

RESEARCH ARTICLE

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Antimicrobial Susceptibility and Detection of the *mecA* Gene in *Staphylococcus* spp. Isolated from the Hands of Healthcare Workers in Maternal and Pediatric Hospital Settings

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Abstract

Healthcare workers' hands may harbor *Staphylococcus* spp. with antimicrobial resistance determinants in hospital settings, including pediatric care units. To characterize the antimicrobial susceptibility profile and detect the *mecA* gene in *Staphylococcus* spp. isolated from the hands of healthcare workers in maternal and pediatric hospital settings. Hand swab samples were collected from 60 healthcare workers, yielding 24 *Staphylococcus* isolates. Phenotypic identification, antimicrobial susceptibility testing by disk diffusion, and PCR detection of *mecA* were performed. Among the 24 isolates, 12 (50.0%) were coagulase-positive and 12 (50.0%) were coagulase-negative; no isolate was confirmed as *Staphylococcus aureus*. Resistance was highest to oxacillin (18/24; 75.0%), followed by clindamycin (15/24; 62.5%), gentamicin (14/24; 58.33%), sulfamethoxazole-trimethoprim (14/24; 58.33%), cefoxitin (14/24; 58.33%), and norfloxacin (13/24; 54.17%). Cefotaxime resistance was 50.0% and tetracycline resistance was 25.0%. The *mecA* gene was detected in 16 isolates (66.67%). *Staphylococcus* spp. recovered from healthcare workers' hands showed substantial antimicrobial resistance, with *mecA* detected in two-thirds of isolates. These findings support continued surveillance and infection prevention measures in maternal and pediatric hospital settings.

Keywords: Antimicrobial Resistance, Methicillin Resistance, Bacterial Carriage, Infection Prevention and Control, Maternal and Pediatric Care

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Citation: de Souza SGP, Dalmagro M, dos Santos IC, et al. Antimicrobial Susceptibility and Detection of the *mecA* Gene in *Staphylococcus* spp. Isolated from the Hands of Healthcare Workers in Maternal and Pediatric Hospital Settings. *J Pure Appl Microbiol*. Published online 28 October 2026. doi: 10.22207/JPAM.20.4.11

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INTRODUCTION

Antimicrobial resistance (AMR) is a growing threat to global health, compromising the effectiveness of antimicrobial treatments and reinforcing the need for surveillance and prevention measures.¹ Hospitals are healthcare environments where different types of microorganisms circulate, including highly pathogenic bacteria.² Healthcare-associated infections (HAIs) include direct transmission of infections between patients and cross-transmission (indirect) through equipment, surfaces, healthcare workers, companions, and the environment itself.³ Although microorganisms found on inanimate surfaces are less likely to transmit an infection, their presence facilitates the process of cross-contamination, especially when the hands of healthcare workers come into contact with them.^{4,5}

Thus, professionals who work daily in these environments may carry microbial strains associated with HAIs⁶; therefore, both patients and healthcare workers are exposed to biological agents. Considering that one of the main routes of transmission of microorganisms within the hospital environment is through the hands of employees, adherence to good hygiene practices becomes essential to increase the biological safety of the location.²

Hand hygiene is an established measure for reducing the occurrence of HAIs by limiting the transmission of microorganisms; however, different factors that directly influence the efficiency of this process are neglected.⁷ Through an integrative review, Costa et al.⁷ reported that the inefficiency of good practices occurs for reasons such as work overload, infrastructure, lack of knowledge, forgetting to carry out the process, lack of incentive, replacing hand hygiene with glove use, and different adherence according to professional classes.

Among Gram-positive bacteria, staphylococci, streptococci, and enterococci stand out as the main agents causing infections, both in hospital environments and in the community in general. With the increasing burden of methicillin-resistant *Staphylococcus aureus* (MRSA) and other resistant staphylococci, the presence of Gram-positive cocci continues to be a growing threat to public health. Considering the number of patients

hospitalized with compromised immune systems, it is extremely important to conduct studies that address the resistance of *Staphylococcus* spp. to antimicrobials.⁸

Antimicrobial resistance can arise through genetic elements that move within or between DNA molecules, and through mobile genetic elements transferred between bacterial cells, such as plasmids and integrative conjugative elements.⁹ In *Staphylococcus* spp., methicillin resistance is commonly associated with the acquisition of the *mecA* gene, which encodes PBP2a and reduces susceptibility to beta-lactam antibiotics.¹⁰ Characterizing *mecA* is therefore relevant for understanding the molecular basis of methicillin resistance in isolates recovered from healthcare workers' hands.

In this context, attention to hand hygiene remains particularly relevant in neonatal and pediatric care, where healthcare workers have frequent contact with vulnerable patients.^{11,12} The assessment of bacterial carriage on the hands of healthcare workers may therefore complement infection-prevention perspectives by identifying *Staphylococcus* spp. and resistance determinants that warrant further investigation.

Thus, the objective of the study was to characterize the antimicrobial resistance profile and the presence of the *mecA* gene in *Staphylococcus* spp. from the hands of healthcare workers related to the child care sectors of a hospital.

