ORIGINAL ARTICLE

Journal of Clinical Microbiology and Infectious Diseases (*JCMID*) 2025, Volume 5, Number 1: 6-11
E-ISSN: 2808-9405

Published By : the Indonesian Society for Clinical Microbiology

Identification of Methicillin-Resistant *Staphylococcus aureus* (MRSA) carriers in the nasal passages of healthcare workers at Universitas Udayana Hospital

Made Illene Winaya[1], Made Agus Hendrayana[2*], Ni Nyoman Sri Budayanti[2,3], Ni Nengah Dwi Fatmawati[2,4]

[1]Medical Student, Faculty of Medicine, Universitas Udayana, Bali, Indonesia;
[2]Clinical Department of Microbiology, Faculty of Medicine, Universitas Udayana, Bali, Indonesia;
[3]Universitas Udayana Hospital, Bali, Indonesia;
[4]Ngoerah Hospital, Bali, Indonesia.

*Corresponding to:
Made Agus Hendrayana;
Clinical Department of Microbiology, Faculty of Medicine, Universitas Udayana, Bali, Indonesia;
agus_hendrayana@unud.ac.id

Received: 2024-12-27
Accepted: 2025-02-16
Published: 2025-03-10

ABSTRACT

Background: Methicillin-resistant Staphylococcus aureus (MRSA) is a major pathogen responsible for healthcare-associated infections (HAIs), with growing global concern due to its resistance to multiple antibiotics, including beta-lactams. Healthcare workers (HCWs), particularly those in critical care settings, are at risk of being asymptomatic carriers, facilitating MRSA transmission. This study aimed to determine the prevalence and distribution of MRSA carriers among healthcare workers (HCWs) at Universitas Udayana Hospital, Bali, Indonesia.

Methods: A descriptive cross-sectional study was conducted from October to November 2024. A total of 44 nasal swab samples were collected from nurses across various hospital wards. Samples were cultured on Mannitol Salt Agar and underwent Gram staining, catalase, and coagulase testing. MRSA identification was confirmed using the cefoxitin disk diffusion method, with inhibition zones of ≤21 mm indicating methicillin resistance, as per CLSI guidelines. Data were analyzed descriptively.

Results: MRSA colonization was identified in 4 out of 44 samples (9.1%), with cases distributed in the NICU (2 cases), ICU (1 case), and Surgical Ward (1 case). In addition, 12 samples (27.3%) were positive for methicillin-sensitive Staphylococcus aureus (MSSA), while 28 samples (63.6%) contained coagulase-negative staphylococci (CNS), predominantly in the outpatient and emergency departments.

Conclusion: The presence of MRSA among HCWs, especially in critical units like NICU and ICU, emphasizes the importance of enhanced infection control measures. Routine screening, strict adherence to hand hygiene, appropriate use of personal protective equipment, and implementation of decolonization protocols, such as mupirocin application and chlorhexidine bathing, should be optimized to reduce MRSA transmission risks within healthcare facilities.

Keywords: MRSA, Healthcare-Associated Infections, *Staphylococcus aureus*, Healthcare Workers, Antibiotic Resistant.
Cite This Article: Winaya, M.I., Hendrayana, M.A., Budayanti, N.N.S., Fatmawati, N.N.D. 2025. Identification of Methicillin-Resistant *Staphylococcus aureus* (MRSA) carriers in the nasal passages of healthcare workers at Universitas Udayana Hospital. *Journal of Clinical Microbiology and Infectious Diseases* 5(1): 6-7. DOI: 10.51559/jcmid.v5i1.82

