Assessment of microbial contamination of mobile phones among medical staff, students, and visitors in a pediatric hematology-oncology ward and its relationship with infections among pediatric patients

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Abstract

Introduction: Healthcare-associated infections (HAIs) remain a significant threat to patient safety. The aim of this study was to evaluate the frequency and extent of microbial contamination of cell phones (CPs) used by medical staff, medical students, and visitors to pediatric patients with hematological and oncological diseases and immune disorders, as well as their potential contribution to microbial dissemination in the hospital environment.
Material and methods: The study was conducted at the Department of Pediatric Hematology, Oncology, and Transplantation at the University Children's Hospital in Lublin between May and July 2025. Samples were collected by swabbing the surfaces of cell phones. The samples were analyzed in an outsourced laboratory in accordance with standard procedures. Additionally, patients' medical records were reviewed for signs of infection.
Results: Forty active CP users were included in the study, including visitors (n = 13), students (n = 12), nurses (n = 8), and doctors (n = 7). Contamination was detected in 32/40 (80%) CP samples. A total of 61 strains were isolated: 60 bacterial strains and 1 mold isolate. The most prevalent species were *Micrococcus luteus* (33.3%; n = 20) and *Staphylococcus epidermidis* (23.3%; n = 14). The highest proportion of contaminated CPs was observed among nurses (87.5%). Symptoms of infection were observed in 7 patients; however, no correlation was found between the microorganisms isolated from CPs and the etiological agents identified in patients with infections.
Conclusions: The results indicate that CPs used by medical staff are frequently contaminated with bacteria. This suggests that, in addition to their communicative function, they may serve as potential reservoirs of microorganisms and therefore warrant attention in infection prevention strategies.

Key words: bacterial contamination, healthcare-associated infections, cell phones, healthcare workers, cross infection, pediatric oncology.

Introduction

Healthcare-associated infections (HAIs) are among the most common adverse events that threaten patient safety worldwide. However, accu-

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rately determining their global scale remains difficult due to a lack of data at the national and regional levels [1]. According to data from the World Health Organization (WHO), HAIs cause approximately 40 000 deaths annually [2]. The incidence of these infections varies by region: in developed countries, it ranges from 5% to 15%, while in developing countries it can reach as high as 25% [3, 4]. It is estimated that there are approximately 400 000 cases of HAIs annually in Poland, which corresponds to 5% of all patients, given an annual number of hospitalizations of 8 million [2].

Cell phones (CPs) have become an integral part of everyday life and are widely used by various social groups around the world [5]. In recent years, CPs have become an indispensable tool for medical staff: they are used for communication, quick access to clinical information, and reviewing laboratory and imaging results [6]. It is estimated that nearly all healthcare workers own a CP (98%), and the vast majority bring them to work (84.5%) [7]. At the same time, CPs remain in close and frequent contact with the skin and are used intensively at the patient's bedside, while routine disinfection of CPs is often irregular or neglected [7, 8]. The high frequency of CP use before, during, and after patient contact, combined with suboptimal hand hygiene, may facilitate colonization of CPs by microorganisms originating from the hospital environment, including multidrug-resistant strains [7–9]. Additionally, favorable physicochemical conditions (moisture, skin temperature of the hands, heat of the CP), and the ability of bacteria to persist for long periods on inanimate surfaces suggest that CPs may become a reservoir of pathogens and a potential link for cross-transmission between staff and patients, which may increase the risk of HAIs and hinder infection control [7, 10, 11].

Previous studies have focused primarily on the detection and characterization of microorganisms isolated from CPs used by medical students and healthcare workers [12–14]. However, few studies have examined the relationship between CP contamination and the occurrence of healthcare-associated infections, especially in the pediatric population of hematology-oncology wards. Reports on the percentage of contaminated CPs are also inconsistent [15].

Some studies indicate that contamination may affect over 80% of CPs used by healthcare workers [6]. At the same time, a review of available studies and scientific publications indicated a lack of analyses addressing this issue in Poland [15].

Given the lack of studies in this area, we conducted an analysis of this issue within the framework of the present study. The objectives were: (i) to determine the frequency and degree of microbiological contamination of CPs used by healthcare personnel, students, and caregivers of patients in a high-risk pediatric ward; (ii) to identify the spectrum of microorganisms; (iii) to compare contamination patterns among user groups; and (iv) to analyze the co-occurrence of documented infections in hospitalized children during the weeks of sample collection.

