susceptibility among studies might be explained by the difference in bacterial strains, hospital environment and empirical treatment practice [29,36].

In our work, 28.4% of isolated *Staph. aureus* were *MRSA* and 25.27% of isolated *CoNS* were MR-*CoNS*. The frequency of *MRSA* isolation in this work is parallel to the results by Khadka *et al.* [37] and Loyola *et al.* [38] who reported 26.8% and 26.7% of their isolated *Staphylococci* were *MRSA* respectively. Lower rates were observed in studies done by Kalyani *et al.* [39], Galazzi *et al.* [40]. They reported that 9.7% and 1.4% of the isolated pathogens from MPs were *MRSA* respectively. Higher rates of isolation of *MRSA* from MPs were detected elsewhere in Egypt in studies by Selim and Abaza [19], and Bakry *et al.* [28] as they reported that 53% and 53.3% of isolates respectively were *MRSA*. This could reflect the differences in carrier states among HCWs in different countries or health care sittings. Coming to *Enterococci*, out of 30 isolates in the current work, 8 isolates (26.6%) were *VRE*. Higher percentage of *VRE* (42.3%) were detected by Loyola *et al.* [38]. While lower rate was detected by Simmonds *et al.*[30] in which *VRE* contributed to only 2.4% of the isolated pathogens.

CONCLUSION

From the existing data provided by the present study, it could be settled that bacterial count on the surface of the majority of tested MPs exceeded the acceptable level of environmental hygiene inside hospitals, especially when used in patient care areas or in restrooms. There was a lower colony count on MPs of HCWs who regularly clean it. In our study; 70% ethyl alcohol, 70% isopropyl alcohol and 0.5% chlorhexidine showed a significant reduction in colony count. Around 84% of tested MPs were contaminated with pathogenic microorganisms particularity *Staphylococci*. A considerable percentage (36.25%) of isolates were MDROs and the percentage was higher from phones of ICUs workers.

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- Each author listed in the manuscript had seen and approved the submission of this version of the manuscript and takes full responsibility for it.
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