Prevalence and associated risk factors of staphylococcus aureus and methicillin-resistant staphylococcus aureus isolates obtained from patients seeking treatment in Nakuru county referral and teaching hospital, Kenya

Scientific Modelling and Research
Vol. 9, No. 1, 1-14, 2024
e-ISSN: 2523-952X

(*Corresponding Author*)

Soi Chelang'at Joan[1]
Karanja Simon[2]
Sang Willie[3]

[1]*Department of Public Health. Jomo Kenyatta University of Agriculture and Technology, Kenya.*
Email: joansoi20@gmail.com
[2]*School of Public Health, Jomo Kenyatta University of Agriculture and Technology, Kenya.*
Email: skaranja@jkuat.ac.ke
[3]*Centre for Microbiology Research, Kenya Medical Research Institute, Kenya.*
Email: williesang01@gmail.com

ABSTRACT

Staphylococcus aureus is a pathogenic bacterium that can evolve rapidly to methicillin-resistant Staphylococcus aureus (MRSA). MRSA is a global health concern that is associated with significant morbidity and mortality. This study was to determine the prevalence and Associated Risk Factors of staphylococcus aureus and MRSA isolates obtained from patients seeking treatment in Nakuru County Referral and Teaching Hospital. A descriptive cross-section study design was used with a laboratory experimental component and it was carried out in Nakuru County Referral and Teaching Hospital, Kenya. A total of 354 laboratory samples were randomly collected from different laboratory samples/sites: blood, urine, wound, nasal swabs, pus, tissue, abscess, sputum, ear swabs, as well as cerebrospinal fluid (CSF) culture, skin swabs and synovial fluid culture over a period of six months. These samples were tested for presence of staphylococcus aureus and MRSA isolates using Culture methods and Antibiotic Sensitivity Tests. The study analyzed 354 participants, with a median age of 35 years. Most participants (56.7%) were from medical wards, 20.4% from outpatient clinics, and 11% from Diabetic Care Centre. Staphylococcus aureus was found in 7.1% of samples, with MRSA present in 2.3%. Other isolated organisms included Coagulase Negative Staphylococci (7.1%), E. coli (6.8%), Proteus spp. (5.1%), and Pseudomonas spp. (5.9%). The prevalence of MRSA among the participants is low.

Keywords: *Methicillin-Resistant staphylococcus aureus, Staphylococcus aureus, Prevalence, Antibiotic resistance, Clinical samples, Risk factors, Infection control, Nakuru County Referral and Teaching Hospital.*

DOI: 10.55284/smr.v9i1.1166
Citation | Joan, S. C., Simon, K., & Willie, S. (2024). Prevalence and associated risk factors of staphylococcus aureus and methicillin-resistant staphylococcus aureus isolates obtained from patients seeking treatment in Nakuru county referral and teaching hospital, Kenya. *Scientific Modelling and Research*, *9*(1), 1–14.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The Ethical Committee of the NACOSTI- National Commission for Science, Technology & Innovation Nakuru County Referral and Teaching Hospital has granted approval for this study on 31 May 2023 (Ref. No. 580350).
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
History: Received: 25 June 2024/ Revised: 16 August 2024/ Accepted: 30 August 2024/ Published: 20 September 2024
Publisher: Online Science Publishing

Highlights of this paper

- This study investigates the prevalence and associated risk factors of Staphylococcus aureus and Methicillin-Resistant Staphylococcus aureus (MRSA) in patients at Nakuru County Referral and Teaching Hospital, Kenya.
- The results indicate a prevalence of 7.1% for Staphylococcus aureus and 2.3% for MRSA among the 354 clinical samples analyzed.
- Key risk factors identified include recent surgical procedures and prolonged antibiotic use, highlighting the need for enhanced infection control measures.

1. INTRODUCTION

Staphylococcus aureus is a global cause of both community and hospital acquired infections, posing a serious threat of antimicrobial resistance [1, 2]. It was first identified in the 1880s from fluids of an infected leg swelling by Ogoston after which it became a leading cause of health care related infections [3, 4].

In the 1960s, MRSA was clinically observed within the first year following the establishment of semi-synthetic anti-staphylococcal penicillin [5]. It has been noted that some groups of people, for example, athletes, children, military personnel in barracks, institutionalized populations such as prisoners and Human Immunodeficiency Virus patients are prone to MRSA [6]. As such, MRSA is a leading cause of most hospital-acquired infections, bacteremia, pneumonia, sepsis, endovascular infection and skin and soft tissues infections (SSTIs) making drug-resistant bacterial pathogens to pose a major challenge in global health [6].

Reports indicate that the prevalence of MRSA is below 50% in five of the six World Health Organization (WHO) regions [7]. Its prevalence in Africa has been reported to be diverse [8]. Data from National Database in some African countries shows MRSA rates to approximate between 12 - 80%, while other countries are above 82% [Centre for Disease Dynamics, Economic and Policy). High prevalence rates of between 31.5% - 42% have been reported in Uganda, East Africa among patients and healthcare workers [9].

At first, between 1961 and 1990, MRSA was associated with healthcare institutions. New cases of MRSA infection were later reported in individuals with no previous history of hospitalization in the 1990s, resulting to the separate definitions for hospital- acquired MRSA (HA-MRSA) and community-associated MRSA (CA-MRSA) [6]. The various risk factors for getting MRSA infections within hospital settings include surgery, hemodialysis and prolonged residence in a healthcare facility [10, 11].

World Health Organization antimicrobial resistance report highlights health burden attributable to MRSA as a significant contributor to bacterium-attributable and Intensive Care Unit mortality, increased post-infection and ICU length of stay which has also contributed to the economic impact of MRSA, measured through resource-use outcomes, and has a greater likelihood of discharge to long-term healthcare facilities [12, 13]. This suggests a higher utilization of resources for the treatment of MRSA infections in both acute and long-term care settings [14]. For example, the increased burden on healthcare resources attributable to MRSA is well-documented globally, with reports indicating that it accounts for more than 60% of Staphylococcus aureus isolates causing nosocomial infections in ICUs [15, 16].

