Saudi Pharmaceutical Journal 32 (2024) 102001

HOSTED BY

Contents lists available at ScienceDirect

Saudi Pharmaceutical Journal

journal homepage: www.sciencedirect.com

Prevalence and antimicrobial susceptibility pattern of methicillin-resistant *Staphylococcus aureus* (MRSA) at a maternity and children hospital in Saudi Arabia: A cross-sectional study

Hadiah Almutairi [a], Heyam Albahadel [b], Abdullah A. Alhifany [c], Hind Aldalbahi [b], Faris S. Alnezary [d], Ibrahim Alqusi [e], Mugahid A. Mobark [b], Masaad Saeed Almutairi [b,*]

[a] Department of Pharmacy Practice, College of Pharmacy, University of Hafr Albatin, Saudi Arabia
[b] Department of Pharmacy Practice, College of Pharmacy, Qassim University, Qassim 51452, Saudi Arabia
[c] Pharmaceutical Practices Department, College of Pharmacy, Umm Al-Qura University, Makkah, Saudi Arabia
[d] Department of Pharmacy Practice, College of Pharmacy, Taibah University, Madinah 41477, Saudi Arabia
[e] Laboratory Department, Maternity and Children Hospital in Buraydah City, Ministry of Health, Qassim, Saudi Arabia

ARTICLE INFO

Keywords:
MRSA
Prevalence
Pediatric
Saudi Arabia
Antibiotic resistance
Infection control

ABSTRACT

Background: Methicillin-resistant *Staphylococcus aureus* (MRSA) pathogens are considered a serious global health threat, leading to increased mortality and antimicrobial resistance. Rates in Saudi Arabia remain high, necessitating continuous surveillance. This study investigates MRSA prevalence and susceptibility at a Saudi maternity and children's hospital.

Method: A cross-sectional study was conducted on pediatric (<18 years) and maternal patients with *S. aureus* infection from Jan. 2020 to March. 2022. Bacterial strains were obtained from patient's clinical specimens and was identified by standard method. The BD Phoenix™ M50 was used for antibiotic susceptibility tests and MRSA detection. Data were analysed using descriptive and inferential statistics (Chi-square test) with SPSS software.

Results: Out of 152 *S. aureus* cases, 114/152 (75 %) were pediatric and 38/152 (25 %) were maternal patients. The overall MRSA infection was 69/152 (45.4 %). Among pediatrics, 31/54 (57.4 %) MRSA cases were female; over 30/54 (56 %) were under 1 year old; and most MRSA infections were obtained from skin 29/54 (53.7 %) compared to other sites of infections ($p = 0.024$). Among maternal cases, 15/38 (39.5 %) were MRSA, primarily from wound infections 14/15 (93.3 %) compared to other sites of infections ($p = 0.39$). All MRSA isolates were sensitive to vancomycin and linezolid. While 51/60(85 %) were sensitive to Trimethoprim/ sulfamethoxazole.

Conclusion: This investigation found a high prevalence of MRSA among pediatrics and maternal inpatients, indicating a significant burden. All MRSA isolates were susceptible to vancomycin but demonstrated variable sensitivity to other antibiotics. These findings highlight the need for ongoing surveillance, infection control strategies, and research into alternative treatment options to combat this major public health threat.

1. Introduction

Staphylococcus aureus is a gram-positive pathogen that causes illnesses ranging from minor skin and soft tissue infections to severe life-threatening bloodstream or invasive infections (Tong et al., 2015). While many strains of *Staphylococcus aureus* (*S. aureus*) are effectively treatable with various antimicrobial agents, managing infections caused by Methicillin-Resistant *Staphylococcus aureus* (MRSA) presents considerably greater challenges to clinical experts (Cimolai, 2010). Antimicrobial resistance (AMR) has become a serious global health issue that is estimated to contribute to millions of deaths worldwide. Over the past few decades, the threat of AMR as a significant public health concern has gained widespread attention. AMR was estimated to have contributed to 1.27 million deaths globally in 2019 and over 100,000 deaths were directly related to MRSA (Collaborators, 2022). It has been reported that those with MRSA infections had a 64 % higher mortality rate compared to those with antibiotics-susceptible infections (WHO, 2021). In particular, poor health outcomes and increased mortality risks

* Corresponding author at: Department of Pharmacy Practice, College of Pharmacy, Qassim University, Qassim 51452, Saudi Arabia.
E-mail addresses: Hkalmutairi@uhb.edu.sa (H. Almutairi), aahifany@uqu.edu.sa (A.A. Alhifany), fnezary@taibahu.edu.sa (F.S. Alnezary), mu.mohammed@qu.edu.sa (M.A. Mobark), mas.almutairi@qu.edu.sa (M. Saeed Almutairi).

https://doi.org/10.1016/j.jsps.2024.102001
Received 25 December 2023; Accepted 20 February 2024
Available online 24 February 2024

were especially pronounced among individuals who acquire invasive or bloodstream MRSA infections (Rasmussen et al., 2011). According to the Centers for Disease Control and Prevention (CDC) in United States (US), over 70,000 severe infections were attributed to MRSA (CDC, 2020). Given the considerable morbidity and mortality burden imposed by MRSA infections, addressing antibiotic resistance through evidence-based measures represents an urgent global priority.

