

Review

Are healthcare workers' mobile phones a potential source of nosocomial infections? Review of the literature

Fatma Ulger¹, Ahmet Dilek¹, Saban Esen², Mustafa Sunbul², Hakan Leblebicioglu²

¹ Department of Anesthesiology and Reanimation, Ondokuz Mayıs University School of Medicine, Samsun, Turkey

² Department of Clinical Microbiology and Infectious Diseases, Ondokuz Mayıs University School of Medicine, Samsun, Turkey

Abstract

Mobile communication devices help accelerate in-hospital flow of medical information, information sharing and querying, and contribute to communications in the event of emergencies through their application and access to wireless media technology. Healthcare-associated infections remain a leading and high-cost problem of global health systems despite improvements in modern therapies.

The objective of this article was to review different studies on the relationship between mobile phones (MPs) and bacterial cross-contamination and report common findings.

Thirty-nine studies published between 2005 and 2013 were reviewed. Of these, 19 (48.7%) identified coagulase-negative staphylococci (CoNS), and 26 (66.7%) identified *Staphylococcus aureus*; frequency of growth varied. The use of MPs by healthcare workers increases the risk of repetitive cyclic contamination between the hands and face (*e.g.*, nose, ears, and lips), and differences in personal hygiene and behaviors can further contribute to the risks.

MPs are rarely cleaned after handling. They may transmit microorganisms, including multiple resistant strains, after contact with patients, and can be a source of bacterial cross-contamination. To prevent bacterial contamination of MPs, hand-washing guidelines must be followed and technical standards for prevention strategies should be developed.

Key words: healthcare workers; mobile phones; bacteria; nosocomial infection; contamination.

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Introduction

The rapid progress of modern technology has contributed not only to medical fields, but also to the development of technologies for individual use. This technology includes personal computers, pagers, mobile hand-held devices (MHDs) (wireless tablets such as iPad, droids, etc.) and mobile phones (MPs), in which improvements have been made at a staggering speed over the past 20 years [1-3]. MPs and MHDs help accelerate in-hospital flow of medical information and information sharing and querying, and contribute to communications in the event of emergencies through their application and access to wireless media technology [1,2]. As technology in this area has evolved, MHDs that provide laboratory and imaging results, patient data, and photographic images are being used by physicians during bedside rounds to engage clinicians, residents, and students. Healthcare workers (HCWs) access pharmaceutical knowledge and literature by MPs and MHDs, which facilitates learning and clinical performance [4,5]. It is possible,

with advanced mobile communications, to closely monitor diseases, such as diabetes and asthma, even without requiring the patient's presence in the hospital. MPs provide unique facilities for situations, such as the treatment of travel infections, vaccinations, and the remote control of epidemics [4,5]. MPs essentially provide access to health workers without limitation to facilitate communication with patients.

However, the MP, which we often carry in our pocket and hold with clean or dirty hands, can lead to potential risks, such as noise, distractions, loss of concentration, data safety, disturbance of patient privacy, and transfer of microorganisms possibly leading to nosocomial infections [6,7].

The infection potential of telephones was first suggested by Aronson *et al.* in 1977 [8]. Then, in 1978, Cozanitis reported that telephones could pose a risk of transmitting infections within the intensive care unit (ICU) [9]. Early in the 1980s, White-Rafferty and Pancoast supported these reports with different studies [10,11]. The first study on MPs was performed by

Borer in 2005, and many articles have been published since [12].

Healthcare-associated infections (HAIs) remain a leading and high-cost problem of global health systems despite improvements in modern therapies. The source is usually defined by the transfer of microorganisms between clinicians, patients, devices, and general surfaces. In daily routines, hands of HCWs are often contaminated by pathogens, and inadequate hand hygiene can allow the transfer that will result in HAIs. Telephones are rarely cleaned after handling and may transmit microorganisms, including multiple resistant ones, after contact with the patient, and can be a source of the bacterial cross-contamination [7,13-15].

There are several studies on the role of MPs as possible sources of HAIs, and these have a wide range of sampling methods and sizes; as a result, it is difficult to draw solid conclusions and establish effective preventive measures. The objective of this article was to review different studies in order to find evidence for the potential role of health workers' MPs as sources in nosocomial infections.