2. LITERATURE REVIEW

2.1. Overview of MRSA and Global Perspective of MRSA

Staphylococcus aureus is a global health concern. Similarly, drug resistance to bacterial infections, malaria, HIV/AIDS or tuberculosis have been reported to cause 700,000 global deaths [17]. Reports indicate that AMR has a yearly impact of 1.5 billion Euros. Globally, only half of antibiotics are used as per prescription. Therefore, it is predicted that by 2050, *10* million people will die every year due to antimicrobial resistance (AMR) [17, 18]. A survey in USA reported that HA-MRSA increased from 127,036 to 278,000 between the years 1992 to 2004 increasing the global need to tackle antibiotic resistance [8, 15]. Data on the prevalence of MRSA based on countries with the

greatest amount of data (Mediterraneana, South Africa and Nigeria) is not clear [19]. Nigeria has recorded an increasing prevalence of MRSA [20]. In East Africa, a cross-sectional study in Tanzania reports a high prevalence of MRSA among ICU patients [21].

2.2. Methicillin Resistant Staphylococcus aureus Colonization

MRSA is common bacteria that are found in the nose and skin without causing any harm, that is, they do not exhibit any signs and symptoms of disease. It is easily spread through contact with individuals and objects containing these staph bacteria. Infections only occur when the bacteria enter the body through a cut or wound [22].

2.3. Common Methicillin Resistant Staphylococcus aureus Infections

Patients diagnosed with *Staphylococcus aureus* may develop sepsis which may result to organ failure. It is reported to cause about 30-50 % death to the infected patients. Methicillin-resistant *Staphylococcus aureus* mostly causes skin infections, lung infection (pneumonia) and wound abscess [23, 24].

2.4. Symptoms of MRSA Infections

Methicillin-resistant *Staphylococcus aureus* bacteria may cause infections on several tissues in the body and enters the system via injuries such as cuts, burns, rashes or scrapes [25]. The symptoms of MRSA infection depend on where you've been infected. MRSA most often appears as a skin infection, like a boil or abscess. It also might infect a surgical wound and the area would be swollen, red, painful, filled with pus. Most staph skin infection is often mistaken for a spider bite. If staph infects the lungs and causes pneumonia, one will have symptoms such as;

- Shortness of breath
- Chills
- Fever

MRSA causes other symptoms such as fever, dizziness and confusion because once it gets into the bloodstream, it can settle in any organ of the body. MRSA can cause an abscess in your spleen, kidney, or spine. It can cause endocarditis, osteomyelitis, joint infections, mastitis, and infections of implanted prosthetic devices [24].

2.5. The Spread and Prevention of Methicillin Resistant Staphylococcus aureus

MRSA can spread either: Endogenously where staphylococci blowouts from one part of the body to another and; exogenously when staphylococci are spread from person to another, for example, skin-to-skin interaction that involves a direct contact with an infected wound, touching contaminated surfaces or coming into contact with objects such as towels and razors that hold drainage from an MRSA skin infection [26]. Other conditions such as packed living situations and poor hygiene can contribute to the spread of MRSA infections. In healthcare settings, MRSA can result to lung, bloodstream, bone, joint, heart and surgical sites infections [2]. Some of the preventive measures of MRSA include: encouraging washing of hands using soap and water or using an alcohol-based hand sanitizer, covering of cuts and wounds with bandages after cleaning them with antibacterial cream, avoiding the sharing of personal items and picking infected areas, regularly washing clothes and equipment with detergents at high temperatures that are safe, taking antibiotics as instructed and, visiting a health facility for diagnosis in case one suspects that they may be infected [24].

2.6 Epidemiology of Methicillin Resistant Staphylococcus aureus

Hospital-associated MRSA is associated with significant mortality and morbidity thereby increasing the economic burden on already scarce healthcare resources [8]. In addition, prevalence rates of MRSA are varied around the world [14]. The prevalence in Europe ranges up to 24% in acute care and long-term settings [8]. This is not far in range from a prison study in USA where 19% prevalence was recorded on entering prison and this increased by 8.4% on day 30 of incarceration [27]. In a Myanmar study, the prevalence was 48% [22].

However, though MRSA is well documented in western countries, data is limited in African countries and highly varied, for example, ranging from 1% to 84% in Kenya [2, 8]. Prevalence in another Kenyan study was reported at 53.4% [14]. In an Eritrean study, MRSA has been reported to be 72% while methicillin-sensitive *S. aureus* (MSSA) is 19.5%. Methicillin-intermediate *S. aureus* (MISA) was the least at 8.5% [8].

Antibiotic susceptibility of *S. aureus* displays variability. In one study, almost all the samples were resistant to penicillin but highly sensitive to nitrofurantoin [22]. In Russia, HA-MRSA showed high resistance to ciprofloxacin, gentamicin and chloramphenicol at 76% - 92%. All the isolates were susceptible to linezolid and tigecycline [28]. On the other hand, in India, some of the HA-MRSA isolates were resistant to vancomycin [29]. Isolates were resistant to vancomycin (15.9%), erythromycin (11%) and gentamicin (1.2%) in Eritrea [8]. In Kenya, isolates were highly susceptible to linezolid, tigecycline, tiecoplanin and vancomycin. There was poor susceptibility to trimethoprim-sulfamethoxazole (17.7%-28.2%) [14]. Other Kenyan studies reported high penicillin resistance with last line and recent antibiotics that include vancomycin, linezolid, teicoplanin and daptomycin still having efficacy [2].

Scientific reports indicate that *Staphylococcus aureus* colonization occurs in the inguinal folds, anterior nares and axilla [30]. Higher frequencies have been reported in skin and soft tissue infections at 52.6% [2]. The major source of MRSA infection was from skin and soft tissue isolates (80%) in a Kenyan study [14].