MRSA strains have eventually exhibited an alarming trend of developing different degrees of resistance to antibiotics that were previously effective. Vancomycin has been known to be the treatment choice of MRSA. However, several reports showed the emergence of vancomycin-resistant MRSA isolates with decreased vancomycin treatment efficacy, as evidenced by high minimum inhibitory concentrations (MICs) ($\geq$2 μg/mL) (Fridkin et., 2003, Howden et al., 2004, Sakoulas et al., 2004). The occurrence of treatment failure has been associated with elevated MIC values (1.5–2 μg/mL), even within the susceptible range (Amatya et al., 2014, Chen et al., 2014, Zorgani et al., 2015). The emergence of vancomycin resistance in MRSA necessitates an urgent, coordinated response encompassing enhanced surveillance, stewardship, alternative agents, and evidence-based protocols to preserve treatment efficacy.

Regional epidemiological data revealed concerning trends in Saudi Arabia's MRSA prevalence. On a global scale, the overall prevalence of MRSA infections, irrespective of the settings, exhibits a broad range from 13 % to 74 % (Köck et al., 2010). In the middle east, the Gulf Corporation Council (GCC) countries have reported varying levels of prevalence related to MRSA infection, with Saudi Arabia showing the highest rate at 29.9 % and Kuwait had the lowest prevalence at 3.3 % (Aly and Balkhy, 2012). A recent review conducted by Thabit and colleagues found that an average MRSA prevalence of 32.5 % among *S. aureus* isolate in Saudi Arabia (Thabit et al., 2023). Among different geographical regions in Saudi Arabia, studies have uncovered high MRSA prevalence with the presence of variety of clonal complexes (Bukharie et al., 2001, Monecke et al., 2012). One study in eastern Saudi Arabia demonstrated a concerning increase in MRSA incidence among hospital admissions over an 8-year period, rising from 9.9 to 67 per 10,000 admissions (Bukharie, 2010). Moreover, Almulhim and colleagues reported an incidence rate of *Staphylococcus* species, including MRSA, among surgical site infection in orthopedic patients to 23/79 (29 %) (Al-Mulhim et al., 2014). Taken together, these data underscore the gravity of the MRSA threat in Saudi Arabia warranting strategic prevention and control measures. Given concerning trends in MRSA epidemiology in Saudi Arabia, targeted surveillance and prevention strategies are warranted. Health authorities employed various strategies to control MRSA spread, including assessing prevalence, incidence as well as continuous evaluation of antibiotic susceptibility pattern (CDC, 2019). Therefore, this study examined MRSA prevalence, susceptibility, and risk factors among pediatric and maternal patients admitted to a Maternity and Children Hospital in Saudi Arabia over 2 years.

2. Method

2.1. Study design, subjects, and setting

A cross-sectional study was conducted at a Maternal and Children Hospital, a 200-bed capacity hospital located in Al-Qassim province, a central region of Saudi Arabia. This study was approved by the Regional Research Ethics Committee-Qassim Province (IRB log No. 704-43-1111). All patients - adults or pediatrics - hospitalized between Jan. 2020 and March 2022 were screened for positive *S. aureus* isolates. Demographic information, specimen collection, culture techniques, site of infections, and antimicrobial susceptibility data were collected from electronic medical records.

2.2. Data stratification, inclusion criteria

Data was classified according to the ward into two pediatric or maternal. Age of pediatrics was grouped into less than a year and 1–18 years. The maternal patients were stratified according to age in to two groups: 19–30 years and $\geq$ 31 years. The clinical department where patients admitted to was also recorded. Information related to infection was categorized according to the infection type, specimen type and site of infection. All patients with positive *S. aureus* infection and complete antimicrobial susceptibility data during the study period were included.

2.3. Bacterial identification, antibiotic susceptibility, and screening of methicillin resistance MRSA

Bacterial strains were obtained from different patient's clinical specimens like pus, abscesses, blood, and surgical wounds. Blood agar media was used for *S. aureus* identification and the American Society for Microbiology (ASM) guideline were followed for Gram-positive identification that include positive catalase and coagulase tests. Antibiotics susceptibility testing was carried out to determine the susceptibility of MRSA infections and identify possible antibiotic resistance (Jorgensen and Ferraro, 2009). In our hospital The BD Phoenix™ M50 was used for antibiotic susceptibility tests and MRSA detection.

2.4. Statistical analysis

Descriptive statistics were used to present the results. The Chi-square test was employed to examine the significance differences among subgroups. Statistical significance was assessed at a significance level of 0.05. Fisher's exact test was specifically used for cells with frequencies less than 5. Microsoft excel program was used for data entry. Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 25.

3. Results

A total of 152 patients were found positive for S. *aureus* infection. Among them, 114/152(75 %) were from pediatric wards and 38/152 (25 %) were maternal patients. The overall prevalence of MRSA among all *S. aureus* isolates was 69/152 (45.4 %).

3.1. Results from pediatric group

Almost half of the included pediatric patients were male 63/114 (55.3 %) and 60/114 (52.6 %) were aged less than one year old. out of the 114 pediatric patients, 54/114 cases (47.4 %) were infected with MRSA and 60/114 (52.6 %) were infected with MSSA. Analysis of the demographic characteristics of MRSA cases revealed a significantly higher proportion of MRSA cases in female 31/51 (60.8 %) compared to 23/63 cases (36.5 %) in males ($p = 0.01$). In regard to MRSA distribution among age groups in pediatrics, MRSA cases were numerically high among children younger than one-year 30/60 (50 %) compared to children over than one year old 24/54 (44.4 %). There were no statistical differences in MRSA distribution among clinical departments (NICU/PICU, pediatric medical/surgical, or other departments, 14/29 (48.3 %), 31/72 (43.1 %), and 9/13 (69.2 %) $p = 0.21$, respectively).. In terms of site of infection, half of the MRSA cases 29/54 (53.7 %) were in skin infection compared to other sites of infection ($p = 0.024$) (Table 1).