INTRODUCTION

Healthcare-associated infections (HAIs) pose a significant challenge in modern medicine, with hospitals having a crucial responsibility to minimize the risk of pathogen transmission. One of the major pathogens responsible for healthcare-associated infections (HAIs) is *Staphylococcus aureus*, which can cause diseases ranging from mild skin abscesses to severe conditions, such as sepsis and pneumonia.[1] Methicillin-resistant Staphylococcus aureus (MRSA) has become a significant concern due to its resistance to many antibiotics, making treatment more difficult. The resistance of MRSA is primarily due to genetic changes, particularly the mecA gene, which results in a reduced affinity for beta-lactam antibiotics, such as methicillin.[2] The spread of MRSA, especially in healthcare settings, is further exacerbated by improper antibiotic use, and the prevalence of MRSA remains a significant global health issue, with varying rates in different regions, including Indonesia.[1]

In hospitals, healthcare workers (HCWs) are at risk of becoming carriers of MRSA, with their nasal passages being a common site of colonization. Identifying MRSA carriers among HCWs is essential to prevent its transmission, especially in high-risk environments like intensive care units (ICU) and neonatal intensive care units (NICU).[3] Studies have shown that HCWs, particularly those with underlying health conditions, are more likely to carry MRSA, and this can contribute to its spread within healthcare settings. Given the challenges posed by MRSA, including its resistance to conventional treatments such as vancomycin, it is crucial to monitor and implement adequate infection control measures.[4] This study aims to identify the presence and prevalence of MRSA carriers in the nasal passages of healthcare workers at Udayana University Hospital, as part of efforts to enhance patient safety and reduce the risk of healthcare-associated infections (HAIs).

Table 1. Distribution of Bacterial Isolates in Research Subjects

Ward	Total (N=44)	Interpretation		
		MRSA (+) (N=4)	MSSA (+) (N=12)	CNS (+) (N=28)
Management, n (%)	1	0 (0.0)	1 (100.0)	0 (0.0)
Isolation, n (%)	2	0 (0.0)	0 (0.0)	2 (100.0)
Labor Ward, n (%)	2	0 (0.0)	1 (50.0)	1 (50.0)
Obstetrics and Pediatrics, n (%)	5	0 (0.0)	1 (20.0)	4 (80.0)
Surgical Ward, n (%)	5	1 (20.0)	3 (60.0)	1 (20.0)
Intermediate Care Unit, n (%)	2	0 (0.0)	0 (0.0)	2 (100.0)
Neonatal Intensive Care Unit, n (%)	5	2 (40.0)	2 (40.0)	1 (20.0)
General Outpatient Clinic, n (%)	7	0 (0.0)	1 (14.3)	6 (85.7)
Emergency Department, n (%)	5	0 (0.0)	0 (0.0)	5 (100.0)
Intensive Care Unit, n (%)	10	1 (10.0)	3 (30.0)	6 (60.0)

METHODS

This healthcare-associated infection study employs a descriptive, cross-sectional approach. The research was conducted at Udayana University Hospital for sample collection and at the Microbiology Laboratory of the Faculty of Medicine, Udayana University for sample examination. The study was carried out from October 2024 to November 2024.

The study involved collecting nasal swabs from 44 healthcare workers (HCWs) across various departments. Nasal swabs were collected using sterile Amies transport swabs. Samples were cultured on Mannitol Salt Agar (MSA) and incubated at 37°C for 24 to 48 hours. Colonies displaying characteristics of Staphylococcus (yellow pigmentation on MSA) were further subjected to Gram staining tests, catalase tests, and coagulase tests. Antibiotic resistance was tested using the cefoxitin disk diffusion method. Colonies of Staphylococcus aureus were transferred to Mueller-Hinton Agar, a 30 µg cefoxitin disk was placed, and the plates were incubated at 37°C for 24-48 hours. Zone diameters ≤21 mm were categorized as MRSA, in accordance with the Clinical and Laboratory Standards Institute (CLSI) guidelines. Data were analyzed descriptively using Microsoft Excel. Prevalence rates were calculated, and results were presented in percentages.

