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RESEARCH ARTICLE

# Effectiveness of Hand Hygiene Interventions in Reducing Microbial Contamination on the Hands of Healthcare Workers in Critical Care Units

**Jesseca Juri[a], Siti Marwanis Anua[a,*], Siti Suraiya[b,c], Nurzafirah Mazlan[d], Muhammad Azim Abdullah[a]**

[a]School of Health Sciences, Health Campus, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia; [b]Department of Medical Microbiology, School of Medical Sciences, Health Campus, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia; [c]Infection Control Unit, Hospital Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia; [d]Borneo Marine Research Institute, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, Malaysia

Abstract Adherence to hand hygiene guidelines is paramount in preventing the transmission of nosocomial infections within healthcare settings. Healthcare workers play a critical role in maintaining aseptic conditions and preventing the spread of pathogens. This study aimed to evaluate the effectiveness of hand hygiene in reducing microbial contamination on the hands of healthcare workers in critical care units, including the Intensive Care Unit, Neurological Intensive Care Unit, Coronary Care Unit, Cardiac Intensive Care Unit and Surgical Intensive Care Unit. A convenient sampling method was utilized to select 44 healthcare workers for the study. Microbial contamination on the hands of these healthcare workers was assessed before and after hand hygiene. Swab samples were collected from the dominant hands and analyzed using microbiological techniques, including culturing on nutrient agar and MacConkey agar, Gram staining and biochemical tests. The results demonstrated a significant reduction in microbial load on the hands of healthcare workers after they practiced hand hygiene (mean before hand hygiene: $6.57 \times 10^8 \pm 2.31 \times 10^8$ CFU/mL compared to after hand hygiene: $2.11 \times 10^8 \pm 1.52 \times 10^8$ CFU/mL), $p = 0.001$. Before the intervention, a large number of hand swab samples had microbial contamination, including potentially pathogenic microorganisms such as *Staphylococcus aureus*, *Staphylococcus* spp., *Escherichia coli*, and *Klebsiella pneumoniae*. However, after the intervention, no microbial growth was observed on any hand sample. In conclusion, these findings unequivocally demonstrate the crucial role of effective hand hygiene in preventing the transmission of nosocomial infections within healthcare settings. Consistent adherence to hand hygiene guidelines is essential for maintaining a safe and hygienic environment for patients and healthcare workers alike.

**Keywords**: Hand hygiene, Hand swab, Critical care units, Healthcare workers.

***For correspondence:**
smarwanis@usm.my

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## Introduction

Healthcare-associated infections (HCAIs) represent a persistent global health challenge, affecting hundreds of millions of patients annually. This problem has resulted in increased morbidity, mortality rate, and healthcare costs. In developed countries, approximately 6 – 7% hospitalized patients will be affected by one type of HCAIs, while in developing countries the incidence rises to 15% [1]. Complications of HCAIs include prolonged hospitalization, long-term injuries, antimicrobial resistance, increased financial pressure, high treatment costs and death.

A major contributor to the transmission of HCAIs is poor hand hygiene among healthcare workers, who serve as both caregivers and potential vectors of infectious microorganisms [2, 3]. Hand hygiene is the most effective measure to reduce the spread of infectious diseases, as hands are the primary pathway for cross-transmission between patients [4]. However, inadequate adherence with hand hygiene protocols remains a global concern, particularly in high-risk clinical settings [5]. For example, an epidemiological study in Sweden during the first phase of the COVID-19 pandemic reported that 33% of healthcare workers contracted COVID-19, with direct patient care and contact with contagious co-workers identified as significant risk factors for transmission [6]. These findings underscore the essential role of rigorous hand hygiene practices in preventing HCAIs and protecting both patients and healthcare personnel.