3.2. Results from maternity group

A total of 38 maternal patients were included, 15/38 (39.5 %) were infected with MRSA and 23/38 (60.5 %) were infected with MSSA. The age distribution of maternal patients was as follow: 21/38 (55.2 %) were aged $\geq$ 31-year-old and 17/38 (44.8 %) were aged between 19 and 30-year-old with no differences in MRSA distribution between these

Table 1
Frequency of MRSA and MSSA among pediatric patients with regard to gender, age, clinical department, specimen type and site of infection (n = 114).

Variable		MRSA (n = 54)	MSSA (n = 60)	Total	P-value
		N (%)	N (%)	N (%)	
Gender	Male	23 (36.5)	40 (63.5)	63 (100)	0.01
	Female	31 (60.8)	20 (39.2)	51 (100)	
Age	<1 year	30 (50)	30 (50)	60 (100)	0.55
	1–18 years	24 (44.4)	30 (55.6)	54 (100)	
Clinical Department	NICU/PICU	14 (48.3)	15 (51.7)	29 (100)	0.21
	Pediatric (Medical/surgical)	31 (43.1)	41 (56.9)	72 (100)	
	Others (OPD, ER)	9 (69.2)	4 (30.8)	13 (100)	
Specimen Type	Pus	23 (47.9)	25 (52.1)	48 (100)	0.97
	Blood	16 (45.7)	19 (54.3)	35 (100)	
	Others: Culture ABS TRAC.A, Umbilical, Wound, Tip, Ear, Eye, Sputum, Body fluid	15 (48.4)	16 (51.6)	31 (100)	
Site of Infection	Skin infection	29 (53.7)	25 (46.3)	54 (100)	0.024
	Bloodstream	10 (28.6)	25 (71.4)	35 (100)	
	Others (infection of lung; wound, breast, bone, ear, GIT, joint, vaginal or urinary tract)	15 (60)	10 (40)	25 (100)	
Total		54 (47.4)	60 (52.6)	114(100)	–

NICU/PICU; Neonatal intensive care unit/ pediatric intensive care unit. OPD; Out-patient department. ER; Emergency room. ABS: Abscesses; GIT: Gastrointestinal tract; MRSA: Methicillin resistance *staphylococcus aureus;* MSSA: Methicillin sensitive *staphylococcus aureus;* TIP: Tip of portacath; TRAC.A: Tracheal aspiration. Significance level of p-value < 0.05.

different age groups (8/17 (47.1 %) and 7/21 (46.6 %) p = 0.38, respectively). In terms of specimen type, pus was the most predominant specimen type 32/38 (84.2 %) with no differences of MRSA distribution between the types of specimen (pus 13/32 (40.6 %) and other specimens 2/6 (33.3 %) p = 1).(Table 2).

3.3. Pattern of antibiotic sensitivity and resistance

Fig. 1 shows the sensitivity data of MRSA isolates from pediatrics and maternal patients. Vancomycin and oxacillin were tested against 69 isolates, while trimethoprim/sulfamethoxazole (TMP/SMX) were test against 60 isolates and tetracycline and erythromycin were tested against 47 and 45 isolates, respectively. The results demonstrated that vancomycin and linezolid retained full efficacy against all MRSA isolates, with 69/69 (100 %) being susceptible. High rates of susceptibility were also observed for (TMP/SMX) 51/60 (85 %) and tetracycline 42/47 (81 %). While the following antibiotics showed moderate sensitivity ciprofloxacin 17/25 (68 %), clindamycin 48/63 (76 %), and Erythromycin 25/45 (55.6 %).

3.4. Mics of selected antibiotics for MRSA isolates

The MICs of different antibiotics of 28 MRSA isolates are shown in Table 3. The results showed that 28/28 (100 %) of MRSA isolates were susceptible to vancomycin (MIC ≤ 1 μg/ml), teicoplanin (MIC ≤ 1 μg/ml), linezolid (MIC ≤ 2 μg/ml), mupirocin (MIC ≤ 256 μg/ml), nitrofurantoin (MIC ≤ 16 μg/ml), moxifloxacin (MIC ≤ 2 μg/ml), and rifampin (MIC ≤ 0.5 μg/ml). High rates of susceptibility were also seen for daptomycin 25/28 (89.2 %; MIC ≤ 1 μg/ml), ciprofloxacin 24/28 (85.7 %; MIC ≤ 0.5 μg/ml), clindamycin 23/28 (82.1 %; MIC ≤ 0.5 μg/ml), erythromycin 22/28 (78.5 %; MIC ≤ 0.25 μg/ml) and 23/28 (82.1 %; MIC ≤ 0.5 μg/ml), and tetracycline 21/28 (75 %; MIC ≤ 0.5 μg/ml). However, MRSA isolates displayed high rates of resistance to gentamicin, cefoxitin, cefotaxime. Ampicillin, penicillin G, oxacillin, and other antibiotics are shown in Table 3.

4. Discussion

This research provides an important insight into the epidemiology, risk factors, and antibiotic resistance profiles of *S. aureus* infections in pediatric and maternal populations at a Maternity and Children Hospital in Saudi Arabia. The prevalence of MRSA among pediatric and maternal patients was alarmingly high in this setting. In overall, 69/152 (45.4 %) isolates were MRSA. This signifies a major MRSA burden among children and mothers admitted to the hospital. This finding indicates the need for implementing prevention policies in pediatric and maternal patients wards such as minimizing the overutilization of antibiotics and implanting antimicrobial stewardship policies to tackle the emergence of bacterial resistance (Spellberg et al., 2011, Pollack and Srinivasan, 2014, Huang et al., 2022).