RESULTS

According to Table 1, 44 nasal swab samples were collected from healthcare workers across various hospital wards. Among these, 4 samples (9.1%) were identified as MRSA, distributed as follows: 1 sample (20%) from the Surgical Ward, 2 samples (40%) from the Neonatal Intensive Care Unit (NICU), and 1 sample (10%) from the Intensive Care Unit (ICU). These findings highlight that MRSA was predominantly found in specialized wards such as the NICU, ICU, and the Surgical Ward, underscoring the need for enhanced infection prevention measures in these areas.

Additionally, 12 samples (27.3%) were identified as Methicillin-Sensitive Staphylococcus aureus (MSSA). These were found in several wards, with the highest occurrences in the NICU (2 samples, 40%), ICU (3 samples, 30%), and the Surgical Ward (3 samples, 60%). Meanwhile, 28 samples (63.6%) were identified as Coagulase-Negative Staphylococci (CNS), predominantly distributed in the General Outpatient Clinic (6 samples, 85.7%) and the Emergency Department (5 samples, 100%). This comprehensive analysis demonstrates the varied distribution of MRSA, MSSA, and CNS across different hospital wards, with a notable prevalence of CNS in outpatient and emergency care settings.

The Gram staining results (Figure 1) showed evenly dispersed cocci-shaped bacteria, which helps differentiate between *Staphylococcus* spp. and *Streptococcus* spp. as potential Gram-positive bacteria. These findings suggest that Gram-positive cocci bacteria may colonize the nasal cavities of healthcare workers, which could be significant for microbiological research and the possible spread of bacteria in hospital settings.

Five typical plates from 44 nasal swab samples taken from medical staff at Universitas Udayana Hospital are

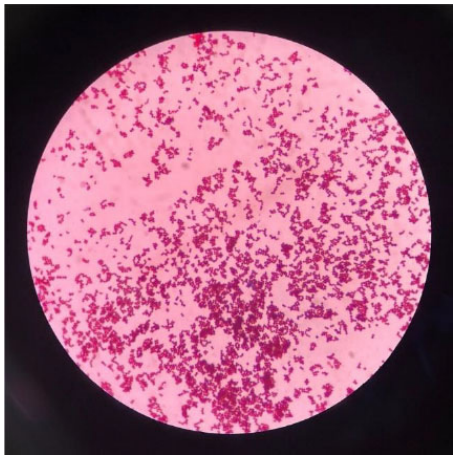

Figure 1. Microscopic View of Gram-Positive Cocci.

displayed in Figure 2, showing growth consistent with *Staphylococcus* spp. Gram staining was performed first, and microscopic analysis confirmed the presence of Gram-positive cocci.

The mannitol fermentation by Staphylococcus aureus, which lowers pH and turns the phenol red indicator yellow, is the cause of the agar's yellow discoloration. The formation of oxygen bubbles when colonies were combined with 3% hydrogen peroxide demonstrated that the bacteria were producing the catalase enzyme, confirming the success of the catalase test. This was confirmed by the immediate production of bubbles upon the addition of hydrogen peroxide, indicating the presence of the catalase enzyme in the bacteria. Additionally, the coagulase test yielded positive findings, showing the presence of coagulase, a characteristic of *Staphylococcus aureus*, as fibrin clots formed upon mixing the bacterial solution with plasma. *Methicillin-resistant Staphylococcus aureus* (MRSA) will be

Figure 2. Coagulase Test for Sample Screening.