When it comes to predictors, there are several predictors related to MRSA. In European countries the main predictor has been documented as the use of more than one concurrent antibiotic per patient. Other predictors were sociocultural behavior of lack of urgency to avoid risk and being male. Historically MRSA cross-transmission has been linked to the hands of health care workers [31]. Higher proportions of MRSA have been reported in older age groups, female patients and in urine samples in some studies [22]. Those living in congregate settings such as prisons are also at higher risk. A study in a prison setting found the predictors of MRSA to heroin use and sharing personal items [27].

2.7 Diagnosis of MRSA

Methicillin Resistant *Staphylococcus aureus* is diagnosed by determining drug-resistant bacteria from tissue samples. Culture used are derived from wounds scrapping, blood, urine and septum [22]. Phenotypic detection of *S. aureus* can be conducted through biochemical tests such as gram staining, thermo nuclease, coagulase and catalase. Molecular typing techniques for characterizing MRSA are SCC*mec* typing methods including Multiplex PCR strategy, Pulsed-Field Gel Electrophoresis (PFGE) and Multi-Locus Sequence Typing (MLST) [32].

2.8 Antibiotic Therapy

Beta-Lactam antibiotics are natural and semisynthetic antibiotics that have a beta-lactam ring embedded on their structure. They include penicillin, methicillin, amoxicillin and oxacillin on the contrast, non-beta lactam antibiotics do not have a beta lactam ring and include vancomycin [33]. Types of oral antibiotics include sulfamethoxazole that is used in the treatment of infections in the respiratory system, urinary and gastrointestinal tract. Clindamycin aids

in treating joint infections, pneumonia, and endocarditis. Oral antibiotics are in the form of capsules, tablets or drinkable liquids. They include linezolid and delafolacin among others [34, 35].

2.9. Hygiene Strategies to Prevent Methicillin-Resistant Staphylococcus aureus

Effective prevention of SSTIs is required in both the community and hospital setting. Humphreys, et al. [36] states that successful prevention and control of MRSA skin infection is dependent on a positive attitude and high standards of professionalism among healthcare workers. The study further concludes that maintaining hand hygiene, isolation and education are necessary as prevention and control measures. A literature review by Alvarez, et al. [37] supports that hand hygiene, isolation of infected patients and decolonization in some situations are effective in controlling MRSA. These measures have been effective in countries such as Denmark and The Netherlands which record the world's lowest nosocomial infections by MRSA. On the contrary, Ellis, et al. [38] reports that personal hygiene measures such as weekly use of chlorhexidine body wash did not prevent SSTI among high-risk military trainees and further studies are required to determine its impact in SSTI prevention.

3. METHODS

3.1. Study Site

The study was conducted in Nakuru County Referral and Teaching Hospital which serves patients in Nakuru County and Neighboring Counties. This study site was selected because it attends to a large population of 3.6 million patients from the South Rift region, North Rift, Nyanza, Western and Central parts of Kenya.

3.2. Study Design

A descriptive cross-section study with a laboratory experimental component was conducted.

3.3. Study Samples

Laboratory samples that were randomly collected from different laboratory samples/sites: blood, urine, wound, nasal swabs, pus, tissue, abscess, sputum, ear swabs, as well as cerebrospinal fluid (CSF) culture, skin swabs and synovial fluid culture in Nakuru County Referral and Teaching Hospital for Microbiology Culture and Sensitivity Test. Patient level factors such as length of stay in hospital, antibiotic use and surgical intervention was collected from the hospital records.

3.4. Sample Size

Sample size was estimated using a proportion from a previous study which reported a prevalence of MRSA of 36% in hospital samples in Moi Teaching and Referral Hospital. The calculation was done using the formula for estimating a single proportion in a population. The confidence interval was set at 95% (Z=1.96) and the margin of error of 5%. The minimum sample size needed to determine prevalence of Staphylococcus aureus and MRSA was 354.

Using Fishers formula and a prevalence of 36%, the study analysed a total of 354 laboratory samples.

$$n = \frac{Z^2 P(1-P)}{d^2}$$

Where:

n – Minimum required sample size.

Z – Standard normal for a 2-sided test at 95% confidence interval (CI) = 1.96.

P – Residual rate of 36%.

d – Margin of error of estimation = 5%.

Substituting into the formula,

$$n = \frac{3.8416 * 36/100(1 - P)}{d^2}$$

n = 354.

3.5. Sampling Method and Processing

All laboratory samples that were collected from different laboratory samples/sites: blood, urine, wound, nasal swabs, pus, tissue, abscess, sputum, ear swabs, as well as cerebrospinal fluid (CSF) culture, skin swabs and synovial fluid culture. The isolated cases were obtained from routinely collected samples from patients in Nakuru County Referral and Teaching Hospital. All collected samples meeting the inclusion criteria were considered for testing.

3.6. Laboratory Testing

3.6.1. Bacterial Culture and Identification of Staphylococcus Aureus

- The collected samples were inoculated in blood agar, Chocolate Blood Agar and MacConkey Agar plates obtained commercially and incubated at 370C for 24 hours.
- S. aureus isolate was identified using catalase and coagulase tests and also gram stain.
- To get pure colonies, Staphylococcus aureus colonies were sub cultured into Mueller-Hinton Agar and incubated for 24 hours at 370C. The pure S. aureus colonies were stored in the freezer at -200C and used whenever it's required.
- 1ml of Tryptic Soy Broth (TSB) was placed in 2 micro vials (1 for Antimicrobial Susceptibility Testing and 1 for Whole Genome Sequencing) and then colonies of S. aureus were applied into the vials, mixed and then stored at -800C until the desired number of isolates were achieved for further testing.
- The frozen staphylococcus aureus isolates stored at -800C whenever we required it was defrosted and sub cultured on blood agar overnight at 370C for later use on AST and Polymerase Chain Reaction.