MATERIALS AND METHODS

Ethical Aspects, Study Location, and Participants

The study was authorized by the Institution's Board of Directors on the condition that its identity would remain confidential and that a report would be submitted at the end of the research. The study was approved by the Human Research Ethics Committee (CEPEH) under protocol number 4,418,027 (CAAE 39601220.0.0000.0109).

The study was conducted in the neonatal intensive care unit (NICU), pediatric intensive care unit (PICU), intermediate child care unit (ICCU), and maternity ward (MW) of a hospital. Participants were eligible if they worked in one of the selected sectors, agreed to participate, had no wounds or skin lesions on their hands, and

provided individual written informed consent. The target sample was defined based on the total number of professionals assigned to the selected sectors according to their work schedules during the study period. A total of 60 eligible professionals participated in the study. The distribution of participants according to professional category and hospital sector is presented in Table 1.

Hand sample collection

Samples were collected at the end of the participants' work shifts, after routine hand hygiene with soap and water and subsequent hand drying. Sampling was performed on the bare right hand, without gloves. A single sterile Rayon swab containing Amies transport medium supplemented with charcoal, previously moistened with distilled water, was used for sampling. The swab was applied to the interdigital spaces of the right hand, specifically to the vertices between the interdigital spaces. Each interdigital space was sampled using the same swab, with a clockwise rotational movement for 5 seconds at each interdigital space, sequentially moving the swab between the interdigital vertices.

Immediately after collection, the swab was placed in its transport medium and transported in a thermal box at ambient temperature to the Microbiological Analysis Laboratory of the University. All samples were transported and processed on the same day as collection.

Bacterial isolation

Each collected swab was inoculated into 3 mL of Brain Heart Infusion (BHI) broth and incubated at 37 °C for 24 hrs to promote bacterial growth. Following enrichment, the cultures were inoculated onto Mannitol Salt Agar and incubated at 37 °C for an additional 24 hrs. Colonies exhibiting morphological characteristics compatible with *Staphylococcus* spp. and growing on Mannitol Salt Agar were selected and subcultured repeatedly until isolated colonies were obtained. The isolates were subsequently maintained in 10% glycerol stocks at -20 °C for further microbiological and molecular analyses.

Identification of isolates

The isolates were subjected to conventional phenotypic tests for the characterization of *Staphylococcus* spp., including microscopic examination, Gram staining, catalase testing, and coagulase testing.¹³ Gram-positive, catalase-positive cocci were classified according to their coagulase reaction as coagulase-positive staphylococci (CoPS) or coagulase-negative staphylococci (CoNS). CoPS isolates were subsequently subjected to PCR for the identification of *Staphylococcus aureus*, using a species-specific primer pair. CoNS isolates were classified based on the phenotypic results and were not further identified to the species level.

Table 1. Distribution of participants according to professional category and hospital sector

Number of participants	Professional category	Hospital sector
02	Pediatric Resident Physicians - R3	Neonatal Intensive Care Unit; Pediatric Intensive Care Unit; Intermediate Child Care Unit
01	Gynecology and Obstetrics Resident Physician - R2	Maternity Ward
05	Nurses	Neonatal Intensive Care Unit; Pediatric Intensive Care Unit; Intermediate Child Care Unit
40	Nursing Technicians	Neonatal Intensive Care Unit; Pediatric Intensive Care Unit; Intermediate Child Care Unit
06	Nursing Technicians	Maternity Ward
02	Physiotherapists	Neonatal Intensive Care Unit; Pediatric Intensive Care Unit; Intermediate Child Care Unit
04	Support and Janitorial Service personnel	Neonatal Intensive Care Unit; Pediatric Intensive Care Unit; Intermediate Child Care Unit
60	Total	

Antimicrobial susceptibility testing

Antimicrobial susceptibility testing was performed using the disk diffusion method on Mueller–Hinton agar, according to the criteria established by the Clinical and Laboratory Standards Institute (CLSI), 2018 edition.¹⁴ Isolated colonies were inoculated into Brain Heart Infusion (BHI) broth and incubated overnight. On the day of testing, the bacterial inoculum was standardized to a 0.5 McFarland turbidity standard and uniformly inoculated onto Mueller–Hinton agar plates using a sterile swab. Sensidisc® antimicrobial disks (DME) were then placed on the inoculated agar surface. The plates were incubated at 37 °C for 18–24 hrs. After incubation, the diameters of the inhibition zones were measured in millimeters and interpreted according to the CLSI criteria as susceptible, intermediate, or resistant. *Staphylococcus aureus* ATCC 25923 was used as the quality-control strain.

The following antimicrobial agents were tested: cefotaxime (30 µg), cefoxitin (30 µg), clindamycin (2 µg), gentamicin (10 µg), norfloxacin (10 µg), oxacillin (1 µg), sulfamethoxazole/trimethoprim (25 µg), and tetracycline (30 µg).

