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Microbial Contamination of Healthcare Personnel and Devices: A Critical Route for Pathogen Transmission

Hubza Ruatt Khan[1], Noor Muhammad[2,3]*, Aysha Tariq[2], Tehmina Bashir[4], Husna Jurrat[2], Mehvish Javeed[1] and Asghar Javaid[5]

[1]Department of Microbiology and Molecular Genetics, The Women University, Multan, Pakistan
[2]Department of Zoology, Government College University, Lahore, Pakistan
[3]Department of Microbiology, Shanghai Jiao Tong University, Shanghai, China
[4]Department of Botany, Government Graduate College, Lahore, Pakistan
[5]Department of Pathology, Nishtar Medical University, Multan, Pakistan

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***Corresponding Author:**
Noor Muhammad
Department of Microbiology, Shanghai Jiao Tong University, Shanghai, China
noormhd@gcu.edu.pk

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ABSTRACT

Since healthcare workers are often exposed to pathogenic organisms, they can unintentionally transfer disease to patients, causing healthcare-associated infections (HAIs). **Objectives:** To isolate healthcare staff and their respective equipment to determine the level of contamination and the pattern of antibiotic resistance. **Methods:** A total of 153 samples were taken out of doctors (n=52), nurses (n=44), lab technicians (n=33), and ward boys (n=24) in Nishtar Hospital, Multan, in this cross-sectional study that was based on laboratory procedures. Hands, stethoscopes, and mobile phones were taken, cultured on selective medium, and identified to the level of genus. Antibiotic susceptibility was evaluated using the Kirby–Bauer disc diffusion method against piperacillin (100 µg), ciprofloxacin (5 µg), levofloxacin (5 µg), gentamicin (10 µg), and imipenem (10 µg). Data were analyzed using ANOVA at a 95% confidence level. **Results:** Out of 153 samples, 93 (60.13%) yielded positive bacterial cultures. The highest number of positive cultures was recorded among lab technicians (63.64%), followed by ward boys (62.50%), doctors (57.69%), and nursing staff (56.82%) ($p<0.05$). The most frequently isolated bacteria were Bacillus sp. (22.58%), Enterococcus sp. (19.35%), and Escherichia sp. (17.20%). Mobile phones (45.16%) showed the highest contamination, followed by hands (37.63%) and stethoscopes (35.48%). All Enterococcus isolates were 100% resistant to Piperacillin, while all Staphylococcus and Klebsiella isolates showed complete resistance to multiple antibiotics. **Conclusions:** Healthcare personnel and their commonly used devices act as reservoirs for multidrug-resistant bacteria. Strict adherence to infection control protocols and specialized training for healthcare staff are essential to minimize cross-contamination and prevent HAIs.

INTRODUCTION

Healthcare-associated infections are increasing mortality rates in hospitals [1]. One of the most important infections is the nosocomial infection. They affect patients admitted to hospitals for non-infectious conditions. These nosocomial infections are the main cause of high mortality rates in hospitals and sometimes lead to costly treatments in healthcare facilities [2, 3]. The pathogens of this disease are resistant to most of the commercial antibiotics, so known as multidrug-resistant bacteria (MDR). These MDR pathogens affect the overall healthcare institutions around the globe and impose a burden on the world economy. In the intensive care unit (ICU) the nosocomial infections are considered one of the most important infections that cause morbidity and mortality. Their main targets are immunocompromised patients admitted to the ICU [4, 5]. Contaminated inanimate surfaces in ICUs contribute to outbreaks and bacterial cross-transmission between patients. Contamination may originate from healthcare