3.6.2. Antimicrobial Susceptibility Testing

To test antimicrobial susceptibility, disk diffusion method was applied. The testing of antimicrobial agents was as follows: penicillin G (10 units), Cefoxitin (30 µg), erythromycin (15 µg), trimethoprim-sulfamethoxazole (25 µg), gentamicin (10 µg), ciprofloxacin (5 µg), clindamycin (10 µg) on the *S. aureus* blood agar plates.

Methicillin-resistant *Staphylococcus aureus* strains were determined by agar diffusion test method where cefoxitin disk is 30 micrograms.

Classification of isolates fall under multidrug resistance, if they were resistant to β-lactam plus more than three groups of antibiotics

3.7. Data Analysis

Data was analyzed using IBM SPSS 21.0 version software. Demographic and clinical characteristics was summarized into frequencies, percentages and median age. Prevalence of Staphylococcus aureus and MRSA was calculated and presented as proportions with 95% confidence interval (CI). Risk factors were determined by associating the prevalence with demographic and clinical characteristics using Chi square test and calculating odds ratios for each category. Median age was compared between groups using Mann Whitney U test. Statistical significance was interpreted at 5% level.

3.8. Ethical Consideration

Ethical approval for the study was obtained from the Kenya Medical Research Institute (KEMRI) Scientific Ethics Review Unit (SERU), the National Commission for Science, Technology and Innovation (NACOSTI), and Nakuru County Teaching and Referral Hospital. Participant anonymity and confidentiality were strictly maintained.

4. RESULTS

4.1. Demographic and Clinical Characteristics of the Participants

A total of 354 participants were included in the study among whom 181 (51.3%) males and the median age was 35 years ranging from 1-day-old baby to 90 years. Majority, 200 (56.7%), were sampled from the medical wards, 72 (20.4%) from outpatient clinics and 39 (11%) were from DCC. The types of samples taken were mainly pus 122 (34.5%), urine 105 (29.7%) and blood 83 (23.4%). While two-thirds 236 (66.7%) of the participants reported no risk factors of infection, the most common risk factors included recent surgical procedure 56 (15.8%) and prolonged antibiotic use 54 (15.3%). Also, more than three quarters 269 (76%) did not have any chronic conditions with 51 (14.4%) having diabetes and 21 (5.9%) were immunocompromised. Use of antibiotics data showed 266 (75.1%) participants had a recent use of antibiotics while 81 (22.9%) had frequent or prolonged use. About a half, 182 (51.4%), of the participants had a history of short-term hospitalization while 109 (30.8%) had long-term hospitalization (Table 1).

Table 1. Demographic and clinical characteristics of the participants.

Variable	n=354
	Frequency (%)
Gender	
Male	182 (51.4)
Female	172 (48.6)
Age in years	
Median (IQR)	35.0 (19.0-53.0)
Min-max	1 day-90 years
Ward	
Medical	200 (56.5)
Outpatient	73 (20.6)
Diabetic care centre	39 (11.0)
Surgical	22 (6.2)
Burns unit	7 (2.0)
Intensive care unit	7 (2.0)
New born unit	5 (1.4)
Ear nose and throat	1 (.3)
Sample type	
Pus	122 (34.5)
Urine	105 (29.7)
Blood	83 (23.4)
Cerebral spinal fluid	28 (7.9)
Pleural fluid	4 (1.1)
Tissue	3 (0.8)
Sinus	2 (0.6)
High vaginal swab	2 (0.6)
Knee aspirate	1 (0.3)
Exudate	1 (0.3)
Bone tissue	1 (0.3)
Aspirate	1 (0.3)
Abscess	1 (0.3)
Risk factor	
Recent surgical procedure	56 (15.8)

Variable	n=354
	Frequency (%)
Prolonged antibiotic use	54 (15.3)
Presence of invasive medical device	5 (1.4)
Catheter	1 (0.3)
Healthcare-associated infections	1 (0.3)
History of healthcare associated infection	1 (0.3)
None	236 (66.7)
Chronic condition	
Diabetes	51 (14.4)
Immunocompromised	21 (5.9)
Renal disease	5 (1.4)
Epilepsy	3 (0.8)
Cancer	1 (0.3)
Cardiovascular disease	1 (0.3)
Peripheral vascular vein	1 (0.3)
Sickle cell	1 (0.3)
None	269 (76.0)
Antibiotic use	
Frequent	3 (0.8)
Frequent/Prolong	81 (22.9)
Recent	266 (75.1)
None	4 (1.1)
Hospital stay	
Long term hospitalization	109 (30.8)
Short term hospitalization	182 (51.4)
No hospitalization	63 (17.8)

4.2. Prevalence of Staphylococcus Aureus and MRSA Isolates

Out of 354 samples, 25 (7.1%: 95% CI: 4.5% - 9.9%) had *Staphylococcus aureus* isolated from them MRSA was isolated in 8 (2.3%, 95% CI: 0.8% - 4.0%) of the population (Table 2). Other main organisms that were isolated from the samples included CONS in 25 (7.1%) samples, E. coli in 24 (6.8%) samples, proteus spp in 18 (5.1%) and pseudomonas spp in 21 (5.9%).

Table 2. Prevalence of Staphylococcus aureus, MRSA and other organisms isolated from the population.