DNA extraction

Genomic DNA was extracted from *Staphylococcus* spp. isolates using the PureLink™ Genomic DNA Kit (Invitrogen) according to the manufacturer's instructions. The extracted DNA was used as the template for PCR assays for identification of *Staphylococcus aureus* and detection of the *mecA* gene.

Identification of *Staphylococcus aureus*

Coagulase-positive *Staphylococcus* isolates were subjected to polymerase chain reaction (PCR) for identification of *Staphylococcus aureus*. Genomic DNA was extracted using the PureLink™ Genomic DNA Kit (Invitrogen) according to the manufacturer's instructions. PCR was performed using the primers Sa442-1 (5'-AAT CTT TGT CGG TAC ACG ATA TTC TTC ACG-3') and Sa442-2 (5'-CGT AAT GAG ATT TCA GTA GAT AAT ACA ACA-3'), based on the methodology described by Martineau et al.¹⁵ Reactions were performed in a final volume of 25 µL, containing 0.5 µL of each primer (10 µM), 20 µL of Supermix, 2 µL of DNA template, and nuclease-free water to a final

volume of 25 µL. Amplification was performed using a Veriti™ 96-Well Thermal Cycler (Applied Biosystems) under the following conditions: initial denaturation at 93 °C for 3 min, followed by 40 cycles of denaturation at 95 °C for 1 sec and annealing-extension at 55 °C for 30 sec.

Amplification products were separated by electrophoresis on a 2% agarose gel using a 100 bp DNA ladder and stained with GelRed (Uniscience, Osasco, Paulo, Brazil). The expected amplification product for *S. aureus* was 241 bp. *S. aureus* ATCC 25923 was used as the positive control.

Detection of the *mecA* Gene

PCR was performed on DNA extracted from all *Staphylococcus* spp. isolates to detect the *mecA* gene. Genomic DNA was extracted using the PureLink™ Genomic DNA Kit (Invitrogen) according to the manufacturer's instructions. PCR reactions were performed in a final volume of 25 µL, containing 0.5 µL of each primer (10 µM), 20 µL of Platinum Supermix, and 4 µL of DNA template. The primers *mecA*1 (5'-AAA ATC GAT GGT AAA GGT TGG-3') and *mecA*2 (5'-AGT TCT GCA GTA CCG GAT TTG-3') were used to amplify a 533 bp fragment, according to the methodology described by Murakami et al.¹⁶

Amplification was performed under the following cycling conditions: initial denaturation at 94 °C for 5 min, followed by 40 cycles of denaturation at 94 °C for 30 sec, primer annealing at 55.5 °C for 30 sec, and extension at 72 °C for 1 min. A final extension was performed at 72 °C for 5 min.

Amplification products were analyzed by electrophoresis on a 2% agarose gel, using a 100 bp DNA ladder as the molecular size marker. The amplification products were visualized after staining with GelRed. DNA from a previously characterized *mecA*-positive *Staphylococcus* isolate (sample 127), obtained from the laboratory's sample bank, was used as the positive control, while *Staphylococcus aureus* ATCC 25923 was used as the negative control. The expected amplification product was 533 bp.

RESULTS

From the 60 hand samples collected from healthcare workers working in the selected

hospital sectors, 24 *Staphylococcus* isolates were recovered (40.0%). The distribution of the samples and isolates according to professional category is presented in Table 2.

Among the 24 *Staphylococcus* isolates recovered, 18 (75.0%) were obtained from nursing technicians, two (8.33%) from nurses, two (8.33%) from physiotherapists, one (4.17%) from a second-year resident physician (R2), and one (4.17%) from the Support and Janitorial Service personnel. Most isolates were recovered from healthcare workers working in the NICU, whereas the isolate obtained from the R2 resident was associated with the Maternity Ward.

Phenotypic characterization classified 12 isolates (50.0%) as coagulase-positive staphylococci (CoPS) and 12 (50.0%) as coagulase-negative staphylococci (CoNS). Among the coagulase-positive isolates, none was identified as *Staphylococcus aureus* by PCR.

Antimicrobial susceptibility testing showed the highest resistance rate for oxacillin (75.0%; n = 18), followed by clindamycin (62.5%; n = 15), gentamicin (58.33%; n = 14), sulfamethoxazole–trimethoprim (58.33%; n = 14), and cefoxitin (58.33%; n = 14). Resistance to norfloxacin was observed in 54.17% (n = 13) of the isolates, while 50.0% (n = 12) were resistant to cefotaxime and 25.0% (n = 6) to tetracycline. For sulfamethoxazole–trimethoprim, one isolate (4.17%) showed intermediate susceptibility and nine (37.50%) were susceptible. The complete antimicrobial susceptibility profile is presented in Table 3, and the resistance rates are illustrated in Figure.