Methodology

Studies on MPs published between 2005 and 2013 were reviewed. A series of cases including the terms *mobile phones*, *nosocomial infection*, *contamination cellular phone*, and *HCW* on PubMed, Medline, Google Scholar, Science Citation Index, and Scopus, as well as letters and articles to the editor, were included. Only data in English were included, and the reference lists of those studies were also reviewed to identify any unlisted studies.

Only the results of cultures of microbiologic materials obtained from MPs used by HCW were considered in the study; studies on pagers, personal digital assistants (PDA), personal computer keyboards, hospital fixed phones, and public telephones were excluded. Results from healthcare staff working in dentistry and veterinary medicine were also taken into account.

Statistical Package for the Social Sciences (SPSS) for Windows version 15.0 was used for data analysis. The demographic characteristics of the studies in the literature (study type, year, country, setting, sample, percentage of contamination rate, and type of bacteria) are presented in Table 1. In all the studies examined, the more common bacterial species isolated (> 5%) were presented as a percentage of microorganisms. Many of the studies did not state a statistical p value, and the groups and the groups' contents were too

dissimilar to perform statistical data meta-analysis; therefore, meta-analysis assessment was not carried in this review.

Results

Between 2005 and 2013, there were 39 studies that identified possible nosocomial infection agents on the MPs of hospital care workers. A total of 4,876 samples were taken, and the prevalence of nosocomial infection agents ranged from 10% to 100%. The results varied by wards, hospitals, and regions where the studies were performed (Table 1). More significant colonizations by microorganisms (> 5% of all colonies assessed) are shown in Figure 1. The most common isolate was *Staphylococcus aureus* (22.81%), followed by CoNS (16.67%). It should be noted that the largest group was "others" (39.47%), which reflected the wide range of the isolated microorganisms. Figure 2 shows the isolation rate of various organisms for all of the reviewed studies; in 39 studies, *S. aureus* was the most frequently isolated microorganism (n = 26; 66.7%), and CoNS again ranked in second place (n = 19; 48.7%).

Most of the studies considered the relationship between age, gender, frequency of use at the hospital, and type of telephone; however, no significant relationship was noted. In a few studies, a difference was found between the clinical and the non-clinical doctors with regard to the frequency of bacterial growth on MPs; however, it was not statistically significant (p > 0.05) [14,16,18].

Figure 1. Distribution of the most significant (> 5% colonies) micro-organisms isolated from all mobile phones from all studies reviewed

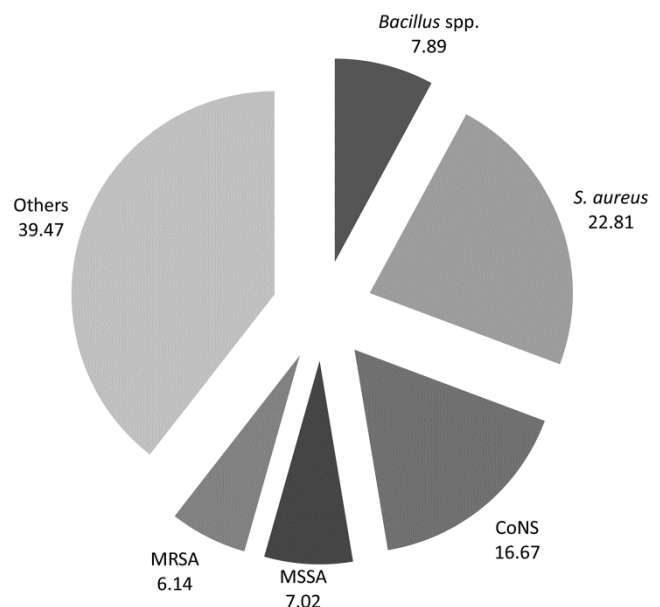
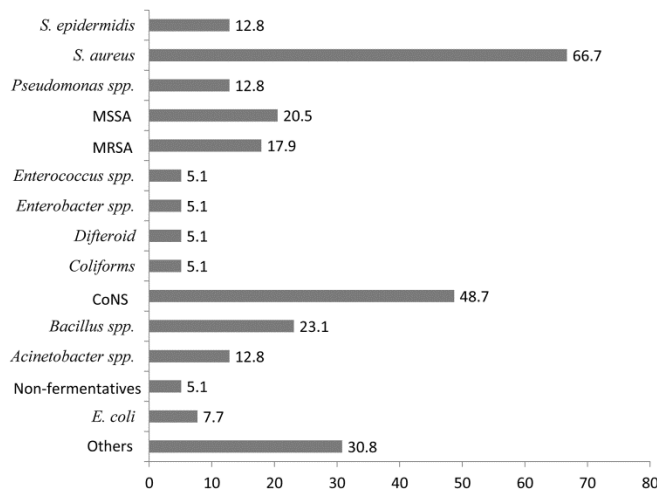