Organism	n=354	
	Frequency (%)	95% CI
Staphylococcus aureus	25 (7.1)	4.5 – 9.9
MRSA isolates	8 (2.3)	0.8 – 4.0
Coagulase negative staphylococci	25 (7.1)	5.5 – 9.9
E. coli	24 (6.8)	4.2 – 9.6
Proteus spp	18 (5.1)	2.8 – 7.3
Pseudomonas spp	21 (5.9)	3.7 – 8.5
Enterococcus spp	12 (3.4)	1.7 – 5.4
Acinetobacter spp	10 (2.8)	1.1 – 4.8
Candida albicans	2 (0.6)	0 – 1.4
Klebsiella spp	2 (0.6)	0 – 1.4
Proteus mirabillis	1 (0.3)	0 – 0.8
Pseudomonas euroginosa	1 (0.3)	0 – 0.8
Staphylococcus pyogenes	1 (0.3)	0 – 0.8
Mixed growth	8 (2.3)	0.8 – 4.0
Heavy mixed growth of organisms	1 (0.3)	0 – 0.8

4.3. Resistance Pattern to Commonly Prescribed Antibiotics on MRSA

In total, 9 (36%) of *S. aureus* were resistant to doripenem, 16 (64%) were resistant to Penicillin G, 8 (32%) to cefoxitin and 16 (64%) to erythromycin. Similarly, 16 (64%) were resistant to clindamycin, 14 (56%) to ciprofloxacin, and 14 (56%) to gentamycin while '6 (24%) were resistant to Sulfamethoxazole (Figure 1).

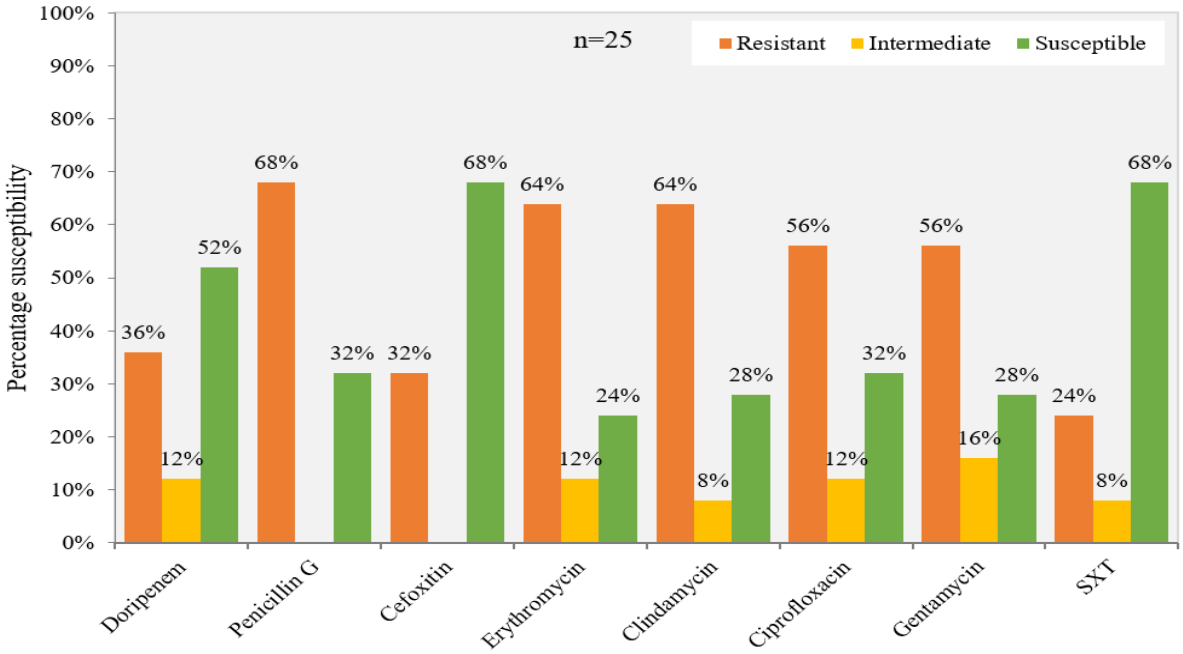

Figure 1. Resistance pattern to commonly prescribed antibiotics on MRSA.

4.4. Factors Associated with Staphylococcus Aureus Infection

There was no S. aureus isolated from patients admitted in ICU, NBU and ENT while the lowest prevalence that recorded was in medical wards at 4.0%. The highest prevalence of *S. aureus* (28.6%) was found among patients in the burns' unit. Hence, patients admitted in the burns' unit were about 10 times more likely to have S. aureus infection compared to those admitted in the medical wards, OR 9.6 [95% CI 1.6-57.3], p=0.003. Similarly, S. aureus was 3.5 times more likely to be isolated in the DCC wards (12.8%) and 5.3 times in the surgical wards (18.2%) compared to the medical wards. There was no significant difference between prevalence in outpatient (8.3%) and that reported in the medical wards, OR 2.2 (95% CI 0.7-6.5), p=0.154. History of antibiotic use had no influence on Staph aureus infection. Also, there was a lower risk of staph aureus infection associated with short-term and long-term hospitalization compared to those with no hospitalization. Those with short-term hospitalization had a prevalence of 4.4% (OR 0.2 [95% CI 0.1-0.6], p=0.004) and those with long-term hospitalization had a prevalence 6.4% (OR 0.4 [OR 95% CI 0.1-1.0], p=0.048) compared to 16.1% in those with no hospitalization at all. In addition, patients with history of prolonged antibiotic use were 3.4 times at a higher risk of *S. aureus* infection compared with no such history; with prevalence of 16.7%, OR 3.4 (95% CI 1.4-8.5), p=0.008 (Table 3).

4.5. Factors Associated with MRSA Infection

MRSA isolation was significantly lower in medical wards compared to outpatient clinics (p=0.018). Conversely, highest prevalence of MRSA was recorded in the burns unit (28.6%) which was 14 times more likely to be isolated compared to the outpatient clinics, OR 14.0 (95% CI 1.6-121.4), p=0.003. Other notable prevalence was in DCC (7.7%) and surgical wards (4.5%) though not significantly different from the outpatient clinics. Also, those who reported

short-term hospitalization had significantly reduced risk of MRSA infection (0.5%), OR 0.1 (95% CI 0.01-0.5), p=0.012, compared to 8.1% in those with no history of hospitalization (Table 4). Antibiotic use and risk factors were not significantly associated with the likelihood of isolation of MRSA in the samples.