Regarding the number of antimicrobials to which the isolates were resistant, two isolates (8.33%) were resistant to all eight antimicrobials tested, four (16.67%) to seven, four (16.67%) to six, three (12.50%) to five, two (8.33%) to four,

Table 2. Distribution of hand samples and *Staphylococcus* isolates according to professional category

Professionals	Samples collected	<i>Staphylococcus</i> isolates	% ^a
Pediatric Resident Physicians - R3	2	0	0.0
Gynecology and Obstetrics Resident Physician - R2	1	1	100.0
Nurses	5	2	40.0
Nursing technicians	46	18	39.1
Physiotherapists	2	2	100.0
Support and Janitorial Service Personnel	4	1	25.0
Total	60	24	40.0

^a Percentages represent the proportion of *Staphylococcus* isolates among the samples collected from each professional category

Table 3. Antimicrobial susceptibility profile of *Staphylococcus* isolates recovered from the hands of healthcare workers^b

Antimicrobial	Resistant n (%)	Intermediate n (%)	Susceptible n (%)
Cefotaxime	12 (50.00)	—	12 (50.00)
Cefoxitin	14 (58.33)	—	10 (41.67)
Clindamycin	15 (62.50)	—	9 (37.50)
Gentamicin	14 (58.33)	—	10 (41.67)
Norfloxacin	13 (54.17)	—	11 (45.83)
Oxacillin	18 (75.00)	—	6 (25.00)
Sulfamethoxazole–trimethoprim	14 (58.33)	1 (4.17)	9 (37.50)
Tetracycline	6 (25.00)	—	18 (75.00)

^b Antimicrobial susceptibility was interpreted according to the Clinical and Laboratory Standards Institute (CLSI, 2018)¹⁴

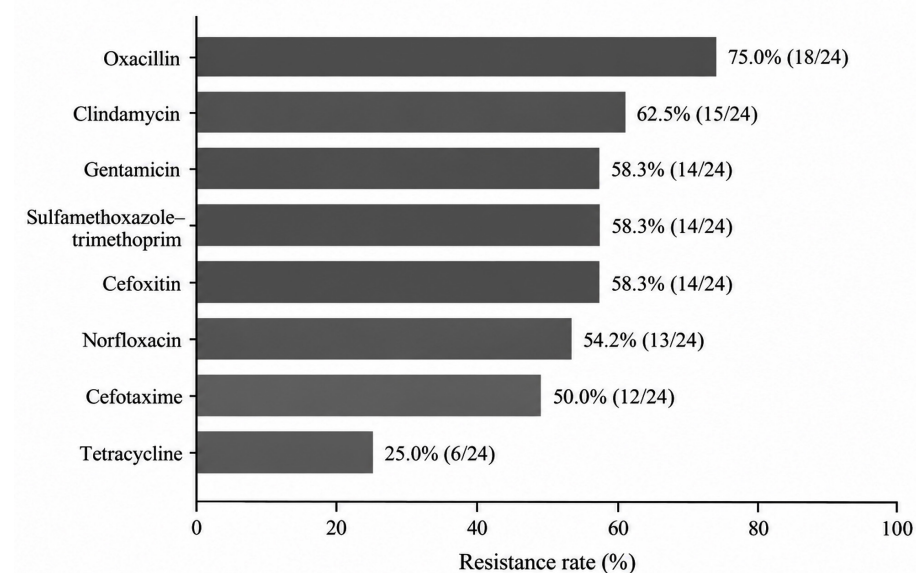


Figure. Antimicrobial resistance profile of *Staphylococcus* isolates recovered from the hands of healthcare workers^d
^aValues indicate the percentage of resistant isolates, with the absolute number of resistant isolates in parentheses (n = 24)

three (12.50%) to three, one (4.17%) to two, and three (12.50%) to one antimicrobial. Two isolates (8.33%) showed no resistance to any of the antimicrobials tested.

The *mecA* gene was detected in 16 of the 24 isolates (66.67%). Among the 18 oxacillin-resistant isolates, 15 (83.33%) were *mecA*-positive and three (16.67%) were *mecA*-negative. Among the six oxacillin-susceptible isolates, one (16.67%) was *mecA*-positive and five (83.33%) were *mecA*-negative. The relationship between oxacillin phenotype and *mecA* detection is presented in Table 4.

Table 4. Association between oxacillin susceptibility phenotype and *mecA* gene detection among *Staphylococcus* isolates

Oxacillin phenotype	<i>mecA</i> -positive n(%) ^c	<i>mecA</i> -negative n(%) ^c	Total n
Resistant	15 (83.33)	3 (16.67)	18
Susceptible	1 (16.67)	5 (83.33)	6
Total	16 (66.67)	8 (33.33)	24

^c The percentages in the first two columns are calculated within each oxacillin phenotype category. Overall, *mecA* was detected in 16 (66.67%) of the 24 isolates

DISCUSSION

Regarding the bacterial prevalence on the hands of professionals, it was observed that, of the 60 swabs collected, 24 resulted in the isolation of *Staphylococcus*, representing a prevalence of 40%. The presence of this bacterium on hands is a well-established concern, as highlighted by previous studies that emphasize the need for rigorous hand hygiene and infection control practices to reduce the risk of healthcare-associated infections.^{11,12} The interplay between patient carriage, environmental contamination, and hand hygiene among healthcare workers has also been highlighted in recent ICU research, reinforcing the relevance of hand hygiene within infection prevention strategies.¹⁷