Table 1. Distribution of studies on contamination

Study	Study type	Year	Country	Setting	Sample	C.Rate %	Type of bacteria
Borer <i>et al.</i> [12]	C	2005	Israel	G	124	10	<i>Acinetobacter</i> spp.
Brady <i>et al.</i> [16]	L	2005	UK	T	105	70.9	CoNS, <i>Micrococcus</i> , <i>Bacillus</i>
Khivsara <i>et al.</i> [17]	CS	2006	India	T	30	40	MSSA, MRSA
Goldblatt <i>et al.</i> [18]	C	2007	Israel	M	400	45	<i>Acinetobacter</i> spp., MRSA, MSSA
Goldblatt <i>et al.</i> [18]	C	2007	USA	M	400	89.3	MRSA
Jeske <i>et al.</i> [19]	CS	2007	Austria	T	40	10	<i>S. aureus</i> , <i>Enterococcus</i> , <i>Acinetobacter</i> spp.
Brady <i>et al.</i> [20]	CS	2007	UK	G	46	11.5	<i>Micrococcus</i> , <i>Bacillus</i>
Karabay <i>et al.</i> [21]	CS	2007	Turkey	T	122	68.5	CoNS, <i>Bacillus</i> , MSSA
Ramesh <i>et al.</i> [2]	CS	2008	Barbados	G	116	45	<i>S. epidermidis</i> , coliforms, <i>Pseudomonas</i> spp.
Tambekar <i>et al.</i> [22]	CS	2008	India	T	75	95	<i>S. aureus</i> , <i>Micrococcus</i> , <i>Pseudomonas</i> spp.
Jayalakshimi <i>et al.</i> [13]	CS	2008	India	T	144	91,6	CoNS, <i>S. aureus</i> , <i>Bacillus</i>
Ulger <i>et al.</i> [23]	CS	2009	Turkey	T	200	94.5	CoNS, <i>S. aureus</i> , non-fermentatives
Akinyemi <i>et al.</i> [6]	CS	2009	Nigeria	T	90	38	<i>S. aureus</i> , CoNS, <i>Enterococcus faecalis</i>
Chawla <i>et al.</i> [24]	CS	2009	India	T	80	92.5	Diphtheroids, MSSA, CoNS
Datta <i>et al.</i> [25]	CS	2009	India	T	200	72	MSSA, MRSA, CoNS
Kilic <i>et al.</i> [26]	CS	2009	Turkey	T	65	61.3	<i>S. epidermidis</i> , <i>S. aureus</i> , <i>Bacillus</i>
Sepehri <i>et al.</i> [27]	CS	2009	Iran	T	147	32	<i>S. epidermidis</i> , <i>S. aureus</i> , yeasts
Singh <i>et al.</i> [14]	CS	2010	India	M	67	98	CoNS, <i>Bacillus</i> spp., diphtheroids
Al-Abdalall <i>et al.</i> [28]	CS	2010	Saudi A.	M	202	100	<i>S. aureus</i> , <i>S. epidermidis</i> , <i>Pseudomonas</i>
Srikanth <i>et al.</i> [29]	CS	2010	Singapore	T	51	94	<i>Acinetobacter</i> spp., MSSA, MRSA
Elkholy <i>et al.</i> [30]	CS	2010	Egypt	T	136	96.5	CoNS, <i>S. aureus</i> , non-fermentative
Mohammadi-Sichani <i>et al.</i> [31]	CS	2011	Iran	T	150	94	<i>Bacillus</i> spp., CoNS, <i>S. aureus</i>
Tekerekoğlu <i>et al.</i> [32]	CS	2011	Turkey	T	200	85.6	CoNS, MRCNS, streptococci
Bhat <i>et al.</i> [33]	CS	2011	India	T	204	99	<i>Pseudomonas</i> spp., MSSA, <i>E. coli</i>
Trivedi <i>et al.</i> [34]	CS	2011	India	T	150	46.6	<i>S. epidermidis</i> , <i>S. aureus</i> , <i>Klebsiella</i> spp.
Brady <i>et al.</i> [35]	CS	2011	UK	T	102	70.3	CoNS, MSSA, MRSA
Morioka <i>et al.</i> [36]	CS	2011	Japan	T	110	79.1	<i>S. aureus</i>
Ustun <i>et al.</i> [15]	CS	2012	Turkey	G	183	97.8	MSCoNS, MRCoNS, ESBL(+) <i>E. coli</i>
Patil <i>et al.</i> [37]	CS	2012	India	T	64	100	<i>Enterobacter</i> spp., <i>S. typhi</i> , <i>S. aureus</i>
Shahaby <i>et al.</i> [38]	CS	2012	Egypt	T	101	77.2	Staphylococci, CoNS, <i>Bacillus</i> spp.
Panchal <i>et al.</i> [39]	CS	2012	India	T	100	65	CoNS, <i>Bacillus</i> spp., <i>S. aureus</i>
Julian <i>et al.</i> [40]	CS	2012	Canada	T	106	13	MRSA, MRSP
White <i>et al.</i> [41]	C	2012	UK	T	16	100	CoNS, <i>S. aureus</i> , coliforms
Brady <i>et al.</i> [42]	CS	2012	UK	T	87	55	<i>S. aureus</i>
Tambe <i>et al.</i> [43]	CS	2012	India	T	120	82.5	<i>S. aureus</i> , micrococci, diphtheroid
Lee <i>et al.</i> [44]	CS	2013	Korean	T	203	100	CoNS, <i>Acinetobacter</i> spp., <i>Enterobacter</i> spp.
Cinar <i>et al.</i> [45]	CS	2013	Turkey	T	40	47.5	CoNS, <i>S. aureus</i>
Amadi <i>et al.</i> [46]	CS	2013	Nigeria	T	50	86	<i>S. aureus</i> , <i>P. aeruginosa</i> , <i>P. mirabilis</i>
Rana <i>et al.</i> [47]	CS	2013	India	T	50	30	<i>S. aureus</i> , CoNS, <i>E. coli</i>