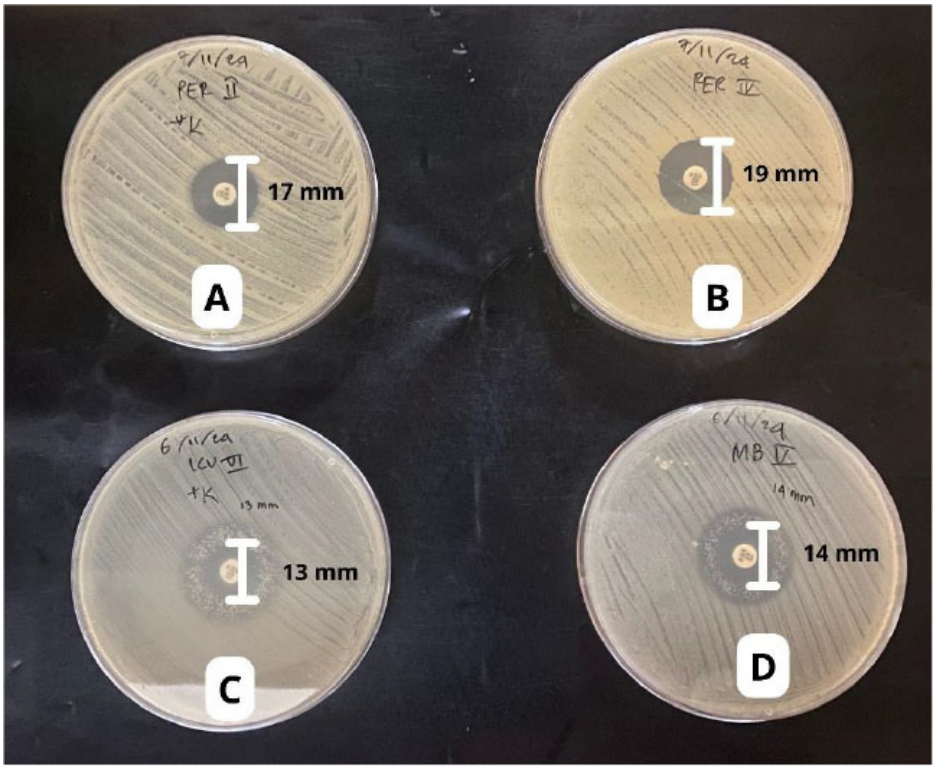

Figure 3. Preparations indicating MRSA.

identified, and resistance trends will be evaluated by analyzing these samples for antibiotic susceptibility.

The measured inhibition zones, as shown in Figure 3, were below 21 mm: 17 mm (A, NICU II), 19 mm (B, NICU IV), 13 mm (C, ICU VI), and 14 mm (D, Surgical Room V). According to CLSI criteria, an inhibition zone diameter of less than 21 mm indicates methicillin resistance, confirming the presence of methicillin-resistant Staphylococcus aureus (MRSA).

DISCUSSION

MRSA isolates were identified in 4 samples (9.1%) out of 44 samples, with distribution across the NICU (40%), ICU (10%), and Surgical Medical Ward (20%). These units have a high patient exposure rate, particularly for vulnerable or critically ill patients, increasing the risk of MRSA colonization among healthcare workers. The prevalence of MRSA carriers in this study is relatively low. It may be influenced by factors such as hand hygiene practices, compliance with the use of personal protective equipment, and adherence to strict sterilization procedures in hospitals.[3] The results of our study indicate a prevalence of 9.1% of healthcare workers as MRSA carriers, with a concentration in critical care units, such as the NICU and ICU. Internationally, the prevalence of MRSA in hospitals varies. In Asia, the highest prevalence of MRSA in nosocomial infections has been reported in Iran at 86.4%, followed by Malaysia at 59%, Nepal at 55.6%, and Singapore at 38.5-48.1%.[8] In Indonesia, the prevalence of MRSA ranges between 25% and 65%, with a national average of 38%.[9] This comparison suggests that the prevalence of MRSA in our hospital is relatively lower than both international and national data, but remains a significant concern. Challenges in MRSA infection control in hospitals include limited microbiology laboratory facilities, a shortage of specialized personnel, and the need to enhance compliance with antimicrobial resistance control programs. Therefore, continuous efforts are necessary to enhance facilities, human resources, and the implementation of infection control programs, addressing the specific challenges within our hospital.