Enhanced hand hygiene practices in healthcare settings have significantly reduced the incidence of HCAIs. While specific figures may vary across studies, several recent publications provide strong evidence supporting this association [4, 7, 8]. A study investigated the impact of electronic hand hygiene monitoring systems (EHHMS) on hand hygiene adherence and HCAI rates found that implementing EHHMS led to sustained improvements in hand hygiene adherence among healthcare workers and a significant reduction in hospital-acquired bloodstream infections, particularly those caused by *Staphylococcus aureus* [8]. Similarly, research conducted in Saudi Arabia demonstrated that a multicomponent hand hygiene intervention increased adherence rates from approximately 50% to over 70%. This improvement was associated with significantly decreasing HCAI rates, including catheter-associated urinary tract infections [7]. The increased hand hygiene practice in health care can reduce cases of HCAIs by up to 50% [4].

Despite widespread education and protocols, microbial contamination remains prevalent on healthcare workers' hands [9]. In Malaysia, such contamination contributes to increased hospital morbidity and mortality, posing challenges for both healthcare providers and the government. A cohort study conducted in Kuala Lumpur, Malaysia identified a high incidence of multidrug-resistant organisms and modifiable risk factors associated with surgical site infections, emphasizing the urgent need for targeted interventions to reduce infection rates and improve patient outcomes [10]. A nationwide survey assessing hand hygiene practices utilized the WHO Hand Hygiene Self-Assessment Framework (HHSAF) tool in Malaysian hospitals reported that public hospitals achieved intermediate to advanced adherence levels, with a median HHSAF score of 450, while private hospitals attained a median score of 455. The teaching hospital involved in the study scored 337.5, indicating room for improvement in hand hygiene practices within academic medical centers [11].

The WHO's multimodal hand hygiene improvement strategy emphasizes the need to monitor healthcare workers' perceptions, performance and knowledge to ensure sustainable hand hygiene adherence [12]. In line with this, Malaysian national healthcare policies prioritize research in clinical institutions to support patient safety initiatives. Therefore, this study aims to evaluate the effectiveness of hand hygiene among healthcare workers at this tertiary teaching hospital by quantifying microbial contamination before and after hand hygiene practices. This approach will offer insights into real-world adherence and its implications for infection control, supporting efforts to reduce HCAIs and improve overall healthcare outcomes [12-15].

In this study, the researcher encompass a comprehensive evaluation of healthcare workers' hand hygiene practices, including the frequency, technique, and adherence to recommended guidelines. Microbial samples were collected before and after hand hygiene, followed by laboratory analysis to quantify the presence of microbial contaminants. Thus, by analyzing the data and considering potential influencing factors, this research aims to provide insights into the tangible impact of hand hygiene practices on healthcare workers' hand hygiene.

## Materials and Methods

This cross-sectional study utilized a convenience sampling method to collect samples from five designated critical units at the teaching hospital: Intensive Care Unit (ICU), Coronary Care Unit (CCU), Surgical Intensive Care Unit (SICU), Neurological Intensive Care Unit (Neuro ICU), and Cardiac Intensive Care Unit (CICU) from August 2023 to January 2024. The selection of these critical units was predicated on the understanding that the efficacy of hand hygiene significantly influences the risk of HCAIs for both patients and healthcare workers. Before obtaining samples, an initial tour inspection was performed in those areas to collect necessary details, clarify the targeted strategy, identify potential risks, and assess current control mechanisms. This research has received approval from the Universiti Sains Malaysia Human Research Ethics Committee (USM/JEPeM/19110715).

Sample collection was conducted utilizing two methods: (i) a survey questionnaire to obtain sociodemographic data and responses regarding hand hygiene practices from subject participants and (ii) a hand swab technique. Hand swab samples were collected twice on the same day, prior to and following hand hygiene intervention. The hand hygiene intervention was delivered via 10-minute talk emphasizing the importance of hand washing in health facilities, the spread of germs through hands and the right way to perform hand hygiene practice before attending a patient following the WHO multimodal guidelines [12]. Morning shift samples were collected from roughly 8:30 a.m. to 11:00 a.m., and evening shift samples from 2:00 p.m. to 4:00 p.m., to mitigate potential biological variability that could influence the research results.

