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Vancomycin Resistance among Methicillin-Resistant *Staphylococcus aureus* Isolated from Clinical Samples in Sana'a City, Yemen

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Abstract

Background: Methicillin-resistant *Staphylococcus aureus* (MRSA**)** is a critical global public health concern. The emergence of Vancomycin-Resistant *S. aureus* (VRSA) poses a severe therapeutic challenge. This cross-sectional study was conducted to determine the prevalence of VRSA and to assess antibiotic resistance patterns in major hospitals in Sana'a City, Yemen.

Objectives: This study aimed to determine the prevalence of vancomycin-resistant MRSA (VR-MRSA) isolates collected from clinical samples in Sana'a city, Yemen.

Methods: A cross-sectional study was conducted between June 2025 and August 2025. A total of 250 confirmed MRSA clinical isolates (including pus, urine, sputum, blood, vaginal swabs, ear swabs, nasal swabs, and body fluids) were analyzed in this study. Standard phenotypic methods were used to identify *S. aureus*, and MRSA was detected using cefoxitin disk diffusion. VRSA isolates were confirmed using the Epsilometer test (E-test) method. Antimicrobial susceptibility testing was performed using the Kirby-Bauer disk diffusion method. Data analysis was performed using SPSS version 26, with statistical significance ($p < 0.05$).

Results: Among the 250 MRSA isolates, eight (3.2%) were confirmed to be VRSA. The highest proportion of MRSA isolates was from pus (58.6%), with a higher VRSA rate among males (62.5%). Significant statistical associations ($p < 0.05$) were found between VRSA and the use of invasive medical devices, central lines, and surgery. Resistance to several antibiotics, including rifampin, teicoplanin, and trimethoprim/sulfamethoxazole, was statistically significant ($p < 0.05$).

Conclusion: This study confirmed the low prevalence of VRSA but documented its local emergence among clinical isolates, highlighting a critical public health threat. While significant resistance was observed to multiple common antimicrobials, linezolid showed superior efficacy. The frequent recovery of resistant strains from pus samples and their strong association with patients with underlying chronic diseases (notably diabetes and hypertension) underscore the need for targeted antimicrobial stewardship and robust infection control programs guided by continuous surveillance data.

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1. INTRODUCTION

Staphylococci are a group of gram-positive, facultative anaerobic, and usually unencapsulated organisms. They are responsible for a wide range of diseases and tissue infection. These bacteria transiently colonize approximately 20–30% of the skin and anterior nares of healthy adults. Recent global surveillance data confirm that these carriage rates remain significant, serving as a primary reservoir for both community- and hospital-acquired infections (CA-MRSA and H-MRSA). Over 30 different types of *Staphylococci* are infectious to humans,

and their related illnesses can range from mild to potentially fatal [1, 2].

Staphylococcus aureus (*S. aureus*) is the most common pathogen, causing a wide range of infections from mild skin and soft tissue infections (abscess, cellulitis, folliculitis, and impetigo) to life-threatening invasive diseases, such as bacteremia, sepsis, toxic shock syndrome, endocarditis, pneumonia, and osteomyelitis [3]. It is part of the normal microbiota of the nose and skin in humans. Despite being frequently isolated from clinical environments [4, 5]

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a major antibiotic-resistant pathogen that causes hospital-acquired (HA-MRSA) infections. These infections are usually caused by MRSA clonally spreading from patient to patient, often with the help of healthcare workers. HA-MRSA strains are common. Currently, MRSA has become a common cause of infections in the community. In healthy individuals, CA-MRSA can spread quickly. Most typical CA-MRSA can manifest as anything from a soft tissue infection to potentially fatal infections, such as necrotizing pneumonia [3].

Vancomycin has been a first-line treatment for MRSA infections for many years. However, clinical isolates of *S. aureus* that are intermediate and completely resistant to vancomycin have emerged in the last two decades and have become a serious public health concern [6]. Recently, alarming levels of MRSA isolates and high cross-resistance of the isolates to other antibiotics (vancomycin in particular) have been reported [7].

Antimicrobial resistance (AMR) in *S. aureus* is a growing global concern. Amoxicillin/clavulanic acid is a broad-spectrum antibiotic combination designed to restore the activity of amoxicillin against beta-lactamase (β-lactam)-producing bacteria. However, reduced susceptibility to this combination has become a major clinical problem, particularly among MRSA isolates, which have demonstrated high levels of resistance in hospital settings [8].