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workers or the surrounding patient environment. The pathogenic MDR bacterial strains have been reported to colonies different surfaces in healthcare facilities, medical equipment, and devices like mobile phones, stethoscopes, etc., associated with medical staff [6]. Microbial contamination of the medical facility is one of the major causes leading to the high prevalence of ICU-associated infection, which results in an elevated occurrence of nosocomial infections, accounting for 40% of ICU admittance [7]. Cross-transmission and dissemination, occupancy density, as well as the utilization of healthcare equipment for multiple patients, such as stethoscopes, gowns, and clothing, all contribute to contamination [8]. Noncompliance with routine hand-washing procedures by health care workers contributes to pathogen dissemination and cross-transmission during interaction with patients or contaminated surroundings [9]. Colonized and infected healthcare workers and patients are also sources of contamination, alongside infectious agents recovered from the patient's immediate environment. The dispersions are dependent on the type of microbe, origin, and contaminants, with surface area, humidity threshold, and size of the suspension [10]. The failures in these basic procedures tend to contribute to the spread of these pathogens, such as Staphylococcus aureus, coagulase-negative staphylococci, Enterococci, and Enterobacteriaceae within the units and hospital location. The emergence of antimicrobial-resistant strains of bacterial organisms also contributes to the increase in nosocomial infections, making it significantly more deadly and morbid, along with the cost of healthcare, not to mention the cost of healthcare [11]. Cell phones are a part of our everyday life. They have a much higher population per capita than a country often [12]. Mobile phones in hospitals can enhance the quality of healthcare, especially regarding faster contact in case of any emergency within the hospital departments. Nevertheless, even considering all the positive features the mobile phones offer, their role in spreading microorganisms should also be mentioned [13]. When dealing with patients and handling their phones, healthcare personnel can easily transmit microbes to their mobile phones. Mobile phones may provide a breeding ground for a wide range of microorganisms due to the combination of constant handling and the heat generated by mobile phones [14]. The scientists found different forms of single microbes that were on the surface of the mobile phones. These microbes are considered natural flora of the skin in certain cases, although researchers have also identified and researched microorganisms that may lead to nosocomial infections [15]. The multiple roles of patients are threatened who report in intensive care as they are linked to multiple tubes, and the introduction of pathogens is very acute and simply facilitated. These patients prove to be highly susceptible to infection by any microorganism that can be spread not only in any of the items that are attached to the patient but also in the mobile phone of HCWs [11]. There is a need to examine whether the HCWs in the ICU clean their mobile phones or not. HCWs in the intensive care unit are supposed to maintain hand hygiene before and after handling mobile phones [16].

Although healthcare-associated infections (HAIs) and antimicrobial resistance have been widely studied globally, there is limited ICU-specific evidence from Pakistan examining microbial contamination of healthcare workers and their personal devices simultaneously. Most local studies focus either on environmental surfaces or single professional groups without assessing comparative contamination patterns and antibiotic resistance profiles across multiple staff categories. Furthermore, data linking device contamination (mobile phones and stethoscopes) with multidrug resistance trends in tertiary care settings remain insufficient. Therefore, this study addressed this gap by evaluating contamination prevalence and antibiotic susceptibility patterns among ICU healthcare personnel and their commonly used devices at Nishtar Hospital. This study aims to isolate and identify bacteria from healthcare workers and their associated devices and to check their antibiotic susceptibility patterns and hospital-acquired complications in Nishtar Medical Hospital, Multan.

METHODS

This was a cross-sectional laboratory-based study conducted to assess bacterial contamination among healthcare personnel and their devices. This research investigation was conducted at Nishtar Hospital in Multan from October 2023 to March 2024. Ethical approval was obtained from Nishtar Hospital, and informed consent was taken from all participants before sampling. In the present study, 52 samples were collected from doctors, 44 from nurses, 33 from lab technicians, and 24 samples were collected from ward boys. A purposive sampling technique was employed to recruit healthcare staff working in the Intensive Care Units (ICUs) of Nishtar Hospital. The sample size of 153 was determined based on the total population of healthcare workers in the ICU departments during the study period. Using an expected contamination rate of 50% (the most conservative estimate), a 95% confidence level, and a 5% margin of error, the required sample size was calculated to be approximately 150 participants, which aligns with our collected sample of 153. A modified sterile swab technique was used for sample collection from the hands, stethoscopes, and mobile phones of healthcare workers [14]. A total of 153 swab samples of hands, mobile