### Sampling and Analysis of Hand Swabs

A total of 44 healthcare workers consented to engage in the study. Each swab sample was collected using a sterile cotton swab wetted with sterile water (5 mL). The healthcare workers' dominant hands were swabbed with uniform pressure horizontally, vertically, and diagonally (palmar and dorsal). The swab samples were then immediately immersed in 10 mL of sterile Brain Heart Infusion Broth (BHIB) contained within a sterile test tube, securely capped, sealed, and properly labeled. To ensure bacterial viability, the collected samples were transported to the laboratory in a temperature-controlled container with ice packs. After being transported to the laboratory, the samples underwent a 48-hour incubation at 37°C to prepare them for microbiological analysis. A tenfold serial dilution was performed, commencing with a $10^{-1}$ dilution and progressing through $10^{-2}$, $10^{-3}$, $10^{-4}$, $10^{-5}$, $10^{-6}$, and $10^{-7}$ dilutions following similar procedures per reported in our previous study [16]. Following the preparation of the dilution series, 0.1 mL from the $10^{-6}$ and $10^{-7}$ dilution tubes was carefully pipetted onto nutrient agar (NA) and MacConkey agar (MAC) plates using different sterile pipette tips. The media were aseptically inoculated and uniformly distributed utilizing a sterile glass spreader. The NA and MAC agar plates were incubated for 24 hours at 37°C. After incubation, the colonies on the plates were enumerated to determine colony-forming unit (CFU), reflecting the bacteria present in the dilution series. The concentration of CFU was calculated based on the following formula:

$$\text{CFU/mL} = \frac{Average\ Colony\ Count\ x\ Dilution\ factor}{Volume\ plated\ (mL)} \quad (1)$$

### Screening and Identification of Bacteria

A macroscopic examination was performed on bacterial colonies grown on the agar plates. In instances of mixed colonies, sterile streaking methods were employed to re-subculture the samples on respective agar in order to obtain pure isolates. Pure bacterial colonies were further characterized using Gram staining and a series of standard biochemical tests. Biochemical identification was conducted using the following tests: triple sugar iron agar (TSI), Simmons citrate agar, urease, methyl red Voges-Proskauer (MRVP), and sulfide indole motility (SIM). These tests enabled the differentiation and presumptive identification of Gram-negative bacilli such as *Escherichia coli* and *Klebsiella pneumoniae*. For Gram-positive cocci such as *Staphylococcus aureus* and other *Staphylococcus* spp., identification was performed using catalase and coagulase tests, as well as other relevant biochemical or selective media as appropriate. All culture media and biochemical reagents were prepared and used according to the manufacturer's instructions and standard microbiological protocols.

### Data Analysis

This study utilized version 26 of the Statistical Package for the Social Sciences (SPSS) for data analysis. Univariate analysis was utilized to ascertain the frequency, range, mean, percentage, and standard deviation of respondents' demographic data and to compute the colony-forming unit (CFU) count on the subjects' hands. Bivariate statistical analysis, including Paired T-tests, was employed to examine the mean differences in total CFU and isolated microbes among hand hygiene practices. A p-value below 0.05 was deemed statistically significant at a 95% confidence level.

## Results and Discussion

### Sociodemographic Data

Table 1 presents the sociodemographic data of the study participants, primarily female (75%, n=33) and predominantly aged 30 to 39 years (65.9%, n=29). The vast majority of them were Malay ethnicity (97.7%, n=43) and married (93.2%, n=41). The majority of subjects possessed 1 to 9 years of professional experience as nurses and healthcare assistants (59.1%, n=26). A minority have considerable experience, with 20.5% (n=9) having 20 to 29 years of experience. The distribution of experience levels might influence hand hygiene, since individuals with greater experience may exhibit

varying compliance rates. Experience in critical units is crucial since these areas require stringent hand hygiene practices to prevent infections.

All healthcare workers underwent hand hygiene training within the past three years, ensuring their knowledge of recommended practices was current. This is crucial for keeping high hand hygiene standards and adherence rates. A majority of healthcare workers preferred hand cleaning with antibacterial soap and water (77.3%, n=34), whilst a minority favored alcohol-based hand sanitizers (22%, n=10). The inclination for conventional soap and water may be associated with perceived efficacy or established routines. The attendance frequency for hand hygiene courses was predominantly once a year (68.2%, n=30), followed by 2 to 3 times a year (29.5%, n=13), and more than three times a year (2.3%, n=1). Consistent training is crucial to promote appropriate hand hygiene procedures and inform personnel of updated protocols. The identified demographic and experience characteristics indicate that focused interventions addressing these variables can improve compliance. Consistent and updated instruction, together with a preference for efficacious hand hygiene practices, can substantially diminish the incidence of HCAIs.