S. aureus strains with minimum inhibitory concentrations (MICs) of vancomycin of 4–8 μg/mL are classified as vancomycin-intermediate (VISA), and those with vancomycin MICs of $\geq$16 μg/ml are classified as vancomycin-resistant (VRSA) [9]. This study is justified by the critical lack of local data regarding the prevalence of these resistant strains in Sana'a, Yemen, making it essential to provide clinical evidence for effective infection control. Resistance to vancomycin appears to develop from pre-existing strains of MRSA in the presence of vancomycin [10]. This study aimed to determine the prevalence of vancomycin resistance among MRSA isolated from clinical samples in Sana'a City, Yemen.

2. MATERIALS AND METHODS:

2.1. Study design

This study was a cross-sectional study.

2.2. Study area

All patients were admitted to major hospitals in Sana'a city, Yemen, and were clinically presumed to have various nosocomial infections. The study included patients who had been admitted for more than 48 h and had clinical evidence of hospital-acquired infections.

2.3. Subjects

This study was conducted on 250 clinical MRSA isolates recovered from patients admitted to general hospitals, including Al-Gumhori, Al-Thawra Hospital, and Al-Mamoon Diagnostic Medical Center in Sana'a,Yemen.

2.3.1. Sample size

The sample size was calculated using Epi Info version 6 software (CDC, Atlanta, USA), assuming an expected prevalence of MRSA of 14.63% based on a previous study from Nepal, with a 95% confidence level (type 1 error α= 0.05) and a margin of 5%. The required sample size was determined to be 250 clinical isolates [11]. Although the referenced study primarily reported MRSA prevalence, the present study specifically focused on the emergence of VRSA among MRSA isolates. This approach is clinically justified because MRSA represents a major high-risk population in which vancomycin resistance significantly compromises treatment efficacy.

2.3.2. Inclusion criteria

Patients admitted for > 48 h with clinical evidence suggestive of hospital-acquired infection were included.

2.3.3. Exclusion criteria

The patients who excluded:

- Repeated isolates from the same patient.
- Hospitalized patients < 48 h.

2.4. Laboratory methods

2.4.1. Sample collection

A total of 250 MRSA isolates collected from patients with suspected bacterial infections were handled according to standard microbiological methods described by Baily and Scott Diagnostic Microbiology [12]. As follow:

❖ **Sputum specimen**

The patient was given a clean, sterile, dry, wide-neck, leak-proof container and requested to cough deeply to produce a sputum specimen. A phenol-containing disinfectant was used to wipe the outside of the container as a safety precaution to prevent the spread of infectious material. The patient was instructed to collect

an early morning sample before using any mouthwash. The container was labeled, and a request form was completed with detailed information about the specimen (patient name, lab number, date, and time of collection).

❖ **Urine specimen**

The patient was provided with a clean, sterile, dry, wide-necked, leak-proof container and requested to collect 10–20 ml of a morning midstream urine specimen. The container was labeled, and a request form was completed with detailed information about the specimen (patient name, lab number, date, and time of collection).

❖ **Pleural fluid specimen**

A surgeon in the medical ward under aseptic hygiene conditions performed this procedure, and 9 ml of the fluid was dispensed into a screw-cap tube, which contained 1 ml of sterile trisodium citrate. The tube was then labeled and sent to the microbiology laboratory together with a request form containing detailed information about the specimen.

❖ **Pus Collection**

Wound or pus samples were obtained following the technique described by Levine. Purulent exudates, pus, and discharge were aseptically collected from the incision depth using a syringe or sterile cotton swabs dipped in normal saline [13]. The cotton swab was inserted into a tube of Brain Heart Infusion transport medium and transferred within 30 min [14].

2.5. Microbiological examination

2.5.1. Isolation and identification of S. aureus isolates

S. aureus identification used Phenotypic approaches were used to identify *S. aureus* isolates and assess their antibiotic susceptibility (AST). To accomplish this, each specimen was examined using a variety of identification techniques, such as blood agar, MacConkey agar, and CLED agar, in the laboratories of Al-Jumhori Hospital. Then plates were incubated aerobically at 37℃ for 18-24 h. *S. aureus* is Gram-positive cocci arranged in clusters, smooth, large, elevated appearance with a golden yellow color and beta hemolysis on blood agar, catalase and coagulase positive, and DNase test positive. The organism also grows on mannitol salt agar and ferments mannitol, producing a yellow color [15]. Reference strains of *S. aureus* (ATCC 25923) and MRSA (NCTC 12493) were used as controls.