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phones, and stethoscopes were collected from nurses, medical technicians, and doctors during this study. Sterile cotton swabs moistened with sterile normal saline were rolled over the region of the mobile phone's outer surfaces (including buttons, lateral and rear side of the phone, and areas that are frequently in touch with fingers). Using the same technique, samples from the hands of nurses, technicians, and doctors' stethoscopes were taken. Samples were obtained from healthcare workers who were working in Intensive Care Units (ICUs). Fewer samples were collected from ward boys due to their limited number and restricted access to ICU zones. Despite this, their high contamination rate (62.5%) still indicates their potential role in pathogen transmission. For continuous variables (such as zone of inhibition measurements), one-way analysis of variance (ANOVA) followed by a post hoc Tukey test was performed to find the significant differences between groups. For categorical data (including contamination rates and frequency distributions), chi-square tests or Fisher's exact tests were used as appropriate. Inclusion criteria were Healthcare staff including doctors, nurses, lab technicians, and ward boys who: (1) were actively working in the ICU during the study period, (2) regularly used stethoscopes and mobile phones during patient care duties, (3) provided written informed consent, and (4) had direct or indirect patient contact as part of their routine responsibilities. Exclusion criteria: Staff members who: (1) were on leave or not actively working during the data collection period, (2) declined to participate in the study, (3) had no direct patient care responsibilities, or (4) were temporary or visiting staff not permanently assigned to the ICU units. Swabs were streaked onto MacConkey agar and nutrient agar petri dishes, and 24-48 hours of incubation at 37°C was performed. Morphologically different colonies were then isolated and purified after incubation by quadrant streaking and re-streaking. The morphological and biochemical characterization and identification of all the isolated bacterial colonies were done to the genus level as per the Bergey Manual of Systematic Bacteriology [17, 18]. Testing of the antibiotic sensitivity was done using the Kirby-Bauer disc diffusion technique. The plates of Muller-Hinton Agar were prepared in sterile conditions [14]. The new cultures of the isolated bacterial strains that had been acclimatized to a 0.5 McFarland turbidity standard were then spread uniformly on the media plates. The plates were labeled, and discs of commercially available antibiotics (piperacillin (100 μg), ciprofloxacin (5 μg), levofloxacin (5 μg), gentamicin (10 μg), imipenem (10 μg)) were added to the inoculated media plates. Incubation of the plates was done at 37 o C overnight. The zone of inhibition (ZOI) was taken after incubation in mm, and the diameters were taken with a digital vernier caliper to avoid errors. Results interpretation was done based on Clinical and Laboratory Standards Institute (CLSI) guidelines, 2023. ANOVA was used and a post hoc Tukey test to identify the significant differences between and among the groups at the level of 95 confidences. The analysis of all the data was done using SPSS software version 21.0 and the graphs were done using SigmaPlot version 15.0 software.

RESULTS

Out of 153, 93 (60.13%) samples showed positive culture. Among them, 63.64% positive cultures were obtained from lab technicians and 62.5% from ward staff. The least positive cultures, about 56.82% as compared to negative cultures (43.18%), were observed among nursing staff. The one-way ANOVA revealed statistically significant differences in contamination rates among healthcare staff categories ($F(3, 149) = 8.45$, $p<0.001$) (Figure 1).

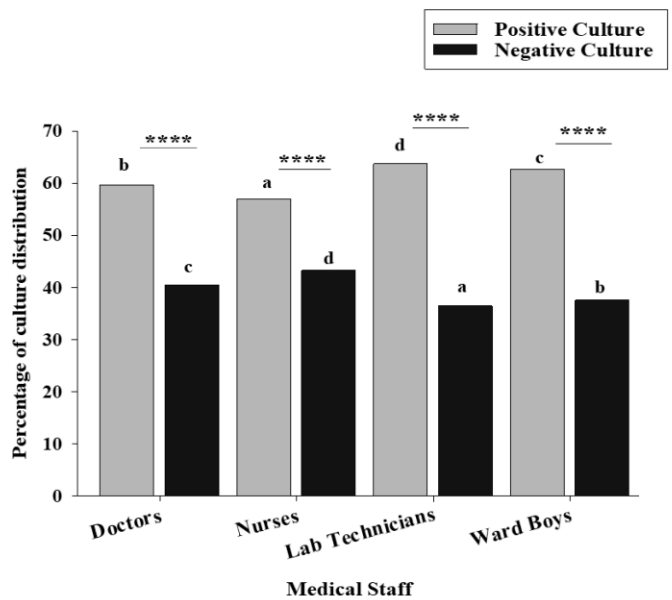

Figure 1: The Occurrence of Positive and Negative Cultures Among the Medical Staff

**** indicate p≤0.001

The distribution of bacterial isolates among positive cultures was represented. *Escherichia* sp., *Enterococcus* sp., and *Bacillus* sp. were found in the highest frequency, about 17.20%, 19.35%, and 22.58%, respectively. While *Staphylococcus* sp. had the lowest frequency of about 12.90% (Table 1).