Out of 44 samples, only 4 were positive for MRSA, indicating a low prevalence of MRSA carriers. Factors such as proper hand hygiene, adherence to the use of personal protective equipment, and strict sterilization procedures contribute to the colonization rate of MRSA. Studies have shown that colonization rates vary depending on the effectiveness of infection prevention policies.[8] Healthcare workers not directly involved in invasive

procedures have a lower risk of being MRSA carriers compared to those working in high-risk environments.[8] The prevalence of MRSA found in this study (9.1%) aligns with the findings of Rohmah et al. (2023), which reported a 23.5% prevalence of MRSA colonization among healthcare workers at Dr. Soemarno Sosroatmodjo General Hospital, Kuala Kapuas, Indonesia, particularly in high-risk areas such as emergency rooms (ER) and intensive care units (ICU). The primary risk factors influencing MRSA colonization include a history of ear, nose, and throat infections (41.7%) and a history of MRSA positivity from other hospitals (60%). Failing to perform hand rubs or proper hand washing was also reported to increase the risk of nasal MRSA colonization significantly. These findings underscore the importance of adhering to strict infection control policies, particularly maintaining good hand hygiene practices, to prevent the spread of MRSA in hospitals.[19] These findings emphasize the importance of maintaining consistent infection prevention policies to achieve and sustain low MRSA carriage rates in hospital settings.

MRSA carriers were more commonly found among nurses working in the NICU, where interaction and direct patient contact are more intensive.[8] Infants in the NICU often require intensive care, including invasive procedures, which increases the risk of MRSA transmission. The dense medical equipment in the NICU also serves as a potential vehicle for MRSA spread, particularly if the equipment cleanliness is not adequately maintained.[9] Additionally, the use of prophylactic antibiotics, such as gentamicin, in premature infants can promote the conversion of Staphylococcus aureus to MRSA if exposed to suboptimal doses of antibiotics over extended periods.[11] Invasive interventions, such as catheter insertion or mechanical ventilation in the NICU, further increase the risk of MRSA colonization. Since neonates in the NICU are particularly vulnerable to infections, strict prevention protocols, including hand hygiene and regular disinfection of medical equipment, are essential to prevent the spread of MRSA.[12] Recent studies in Indonesia also found MRSA colonization in NICU settings, emphasizing the risks associated with intensive care environments. For instance, Suyasa and Mastra (2020) reported MRSA colonization among healthcare workers in the NICU and other critical units at Wangaya Hospital, Denpasar.[19] Similarly, Dwiyanti et al. (2015) identified the presence of MRSA among paramedics working in NICUs and ICUs at Ratu Zalecha Martapura General Hospital.[19]

Out of 44 samples, 12 (27.3%) were positive for MSSA, with the infection distributed across nearly all wards, including the ICU (30%) and the Surgical Ward (60%). The high prevalence of MSSA suggests that *Staphylococcus aureus* remains a standard component of the normal flora in the nasal passages of healthcare workers. Although MSSA is not methicillin-resistant, its presence is significant due to its potential to convert into MRSA through the transfer of resistance genes.[13] Environmental factors, medical procedures, and the patient population in the ICU and Surgical Wards contribute to the higher rates of MSSA colonization.

The ICU is a primary site for MSSA colonization due to critically ill patients requiring invasive interventions, such as mechanical ventilation and catheter use, which increase the risk of contamination. In Surgical Wards, procedures like surgeries and wound care also facilitate the transfer of bacteria between healthcare workers and patients.[9] Recent studies have provided additional support for the findings on MSSA colonization in high-risk hospital wards. Maheasy et al. (2013) identified Staphylococcus aureus colonization in healthcare personnel working in ICUs and surgical wards at Abdul Moeloek General Hospital, highlighting the association between invasive procedures and higher colonization rates. Similarly, Santosaningsih et al. (2017) reported risk factors for MSSA carriage among surgical patients in resource-limited hospitals, emphasizing the role of strict hygiene protocols in minimizing transmission. These studies underscore the importance of robust infection control practices in mitigating nosocomial infections caused by methicillin-susceptible Staphylococcus aureus (MSSA). These findings highlight the importance of adhering to strict infection prevention protocols, including hand hygiene, the use of personal protective equipment, and routine monitoring of MSSA colonization among healthcare staff, to prevent nosocomial infections in critically ill patients.[8]