Material and methods

The study had an observational, cross-sectional, single-center, and pilot design, incorporating elements of comparative analysis between the study groups. As a pilot study, no formal sample size calculation was performed. The study was designed to provide preliminary data on the frequency and spectrum of microbial contamination of CPs in a pediatric hematology-oncology ward and to assess the feasibility of conducting a larger-scale investigation in the future. Therefore, all analyses should be considered exploratory. It was conducted at the Department of Pediatric Hematology, Oncology and Transplantation of the University Children's Hospital in Lublin.

The study sample consisted of purposively selected participant groups, identified among individuals who actively used CPs in the ward during the study period:

1. Healthcare workers (HCWs):
– Medical staff – doctors and nurses on duty on selected study days;
– Medical students – fourth- to sixth-year students undergoing clinical training in the ward.
2. Non-healthcare workers (non-HCWs):
– Visitors – individuals who spent the longest time with the child, remained in direct contact with the child, and used CPs during the study period.

Participants were informed about the nature and purpose of the study and subsequently provided informed consent to participate.

Inclusion criteria: (i) active use of CPs within the ward; (ii) provision of informed consent. Exclusion criteria: (i) no use of CPs within the ward; (ii) lack of consent.

Swabs were collected once a week on a selected day between May and July 2025. During each sampling session, one swab was collected from the CP of a doctor, a nurse, a student, and a patient visitor. Each CP was tested once. Samples were collected using sterile cotton-tipped swabs moistened with sterile 0.9% NaCl solution. The swabs were used to sample the exposed surfaces of each CP, including the touchscreen, buttons/keyboard, and rear casing, i.e., the areas most frequently in contact with the user. Each of these surfaces was thoroughly swabbed. After collection, the swabs were placed in a transport medium designed to protect the biological material from degradation and were assigned unique identification numbers. The samples were immediately sent to a microbi-

ology laboratory (no later than 2 h after collection) for microbiological analysis.

All microbiological analyses were performed by an external certified diagnostic microbiology laboratory in accordance with routine quality-controlled laboratory procedures. Samples obtained from the swabs were inoculated onto nutrient agar and incubated at 37°C for 48 h to allow microbial growth. Preliminary identification was performed using both solid and liquid culture media (including blood agar, MacConkey agar, and Chapman agar), as well as based on colony morphology and direct smear evaluation with Gram staining. Depending on the phenotype of the suspected microorganism, biochemical tests were conducted, including catalase, coagulase, oxidase, and urease assays. For isolates belonging to the genus *Staphylococcus*, antimicrobial susceptibility testing was additionally performed as part of routine laboratory diagnostics, enabling classification of coagulase-negative staphylococci as methicillin-susceptible (MSCNS) or methicillin-resistant (MRCNS).

All obtained results were appropriately categorized and entered into Microsoft Excel spreadsheets. Statistical analyses were performed using Statistica software (version 13.3, StatSoft Polska Sp. z o.o., Krakow, Poland). Categorical variables were compared using Fisher's exact test. Statistical significance was set at $p < 0.05$. The choice of test was determined by the qualitative nature of the variables. For quantitative variables, measures of central tendency (mean, median, and mode) as well as measures of variability (standard deviation and range) were calculated.

The medical records of each patient were thoroughly reviewed for symptoms suggestive of HAIs, with particular attention to body temperature and upper respiratory tract symptoms. The dates of symptom onset and the treatments administered were also recorded. In all patients presenting with the above-mentioned symptoms, the following investigations were performed: blood cultures for aerobic and anaerobic bacteria, nasopharyngeal swab testing for 23 of the most common pathogens responsible for upper respiratory tract infections, and assessment for the presence of fungi.

Results

Characteristics of the participants

The study analyzed a total of 40 samples, of which 27 (67.5%) came from HCWs, and 13 (32.5%) from non-HCWs. In the HCWs group, the largest number of samples came from medical students (n = 12), followed by nurses (n = 8) and doctors (n = 7) (Figure 1).