When analyzing the distribution by category, no *Staphylococcus* was isolated from R3 resident physicians, while support and janitorial professionals, nursing technicians, and nurses had 25%, 39.1% and 40% of isolations, respectively. All physical therapists and R2 resident physicians surveyed had *Staphylococcus* on their hands. These findings should be interpreted cautiously because the corresponding professional groups comprised only one or two participants. Most of the professionals carrying bacteria on their

hands worked mainly in the NICU. Variation in isolation rates among healthcare workers may be associated with differences in work routines and exposure patterns, although these cannot be established from the present cross-sectional design, highlighting the importance of adherence to specific hand hygiene good practice protocols across all categories to prevent HAIs.^{18,19}

Regarding the isolated *Staphylococcus* species, both coagulase-positive and coagulase-negative were found in equal proportions (50%), while *Staphylococcus aureus* was not detected, with no predominance of either group.

Regarding antimicrobial resistance patterns, it was observed that for six of the eight antimicrobials tested, *Staphylococcus* presented resistance rates above 50%, while cefotaxime showed 50% and tetracycline 25%. It is also noteworthy that the isolates were resistant to different classes of antimicrobials, indicating resistance to multiple antimicrobial agents.

Resistance to oxacillin and clindamycin raises concerns, especially because these agents represent clinically relevant options for the management of staphylococcal infections. The similar resistance to cefoxitin, gentamicin, and sulfamethoxazole-trimethoprim suggests a comparable resistance pattern among these agents, although its clinical significance should be interpreted cautiously because the isolates were recovered from hands rather than clinical infections.

The 54.17% resistance rate to norfloxacin, an antibiotic of the fluoroquinolone class, raises concerns, especially considering that this class is frequently used in the treatment of urinary tract infections and other bacterial infections.²⁰

Resistance to multiple antimicrobial agents can complicate the treatment of bacterial infections. However, because these isolates were obtained from healthcare workers' hands, the present findings should not be directly extrapolated to clinical treatment outcomes. Antibiotic selection should be guided by the results of sensitivity testing, although the prevalence of resistance may influence treatment strategies.²¹

It is essential to monitor resistance rates in healthcare settings, as this information highlights the importance of antimicrobial resistance surveillance. Regular monitoring is

essential to assess trends over time and adjust antimicrobial prescribing practices as needed.²²

The absence of *Staphylococcus aureus* is an interesting observation, considering its association with more serious infections. Further studies with larger and more balanced groups would be useful to investigate differences in isolation rates across professional categories. The increasing resistance to antimicrobials among *Staphylococcus* spp. highlights the need for continuous monitoring and strategies for the rational use of these drugs,²³ contributing to reducing the selective pressure that drives the emergence of resistance.²⁴

Oxacillin resistance, a phenotypic indicator of methicillin resistance, is particularly relevant.^{25,26} The relationship between antimicrobial resistance outcomes and antimicrobial prescribing practices in the healthcare institution could be investigated in future studies to better understand the factors affecting resistance.

Assessing these resistance patterns is crucial, taking into account the clinical context, the infection control measures implemented, and the sensitivity of the detection methods used. Furthermore, the use of complementary phenotypic and molecular approaches may improve the characterization of methicillin resistance, particularly in isolates showing discordant phenotypic and genotypic results.²⁷

As for the *mecA* gene, it plays a crucial role in antibiotic resistance, especially in staphylococci. It is a major determinant of methicillin resistance and is carried on the staphylococcal cassette chromosome *mec* (*SCCmec*). The protein encoded by *mecA*, *PBP2a*, has reduced affinity for β -lactam antibiotics, contributing to resistance.²⁸

Monitoring and understanding the presence of the *mecA* gene, along with other antibiotic resistance determinants, is essential to implementing effective infection control strategies and preserving antibiotic efficacy.²⁹ The *mecA* gene was detected in 16 of the 24 isolates (66.67%), including one isolate that was phenotypically susceptible to oxacillin; this discordance cannot by itself establish whether *mecA* was expressed. Another interesting finding was that three oxacillin-resistant isolates were *mecA*-negative, suggesting phenotypic-genotypic discordance that may be associated with other resistance determinants or

mechanisms, including genes such as *mecC*,³⁰ which was not investigated in the present study. The comparison of phenotypic and genotypic methods in healthcare workers has demonstrated the importance of using complementary approaches when characterizing methicillin resistance, particularly when phenotypic results do not fully correspond to molecular findings.¹⁰

The data from this research contribute to a better understanding of antimicrobial resistance patterns among *Staphylococcus* spp. isolated from healthcare workers in the hospital environment, including those working in environmental cleaning sectors. The data are of particular interest, since *Staphylococcus* species present different virulence factors, which are not restricted to *S. aureus*. In coagulase-negative *Staphylococcus*, for example, biofilm production is a virulence factor frequently found in infections caused by these strains, which makes their control even more difficult. According to Pedretti et al.,³¹ further investigations into the genetic relationship between strains of different origins are useful for epidemiological and monitoring purposes, in addition to enabling the development of new strategies to contain the spread of *Staphylococcus* spp. not only in the clinical field but also in other related environments.