This study found CNS in 28 out of 44 samples (63.6%), with the highest proportions in the General Outpatient Clinic (85.7%) and the Emergency Department (100%). Although CNS is generally non-pathogenic, its high prevalence among healthcare workers suggests that it can serve as commensal flora that may cause opportunistic infections, especially in immunocompromised patients.[14] CNS can serve as a source of nosocomial infections through direct contact or contaminated medical equipment, particularly in patients who use invasive medical devices, such as catheters or ventilators. The General Outpatient Clinic, with its high level of patient and healthcare worker interaction, poses an increased risk of central nervous system (CNS) colonization and infection.[15] Staphylococcus epidermidis, the most common CNS species, is often associated with nosocomial infections in patients with medical devices, highlighting the importance of hand hygiene and disinfection of medical equipment as critical preventive measures.[16] A study by Putra et al. (2022) at RSUP Dr. Sardjito Yogyakarta reported that CNS was identified in nasal swabs of healthcare workers, with an incidence of Methicillin-Resistant CoNS (MRCoNS) at 33.33%. This study highlights the central nervous system (CNS) as a potential source of nosocomial infections. While often considered contaminants, CNS detection should be carefully evaluated, and further research is needed to determine its exact role in hospital infections and practical strategies to mitigate its spread in medical environments.

The findings of MSSA (27.3%) and CNS (63.6%) in this study have the potential to influence nosocomial infection patterns and antibiotic resistance in hospitals. MSSA, although not methicillin-resistant, remains a serious threat as it can cause various infections, including bacteremia, pneumonia, endocarditis, as well as skin

and soft tissue infections.[15] Additionally, MSSA can exchange resistance genes and develop into MRSA, especially in hospital environments with high antibiotic exposure. Meanwhile, CNS, including Staphylococcus epidermidis, Staphylococcus saprophyticus, and Staphylococcus haemolyticus, are often found as normal flora but can cause opportunistic infections, particularly in patients with invasive medical devices.[17] Previous studies have demonstrated that the central nervous system (CNS) plays a role in bloodstream infections and catheter-related infections, highlighting the importance of hand hygiene and medical equipment disinfection in reducing transmission risks.[18]

The distribution of MRSA, MSSA, and CNS among healthcare workers in various hospital wards highlights the importance of hygiene protocols and preventive measures, particularly in high-risk areas. Healthcare workers acting as potential carriers of MRSA can increase the risk of nosocomial infection transmission to patients. Preventive actions such as proper hand hygiene, correct use of personal protective equipment (PPE), and regular disinfection of medical equipment are essential to minimize the spread of MRSA in hospitals.[17] Studies have shown that regular training and the implementation of alcohol-based hand hygiene protocols can significantly reduce the incidence of MRSA infections in hospital settings.[18]

This study employed the cefoxitin disk diffusion method for MRSA identification, following the guidelines of the Clinical and Laboratory Standards Institute (CLSI), due to its practicality and rapid results, making it ideal for screening. Although molecular techniques such as PCR for the mecA gene are the gold standard for MRSA confirmation, their use in routine screening is limited due to high costs and resource requirements. The cefoxitin disk diffusion method, although effective, has limitations, including the potential for false-negative or false-positive results due to heteroresistance.[2] These limitations underscore the importance of adhering to strict laboratory protocols and conducting additional testing when necessary.