**Table 1.** The sociodemographic data of healthcare workers in critical units

| Variables | Sub-categories of Variables | Frequency (%) |
|---|---|---|
| Gender | Male | 11 (25) |
| | Female | 33 (75) |
| Age (years) | 20-29 | 6 (13.6) |
| | 30-39 | 29 (65.9) |
| | 40-49 | 8 (18.2) |
| | 50-59 | 1 (2.3) |
| Ethnicity | Malay | 43 (97.7) |
| | Indian | 1 (2.3) |
| Education level | SPM//STPM | 6 (13.6) |
| | Diploma | 25 (56.8) |
| | Diploma with Post Basic | 7 (15.9) |
| | Degree | 6 (13.6) |
| Working experience (years) | < 9 months | 2 (4.5) |
| | 1-9 years | 26 (59.1) |
| | 10-19 years | 7 (15.9) |
| | 20-29 years | 9 (20.5) |
| Frequency of attended hand hygiene courses | Once a year | 30 (68.2) |
| | 2-3 times a year | 13 (29.5) |
| | More than three (3) times | 1 (2.3) |
| Hand hygiene routine | Alcohol-based sanitizer hand rub | 10 (22.7) |
| | Antibacterial soap and water | 34 (77.3) |

## The Mean Difference of Microbial Contamination on Healthcare Workers Dominant Hands Pre- and Post-hand Hygiene Intervention

Table 2 shows the total CFU count of bacteria detected on healthcare workers' hands between pre- and post-hand hygiene, measured in CFU/mL. A paired T-test was employed to compare the total CFU counts on both NA and MAC agar plates across each of the critical care units. The data presented in the table indicates that the mean total number of colony-forming units on the NA plate prior to the hand hygiene intervention for all healthcare workers in critical units was substantially more ($6.57x10^8$ ± $2.31x10^8$ CFU/mL) than post-hand hygiene ($2.11x10^8$ ± $1.52x10^8$ CFU/mL), p=0.001. The mean total colony-forming units on the MacConkey plate significantly dropped from $0.78x10^8$ ± $1.53x10^8$ CFU/mL prior to hand hygiene to $0.13x10^8$ ± $4.07x10^8$ CFU/mL following hand hygiene intervention, p=0.034.

There were significant differences in the total CFU for both pre- and post-hand hygiene at all the critical units for NA ($p<0.05$), except for the CCU ($p > 0.05$). Among all, the highest bacterial load was at SICU, which showed a significantly higher CFU on NA for pre-hand hygiene ($7.76 \times 10^8 \pm 2.81 \times 10^8$) compared to post-hand hygiene ($1.56 \times 10^8 \pm 1.56 \times 10^8$), $p=0.001$. The previous study showed that the mean bacterial count on hand of healthcare workers was $1.5 \times 10^8$ [17]. This study suggests that the elevated bacterial contamination rate on healthcare workers' hands may result from patient interaction, the work environment, and the use of various instruments or devices, including mobile phones. A prior study indicated that 75.15% (n=157) of mobile phones belonging to healthcare personnel were contaminated with pathogenic germs [18].

However, relative to MAC agar plates, the data analysis revealed no statistically significant variations in CFU between pre- and post-hand hygiene across all critical units ($p > 0.05$), with the exception of SICU ($p=0.034$). The results demonstrated a substantial difference in total CFU, with a markedly higher MAC for pre-hand hygiene ($1.67x\ 10^8 \pm 1.68x10^8$) compared to post-hand hygiene ($0.43x10^8 \pm 0.83x\ 10^8$) in the SICU. The study conducted in Pakistan by Khan *et al*. [18] indicated considerable disparities between hand hygiene practices and microbiological contamination on healthcare personnel' hands. The significant microbial contamination is present not just on hands but also on lab coats, uniforms, and mobile phones [19].