Table 3. Factors associated with Staphylococcus aureus isolation from patients.

Variable	Staph aureus isolate		OR (95% CI)	P value
	Yes	No		
Median age in years (IQR)	34 (19-52.5)	42 (23-53)	-	0.486
Ward				
Medical	8 (4.0)	192 (96.0)	1.0	
Outpatient	6 (8.2)	67 (91.8)	2.2 (0.7-6.5)	0.154
Diabetic care centre	5 (12.8)	34 (87.2)	3.5 (1.1-11.4)	0.026
Surgical	4 (18.2)	18 (81.8)	5.3 (1.5-19.5)	0.005
Burns unit	2 (28.6)	5 (71.4)	9.6 (1.6-57.3)	0.003
Intensive care unit	0	7 (100.0)	-	1.000
New born unit	0	5 (100.0)	-	1.000
Ear nose and throat	0	1 (100.0)	-	1.000
Antibiotic use				
Frequent	0	3 (100.0)	-	0.999
Frequent/Prolonged	9 (11.1)	72 (88.9)	1.9 (0.8-4.6)	0.128
Recent	16 (6.0)	250 (94.0)	1.0	
None	0	4 (100.0)	-	0.999
Hospital stay				
Long term hospitalization	7 (6.4)	102 (93.6)	0.4 (0.1-1.0)	0.048
Short term hospitalization	8 (4.4)	174 (95.6)	0.2 (0.1-0.6)	0.004
No hospitalization	10 (15.9)	53 (84.1)	1.0	
Risk factor				
Recent surgical procedure	3 (5.4)	53 (94.6)	1.0 (0.3-3.5)	0.959
Prolonged antibiotic use	9 (16.7)	45 (83.3)	3.4 (1.4-8.5)	0.008
Presence of invasive medical device	0	5 (100.0)	-	0.999
Catheter	0	1 (100.0)	-	1.000
Healthcare-associated infections	0	1 (100.0)	-	1.000
History of healthcare associated infection	0	1 (100.0)	-	1.000
None	13 (5.5)	223 (94.5)	1.0	

Table 4. Factors associated with MRSA isolation from patients.

Variable	MRSA isolates		OR (95% CI)	P value
	Yes	No		
Median age in years (IQR)	34 (19-52)	47.5 (28-61.5)	-	0.300
Ward				
Medical	0	200 (100.0)	-	0.018
Outpatient	2 (2.7)	71 (97.3)	1.0	
Diabetic care centre	3 (7.7)	36 (92.3)	2.9 (0.5-18.3)	0.234
Surgical	1 (4.5)	21 (95.5)	1.7 (0.1-19.3)	1.000
Burns unit	2 (28.6)	5 (71.4)	14.0 (1.6-121.4)	0.003
Intensive care unit	0	7 (100.0)	-	1.000
New born unit	0	5 (100.0)	-	1.000
Ear nose and throat	0	1 (100.0)		1.000
Antibiotic use				
Frequent	0	3 (100.0)	-	0.999
Frequent/Prolonged	4 (4.9)	77 (95.1)	3.4 (0.8-13.9)	0.090
Recent	4 (1.5)	262 (98.5)	1.0	
None	0	4 (100.0)	-	0.999
Hospital stay				
Long term hospitalization	2 (1.8)	107 (98.2)	0.2 (0.04-1.1)	0.070
Short term hospitalization	1 (0.5)	181 (99.5)	0.1 (0.01-0.5)	0.012

Variable	MRSA isolates		OR (95% CI)	P value
	Yes	No		
No hospitalization	5 (7.9)	58 (92.1)	1.0	
Risk factor				
Recent surgical procedure	0	56 (100.0)	-	1.000
Prolonged antibiotic use	3 (5.6)	51 (94.4)	2.7 (0.6-11.7)	0.182
Presence of invasive medical device	0	5 (100.0)	-	0.999
Catheter	0	1 (100.0)	-	1.000
Healthcare-associated infections	0	1 (100.0)	-	1.000
History of healthcare associated infection	0	1 (100.0)	-	1.000
None	5 (2.1)	231 (97.9)	1.0	

5. DISCUSSION

The study found a prevalence of 7.1% for Staphylococcus aureus with as low as 4.2% and high of 9.9% in the 95% confidence interval scale and 2.3% with a range between 0.8% and 3.7% in the 95% confidence interval for MRSA among the sampled patients. This aligns with other studies in Africa, such as a cross-sectional study in Tanzania reporting high MRSA prevalence among ICU patients [2]. In contrast, a higher prevalence of MRSA (53.4%) was reported in Kenya [14] reflecting variability in MRSA prevalence across different regions and settings within Africa. The highest prevalence of Staphylococcus aureus (28.6%) was observed in the burns unit, consistent with global trends indicating high MRSA rates in high-risk areas like burn units [6]. This was even higher around the Eastern African region with an Eritrean study reporting 72% MRSA prevalence [8]. The prevalence in Europe ranges up to 24% in acute care and long-term settings [8]. This is not far in range from a prison study in USA where 19% prevalence was recorded on entering prison and this increased by 8.4% on day 30 of incarceration [5]. In a Myanmar study, the prevalence was 48% [22].

MRSA isolates showed significant resistance to penicillin G, erythromycin, and clindamycin ranging between 56-64%. These findings are comparable to resistance patterns observed globally. For instance, in South Africa, 59% of MRSA isolates were resistant to clindamycin and 63% to erythromycin [5]. Similarly, high resistance rates were reported in a Myanmar study Soe, et al. [22]. indicating a widespread challenge in treating MRSA due to antibiotic resistance. In Kenya, isolates showed high resistance to penicillin but were highly susceptible to linezolid, tigecycline, and vancomycin, similar to our findings [2]. The isolates were most susceptible to SXT at 68% with moderate susceptibility on doripenem and cefoxitin. Another study in Kenya reported contrary findings - trimethoprim-sulfamethoxazole had poor susceptibility of 17.7%-28.2% [14]. Higher resistance level was reported in Russia that showed HA-MRSA resistance at 76% - 92% for ciprofloxacin, gentamicin and chloramphenicol [8].