The overall prevalence of MRSA in our study (45.4 %) was higher than other recent studies conducted in various regions of Saudi Arabia. The higher rate in our study may be partly attributable to the vulnerable maternal and pediatric patient population assessed, as well as the risk of vertical MRSA transmission at delivery (Ogura et al., 2021). Past studies have reported lower MRSA prevalence compared to our finding. Alhussaini et al. conducted a surveillance study in the central region and found a 22 % MRSA prevalence (Alhussaini, 2016). Additionally, a retrospective study by Farah et al. at a major medical city in Riyadh revealed a 17.5 % MRSA prevalence from 2010 to 2015 (Farah et al., 2019). Furthermore, Taha et al. found a 39 % MRSA prevalence in a 6-month cross-sectional study in the Northern region (Taha et al., 2022).

Table 2
Frequency of MRSA and MSSA among maternal female patients with regard to age, specimen type and site of infection (n = 38).

Variable		MRSA (n = 15)	MSSA(n = 23)	Total	P-value
		N (%)	N (%)	N (%)	
Age	19–30 years	8 (47.1)	9 (52.9)	17 (100)	0.38
	≥31 years	7 (46.6)	14 (60.8)	21 (100)	
Specimen type	Pus	13 (40.6)	19 (59.4)	32 (100)	1*
	Others: blood, culture ABS, wound, body fluid	2 (33.3)	4 (66.7)	6 (100)	
Site of infection	Wound infection	14 (37.8)	23 (62.2)	37 (100)	0.39*
	Others (infection of; bone, ear, GIT, joint, vaginal or urinary tract)	1 (100)	0.0 (0)	1(100)	
Total		15 (39.5)	23 (60.5)	38 (100)	

ABS: Abscesses; GIT: Gastrointestinal tract; MRSA: Methicillin resistance *staphylococcus aureus;* MSSA: Methicillin sensitive *staphylococcus aureus;*TIP: Tip of portacath; TRAC.A: Tracheal aspiration. Significance level of p-value < 0.05. * Fisher's exact test.

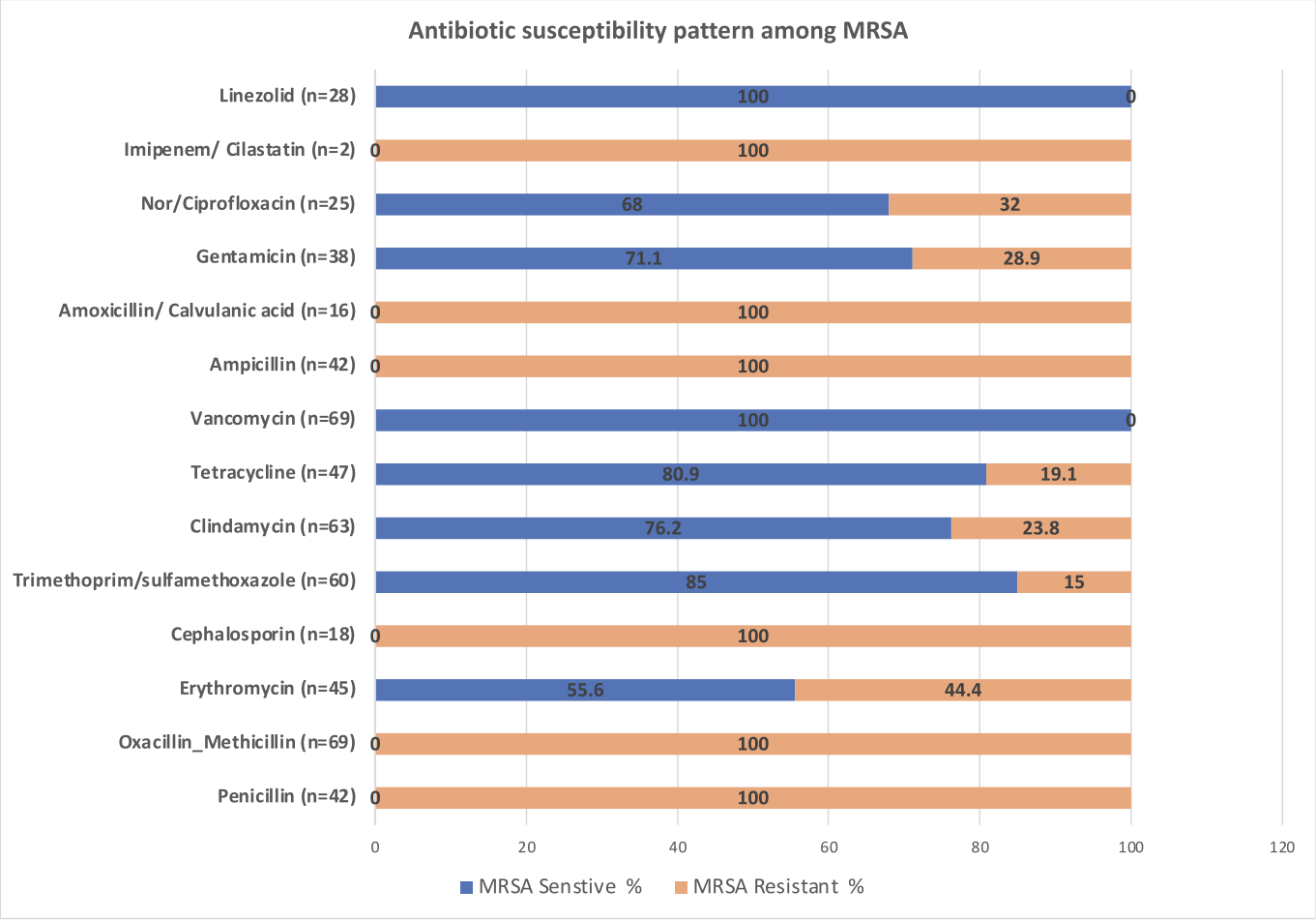

Fig. 1. Antibiotics susceptibility pattern among MRSA isolates.