**Table 2**. Comparison of mean bacterial count (CFU/mL) on the dominant hands of subjects between pre- and post-hand hygiene

| Critical units | Nutrient Agar (Mean ± SD) | | | Mac Conkey Agar (Mean ± SD) | | |
|---|---|---|---|---|---|---|
| | Pre-hand hygiene | Post-hand hygiene | P value | Pre-hand hygiene | Post-hand hygiene | P value |
| ICU | $4.91 \times 10^8 \pm 2.63 \times 10^8$ | $1.21 \times 10^8 \pm 1.18 \times 10^8$ | 0.003* | $0.34 \times 10^8 \pm 1.08 \times 10^8$ | $0.06 \times 10^8 \pm 0.20 \times 10^8$ | 0.343 |
| Neuro-ICU | $5.94 \times 10^8 \pm 1.49 \times 10^8$ | $2.14 \times 10^8 \pm 1.22 \times 10^8$ | 0.001* | $0.16 \times 10^8 \pm 0.34 \times 10^8$ | $0.07 \times 10^8 \pm 0.23 \times 10^8$ | 0.272 |
| CICU | $7.67 \times 10^8 \pm 1.35 \times 10^8$ | $1.94 \times 10^8 \pm 1.27 \times 10^8$ | 0.001* | $1.24 \times 10^8 \pm 2.05 \times 10^8$ | $0.15 \times 10^8 \pm 0.49 \times 10^8$ | 0.086 |
| CCU | $7.06 \times 10^8 \pm 2.81 \times 10^8$ | $4.10 \times 10^8 \pm 1.49 \times 10^8$ | 0.072 | $0.71 \times 10^8 \pm 1.87 \times 10^8$ | $0.16 \times 10^8 \pm 0.44 \times 10^8$ | 0.356 |
| SICU | $7.76 \times 10^8 \pm 2.81 \times 10^8$ | $1.56 \times 10^8 \pm 1.07 \times 10^8$ | 0.001* | $1.67 \times 10^8 \pm 1.68 \times 10^8$ | $0.43 \times 10^8 \pm 0.83 \times 10^8$ | 0.034* |
| All | $6.57 \times 10^8 \pm 2.31 \times 10^8$ | $2.11 \times 10^8 \pm 1.52 \times 10^8$ | 0.001* | $0.78 \times 10^8 \pm 1.53 \times 10^8$ | $0.13 \times 10^8 \pm 4.07 \times 10^8$ | 0.002* |

SD – Standard deviation, Statistical test: Paired t-test, *$p<0.05$

## The presence of Isolated Microorganisms on Healthcare Workers' Dominant Hands at Critical Units

Table 3 shows the presence of isolated bacteria on the hands of healthcare workers in critical units. The table indicates that 31 (70.4%) isolated samples were identified as Gram-positive, whilst 6 (13.6%) samples were Gram-negative organisms, with the remaining samples exhibiting no microbial growth. This underscores a notable presence of Gram-positive organisms in the healthcare setting, potentially facilitating HCAIs. Within the group of Gram-positive bacteria, 25 (55.6%) samples were identified as *Staphylococcus* spp. *Staphylococcus* spp. is a prevalent skin resident, and its presence on healthcare personnel' hands may provide a transmission risk to patients, contributing to HCAIs.

A concurrent investigation by Kulshrestha *et al*. [20] indicated a similar tendency, with 49.2% (n=199) of samples colonized by *Staphylococcus* spp. Furthermore, *Staphylococcus aureus* was detected in around 14.5% (n=199) of the samples. The uniformity across research emphasizes the ongoing presence of *Staphylococcus* contamination on the hands of healthcare workers in medical environments. Notably, 15.9% (n=7) of the samples in this previous investigation exhibited no organism development. This discovery indicates that a segment of healthcare workers may have hands devoid of detectable microbial contamination, underscoring the efficacy of proper hand hygiene practices. In support of the notion of keeping hands free from detrimental microbial pollutants, a study by Heidi *et al*. [21] indicated that 18.6% (n=56) of healthcare professionals' hands were not contaminated with germs.