Table 1: Distribution of Bacterial Isolates from Positive Cultures (n=93)

Staff Category	Total Samples	Positive Cultures n (%)	Negative Cultures n (%)
Doctors	52	30 (57.7%)	22 (42.3%)
Nurses	44	25 (56.8%)	19 (43.2%)
Lab Technicians	33	21 (63.6%)	12 (36.4%)
Ward Boys	24	15 (62.5%)	9 (37.5%)

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Total	153	91 (59.5%)	62 (40.5%)

Mobile phone showed the highest level of contamination (up 45%) except Escherichia sp. for all the bacterial isolates. Mobile phones were the most contaminated surfaces (45%), followed by hands (37.6%) and stethoscopes (35.4%) ($p\leq0.001$). The Escherichia sp. was equally distributed (31.82%) between hands and the stethoscope. The statistical analysis revealed that the distribution of all bacterial isolates was highly significant ($p\leq0.01$ to ≤0.000) among hands, stethoscopes, and mobile phone surfaces (Figure 2).

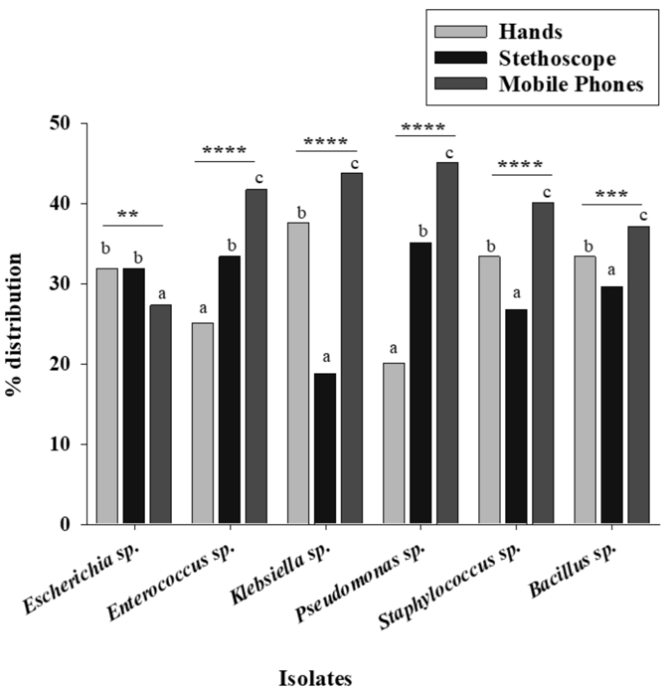

Figure 2: Percentage Distribution of Bacterial Isolates

(*Escherichia* sp., *Enterococcus* sp., *Klebsiella* sp., *Pseudomonas* sp., *Staphylococcus* sp., and *Bacillus* sp.) Across Hands, Stethoscopes, and Mobile Phones. ** represent $p\leq0.01$, *** represent $p\leq0.001$ while **** represent $p\leq0.001$

Among all the bacterial isolates, all the strains of *Enterococcus* sp. were 100.00% resistant against Piperacillin antibiotic, *Staphylococcus* sp. against Ciprofloxacin, Imipenem, and Levofloxacin, and all the strains of *Klebsiella* sp. were 100% resistant against Levofloxacin and Gentamycin. No isolated bacterial strain showed 100% sensitivity against any tested antibiotic. Maximum of the isolates were resistant to almost all the tested antibiotics in this study. The one-way ANOVA followed by post hoc Tukey test indicated that the number of resistant bacterial strains as compared to sensitive strains was statistically significant ($p\leq0.000$) (Figure 3).