L: Letter to editor; C: cohort; CS: cross-sectional; G: general hospital; T: teaching hospital; M: medical school; MRSA: methicillin-resistant *Staphylococcus aureus*; MSSA: methicillin-sensitive *Staphylococcus aureus*; CoNS: coagulase-negative staphylococci; MSCoNS: methicillin-sensitive coagulase-negative *Staphylococcus aureus*; MRCoNS: methicillin-resistant coagulase-negative *Staphylococcus aureus*; ESBL: extended-spectrum beta-lactamase; MRSP: methicillin-resistant *Staphylococcus pseudintermedius*

Figure 2. Distribution of main types of bacteria in all studies reviewed

Discussion

The results of most studies on MPs show that these items constitute a potential risk for the colonization of microorganisms and nosocomial infections [7,15,16,18-24,35,48]. The use of MPs by HCWs increases the risk of repetitive cyclic contamination between the hands and face (e.g., nose, ears, and lips), and differences in personal hygiene and behaviors can further contribute to the risk [23].

HCWs' MPs provide a reservoir for bacteria that are known to cause nosocomial infections. Phones are ideal breeding sites for these microbes, providing humidity and proper temperature for the survival of microbes. MHDs share characteristics with both MPs and laptop computers, which are more portable and easy to use. These devices have touch screens used with fingers and finger tips, and thereby act as a potential vehicle for the transmission of nosocomial pathogens. Furthermore, MPs of HCWs move daily between work, home, and other places, and children especially may be at risk because they commonly use the devices for their multimedia functions [15].

The spread to non-colonized areas within bacterial cross-contamination will be inevitable when the transfer of microorganisms is not avoided. More importantly, MPs can lead to bacterial cross-contamination and can be a cause of nosocomial infections, contributing to the spread of resistant hospital infections within the cycle of operating rooms, ICUs (adult and pediatric), wards, and burn units, which are at high risk of infection [12,14,16]. MP contaminations show personal and social variations by country, frequency of daily use, and personal hygiene behaviors [6,16,19,21-23,31,33].

Bacteria known to cause HAIs have varied by clinical setting and have included methicillin-resistant *Staphylococcus aureus* (MRSA), *Acinetobacter baumannii*, and *Pseudomonas* species [12,17,18,25,40].