When it comes to maternal and child care, such as that in which the volunteers in this research worked, the presence of resistant staphylococci on the hands of healthcare workers underscores the importance of infection prevention, particularly because hospitalized patients in these settings may be more vulnerable to infections and complications.

Thus, proper hand hygiene emerges as an effective strategy in preventing hospital infections, contributing to patient safety by reducing the spread of harmful microorganisms. Healthcare workers, who are frequently exposed to pathogens, should therefore maintain consistent hand hygiene practices as part of routine infection prevention measures.³² Evidence from an intervention study further indicates that strengthening hand hygiene practices can be accompanied by a reduction in methicillin-resistant *S. aureus* carriage among healthcare workers.³³

In addition to playing a crucial role in disseminating knowledge about the importance of hygiene, these professionals act as role models

by incorporating exemplary practices, fostering adherence among colleagues, and contributing to safer environments.³⁴

Preventing infections not only reduces treatment costs but also prevents extended hospital stays and minimizes negative effects on patients' quality of life. In this scenario, healthcare workers play a fundamental role in ensuring compliance with regulatory standards, an essential condition for maintaining quality and safety in healthcare services.³⁵

Both healthcare workers and those responsible for cleaning maternal and child wards may represent potential reservoirs for carriage of resistant *Staphylococcus* within the healthcare environment; however, the cross-sectional design of this study does not allow inference of transmission or direct risk to mothers and newborns. These findings reinforce the need for educational measures and ongoing training for all those involved in the care and maintenance of the hospital environment, as well as the implementation of rigorous surveillance and infection control protocols, especially in critical areas such as the NICU. Furthermore, they highlight the importance of the rational use of antimicrobials as a central strategy in tackling bacterial resistance, currently considered a global public health challenge.

The present study was conducted in a single hospital, with a reduced sample of professionals and a restricted collection period, factors that limit the extrapolation of the findings. The sample was also unevenly distributed across professional categories, and the cross-sectional design, absence of hand hygiene compliance data, and the absence of patient and environmental data in the present analysis limit interpretation of potential sources of carriage. In addition, molecular typing was not performed, and only *mecA* was investigated, preventing assessment of isolate relatedness and other resistance determinants such as *mecC*. Given the small subgroup sizes, comparisons among professional categories should be interpreted as descriptive rather than inferential, and transmission between healthcare workers, patients, and the environment cannot be established. Multicenter studies with a larger number of participants and clonal profile analyses are recommended to more accurately

track sources of contamination and provide more robust evidence on the spread of resistant microorganisms in hospital settings.

CONCLUSION

The presence of *Staphylococcus* spp. on healthcare workers' hands, associated with high resistance rates to different antimicrobials and the detection of *mecA*, highlights the relevance of microbiological surveillance in this context and reinforces the need to interpret these findings in an integrated manner. These results contribute to a better understanding of the resistance profile of isolates recovered from healthcare workers' hands in maternal and pediatric care settings and may support subsequent monitoring and further investigation strategies.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Coordination for the Improvement of Higher Education Personnel (CAPES), Financing Code 001, for providing scholarship support through the PROSUP program. The authors also thank Universidade Paranaense (UNIPAR) for institutional support. The authors also gratefully acknowledge the healthcare institution for authorizing the conduct of the study and facilitating the collection of data, as well as the healthcare workers who participated in the research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTION

SGPS, ICS, LNB, and DDG conceptualized the study. LNB supervised the study and managed the overall project. DDG and LNB performed funding acquisition. LMRR, CD, LNB, and SGPS developed and implemented the methodology. SGPS, LMRR, and LNB conducted the investigation. MD, FGCB, DDG, and LNB performed formal analysis. CD performed visualization. ICS, SGPS, MD, MCS, FGCB, and LNB performed validation. SGPS and LNB were responsible for data curation. SGPS, MD, FGCB, MCS and DDG wrote the original draft. SGPS and LNB contributed to writing, reviewing, and editing the manuscript.

All authors read and approved the final manuscript for publication.

FUNDING

None.

DATA AVAILABILITY

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

ETHICS STATEMENT

This study was approved by the Human Research Ethics Committee - CEPEH under Opinion number 4,418,027 (CAAE 39601220.0.0000.0109).

INFORMED CONSENT

Written informed consent was obtained from the participants before enrolling in the study.