Lower resistance was reported in Eritrea - 15.9% for vancomycin, 11% for erythromycin and 1.2% for gentamicin [8]. The findings highlight the necessity for routine antibiotic susceptibility testing to guide effective antibiotic therapy and reduce the misuse of antibiotics, which can drive resistance.

The study found significant associations between patient-level factors and MRSA infections, with the highest prevalence observed in the burns unit. Similar findings have been reported globally, highlighting the vulnerability of burn patients to MRSA [22]. Short-term hospitalization was associated with a reduced risk of MRSA infection, while prolonged antibiotic use increased the risk, emphasizing the importance of prudent antibiotic use [6]. These patient-level factors are consistent with global predictors of MRSA infections, including prolonged hospital stays and antibiotic use [8].

REFERENCES

[1] A. M. Aiken, I. M. Mutuku, A. J. Sabat, and V. Akkerboom, "Carriage of staphylococcus aureus in Thika level 5 Hospital, Kenya: A cross-sectional study," in "Antimicrobial Resistance and Infection Control," Retrieved: https://aricjournal.biomedcentral.com/articles/10.1186/2047-2994-3-22. [Accessed 2014.

[2] J. Nyasinga *et al.*, "Epidemiology of Staphylococcus aureus infections in Kenya: Current state, gaps and opportunities," *Open Journal of Medical Microbiology*, vol. 10, pp. 204-221, 2020. https://doi.org/10.4236/ojmm.2020.104018

[3] J. B. Parsons, A. C. Westgeest, B. P. Conlon, and V. G. Fowler Jr, "Persistent methicillin-resistant Staphylococcus aureus bacteremia: Host, pathogen, and treatment," *Antibiotics*, vol. 12, no. 3, p. 455, 2023. https://doi.org/10.3390/antibiotics12030455

[4] S. W. B. Newsom, "Ogoston's coccus," *Journal of Hospital Infection*, vol. 70, no. 4, pp. 369-372, 2008. https://doi.org/10.1016/j.jhin.2008.10.001

[5] C. P. Harkins *et al.*, "Methicillin-resistant Staphylococcus aureus emerged long before the introduction of methicillin into clinical practice," *Genome Biology*, vol. 18, pp. 1-11, 2017. https://doi.org/10.1186/s13059-017-1252-9

[6] N. A. Turner *et al.*, "Methicillin-resistant Staphylococcus aureus: An overview of basic and clinical research," *Nature Reviews Microbiology*, vol. 17, no. 4, pp. 203-218, 2019.

[7] World Health Organization, "Antimicrobial resistance," Retrieved: https://www.who.int/health-topics/antimicrobial-resistance. [Accessed 2021.

[8] E. Y. Garoy *et al.*, "Methicillin-resistant staphylococcus aureus (MRSA): prevalence and antimicrobial sensitivity pattern among patients - A multicenter study in Asmara, Eritrea," *Canadian Journal of Infectious Diseases and Medical Microbiology*, vol. 2019, no. 1, p. 8321834, 2019. https://doi.org/10.1155/2019/8321834

[9] D. P. Kateete *et al.*, "High prevalence of methicillin resistant Staphylococcus aureus in the surgical units of Mulago hospital in Kampala, Uganda," *BMC Research Notes*, vol. 4, pp. 1-5, 2011. https://doi.org/10.1186/1756-0500-4-326

[10] A. H. Bartlett and R. S. Daum, "Epidemiology of Staphylococcus aureus and enterococci and an overview of antimicrobial resistance," *Antimicrobial Stewardship: Principles and Practice*, pp. 137-151, 2017. https://doi.org/10.1079/9781780644394.0137

[11] F. R. DeLeo, M. Otto, B. N. Kreiswirth, and H. F. Chambers, "Community-associated meticillin-resistant Staphylococcus aureus," *The Lancet*, vol. 375, no. 9725, pp. 1557-1568, 2010.

[12] M. R. Mulvey and A. E. Simor, "Antimicrobial resistance in hospitals: How concerned should we be?," *Canadian Medical Association Journal*, vol. 180, no. 4, pp. 408-415, 2009. https://doi.org/10.1503/cmaj.080239

[13] Y. Jin *et al.*, "Genomic epidemiology and characterization of methicillin-resistant Staphylococcus aureus from bloodstream infections in China," *MSystems*, vol. 6, no. 6, pp. e00837-21, 2021. https://doi.org/10.1128/msystems.00837-21

[14] F. K. Wangai, M. M. Masika, M. C. Maritim, and R. A. Seaton, "Methicillin-resistant staphylococcus aureus (MRSA) in East Africa: Red alert or red herring?," *BMC Infectious Diseases*, vol. 19, pp. 1-10, 2019. https://doi.org/10.1186/s12879-019-4245-3

[15] National Nosocomial Infection Surveillance (NNIS) System Report, "Data summary from January 1992 through June 2004, issued October 2004. (2014). American Journal of Infection Control," Retrieved: https://www.ajicjournal.org/article/S0196-6553(04)00542-5/fulltext. [Accessed 2014.

[16] P. S. Sit *et al.*, "Prevalence of methicillin-resistant Staphylococcus aureus (MRSA) infection and the molecular characteristics of MRSA bacteraemia over a two-year period in a tertiary teaching hospital in Malaysia," *BMC Infectious Diseases*, vol. 17, pp. 1-14, 2017. https://doi.org/10.1186/s12879-017-2384-y

[17] Review on Antimicrobial Resistance, "Review on antimicrobial resistance," Retrieved: https://amr-review.org/. [Accessed 2016.