2.5.2. Detection of MRSA

S. aureus suspension was prepared and inoculated onto Mueller-Hinton Agar (MHA) according to the aforementioned procedure. A cefoxitin disc (30 μg) was then applied to the agar surface, and the plates were incubated for 18 h at 37℃ in ambient air. Following the incubation period, the results were interpreted based on the zone of inhibition; a diameter of < 21 mm was classified as MRSA in accordance with the standard diagnostic criteria by guidelines in 2024 [9].

2.5.3. Detection of vancomycin resistance

Pure isolates were suspended in a phosphate buffer solution and adjusted to achieve turbidity equivalent to the 0.5 McFarland standard. This standardized bacterial suspension was uniformly inoculated onto the surface of Mueller-Hinton Agar (MHA) plates using a sterile cotton swab to ensure confluent growth. The vancomycin E-test was performed on all MRSA isolates to determine their MICs (Liofilchem s.r.l., Roseto degli Abruzzi, Italy) was subsequently placed on the inoculated MHA medium, followed by aerobic incubation for 24 h at 37℃. The resulting Minimum Inhibitory Concentrations (MICs) were interpreted in accordance with the Clinical and Laboratory Standards Institute (CLSI) guidelines (18). Based on these criteria, isolates were categorized as susceptible (S) if the MIC was $\leq$ 2 μg/ml, intermediate (I) for MIC values between 4 and 8 μg/ml, and resistant (R) if the MIC was $\geq$ 16 μg/ml [9].

2.5.4. Antibiogram Susceptibility Test

All procedures in susceptibility testing were performed according to the Clinical Laboratory Standard Institute (CLSI) guidelines in 2024. Antimicrobial susceptibility testing was performed using the disc diffusion method of Kirby-Bauer on Muller-Hinton agar (MH). Standardized suspension of *S. aureus* inoculums was compressed to 0.5 McFarland standard turbidity and then inoculated on three Muller Hinton agar plates using a sterile cotton swab by streaking the swab over the entire sterile agar surface three times. The plates were then allowed to dry, and antimicrobial discs were placed at the recommended distance from each other. All plates were aerobically incubated at 37ºC for 24-48 hours before the zone sizes were recorded (the diameter of inhibition zones was measured and recorded in millimeters with the help of sliding calipers), and an organism was labeled as sensitive, intermediate, or resistant as per CLSI guidelines [9]. The antibiotics tested were azithromycin (15μg), clindamycin (2μg), trimethoprim/sulfamethoxazole (25μg), erythromycin (15μg), minocycline (30μg), linezolid (10μg), nitrofurantoin (300μg), rifampin (5μg), and teicoplanin (30μg) (HiMedia, India) [8].

2.6. Data Collection and Statistical Analysis

Patient data were collected using a predesigned questionnaire, including personal data and a history of preexisting chronic diseases, such as diabetes or hyperten-

Table[1]: The distribution of variable characteristics among clinical samples in Sana'a city

Variables		*Staphylococcus aureus*			
		VRSA n=8		MRSA n=242	
		No.	%	No.	%
Age	Median (IQR)	45.0 (32.5–57.5)		30.0 (21.8–45.0)	
Gender	Male	05	62.5	138	57.0
	Female	03	37.5	104	42.9
Residence	Urban	07	87.5	233	96.2
	Rural	10	12.5	09	3.7
Total (n=250)		08	3.2	242	96.8
Specimens	Pus	04	50.0	142	58.6
	Sputum	02	25.0	09	3.7
	Body fluid	00	0	03	1.2
	Blood	01	12.5	01	0.4
	Vaginal	00	0	10	4.1
	Nasal	00	0	02	0.8
	Urine	01	12.5	67	27.6
	Ear	00	0	08	3.3

sion.

All data were collected and analyzed using statistical software (SPSS Version 26; SPSS Inc., Chicago, USA). Qualitative data were expressed as percentages. A chi-square (x^2) test was used for the comparison of two variables to determine the *p* value, and an odds ratio (OR) was used with a 95% confidence interval. *p.* value < 0.05. All tests were performed with a 95% confidence interval (CI).

2.7. Ethical Considerations

The study was approved by the Ethical Committee of the Faculty of Medicine and Health Sciences, Sana'a University, Yemen.

3. RESULTS

This study included 250 patients from June 2025 to August 2025 to determine vancomycin resistance in methicillin-resistant *Staphylococcus aureus* in clinical samples from a general hospital in Sana'a city, Yemen.