Table 3
MICs of selected antibiotics for MRSA isolates (n = 28).

Antibiotic	MIC(µg/ml)	N (%)	Interpretation	Antibiotic	MIC(µg/ml)	N (%)	Interpretation
Gentamicin	≤2	18 (64.2)	S	Trimethoprim/ sulfamethoxazole	≤1\19	14 (50.0)	S
	>8	10 (35.8)	**R**		≤1\9	11 (39.4)	S
					>4/76	1 (3.5)	S
						2 (7.1)	**R**
Cefoxitin	4	1 (3.6)	**R**	Teicoplanin	≤1	28 (100.0)	S
	8	7 (25.0)	**R**	Vancomycin	1	28 (100.0)	S
	>8	20 (71.4)	**R**	Clindamycin	≤0.5	23 (82.1)	S
						4 (14.3)	**R**
Cefotaxime	≤8	19 (67.9)	**R**		>2	1 (3.6)	**R**
	16	3 (10.7)	**R**	Erythromycin	≤0.25	22 (78.6)	S
	32	3 (10.7)	**R**		0.5	1 (3.5)	S
	>32	3 (10.7)	**R**		>4	5 (17.9)	**R**
Ampicillin	>1	28 (100.0)	**R**	Linezolid	≤1	12 (42.8)	S
Penicillin G	>0.25	28 (100.0)	**R**		2	16 (57.2)	S
Oxacillin	≤2	7 (25.0)	**R**	Mupirocin	≤256	28 (100.0)	S
	>2	21 (75.0)	**R**	Nitrofurantoin	≤16	28 (100.0)	S
Amoxicillin/ Clavulanic acid	≤1/0.5	8 (28.6)	**R**	Ciprofloxacin	≤0.5	24 (85.8)	S
	>4/2	6 (21.4)	**R**		>2	4 (14.2)	**R**
	2/1	10 (35.7)	**R**	Rifampin	≤0.5	28 (100.0)	S
	4/2	4 (14.3)	**R**	Daptomycin	≤1	25 (89.3)	S
						3 (10.7)	**R**
Moxifloxacin	≤0.5	24 (85.8)	S	Tetracycline	≤0.5	21 (75.0)	S
	1	1 (3.5)	S		>8	7 (25.0)	**R**
	2	3 (10.7)	S				

R: Resistant; S: Sensitive; MIC: Minimum inhibitory concentration; MRSA: Methicillin resistance staphylococcus aureus

Locally, Alaklobi and colleagues found that the prevalence of MRSA was 23.3 % among outpatient children in Riyadh Saudi Arabia (Alaklobi et al., 2015). While MRSA prevalence was 60 % in a maternity hospital in Hafar Al-Batin in eastern region in Saudi Arabia (Aljeldah et al., 2022). Globally, the range of MRSA prevalence in maternal patients ranges from 2.1 % to 41 % (Chen et al., 2006, Reusch et al., 2008, Nourollahpour Shiadeh et al., 2022). In 2022, a meta-analysis assessed the prevalence of MRSA among maternal patients with 55 study and more than 110,000 pregnant women included. They found that the pooled prevalence was 3.2 % with the highest pooled prevalence in Africa 9.13 % (4.3–15.3 %) compared to other continents. Further analysis found that Cameroon had the highest prevalence of MRSA among maternal patients 41 % (32.5–50 %) (Nourollahpour Shiadeh et al., 2022). On the other hand, the prevalence of MRSA in children in our study was higher than in other studies worldwide. An epidemiological study in Italy between 2017 and 2021 found that the prevalence of MRSA in children was 30 % (La Vecchia et al., 2022). Additionally, it was 34.1 % in pediatrics in a Korean study (Park et al., 2019) and 18.2 % in pediatric in a Turkish study (Arikan et al., 2020). The considerably high burden uncovered in our obstetric and pediatric population underscores the need for targeted interventions.

The 100 % vancomycin susceptibility rate among MRSA isolates aligns with findings from other national and international investigations (La Vecchia et al., 2022). However, despite the current susceptibility, continued monitoring for any shifts is advisable (Zorgani et al., 2015) given sporadic but concerning global reports of decreasing susceptibility and emerging resistance among some MRSA strains (Chang et al., 2003, Amatya et al., 2014).

In the United States, limited cases of intermediary resistance have been documented, often linked to specific hospital-associated clones (McGuinness et al., 2017). If more widespread susceptibility declines or resistant subtypes emerge locally, alternative antibiotic options may need to be explored as substitutes for vancomycin (Lynch and Zhanel, 2023). Of particular concern is horizontal transfer of resistance genes between strains. For now, vancomycin remains reliably effective based on these results. Nonetheless, the threat of resistance underscores the importance of ongoing surveillance coupled with research into alternative MRSA treatment strategies, even in settings where vancomycin efficacy is currently intact.