Frequency of contamination

Microbial contamination was detected in a total of 32 (80%) CPs belonging to the study participants. In the HCW group, 77.8% of CP (21/27) were contaminated. The highest contamination rate was observed among nurses at 87.5% (7/8),

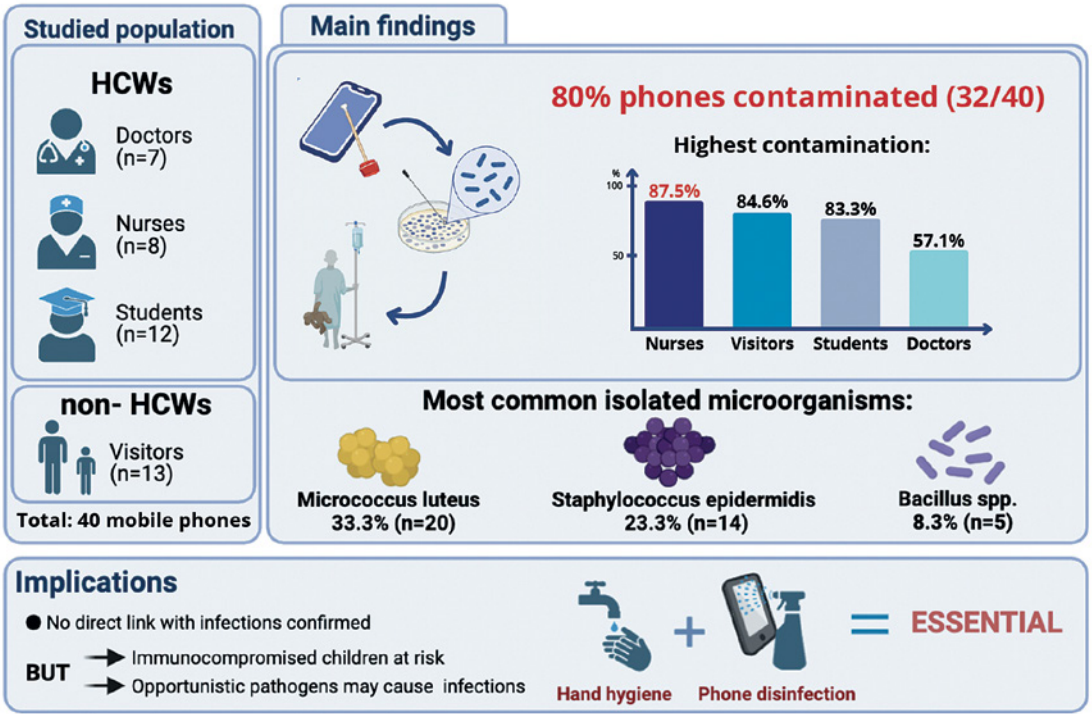

Figure 1. Mobile phones as reservoirs of microorganisms in pediatric hemato-oncology wards

HCWs – healthcare workers, non-HCWs – non-healthcare workers.

followed by medical students at 83.3% (10/12), while the lowest rate was observed among doctors at 57.1% (4/7) (Figure 2). In the non-HCW group, contamination was found in 84.6% of cases (11/13).

No statistically significant difference in the frequency of microbial contamination was observed between HCWs and non-HCWs (Fisher's exact test, $p = 1.00$).

Spectrum of microorganisms

A total of 60 bacterial strains and 1 fungal isolate were identified.

Among the bacterial isolates, the most frequently detected species were:

– *Micrococcus luteus* – 20 isolates (33.3%),
– *Staphylococcus epidermidis* – 14 isolates (23.3%), comprising 7 MSCNS and 7 MRCNS,
– *Bacillus species* – 5 isolates (8.3%),
– *Staphylococcus capitis* – 5 isolates (8.3%),
– *Staphylococcus warneri* – 4 isolates (6.7%),
– *Staphylococcus hominis* subsp. *hominis* (MSCNS) – 2 isolates (3.3%).

Single isolates (1.7%; $n = 1$) were identified for: *Staphylococcus auricularis* (MSCNS), *Staphylococcus haemolyticus* (MRCNS), *Staphylococcus cohnii* subsp. *cohnii* (MSCNS), *Kocuria rhizophila*, *Kocuria rosea*, *Pantoea species*, *Pseudomonas oryzihabitans*, *Rothia kristinae*, *Arcanobacterium haemolyticum*, *Corynebacterium urealyticum*. Additionally, one mold isolate was identified.