[18] C. J. Murray *et al.*, "Global burden of bacterial antimicrobial resistance in 2019: A systemic analysis," *Lancet*, vol. 399, no. 10325, pp. 629-655, 2022. https://doi.org/10.1016/S0140-6736(21)02724-0

[19] M. E. Falagas, D. E. Karageorgogopoulous, and I. P. Korbila, "MRSA in Africa: Filling the global map of antimicrobial resistance. Plos One," Retrieved: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0068024. [Accessed 2013.

[20] U. Abubakar and S. A. Sulaiman, "Prevalence, trend and antimicrobial susceptibility of Methicillin Resistant Staphylococcus aureus in Nigeria: A systematic review," *Journal of Infection and Public Health*, vol. 11, no. 6, pp. 763-770, 2018. https://doi.org/10.1016/j.jiph.2018.05.013

[21] A. Geofrey, A. Abade, and S. Aboud, "Methicillin-resistant staphylococcus aureus (MRSA) colonozation among intensive care unit (IC) patients and health care workers at Muhimbili National Hospital, Dar Es Salaam, Tanzania," *Pan African Medical Journal*, vol. 21, p. 211, 2015. https://doi.org/10.11604/pamj.2015.21.211.4207

[22] P. E. Soe *et al.*, "High prevalence of methicillin-resistant Staphylococcus aureus among healthcare facilities and its related factors in Myanmar (2018–2019)," *Tropical Medicine and Infectious Disease*, vol. 6, no. 2, p. 70, 2021. https://doi.org/10.3390/tropicalmed6020070

[23] University of Calgary, "Why sepsis from a staph infection causes organ failure. Science Daily," Retrieved: https://www.sciencedaily.com/releases/2018/07/180726162039.htm#:~:text=For%20patients%20diagnosed%20with%20a,the%20people%20who%20develop%20it. [Accessed 2018.

[24] Center for Disease Control and Prevention, "Preventing the spread of MRSA," Retrieved: https://www.cdc.gov/mrsa/healthcare/index.html. [Accessed 2019.

[25] C. P. Davis, "MRSA: Causes, symptoms, and treatment. On health," Retrieved: https://www.onhealth.com/content/1/mrsa_infection_resistant. [Accessed 2021.

[26] R. Daum, "Community-associated MRSA infections. Principles and practice of pediatric infectious diseases," Retrieved: https://www.sciencedirect.com/topics/medicine-and-dentistry/methicillin-resistant-staphylococcus-aureus-infection. [Accessed 2018.

[27] K. J. Popovich *et al.*, "Genomic epidemiology of MRSA during incarceration at a large inner-city jail," *Clinical Infectious Diseases*, vol. 73, no. 11, pp. e3708-e3717, 2021. https://doi.org/10.1093/cid/ciaa1937

[28] V. Gostev *et al.*, "Molecular epidemiology and antibiotic resistance of methicillin-resistant Staphylococcus aureus circulating in the Russian Federation," *Infection, Genetics and Evolution*, vol. 53, pp. 189-194, 2017. https://doi.org/10.1016/j.meegid.2017.06.006

[29] R. Sunagar, N. R. Hegde, G. J. Archana, A. Y. Sinha, K. Nagamani, and S. Isloor, "Prevalence and genotype distribution of methicillin-resistant Staphylococcus aureus (MRSA) in India," *Journal of Global Antimicrobial Resistance*, vol. 7, pp. 46-52, 2016. https://doi.org/10.1016/j.jgar.2016.07.008

[30] S. A. Fritz *et al.*, "Staphylococcus aureus colonization in children with community-associated Staphylococcus aureus skin infections and their household contacts," *Archives of Pediatrics & Adolescent Medicine*, vol. 166, no. 6, pp. 551-557, 2012. https://doi.org/10.1001/archpediatrics.2011.900

[31] M. A. Borg and L. Camilleri, "What is driving the epidemiology of Methicillin-Resistant staphylococcus aureus infections in Europe?," *Microbial Drug Resistance*, vol. 27, no. 7, pp. 889-894, 2021. https://doi.org/10.1089/mdr.2020.0259

[32] P. K. David, "Molecular characterization of staphylococcus aureus from patients with surgical site infections at mulago hospital in Kampala, Uganda," *Plos One*, vol. 8, no. 6, p. e66153, 2013. https://doi.org/10.1371/journal.pone.0066153

[33] Merriam-Webster, "Medical dictionary," Retrieved: https://www.merriam-webster.com/medical/beta-lactam. [Accessed 2022.

[34] NHS, "Antibiotics. NHS infrome," Retrieved: https://www.nhsinform.scot/tests-and-treatments/medicines-and-medical-aids/types-of-medicine/antibiotics#:~:text=oral%20antibiotics%20%E2%80%93%20tablets%2C%20capsules%20or,used%20to%20treat%20skin%20infections [Accessed 2021.

[35] K. McCarthy and M. Avent, "Oral or intravenous antibiotics? Australian prescriber," Retrieved: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7186270/. [Accessed 2020.

[36] H. Humphreys, H. Grundmann, R. Skov, J.-C. Lucet, and R. Cauda, "Prevention and control of methicillin-resistant Staphylococcus aureus," *Clinical Microbiology and Infection*, vol. 15, no. 2, pp. 120-124, 2009.

[37] C. Alvarez, J. Labarca, and M. Salles, "Prevention strategies for methicillin-resistant Staphylococcus aureus (MRSA) in Latin America," *Brazilian Journal of Infectious Diseases*, vol. 14, pp. 107-108, 2010. https://doi.org/10.1590/s1413-86702010000800006

[38] M. W. Ellis *et al.*, "Hygiene strategies to prevent methicillin-resistant Staphylococcus aureus skin and soft tissue infections: A cluster-randomized controlled trial among high-risk military trainees," *Clinical Infectious Diseases*, vol. 58, no. 11, pp. 1540-1548, 2014. https://doi.org/10.1093/cid/ciu166