The current study data indicated that samples were contaminated by Gram-negative bacteria such as *Escherichia coli* (8.9%), and *Klebsiella pneumoniae* (n=2, 4.4%). This underscores the importance of

*Escherichia coli* as a source of Gram-negative bacterial contamination, highlighting the necessity for specific preventive strategies. Studies have frequently indicated concerns about *Escherichia coli* infection on hands. Research, including a study conducted in Wales, revealed that the hands of healthcare personnel were often contaminated, with rates varying from 62.3% to 100% across different studies [9]. Subsequently, following hand hygiene, the data in Table 3 indicated that 44 (100%) of the samples obtained from healthcare workers' hands had no microbial growth.

**Table 3.** Presence of microorganisms isolated on the hands of healthcare workers (N=44)

| No. | Study variable | Frequency (%) | |
|---|---|---|---|
| | | Pre-hand hygiene | Post-hand hygiene |
| 1 | Gram staining | | |
| | Gram-positive | 31(70.4) | 0(0) |
| | Gram-negative | 6(13.6) | 0(0) |
| | No growth organism was detected | 7(15.9) | 44(100) |
| 2 | Gram-positive bacteria | | |
| | *Staphylococcus aureus* | 6(13.6) | 0(0) |
| | *Staphylococcus* spp. | 25(55.6) | 0(0) |
| 3 | Gram-negative bacteria | | |
| | *Escherichia coli* | 4(8.9) | 0(0) |
| | *Klebsiella pneumoniae* | 2(4.4) | 0(0) |

## The Identification of Isolated Bacteria

Table 4 shows the number of isolated bacteria detected on the hands of healthcare workers across different critical units. The highest hand contamination in the ICU was *Staphylococcus* spp, affecting 7 (15.9%) healthcare workers. The least prevalent isolated bacteria were *Staphylococcus aureus* and *Escherichia coli,* each represented by one sample (2.3%), with no contamination of *Klebsiella pneumoniae*. In the Neuro-ICU unit, 7 isolated samples (15.9%) indicated contamination of participants' hands. Furthermore, a solitary sample (2.3%) of both *Staphylococcus aureus* and *Escherichia coli* was recovered, with no instances of *Klebsiella pneumoniae* detected. Nonetheless, a singular sample of *Klebsiella pneumoniae* was detected on the hands of individuals in the CICU and SICU wards. All 44 subjects showed no presence of bacteria isolated after hand hygiene intervention at each critical unit (results were not tabulated). Contamination can arise from multiple sources, including healthcare workers' hands, patient skin, and medical devices. Contamination may originate from various sources, such as the hands of healthcare personnel, patient dermis, and medical apparatus. Bhatta *et al*. [22] emphasized the significance of comprehending bacterial contamination in ICUs as a crucial element in the increasing prevalence of nosocomial infections. Furthermore, surfaces adjacent to ICU patients, including bed rails, tables, and electronic gadgets, are susceptible to contamination. Our recent research [16] reported median CFU of surface swab samples that include personal table, curtain, bed auto-crank and bed hand reels was slightly higher on NA ($2.4 \times 10^8$ CFU/mL) than on MAC agar ($1.1 \times 10^8$ CFU/mL).

The examination of hand contamination in the current study yielded substantial results. The predominant bacteria discovered belonged to the *Staphylococcus* spp. (n=25; 56.8%). This prevalence underscores the ongoing difficulty of managing *Staphylococcus* spp in critical care settings. *Staphylococcus* spp. are frequently present on diverse surfaces and medical apparatus in intensive care units. The ubiquity of these bacteria in such surroundings is a significant issue owing to their capacity to persist on inanimate surfaces and their potential to induce serious illnesses. The research conducted by Menezes *et al*. [23] indicates that multidrug-resistant *Staphylococcus* spp. constitute 2% to 5% of healthcare-associated infections in neonatal intensive care units, resulting in considerable neonatal morbidity and mortality.