Udayana University Hospital implements standard precautions to prevent the spread of Methicillin-resistant Staphylococcus aureus (MRSA), including hand hygiene, the use of personal protective equipment, and environmental disinfection. Routine screening is conducted on high-risk patients and healthcare workers to detect MRSA carriers. For identified carriers, decolonization therapy includes the application of intranasal mupirocin 2% twice daily for five days and bathing with 4% chlorhexidine to reduce the risk of colonization and transmission.[19] The findings of this study can strengthen infection control policies by optimizing preventive strategies in high-risk hospital units.

CONCLUSION

Based on the results of the study on the Identification of Methicillin-Resistant Staphylococcus aureus Carriers in the Nasal Passages of Healthcare Workers at the Universitas Udayana Hospital, with 44 samples meeting the inclusion criteria, it can be concluded that 4 out of 44 healthcare workers were identified as MRSA carriers, with distribution across the Surgical Ward, NICU, and ICU. The overall prevalence of MRSA carriers among healthcare workers was 9.1%, with the highest percentage found in the neonatal intensive care unit (NICU).

CONFLICT OF INTEREST

No conflicts of interest.

ETHICS CONSIDERATION

Data collection will commence after obtaining research approval from the Research Ethics Commission of the Faculty of Medicine, with protocol number 1438/UN14.2.2.VII.14/LT/2024.

FUNDING

No external funding.

AUTHOR CONTRIBUTION

MIW was responsible for the conceptualization and design of the study. The definition of intellectual content, literature search, clinical and experimental studies, as well as data acquisition, was carried out by MIW, MAH, and NNSB. Data and statistical analyses were performed by MIW and MAH. MIW, MAH, and NNSB conducted manuscript preparation, editing, and review. MIW and MAH served as the guarantors of the study. All authors have read and approved the final version of the manuscript.

REFERENCES

1. Jaradat ZW, Ababneh QO, Sha'aban ST, Alkofahi AA, Assaleh D, Al Shara A. Methicillin Resistant Staphylococcus aureus and public fomites: a review. Pathog Glob Health. 2020;114(8):426-450. doi:10.1080/20477724.2020.1824112.
2. Lakhundi S, Zhang K. Methicillin-Resistant Staphylococcus aureus: Molecular Characterization, Evolution, and Epidemiology. Clin Microbiol Rev. 2018;31(4):e00020-18. doi:10.1128/CMR.00020-18.
3. Duong TB, Duong MC, Campbell JI, Nguyen HVM, Nguyen HH, Bui HTB, et al. MRSA carriage among healthcare workers in a Vietnamese intensive care unit: a prospective cohort study. Drug Target Insights. 2022;16:71-77. doi:10.33393/dti.2022.2504
4. Okwu MU, Olley M, Akpoka AO, Izevbuwa OE. Methicillin-resistant Staphylococcus aureus (MRSA) and anti-MRSA activities of extracts of some medicinal plants: A brief review. AIMS Microbiol. 2019;5(2):117-137. doi:10.3934/microbiol.2019.2.117
5. Dewi AK. Isolasi, identifikasi dan uji sensitivitas Staphylococcus aureus terhadap amoxicillin dari sampel susu kambing peranakan Ettawa (PE) penderita mastitis di wilayah Girimulyo, Kulonprogo, Yogyakarta. J Sain Veteriner. 2013;31(2):138–150. doi:10.22146/jsv.3780.
6. Missiakas DM, Schneewind O. Growth and laboratory maintenance of Staphylococcus aureus. Curr Protoc Microbiol. 2013;Chapter 9:Unit-9C.1. doi:10.1002/9780471729259.mc09c01s28.
7. Humphries R, Bobenchik AM, Hindler JA, Schuetz AN. Overview of Changes to the Clinical and Laboratory Standards Institute Performance Standards for Antimicrobial Susceptibility Testing, M100, 31st Edition. J Clin Microbiol. 2021;59(12):e0021321. doi:10.1128/JCM.00213-21.
8. Fitria A, Widiasi DE, Airlangga HRMH. Systematic Literature Review: Prevalensi Methicillin-Resistant Staphylococcus aureus (MRSA) terhadap Infeksi Nosokomial di Asia. Jurnal Sains Veteriner. 2023;41(1):1–12. doi: 10.20473/jsv.Vol41.Iss1.2023.1-12.
9. Syahniar R, Farsida F, Setyani RL, Malayanti M, Siswanti RT, Asmawati WO, et al. Edukasi Pencegahan dan Tatalaksana MRSA pada Tenaga Kesehatan. Jurnal Abdimas Kedokteran dan Kesehatan (JARAS). 2024;2(1):42–47. doi:10.24853/jaras.2.1.42-47
10. Vasudevan R, Shin JH, Chopyk J, Peacock WF, Torriani FJ, Maisel AS, et al. Aseptic Barriers Allow a Clean Contact for Contaminated