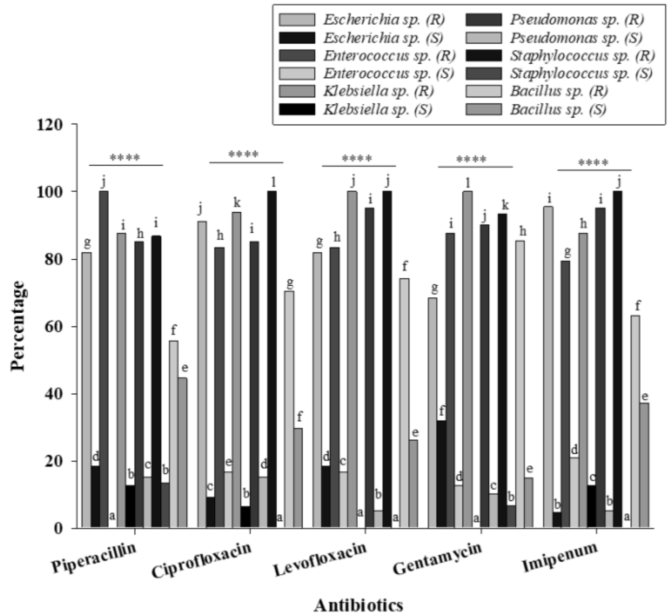

Figure 2: The percentage of Resistance (R) and Sensitivity (S) of Isolated Bacterial Strains Against Antibiotics

**** indicate $p\leq0.001$

DISCUSSION

Healthcare professionals have hands as one of the major routes through which microorganisms causing healthcare-associated infections are transmissible. Healthcare-associated infections (HAIs) represent a challenge that healthcare institutions face and may cause severe mortality and morbidity outcomes [19]. Correct hand hygiene practices are very important in reducing the transmission of pathogens and avoiding healthcare-associated infections. Healthcare professionals typically use various medical equipment (including stethoscopes) and personal electronic gadgets (including mobile phones) in healthcare settings. In recent research, there have been suggestions of the possibility of transmission of pathogenic bacteria through the use of mobile phones by medical practitioners [20]. Our research findings revealed that microbial contamination of the objects used by health care practitioners was very prevalent, and 60.13 percent were positive in cultures. Nevertheless, it should be remembered that the present study was limited to the ICU employees alone, and this might influence the extrapolation of our results to other hospital units or healthcare facilities having different workflow patterns and infection control behaviors. Further, 63.64% of lab technicians, 62.5% of ward boys, and 56.82% of the nursing staff were the highest contaminators. The results of this paper accentuate the great role of accessories as potential sources of spreading pathogens in the healthcare setting. The findings of the present study align with the recent