Notably, *Staphylococcus aureus* and *Escherichia coli* were detected in markedly reduced quantities. Conversely, *Escherichia coli*, a Gram-negative bacterium integral to the natural flora of the lower intestine, can induce ailments including diarrhea, abdominal cramping, and nausea. It frequently contaminates food through the fecal-oral pathway via contaminated hands and a high infection rate in

critical care units. This is corroborated by Anum *et al*. [24], who identified a higher contamination rate of *Escherichia coli* on critical units of healthcare workers' hands at 20% (n=50). The lack of *Klebsiella pneumoniae* in the ICU samples is significant, indicating potentially successful control methods against this pathogen in this particular setting. In the Neuro-ICU, contamination by *Staphylococcus* spp was most prevalent. This suggests an elevated risk of hand contamination in this ward, potentially attributable to patient demographics or particular therapeutic practices. Only a single sample of *Klebsiella pneumoniae* was recovered in CICU and SICU, indicating a reduced prevalence of this pathogen compared to the Neuro-ICU. The post-intervention results are promising, as no bacteria were detected on the hands of any participants in any critical units (ICU, Neuro-ICU, CICU, SICU). This indicates that the hand hygiene protocols established were exceptionally effective in eradicating bacterial contamination universally.

**Table 4.** Identification of isolated bacteria (Pre-HH)

| Critical units | N | Frequency of bacteria (%) | | | | |
|---|---|---|---|---|---|---|
| | | *Staphylococcus aureus* | *Staphylococcus* spp. | *Escherichia coli* | *Klebsiella pneumoniae* | No growth of organisms (NOG) |
| ICU | 10 | 1 (2.3) | 7 (15.9) | 1 (2.3) | 0 (0) | 1 (2.3) |
| Neuro-ICU | 10 | 1 (2.3) | 7 (15.9) | 1 (2.3) | 0 (0) | 1 (2.3) |
| CICU | 10 | 1 (2.3) | 5 (11.4) | 0 (0) | 1 (2.3) | 2 (2.3) |
| CCU | 7 | 2 (4.5) | 3 (6.81) | 1 (2.3) | 0 (0) | 2 (4.5) |
| SICU | 7 | 1 (2.3) | 3 (6.81) | 1 (2.3) | 1 (2.3) | 1 (2.3) |
| Total | 44 | 6 (13.6) | 25 (56.8) | 4 (9.1) | 2 (4.5) | 7 (15.9) |

## Conclusions

Healthcare workers play a central role in delivering patient care and are frequently in close contact with patients, especially in critical care settings. This proximity, combined with the manual nature of clinical procedures, increases the risk of transmitting harmful microorganisms. The findings from this study conducted in the critical care units of this teaching hospital reveal a concerning prevalence of microbial contamination on healthcare workers' hands prior to hand hygiene. Before intervention, hand swab samples showed microbial contamination, including Gram-positive bacteria such as *Staphylococcus aureus* and *Staphylococcus* spp., as well as Gram-negative pathogens like *Escherichia coli* and *Klebsiella pneumoniae.* These organisms are known to cause serious HCAIs and highlight the risks posed by lapses in hand hygiene. Notably, *Staphylococcus aureus* is linked to a wide range of clinical conditions due to its virulence, while the presence of *Escherichia coli* and *Klebsiella pneumoniae* on healthcare workers' hands raises serious concerns about the potential transmission of multidrug-resistant organisms.

This study provides robust evidence that effective hand hygiene interventions can completely eliminate detectable bacterial contamination on healthcare workers' hands, with a marked reduction in microbial counts ($p = 0.001$) and total absence of post-intervention growth. These results demonstrate a direct and impactful link between hand hygiene adherence and the reduction of bacterial transmission in hospital settings. These findings emphasize that consistent adherence to effective hand hygiene practices is not only critical for patient safety but also essential for protecting healthcare workers from occupational exposure.

Given these outcomes, there is a clear need for future studies with larger sample sizes and broader scopes to explore additional variables influencing hand hygiene efficacy and nosocomial infection rates. Continued research and targeted interventions will further strengthen infection control strategies and support safer healthcare environments.

## Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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