REFERENCES

1. World Health Organization. Global antibiotic resistance surveillance report 2025. Geneva: World Health Organization. 2025. <https://www.who.int/publications/i/item/9789240116337>
2. Rozanska A, Romaniszyn D, Chmielarczyk A, Bulanda M. Bacteria contamination of touch surfaces in Polish hospital wards. *Med Pr Work Health Saf.* 2017;68(4):459-467. doi: 10.13075/mp.5893.00575
3. Haley RW, Hightower AW, Khabbaz RF, et al. The emergence of methicillin-resistant *Staphylococcus aureus* infections in United States hospitals. Possible role of the house staff-patient transfer circuit. *Ann Intern Med.* 1982;97(3):297-308. doi: 10.7326/0003-4819-97-3-297
4. de Souza SGP, de Santos IC, Bondezan MAD, et al. Bacteria with a potential for multidrug resistance in hospital material. *Microb Drug Resist.* 2021;27(6):835-842. doi: 10.1089/mdr.2019.0305
5. Santos AB, Batista Silva KS, Santana MMR, Marques MW, Naue CR. Perfil bacteriano das superficies e equipamentos do Bloco Cirurgico de um Hospital Universitario [Bacterial profile of surfaces and equipment in the surgical suite of a University Hospital]. *VITTALLE.* 2020;32(1):101-107. doi: 10.14295/vittalle.v32i1.11048
6. Tajeddin E, Rashidan M, Razaghi M, et al. The role of the intensive care unit environment and health-care workers in the transmission of bacteria associated with hospital acquired infections. *J Infect Public Health.* 2016;9(1):13-23. doi: 10.1016/j.jiph.2015.05.010
7. Costa JG, Araujo LDP, Neiva M, et al. Fatores impactantes na pratica da higienizacao das mto os [Factors influencing hand hygiene practices]. *Recien.* 2022;12(38):278-291. doi: 10.24276/rrecien2022.12.38.278-291