S. aureus and CoNS are the most common Gram-positive agents isolated from the surface of MPs [13,14,21,29,32]. *S. aureus*, which is a coagulase-positive pathogen, can cause infections of the skin and other organs in immune-competent patients, whereas CoNS is involved in the infectious processes in immune-compromised patients or patients using catheters [49-50]. Relatively innocuous CoNS such as *S. haemolyticus*, which is a frequent colonizer of human skin second in frequency only to *S. epidermidis*, has been regarded by many studies as an important nosocomial microorganism with a tendency to develop multiple resistances [51]. It is significant that CoNS have been isolated with a high frequency from HCWs' mobile devices.

The most common Gram-negative bacteria isolated from MP are *Acinetobacter* spp. In addition, *P. aeruginosa*, *K. pneumoniae*, *E. coli*, and MRSA were also isolated in many studies [2,12,18,25,29,33-35]. Many pathogens, particularly *Acinetobacter* spp. and *P. aeruginosa*, have been proven to remain viable for months on inanimate surfaces [50]. No studies were published on the possible role of MHDs in viral, zoonotic, or mycobacterial cross-contamination, although attention was drawn to these in some reviews [14,40]. This may be due to the fact that viruses are obligate intracellular organisms and mycobacteria require very special requirements for growth, and they are unlikely to colonize MPs.

Other studies have shown that the microbial flora of MPs closely reflect those of the hands of the owners. Khivsara *et al.* (2006) reported 6.7% co-contamination by genetically identical *S. aureus* on the hands of doctors and their phones [17]. Similarly, Borer *et al.* (2005) found that 10% of the study participants had co-contamination of multidrug-resistant *Acinetobacter* spp. their hands and MPs [12]. Jeske *et al.* (2007) showed that a one-minute talk on an MP resulted in 10% hand contamination in anesthesiologists [19]. The risk of contamination with pathogens, their ability to survive on surfaces, the duration of survival, and the risk of patient exposure to the pathogens needs to be further investigated [7].

Two studies focused on the effects of MP design in terms of smart versus non-smart with respect to bacterial contamination. Lee *et al.* (2013) showed that smart phones were more severely contaminated by

microorganisms than were non-smart phones, and suggested that this may be caused by the wider screen and more intense usage pattern of the former [44]. Pal *et al.* (2013) also showed that touch-screen MPs had lower bacterial contamination when compared with MPs with keypads, which they reported was due to the more complex surface structure of the latter [52]. These studies show that MP design and the materials used in MPs further contribute to the risk of bacterial transmission by MPs and MHDs.

A study conducted on female HCWs showed that their handbags could play a role in bacterial transmission and that MPs can be further contaminated by being carried inside handbags [53]. In fact, any contaminated item (*e.g.*, MP accessories) on the move with a HCW can easily transfer microorganisms between HCWs and patients.

Sharing patients' and patients' relatives' MPs can also be a cause of bacterial transmission and contribute to cross-contamination in the cycle of clinician-patient-patient's family [32,35].

Despite the body of evidence demonstrating MP contamination by hands, it cannot be definitively stated that microbial flora of an MP can cause a nosocomial infection. Most studies relate the hand flora to MP contamination, and we do not know yet how microbial agents survive, reproduce, and disseminate from MPs. On the other hand, most studies do show that the micro flora of an MP and that of the owner's hand are closely related, a solid finding from which recommendations can be drawn. For instance, it seems logical that any attempt to decontaminate the phone should also include simultaneous decontamination of the hands and perhaps even the face. Another important rule would be keeping the use of MPs strictly personal and refraining from sharing devices with co-workers, patients, patients' relatives, and family members.

Although a hospital environment can cause rapid contamination of the electronic devices, it seems that the contaminating microorganisms can be effectively cleaned. One study on cross-contamination [41] showed that MPs contained significant amounts of pathogenic microorganisms, but that the bacterial contamination could easily be terminated by cleaning. Zhao *et al.* (2008) [54], by Morioka *et al.* (2011) [56], and others [31,55,42] showed that the contaminations of the MPs used by medical employees can be effectively reduced by hand washing with water or alcohol and that MPs can be disinfected by the use of 70% ethyl or isopropyl alcohol.

Several studies also revealed that HCWs do not consider MPs to be contaminated items and rarely disinfect their phones [2,24,31,33,42,44].

Hand washing is the most effective method for the prevention of bacterial transmission. Although there are strict rules on hand hygiene in hospitals, it is not possible to provide decontamination, disinfection, or sterilization of each device used personally. Even though the presence of some items can be restricted in the hospital setting, it is not possible to limit the use of MPs and MHD by healthcare workers due to their indispensable benefits.