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research that highlights the dangers associated with the usage of personal accessories by healthcare workers. One of the studies established that nursing professionals often put on jewelry when attending to patients, which can undermine biosafety by acting as reservoirs of bacterial contamination [21]. A survey carried out in Karachi revealed that the micro-organisms, like methicillin-resistant strains, were found to contaminate 33.3 per cent of stethoscopes in the private hospitals and 51.6 per cent in the government hospitals. The fact that only 18 percent of the healthcare workers wash their stethoscopes is of great concern, which highlights the non-conformity to infection control measures [22]. We found *Bacillus* sp. (21.77%), *Enterococcus* sp. (19.35%), and *Escherichia* sp. (17.74%) as the most prevalent bacterial isolates on the accessories of healthcare workers, with *Staphylococcus* sp. (12.09%) being the least common. The results suggested that the wearings of healthcare employees serve as the reservoir of numerous species of bacteria. Our samples indicate that Bacillus sp. thrives, which agrees with the literature that shows how these spore-forming bacteria survive on inanimate surfaces and equipment, hence posing a potential source of contamination in medical facilities[23]. Similarly, the significant appearance of *Enterococcus* sp and *Escherichia* sp conforms to results in which the organisms are highlighted as common ones on accessories of the healthcare workers. One study that was conducted in Northwest Ethiopia has found that *Escherichia* coli is a major isolate of inanimate objects used by healthcare providers and the importance of such objects in harboring potential pathogens [23]. We have found that *Staphylococcus* sp., and *S. aureus*, in particular, were the least common, with 12.093 in contrast to the investigations that have found such organisms to be common contaminants on the accessories of healthcare workers. As a case study, *S. aureus*, and especially those resistant to methicillin (MRSA), have been well documented as a universal contaminant on stethoscopes and mobile phones in hospital settings, with this being a significant hazard in terms of transmission[24]. That *Bacillus* sp., *Enterococcus* sp., and *Escherichia* sp. have different prevalences than *Staphylococcus* sp. may mean hygiene practice, environmental, or material differences in the accessories. The same tendencies are found in research carried out in Africa, which shows that the degree of contamination depended on the functions of healthcare employees and their adherence to the disinfection procedures [25]. Our study results also revealed that the contamination of mobile phones was the highest among the whole bacterial isolates, with the lowest level of 45% and the highest of 60, respectively, and the contamination of the stethoscopes and hands was found to be 18.75-35.00% and 20.00-37.50% respectively. The findings are consistent with the current studies that highlight the role of mobile phones as the primary sources of bacterial contamination in healthcare settings [11]. In a research conducted in Saudi Arabia, contamination of mobile phones by bacteria was found in 72.11 percent of mobile phones used in central hospitals and 81.13 percent in peripheral hospitals, which indicates the importance of mobile devices as potential reservoirs of pathogens [26]. It has been found that worrying rates of antibiotic resistance exist in bacterial isolates sampled in healthcare-associated environments. The findings are consistent with the current research in the world, which highlights the emerging trend of antimicrobial resistance (AMR) in health care settings. According to a study on the bacterial distribution and drug resistance in 2018-2022 intensive care units, the resistance rates of Klebsiella pneumoniae to imipenem and meropenem were 14.0% and 14.4%, respectively, which indicates that the problem of resistance to this pathogen remains unsolved [27]. The overall resistance of Enterococcus sp. to topiperacillin observed in our experiment is similar to the natural resistance mechanisms that exist in enterococci. Naturally, enterococci tend to be less sensitive to penicillins, including piperacillin, due to the presence of low-affinity penicillin-binding proteins, rendering the treatment with such antibiotics less effective [28]. Strong resistance to ciprofloxacin, imipenem, and levofloxacin is a cause of major concern, as these antibiotics can often be utilized in the management of Staphylococcus infections. The identified resistance may be attributed to overuse and inappropriate utilization of the fluoroquinolones and carbapenems, which have led to the rise of resistance strains. There have been minimal decreases in the resistance rates of *K. pneumoniae* to the key antibiotics over the past years, meaning that persistent monitoring and stringent infection control measures are needed to prevent the spread of resistant strains[29].

This study was limited by its cross-sectional design, single-center setting, and purposive sampling restricted to ICU staff, which may limit generalizability to other hospital departments. Identification of isolates was performed only to the genus level, and molecular characterization of resistance genes was not conducted. Future research should include multicenter longitudinal studies, molecular analysis of resistance mechanisms, and evaluation of the effectiveness of structured infection control interventions and mobile device disinfection protocols to reduce

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multidrug-resistant organism transmission.

CONCLUSIONS

The conclusion was made that cross-contamination is caused by the medical personnel and their devices. The results, even though important, can be applied mostly to the ICU setting and cannot be generalized to other healthcare settings. Consequently, the present research paper indicates that the medical personnel should adhere to the precautionary steps to minimize the bacterial infection. Further research could be undertaken to verify the number of people who contracted bacterial infections by the staff. This paper goes further to propose that the medical staff must be given personalized training by the healthcare department, and the medical staff should not be a contamination source to other patients, including non-diseased patients.

Authors' Contribution

Conceptualization: NM
Methodology: HRK, MJ, AJ
Formal analysis: NM
Writing and Drafting: HRK, NM, AT, TB, HJ, MJ
Review and Editing: NM, HRK, MJ, AJ, NM, AT, TB, HJ

All authors approved the final manuscript and take responsibility for the integrity of the work.

Conflicts of Interest

The authors declare no conflict of interest.

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