8. Miyahira RF, Santos EA, Leao RS, de Freitas-Almeida AC, Queiroz ML. Antimicrobial susceptibility and enterotoxin-encoding genes in *Staphylococcus* spp. recovered from kitchen equipment from a University Hospital in Rio de Janeiro, Brazil. *Microb Drug Resist.* 2018;24(7):995-1001. doi: 10.1089/mdr.2016.0309
9. Partridge SR, Kwong SM, Firth N, Jensen SO. Mobile genetic elements associated with antimicrobial resistance. *Clin Microbiol Rev.* 2018;31(4):e00088-17. doi: 10.1128/CMR.00088-17
10. Sisodia K, Anveshi AK, Ranga D, Kumar D, Gaiind R. Phenotypic and genotypic characterization of MRSA isolated from health care workers in tertiary care hospital. *Indian J Med Microbiol.* 2025;56:100871. doi: 10.1016/j.ijmm.2025.100871
11. Allegranzi B, Pittet D. Role of hand hygiene in healthcare-associated infection prevention. *J Hosp Infect.* 2009;73(4):305-315. doi: 10.1016/j.jhin.2009.04.019
12. Lago PN, Simoes e Silva R, Benedito OK, et al. Seguranca do paciente: higiene das maos como ferramenta para a prevencao de infeccoes relacionadas a assistencia A saude [Patient Safety: Hand hygiene as a tool for preventing healthcare-associated infections]. *REMECS.* 2021;27:27. Accessed April 6, 2026. <https://www.revistaremeccs.com.br/index.php/remecs/article/view/679>
13. Koneman EW, Winn W. *Koneman's Color Atlas and Textbook of Diagnostic Microbiology*. 6th ed. Guanabara Koogan; 2008.
14. Clinical and Laboratory Standards Institute. *Performance Standards for Antimicrobial Susceptibility Testing*. 28th ed. CLSI document M100-S28. Clinical and Laboratory Standards Institute. 2018.
15. Martineau F, Picard FJ, Roy PH, Ouellette M, Bergeron MG. Species-specific and ubiquitous-DNA-based assays for rapid identification of *Staphylococcus aureus*. *J Clin Microbiol.* 1998;36(3):618-623. doi: 10.1128/JCM.36.3.618-623.1998
16. Murakami K, Minamide W, Wada K, Nakamura E, Teraoka H, Watanabe S. Identification of methicillin-resistant strains of staphylococci by polymerase chain reaction. *J Clin Microbiol.* 1991;29(10):2240-2244. doi: 10.1128/jcm.29.10.2240-2244.1991
17. Yang X, Liu Y, Yang Q, Zu S, Xu Z. The Impact of Environmental Contamination and Carriage of Methicillin-Resistant Staphylococci by Patients on the Hand Hygiene of Healthcare Workers. *Nurs Crit Care.* 2026;31(1):e70284. doi: 10.1111/nicc.70284
18. Pittet D, Hugonnet S, Harbarth S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. Infection Control Programme. *Lancet.* 2000;356(9238):1307-1312. doi: 10.1016/S0140-6736(00)02814-2
19. Sampaio LA, de Silva HC, de Carmo TG. Role of the hospital infection control committee in cases of multi-resistant bacteria. *Res Soc Dev.* 2023;12(7):e4912742463. doi: 10.33448/rsd-v12i7.42463
20. Moraes AFP, Fabri Tomazini MH, Paula MC, Pedigone MAMC. Resistencia bacteriana em ITU comunitarias: importância da analise periodica da urocultura para tratamento adequado [Antimicrobial Resistance in Community-Acquired Urinary Tract Infections: The Importance of Regular Urine Culture Testing for Appropriate Treatment]. *Manuscripta Medica.* 2021;4:20-30. <https://manuscriptamedica.com.br:443/revista/index.php/mm/article/view/55>.
21. dos Santos Monteiro RF, dos Santos VRR, Ferreira AACT, de Abreu JRG. The indiscriminate use of antimicrobials for the development of resistant microorganisms. *REAS.* 2020;53:e3597. doi: 10.25248/reas.e3597.2020
22. Bertuol RF, Rampelotto RF. Antimicrobial resistance due to the indiscriminate use of antibiotics. *REVIVA.* 2023;2(1). <https://revistas.uceff.edu.br/reviva/article/view/260>.
23. World Health Organization. WHO's first global report on antibiotic resistance reveals serious, worldwide threat to public health. April 30, 2014. Geneva, Switzerland: World Health Organization; 2014. Accessed March 25, 2026. <https://www.who.int/news/item/30-04-2014-who-s-first-global-report-on-antibiotic-resistance-reveals-serious-worldwide-threat-to-public-health>
24. Garcia JVAS, Comarella L. The indiscriminate use of antibiotics and the increase of bacterial resistance. *Saude e Desenvolvimento.* 2021;10(18):78-87. <https://www.cadernosuninter.com/index.php/saude-e-desenvolvimento/article/view/866/1420>.
25. Hiramatsu K, Hanaki H, Ino T, Yabuta K, Oguri T, Tenover FC. Methicillin-resistant *Staphylococcus aureus* clinical strain with reduced vancomycin susceptibility. *J Antimicrob Chemother.* 1997;40(1):135-136. doi: 10.1093/jac/40.1.135
26. Cunha HP, Baiense ASR. Use of Vancomycin In The Treatment of Infections Caused by Methicillin-resistant *Staphylococcus aureus* (MRSA). *REASE.* 2023;9(4):9242-9258. doi: 10.51891/rease.v9i4.9642
27. Duarte FC, Olak APS, Cardim SL, et al. Phenotypic and genotypic characteristics of *mecA*-positive oxacillin-sensitive *Staphylococcus aureus* isolated from patients with bloodstream infection in a tertiary hospital in Southern Brazil. *Braz J Microbiol.* 2024;55(3):2705-2713. doi: 10.1007/s42770-024-01420-z
28. Rafif Khairullah A, Rehman S, Agus Sudjarwo S, et al. Detection of *mecA* gene and methicillin-resistant *Staphylococcus aureus* (MRSA) isolated from milk and risk factors from farms in Probolinggo, Indonesia. *F1000Res.* 2022;11:722. doi: 10.12688/f1000research.122225.3
29. Trajano SC, Aragao BB, Silva JG, et al. Ocorrência de *Staphylococcus pseudintermedius* resistentes A metilicina isolados do campo operatorio de cadelas submetidas A ovariohisterectomia [Occurrence of methicillin-resistant *Staphylococcus pseudintermedius* isolated from the surgical field of female dogs undergoing ovariohysterectomy]. *Med Vet.* 2022;16(2):113-120. doi: 10.26605/medvet-v16n2-4986
30. Andrzejczuk S, Cygan M, Dluski D, Stepień-Pysniak D, Kosikowska U. Staphylococcal resistance patterns, *blaZ* and *SCCmec* cassette genes in the nasopharyngeal microbiota of pregnant women. *Int J Mol Sci.* 2023;24(9):7980. doi: 10.3390/ijms24097980
31. Pedretti N, Iseppi R, Condo C, et al. Characterization

- of virulence factors and antimicrobial resistance in *Staphylococcus* spp. isolated from clinical samples. *Folia Microbiol.* 2024;69:1043-1052. doi: 10.1007/s12223-024-01148-1
32. Silva NK, Lima MKS, Barbosa HCV, et al. Segurança do paciente: mensurando o controle de infeccoes na UTI [Patient Safety: Measuring Infection Control in the Intensive Care Unit (ICU)]. *Recien.* 2021;11(33):260-269. doi: 10.24276/rrecien2021.11.33.260-269
33. Alwashaish MM. Impact of a multimodal hand hygiene intervention on methicillin-resistant *Staphylococcus aureus* carriage among healthcare workers in Libya: a quasi-experimental pre-post study. *Antimicrob Resist Infect Control.* 2026;15(1):39. doi: 10.1186/s13756-026-01721-y
34. Azevedo AP, Medeiros FP, Souto FL, et al. Adhesion of hand hygienization among multidisciplinary teams in intensive care units in a hospital reference in infectology. *REAEEnF.* 2021;9:e5008. doi: 10.25248/reaenf.e5008.2021
35. Azevedo TT, Souza CJ, Silvino ZR, et al. Good practices for disinfection of bed in intensive care units. *REAS.* 2023;23(7):e12886. doi: 10.25248/REAS.e12886.2023