The Centers for Disease Control and Prevention (CDC)'s *Guidelines for Environmental Infection Control in Health-Care Facilities* recommends periodic disinfection after cleaning instruments and surfaces that often come into contact with the hands, such as computer keyboards and mice, as defined by the infection control committee [57].

Despite the guidelines on noise, cameras, and patient privacy, there are still no regulations on the in-hospital use of mobile telephones to prevent bacterial transmission. Manning *et al.* (2013) published an iPad cleaning bundle and disinfection methods, but disinfection of MPs is still ignored [3,58].

There should be regulations around the use of mobile telephones in hospital settings due to their potential to contribute to nosocomial infections. Such regulations could include i) consideration of restrictions regarding use of mobile telephones in high-risk hospital units (ICU, burn units, etc.); ii) periodic cleaning of mobile telephones and regular use of hand hygiene techniques by HCWs and patients; iii) use of Bluetooth earphones or antibacterial covers appropriate for MPs; and iv) promotion of washable or easy-clean MP usage by HCWs. In addition to cross-contamination, the use of MPs raises concerns due to noise pollution in the hospital, distraction, patient care compromise, increased intensity of electromagnetic interference (EMI) [59,60], disruption of privacy limits, and fire hazards near oxygen supplies [4]. Therefore, regulations should also extend to minimize the noise, distraction, and electromagnetic interference.

The production of a new generation mobile telephones with hands-free features, the widespread use of Bluetooth earphones, antibacterial surface covers, and the production of specific chemicals can provide alternative solutions. Development of waterproof or washable mobile telephones could provide a new approach to the prevention of bacterial transmission.

One promising new opportunity lies in the antibacterial nanomaterial coatings, and titanium dioxide, silver oxide, or zinc dioxide-based materials provide new horizons [7,47]. Other decontamination or contamination-reducing suggestions include sterilization by ultraviolet irradiation and the use of silicon cell phone covers [7,32]. Perhaps a good solution for very sensitive areas and patients would be the combined use of Bluetooth devices and disposable phone covers. Contamination of HCWs' MPs and solutions to these issues are shown in Figure 3.

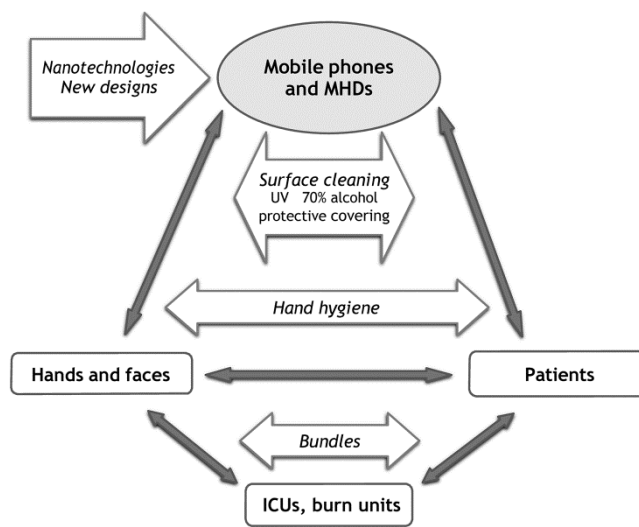
Conclusions

Numerous studies have documented the bacterial contamination of the MPs of HCWs; however, there is no evidence of a direct relationship between environmental pathogens on MPs and the rate of HAIs, and studies revealing the true risks and mechanisms for MHD-related nosocomial infections are still needed. Adoption of new communication technologies will always be a part of clinical medicine and healthcare facilities, and there will always be cross-contamination risks of mobile communication devices. Furthermore, isolated patients also suffer from emotional problems (anxiety, anger, and depression), and the use of MPs to communicate with family and friends can alleviate the discomfort. Therefore, there is a need to develop regulations around the usage and decontamination of MHDs and MPs, especially in critical areas. Finally, new designs and technologies, especially new materials to reduce handling, contamination, and to ease cleaning, are welcome.

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Figure 3. Contamination cycle of mobile phones and summary of solutions



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Corresponding author

Fatma Ulger
Ondokuz Mayıs University School of Medicine
Bafra Street, Kurupelit, Samsun
55139, Turkey
Phone: +90 362 3121919 / 3629
Fax: +90 362 4576041
Email: faulger@gmail.com; fulger@omu.edu.tr

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