In this study, 53.4 % and 18.5 % of the pediatric MRSA cases were obtained from skin and bloodstream infections, respectively. Among maternal cases, 93 % of MRSA isolates were collected from wound infections. The high burden of skin infections may relate to vertical transmission from mothers, although specific mother-infant connections were unable to be traced in this dataset (Huang et al., 2009, Ogura et al., 2021). Otherwise, the distribution of sites appears relatively consistent with past literature. For instance, Alrabiah et al. found 31 % of pediatric MRSA cases were bloodstream infections, reasonably aligned with our 18.5 % finding (Alrabiah et al., 2016).

Furthermore, a study in the Western Saudi region documented 39 % of MRSA infections originating from miscellaneous sites like skin, wounds, and stool (Alam, Alam et al., 2017). This indicates potential geographic variability warranting localized surveillance. While blood and skin sources are common, the proportion at each site may differ across settings and populations. Ongoing monitoring of local epidemiology is key to guiding effective prevention approaches tailored to infection patterns in priority groups like maternal/pediatric patients.

Key strengths of this study include providing recent, localized data on an important but understudied population - Saudi maternal/pediatric patients. Standardized laboratory procedures, a clinically relevant antibiotic panel, and statistical analysis of subgroups enhanced the methodological rigor. Granular categorization of specimen and infection site data generates clinically actionable insights. The focus on a high-risk population addresses a critical knowledge gap in the region. Findings can directly inform local infection control and treatment policies. This establishes a baseline for ongoing surveillance, highlighting the continuing threat of MRSA. On the other hand, the study has several limitations that should be acknowledged. First, the retrospective design and reliance on existing medical records introduces potential for missing or erroneous data that could bias results. The single-center nature of the study also restricts generalizability of the findings to other settings. Additionally, the relatively small sample size over a short time period limits statistical power for detecting significant effects and trends over time. There are also limitations related to microbiological methods. The lack of molecular characterization of MRSA isolates represents missed opportunities to identify strains, origins, and transmission patterns. Antibiotic susceptibility tests relied on the BD Phoenix™ M50 instead of utilizing broth microdilution (BMD), which is the "gold standard" according to international laboratory standards (EUCAST, 2003, Wayne, 2010). The restricted antibiotic panel may have prevented fully defining resistance profiles. Finally, the lack of clinical data limits understanding the full clinical impact of MRSA in this population. The study did not correlate outcomes, comorbidities, or risk factors with MRSA infections. The limited demographic data prevents more detailed analysis of particularly high-risk groups. The lack of screening for asymptomatic carriers also means prevalence was likely underestimated.

5. Conclusion

The study reveals a high prevalence of MRSA representing nearly half of *S. aureus* cases among pediatric patients and over a third of maternal cases in a Saudi hospital. The significant burden, especially among young infants and females, underscores risks of adverse outcomes and need for improved prevention efforts. Despite limitations, the study provides important baseline epidemiology on this vulnerable population to inform infection control policies and antimicrobial stewardship. Key findings demonstrating the considerable threat of MRSA in maternal and pediatric patients highlight the need for heightened surveillance, targeted interventions, and robust prevention programs to mitigate transmission and associated morbidity. Further research through multicenter studies and integrating clinical data is warranted to guide evidence-based strategies against this critical healthcare challenge.

CRediT authorship contribution statement

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Researchers would like to thank the Deanship of Scientific Research, Qassim University for funding publication of this project

References

Alaklobi, F., Aljobair, F., Alrashod, A., Alhababi, R., Alshamrani, M., Alamin, W., Lytvyn, L., Alrouki, F., Mertz, D., 2015. The prevalence of community-associated methicillin-resistant Staphylococcus aureus among outpatient children in a tertiary hospital: A prospective observational study in Riyadh, Saudi Arabia. Int. J. Pediatr. Adolesc. Med 2 (3–4), 136–140.

Alam, M.Z., Alam, Q., Man, A.G., Shukri, H.A., Haque, A., 2017. A surveillance study on the prevalence and antimicrobial resistance pattern among different groups of bacteria isolated from Western province of Saudi Arabia. Biomed. Res. (India) 28 (2), 898–906.

Alhussaini, M.S., 2016. Methicillin-resistant Staphylococcus aureus nasal carriage among patients admitted at Shaqra general Hospital in Saudi Arabia. Pak. J. Biol. Sci. 19 (5), 1.

Aljeldah, M., Al Shammari, B., Farrag, E.S., Taha, E.M., Mahmoud, S.Y., 2022. Prevalence of Multidrug-Resistant Methicillin-Resistant Staphylococcus aureus in Northeastern Saudi Hospitals. J. Pure. Appl. Microbiol 2, 1192–1199.

Al-Mulhim, F.A., Baragbah, M.A., Sadat-Ali, M., Alomran, A.S., Azam, M.Q., 2014. Prevalence of surgical site infection in orthopedic surgery: a 5-year analysis. Int. Surg 99 (3), 264–268.

Alrabiah, K., Al Alola, S., Al Banyan, E., Al Shaalan, M., Al Johani, S., 2016. Characteristics and risk factors of hospital acquired - Methicillin-resistant Staphylococcus aureus (HA-MRSA) infection of pediatric patients in a tertiary care hospital in Riyadh, Saudi Arabia. Int. J. Pediatr. Adolesc. Med 3 (2), 71–77.