Comparative analysis of groups

Analysis of results across individual groups showed that:

1) among doctors and nurses, *Micrococcus luteus* was the most frequently isolated species (42.9%; $n = 3$ and 33.3%; $n = 5$, respectively);

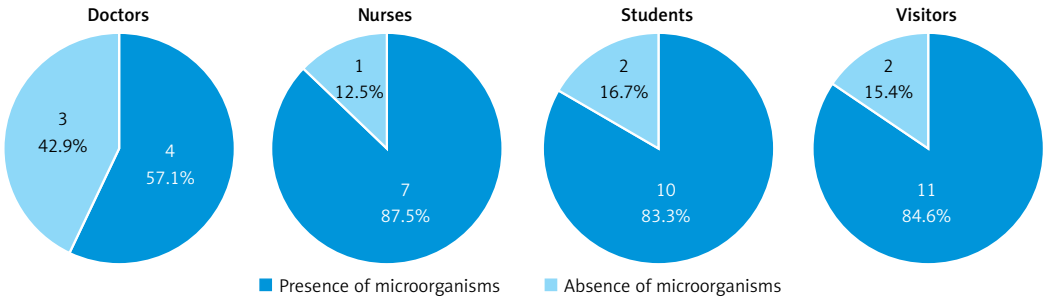

Figure 2. Percentage of contaminated mobile phones across the studied groups

Table I. Distribution of microorganisms isolated from cell phones according to participant group

Microorganisms isolated ($n = 61$)	Doctors ($n = 7$)	Nurses ($n = 8$)	Students ($n = 12$)	Visitors ($n = 13$)
Micrococcus luteus (20)	3	5	8	4
Staphylococcus epidermidis (MSCNS) (7)	1	1		5
Staphylococcus epidermidis (MRCNS) (7)		2		5
Bacillus ssp. (5)			4	1
Staphylococcus capitis (5)	1	1	3	
Staphylococcus warneri (4)	1	1	2	
Staphylococcus hominis subsp. *hominis* (MSCNS) (2)		1		
Staphylococcus auricularis (MSCNS) (1)				1
Staphylococcus haemolyticus (MRCNS) (1)		1		
Staphylococcus cohnii subsp. *cohnii* (MSCNS) (1)			1	
Kocuria rhizophila (1)				1
Kocuria rosea (1)				1
Pantoea ssp. (1)				1
Pseudomonas oryzihabitans (1)			1	
Rothia kristinae (1)	1			
Arcanobacterium haemolyticum (1)				1
Corynebacterium urealyticum (1)		1		
Mold (1)		1		
Total	7	15	19	20

MSCNS – methicillin-susceptible coagulase negative staphylococci, MRCNS – methicillin-resistant coagulase-negative staphylococci.

2) among students, *Micrococcus luteus* (42.1%; *n* = 8) and *Bacillus* spp. (21.1%; *n* = 4) predominated;
3) in the visitor group, *Staphylococcus epidermidis* was most commonly detected (50%; *n* = 10, including 5 MSCNS and 5 MRCNS), followed by *Micrococcus luteus* (20%; *n* = 4) (Table I).

Data on patients and infectious episodes

During the study period, a total of 78 patients were hospitalized in the pediatric hematology-oncology ward, including 43 (55.1%) girls and 35 (44.9%) boys. The mean age was 8 years and 8 months (SD 4.9; median 8 years; range: 9 months–17 years). The median length of hospital stay was 3 days (IQR: 2–7 days; range: 1–28 days).

The most common reason for hospitalization was acute lymphoblastic leukemia (ALL; *n* = 13; 16.7%), followed by patients with central nervous system tumors (*n* = 6; 7.7%), Hodgkin lymphoma (*n* = 5; 6.4%), thrombocytopenia (*n* = 4; 5.1%), Wilms tumor (*n* = 3; 3.9%), mucopolysaccharidosis type II (*n* = 3; 3.9%), and primary immunodeficiency disorders (*n* = 2; 2.6%). Other diagnoses occurred sporadically.

Symptoms of upper respiratory tract infection (fever, dry cough/rhinorrhea with discharge, and/or elevated C-reactive protein) were observed in 7 (9%) patients. In the panel of 23 respiratory pathogens, rhinovirus was detected in 2 (28.6%) patients. In 1 (14.3%) patient, Enterobacter cloacae complex and Candida spp. were identified in culture.