Stethoscope Diaphragms. Mayo Clin Proc Innov Qual Outcomes. 2020;4(1):21-30. doi:10.1016/j.mayocpiqo.2019.10.010

11. Rohmah SN, Asdie RH, Yasopa I, Daryadijaya D. Identification of Risk Factors for Nasal Colonization of Methicillin-resistant Staphylococcus aureus and Vancomycin-resistant Staphylococcus aureus in Health Workers at a Tertiary Hospital, Indonesia. Open Access Maced J Med Sci. 2023;11(B):205–211. doi: 10.3889/oamjms.2023.11441.
12. Wang L, Pang X, Zhao J, Jin H, Yang X, Fu S, et al. Isolation and characteristics of new phage JK004 and application to control Cronobacter sakazakii on material surfaces and powdered infant formula. LWT - Food Science and Technology. 2022;153:112571. doi:10.1016/j.lwt.2021.112571.
13. Galuszka JE, Thomsen K, Knudsen JD, Stenkjaer RL, Nielsen R, Nielsen KL, et al. Risk factors for methicillin-resistant Staphylococcus aureus colonization in a level-IV neonatal intensive care unit: a retrospective study. Antimicrob Steward Healthc Epidemiol. 2023;3(1):e194. doi:10.1017/ash.2023.482
14. Jia P, Zhu Y, Li X, Kudinha T, Yang Y, Zhang G, et al. High Prevalence of Extended-Spectrum Beta-Lactamases in Escherichia coli Strains Collected From Strictly Defined Community-Acquired Urinary Tract Infections in Adults in China: A Multicenter Prospective Clinical Microbiological and Molecular Study. Front Microbiol. 2021;12:663033. Published 2021 Jul 7. doi:10.3389/fmicb.2021.663033.
15. Lee AS, de Lencastre H, Garau J, Kluytmans J, Malhotra-Kumar S, Peschel A, et al. Methicillin-resistant Staphylococcus aureus. Nat Rev Dis Primers. 2018;4:18033. doi:10.1038/nrdp.2018.33.
16. Khairalla AS, Wasfi R, Ashour HM. Carriage frequency, phenotypic, and genotypic characteristics of methicillin-resistant Staphylococcus aureus isolated from dental health-care personnel, patients, and environment. Sci Rep. 2017;7(1):7390. doi:10.1038/s41598-017-07713-8
17. Becker K, Heilmann C, Peters G. Coagulase-negative staphylococci. Clin Microbiol Rev. 2014;27(4):870-926. doi:10.1128/CMR.00109-13
18. Boyce JM. Hand and environmental hygiene: respective roles for MRSA, multi-resistant gram negatives, Clostridioides difficile, and Candida spp. Antimicrob Resist Infect Control. 2024;13(1):110. Published 2024 Sep 27. doi:10.1186/s13756-024-01461-x
19. Otter JA, French GL. Guidelines for the control and prevention of meticillin-resistant Staphylococcus aureus (MRSA) in healthcare facilities. J Hosp Infect. 2011;79(1):1–22. doi:10.1016/j.jhin.2011.01.024.