Aly, M., Balkhy, H.H., 2012. The prevalence of antimicrobial resistance in clinical isolates from Gulf Corporation Council countries. Antimicrob. Resist. Infect. Control 1 (1), 26.

Amatya, R., Devkota, P., Gautam, A., 2014. Reduced susceptibility to vancomycin in methicillin resistant staphylococcus aureus: a time for action. Nepal. Med. Coll. J 16 (1), 42–44.

Arikan, K., Karadag-Oncel, E., Aycan, A.E., Yuksekkaya, S., Sancak, B., Ceyhan, M., 2020. Epidemiologic and Molecular Characteristics of Staphylococcus aureus Strains Isolated From Hospitalized Pediatric Patients. Pediatr. Infect. Dis. J 39 (11), 1002–1006.

Bukharie, H.A., 2010. Increasing threat of community-acquired methicillin-resistant Staphylococcus aureus. Am. J. Med. Sci 340 (5), 378–381.

Bukharie, H.A., Abdelhadi, M.S., Saeed, I.A., Rubaish, A.M., Larbi, E.B., 2001. Emergence of methicillin-resistant Staphylococcus aureus as a community pathogen. Diagn. Microbiol. Infect. Dis 40 (1–2), 1–4.

CDC. (2019). What CDC is Doing to Combat MRSA. Retrieved January 18, 2024, from https://www.cdc.gov/mrsa/tracking/index.html.

CDC. (2020). Methicillin-resistant *Staphylococcus aureus:* Preventing Infections in Healthcare. Retrieved 03/Nov/2023, from https://www.cdc.gov/mrsa/healthcare/inpatient.html#print.

Chang, S., Sievert, D.M., Hageman, J.C., Boulton, M.L., Tenover, F.C., Downes, F.P., Shah, S., Rudrik, J.T., Pupp, G.R., Brown, W.J., Cardo, D., Fridkin, S.K., 2003. Infection with Vancomycin-Resistant Staphylococcus aureus Containing the vanA Resistance Gene. N. Engl. J. Med. 348 (14), 1342–1347.

Chen, K.T., Huard, R.C., Della-Latta, P., Saiman, L., 2006. Prevalence of methicillin-sensitive and methicillin-resistant Staphylococcus aureus in pregnant women. Obstet. Gynecol 108 (3 Pt 1), 482–487.

Chen, S.Y., Liao, C.H., Wang, J.L., Chiang, W.C., Lai, M.S., Chie, W.C., Chang, S.C., Hsueh, P.R., 2014. Method-specific performance of vancomycin MIC susceptibility tests in predicting mortality of patients with methicillin-resistant Staphylococcus aureus bacteraemia. J. Antimicrob. Chemother 69 (1), 211–218.

Cimolai, N., 2010. Methicillin-resistant Staphylococcus aureus in Canada: a historical perspective and lessons learned. Can. J. Microbiol 56 (2), 89–120.

Collaborators, A.R., 2022. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet 399 (10325), 629–655.

Eucast, 2003. European Committee for Antimicrobial Susceptibility Testing (EUCAST) of the European Society of Clinical Microbiology and Infectious Diseases (ESCMID): terminology relating to methods for the determination of susceptibility of bacteria to antimicrobial agents. Clin. Microbiol. Infec 9, 1–7.

Farah, S.M., Alshehri, M.A., Alfawaz, T.S., Alasmeri, F.A., Alageel, A.A., Alshahrani, D.A., 2019. Trends in antimicrobial susceptibility patterns in King Fahad Medical City, Riyadh, Saudi Arabia. Saudi. Med. J. 40 (3), 252.

Fridkin, S.K., Hageman, J., McDougal, L.K., Mohammed, J., Jarvis, W.R., Perl, T.M., Tenover, F.C., V.-I. S. a. E. S. Group, 2003. Epidemiological and microbiological characterization of infections caused by Staphylococcus aureus with reduced susceptibility to vancomycin, United States, 1997–2001. Clin. Infect. Dis 36 (4), 429–439.

Howden, B.P., Ward, P.B., Charles, P.G., Korman, T.M., Fuller, A., du Cros, P., Grabsch, E.A., Roberts, S.A., Robson, J., Read, K., Bak, N., Hurley, J., Johnson, P.D., Morris, A.J., Mayall, B.C., Grayson, M.L., 2004. Treatment outcomes for serious infections caused by methicillin-resistant Staphylococcus aureus with reduced vancomycin susceptibility. Clin. Infect. Dis 38 (4), 521–528.

Huang, Y.C., Chao, A.S., Chang, S.D., Chen, Y.J., Peng, M.T., Sung, J.H., Chen, C.J., 2009. Association of Staphylococcus aureus colonization in parturient mothers and their babies. Pediatr. Infect. Dis. J 28 (8), 742–744.

Huang, L.J., Chen, S.J., Hu, Y.W., Liu, C.Y., Wu, P.F., Sun, S.M., Lee, S.Y., Chen, Y.Y., Lee, C.Y., Chan, Y.J., Chou, Y.C., Wang, F.D., 2022. The impact of antimicrobial stewardship program designed to shorten antibiotics use on the incidence of resistant bacterial infections and mortality. Sci. Rep 12 (1), 913.

Jorgensen, J.H., Ferraro, M.J., 2009. Antimicrobial susceptibility testing: a review of general principles and contemporary practices. Clin. Infect. Dis 49 (11), 1749–1755.