Discussion

As early as the 19th century, Semmelweis demonstrated the crucial role of contact transmission and the importance of hand hygiene in preventing infections, showing that microorganisms can be transmitted from the hands of healthcare personnel to patients [16]. In 1997, Aronson *et al.* were the first to highlight the potential of CP to contribute to infection transmission [17].

HAIs represent a growing problem in healthcare settings worldwide [15, 18]. Numerous studies have identified medical equipment and fomites as potential sources of microbial transmission [19]. Due to their frequent contact with hands and close proximity to patients, CPs may also constitute an important source of microorganism transmission, particularly among immunocompromised individuals.

Our study is likely the first in Poland to compare bacterial load levels and the presence of potential pathogens on CPs from HCWs and non-HCWs.

In this study, microorganisms were detected on 77.8% of HCWs' CPs and on 84.6% of non-HCWs' CPs. The level of CP contamination among HCWs is similar to the results of studies conducted by Mushabati *et al.* [7] and Girma *et al.* [20]. Other studies have reported even higher contamination rates, exceeding 90% [6, 11, 21–27].

High levels of CP contamination were also observed in the group of non-HCWs we studied. In most other studies, these values were lower, at around 56–58% [20, 21]. However, some studies indicate significantly higher levels of contamination: 92.5% and 80% in the studies by Chawla *et al.* [25] and Neha *et al.* [24], respectively.

The observed variability in results across studies may be attributed to multiple factors, including differences in adherence to infection prevention and control measures, the frequency of CP cleaning and disinfection, hand hygiene practices, and institutional policies regarding CP use in healthcare settings. Additionally, variations in study methodology, sample size, geographic location of the studied populations, and the level of awareness regarding the role of CPs in microbial transmission may also contribute to these discrepancies. The higher number of isolates observed in the non-HCW group may further result from the fact that these individuals operate outside the hospital environment and bring CPs into the ward without prior disinfection, potentially facilitating the introduction of additional microorganisms.

In our study, the most frequently isolated microorganism from CPs was *Micrococcus luteus*. Bacteria of the genus Micrococcus are part of the normal microbiota of human skin and mucous membranes. Due to the absence of a capsule and lack of toxin production, they have traditionally been considered organisms with low pathogenic potential [28]. However, increasing evidence in the literature indicates that these bacteria may cause infections, particularly in immunocompromised patients. Predisposing factors include invasive procedures, the presence of catheters and drains, prior bacterial or viral infections, malignancies, and the use of immunosuppressive therapy [29, 30]. Between 1953 and 1997, more than 50 cases of infections caused by micrococci were reported, approximately 80% of which occurred in immunocompromised patients with underlying conditions such as leukemia, cancer, or endocarditis [30]. An interesting finding of the present study is that *Micrococcus luteus* was isolated more frequently than *Staphylococcus* spp., which are typically reported as the dominant group of microorganisms on CP in most studies. In many studies, *Staphylococcus epidermidis* was the most commonly isolated bacterium [7, 26, 27, 31], ranking second in our study. In other studies, investigating CP contamination among HCWs, *Micrococcus* spp. were isolated less frequently and accounted for only

a small proportion of all cultured microorganisms [26, 32].

The second most frequently isolated bacterium from CP was *Staphylococcus epidermidis*, which is part of the normal human skin microbiota and typically does not pose a threat to healthy individuals. Nevertheless, under certain conditions, it may act as an opportunistic pathogen, particularly in immunocompromised patients, neonates, and individuals with indwelling medical devices such as prosthetic valves, implants, or catheters [33]. Its high frequency of isolation from CPs may be attributed to the direct contact of these devices with the skin of users' hands. Similar contamination rates of CP have been reported in studies conducted in various countries, including Italy (97%) [31], Pakistan (62%) [26], Zambia (50%) [7], Nigeria (42.9%) [27], and India (30.5%) [32].

Staphylococcus epidermidis is currently recognized as one of the leading causes of healthcare-associated infections and device-related infections [33, 34]. A key factor contributing to its pathogenicity is its ability to form biofilms on biomaterial surfaces, which facilitates colonization and hinders eradication [34, 35].

It is also noteworthy that in our study, *S. epidermidis* was the most frequently isolated bacterium among non-HCWs, while it was not detected on CPs used by students. This may suggest that individuals outside the hospital environment could serve as an additional source of microbial introduction into hospital wards, particularly in the absence of CP disinfection prior to entering healthcare facilities.

Bacillus spp. were also detected in the analyzed samples, primarily on students' CPs. This may confirm the widespread presence of these bacteria in the environment and the ability of their spores to survive under variable environmental conditions, including resistance to dry heat and certain disinfectants for a certain period of time [7]. This may be related to the fact that students participate in clinical rotations in various wards, which facilitates contact with different bacterial flora. It is worth noting that bacteria of this genus were not detected in the other groups, which may suggest that they originated from outside the studied ward.

Among the individual microbial isolates identified, *Staphylococcus haemolyticus* (MRCNS) may be of particular clinical significance due to its potential multidrug resistance and its role in hospital-acquired infections [36]. In contrast, the presence of *Arcanobacterium haemolyticum* may be considered relatively uncommon.

Particular attention should be paid to the markedly higher level of CP contamination observed among nurses (87.5%) compared to doctors (57.1%). Additionally, a mold fungus was detected on the CP of one of the nurses. This difference may be attributed to the greater number of direct contacts nurses have with patients and environmental surfaces, which may increase exposure to potential sources of microorganisms. It may also be related to differences in habits regarding CP disinfection.

According to de Groote *et al*., previous studies have not demonstrated a clear association between CP contamination and the occurrence of HAIs or cross-colonization [15]. In the present study, an attempt was made to assess the potential relationship between microorganisms isolated from CPs and the occurrence of infections in patients. Although symptoms of respiratory tract infection were observed in 7 patients, no concordance was found between the bacteria isolated from CPs and the microorganisms potentially responsible for these infections.

Nevertheless, the high rate of contamination of CPs may indicate their potential role as reservoirs of microorganisms in the hospital environment. While demonstrating the presence of microorganisms on CP surfaces is relatively straightforward, establishing a direct link between contaminated CPs and specific healthcare-associated infections is methodologically challenging. Even in cases where the same microorganism is isolated from both a CP and a patient, determining the direction of transmission and identifying which event occurred first remains difficult. For this reason, most existing studies point only to the potential risk that CPs may act as vectors for microbial transmission, while clear evidence confirming their direct involvement in the spread of healthcare-associated infections is lacking [15]. This issue may be particularly relevant in high-risk settings such as hematology-oncology wards, where hospitalized children are often immunocompromised. In this patient population, even opportunistic microorganisms, typically regarded as part of the normal skin microbiota, may lead to severe infections. Therefore, the presence of potentially pathogenic microorganisms on CPs in such environments may constitute a significant clinical risk.

One of the most important elements of infection prevention remains proper hand hygiene, recognized as the most effective method for reducing the transmission of microorganisms [21]. In situations where the use of CPs in the hospital environment is unavoidable, it appears justified to introduce guidelines requiring mandatory hand disinfection after CP use. Additionally, regular disinfection of CPs themselves is recommended. Manufacturers of major CP brands, such as Apple and Samsung, recommend the use of 70% isopropyl alcohol or dedicated disinfectant wipes to gently clean the surface of a powered-off device. However, the use of harsh chemicals, such as bleach, should be avoided, and care should be

taken to prevent moisture from entering the device, as this may damage the oleophobic coating of the screen and impair touchscreen functionality [37, 38].

Several limitations of the present study should be acknowledged. The analysis included only bacterial microorganisms; therefore, the presence of other infectious agents, such as viruses, cannot be excluded. Consequently, the actual potential of CPs as carriers of pathogens may be underestimated. This is particularly relevant for viruses such as noroviruses, which can persist on inanimate surfaces for extended periods and require only a low infectious dose to cause symptomatic infection. Future studies should consider expanding the scope of analysis to include non-bacterial microorganisms and the application of molecular methods to enable more precise identification of potential transmission pathways. Additional limitations of this study include its single-center design, small sample size, and non-random sampling approach.

In conclusion, our observations suggest that, in addition to their communicative function, CP may serve as carriers of potentially pathogenic microorganisms. To reduce the risk of HAIs, it is essential to consistently adhere to hand hygiene guidelines and to raise awareness among healthcare personnel and other CP users regarding their potential role in the transmission of microorganisms. The introduction of clear guidelines for the use of CPs in healthcare facilities, as well as regular disinfection of CPs, can be an important component of healthcare-associated infection prevention.

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Ethical approval

Not applicable.

Conflict of interest

The authors declare no conflict of interest.

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