Köck, R., Becker, K., Cookson, B., van Gemert-Pijnen, J.E., Harbarth, S., Kluytmans, J., Mielke, M., Peters, G., Skov, R.L., Struelens, M.J., Tacconelli, E., Navarro Torné, A., Witte, W., Friedrich, A.W., 2010. Methicillin-resistant Staphylococcus aureus (MRSA): burden of disease and control challenges in Europe. Euro. Surveill 15 (41), 19688.

La Vecchia, A., Ippolito, G., Taccani, V., Gatti, E., Bono, P., Bettocchi, S., Pinzani, R., Tagliabue, C., Bosis, S., Marchisio, P., Agostoni, C., 2022. Epidemiology and antimicrobial susceptibility of Staphylococcus aureus in children in a tertiary care pediatric hospital in Milan, Italy, 2017–2021. Ital. J. Pediatr 48 (1), 67.

Lynch, J.P., Zhanel, G.G., 2023. Escalation of antimicrobial resistance among MRSA part 1: focus on global spread. Expert. Rev. Anti. Infect. Ther 21 (2), 99–113.

McGuinness, W.A., Malachowa, N., DeLeo, F.R., 2017. Vancomycin Resistance in Staphylococcus aureus. Yale. J. Biol. Med 90 (2), 269–281.

Monecke, S., Skakni, L., Hasan, R., Ruppelt, A., Ghazal, S.S., Hakawi, A., Slickers, P., Ehricht, R., 2012. Characterisation of MRSA strains isolated from patients in a hospital in Riyadh, Kingdom of Saudi Arabia. BMC. Microbiol 12, 146.

Nourollahpour Shiadeh, M., Sepidarkish, M., Mollalo, A., As'adi, N., Khani, S., Shahhosseini, Z., Danesh, M., Esfandyari, S., Mokdad, A.H., Rostami, A., 2022. Worldwide prevalence of maternal methicillin-resistant Staphylococcus aureus colonization: A systematic review and meta-analysis. Microb. Pathog 171, 105743.

Ogura, J., Inayama, Y., Sasamoto, N., Hirayama, T., Ohara, T., Sakai, M., Suzuki, H., Yasumoto, K., Suginami, K., Yamanoi, K., 2021. Vertical transmission of methicillin-resistant Staphylococcus aureus at delivery and its clinical impact: An observational, prospective cohort study. Acta. Obstet. Gynecol. Scand 100 (11), 1986–1994.

Park, S.G., Lee, H.S., Park, J.Y., Lee, H., 2019. Molecular Epidemiology of Staphylococcus aureus in Skin and Soft Tissue Infections and Bone and Joint Infections in Korean Children. J. Korean. Med. Sci 34 (49), e315.

Pollack, L.A., Srinivasan, A., 2014. Core elements of hospital antibiotic stewardship programs from the Centers for Disease Control and Prevention. Clin. Infect. Dis 59 (Suppl 3), S97–S100.

Rasmussen, R.V., Fowler, V.G., Skov, R., Bruun, N.E., 2011. Future challenges and treatment of Staphylococcus aureus bacteremia with emphasis on MRSA. Future. Microbiol 6 (1), 43–56.

Reusch, M., Ghosh, P., Ham, C., Klotchko, A., Singapuri, S., Everett, G., 2008. Prevalence of MRSA colonization in peripartum mothers and their newborn infants. Scand. J. Infect. Dis 40 (8), 667–671.

Sakoulas, G., Moise-Broder, P.A., Schentag, J., Forrest, A., Moellering, R.C., Eliopoulos, G.M., 2004. Relationship of MIC and bactericidal activity to efficacy of vancomycin for treatment of methicillin-resistant Staphylococcus aureus bacteremia. J. Clin. Microbiol 42 (6), 2398–2402.

Spellberg, B., Blaser, M., Guidos, R.J., Boucher, H.W., Bradley, J.S., Eisenstein, B.I., Gerding, D., Lynfield, R., Reller, L.B., Rex, J., Schwartz, D., Septimus, E., Tenover, F. C., Gilbert, D.N., 2011. Combating antimicrobial resistance: policy recommendations to save lives. Clin. Infect. Dis 52 (Suppl), S397–S428.

Taha, A.E., Al-Ruwaili, N.M., El-Masry, E.A., Saad, A.E., Taher, I.A., 2022. MRSA as an indicator of infection control measures in Turaif General Hospital, Northern Area-Saudi Arabia. J. Infect. Devel. Countries 16 (06), 1037–1044.

Thabit, A.K., Alabbasi, A.Y., Alnezary, F.S., Almasoudi, I.A., 2023. An overview of antimicrobial resistance in Saudi Arabia (2013–2023) and the need for national surveillance. Microorganisms 11 (8), 2086.

Tong, S.Y., Davis, J.S., Eichenberger, E., Holland, T.L., Fowler, V.G., 2015. Staphylococcus aureus infections: epidemiology, pathophysiology, clinical manifestations, and management. Clin. Microbiol. Rev 28 (3), 603–661.

Wayne, P., 2010. Clinical and Laboratory Standards Institute: Performance standards for antimicrobial susceptibility testing: 20th informational supplement. CLSI. Document M100–M120.

WHO. (2021). "Antimicrobial Resistance." Retrieved 08Oct.2023, 2023, from https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance.

Zorgani, A.A., Elahmer, O., Abaid, A., Elaref, A., Elamri, S., Aghila, E., Tubbal, A., 2015. Vancomycin susceptibility trends of methicillin-resistant Staphylococcus aureus isolated from burn wounds: a time for action. J. Infect. Dev. Ctries 9 (11), 1284–1288.