Table (1) shows the distribution of variable characteristics between MRSA and VRSA among clinical samples in Sana'a City. All 250 clinical samples were identified as MRSA. In terms of VRSA prevalence, there were (n=08; 3.2%). Most of the patients infected with VRSA were males (n=05; 62.5%), and females were (n=03; 37.5%); their median age was (45.0) and the highest prevalence of patients from urban areas was (n=07; 87.5%). The remaining MRSA prevalence was (n=242; 96.8%), the highest prevalence of the patients were males (n=138; 57.0%) and females were (n=104; 42.9%), and the median age of MRSA was (30.0). In addition, the highest prevalence of MRSA in clinical samples from urban areas was (n=233; 96.2%). The majority of MRSA isolates were obtained from pus specimens (n=142, 58.6%).

Table (2) shows the distribution of MRSA and VRSA according to patient characteristics. The majority of patients (96.0%) were from urban areas, with no statistically significant difference (*p*= 0.2). The highest rate of inpatients (n=187; 74.8%) was observed in general hospitals (admitted >48 h) with no statistically significant difference (*p* = 0.4), while outpatients were (n= 63; 25.2%) from Al-Mamoon center with no statistically significant difference between hospital-acquired and outpatient infections (*p* = 0.9).

Table (3) shows the risk factors and clinical interference between MRSA and VRSA in clinical samples. A statistically significant was found with the use of invasive medical devices (62.5% x^2 =10.3, *p* = 0.001), central line (25.0% x^2 =3.9, *p* = 0.04), and surgery (50% x^2 =3.9, *p* = 0.04). However, no significant association was found with diabetic foot, diabetes and hypertension, renal diseases, catheters, respiratory, ICU stay, and antibiotic use (*p* > 0.05).

Table (4) shows the antibiotic pattern between MRSA and VRSA among clinical samples in Sana'a city, Yemen. Out of 250 patients with MRSA and VRSA, there was a highly significant correlation of antibiotic resistance for rifampin, teicoplanin, and trimethoprim/sulfamethoxazole (89.2%, x^2=9.0, *p* = 0.002), (76.8%, x^2=7.1, *p* = 0.007), and (68.4%, x^2 = 7.2, *p* = 0.007), respectively. No significant correlation was observed between antibiotic resistance and azithromycin, clindamycin, erythromycin, nitrofurantoin, minocycline, and linezolid.

Table[2]: Distribution of the study population according to MRSA and VRSA isolates in the clinical samples.

Characteristics		*Staphylococcus aureus*				Total		OR	CI95%	χ^2	p
		VRSA n=8		MRSA n=242							
		No.	%	No.	%	No.	%				
Residence	Urban	07	87.5	233	96.2	240	96.0	0.3	0.03–2.4	1.6	0.2
	Rural	01	12.5	09	3.7	10	4.0				
Health unit	General hospitals	05	62.5	182	75.2	187	74.8	0.5	0.1–2.3	0.6	0.4
	Al-Mamoon center	03	37.5	60	24.7	63	25.2				
Patients	Inpatients	06	75.0	181	74.7	187	74.8	1.0	0.2–5.0	0.002	0.9
	Outpatients	02	25.0	61	25.2	63	25.2				

Table[3]: Risk factors and clinical interference between MRSA and VRSA in clinical samples.

Risk Factors and Clinical Interfering		*Staphylococcus aureus*				Total N=250		OR	CI95%	χ^2	p
		VRSA n=8		MRSA n=242							
		No.	%	No.	%	No.	%				
Renal diseases	Yes	01	12.5	10	4.1	11	4.4	3.3	0.3–29.5	1.3	0.2
	No	07	87.5	232	95.9	239	95.2				
Diabetic Foot	Yes	01	12.5	02	0.8	03	1.2	17.1	2.0–68.3	8.9	0.09
	No	07	87.5	240	99.2	247	98.8				
Diabetes & hypertension	Yes	04	50.0	72	29.8	76	30.4	2.4	0.6–9.7	1.5	0.2
	No	04	50.0	170	70.2	174	69.6				
Catheters	Yes	02	25.0	20	8.3	22	8.8	3.7	0.7–19.5	2.7	0.1
	No	06	75.0	222	91.7	228	91.2				
Respiratory	Yes	01	12.5	08	3.3	09	3.6	4.1	0.4–38.1	1.8	0.16
	No	07	87.5	234	96.7	241	96.4				
Central line	Yes	02	25.0	16	6.6	18	7.2	4.7	0.8–25.2	3.9	0.04
	No	06	75.0	226	93.4	232	92.8				
ICU staying	Yes	02	25.0	19	7.9	21	8.4	3.9	0.7–20.7	2.9	0.08
	No	06	75.0	223	92.1	229	91.6				
Invasive medic devices	Yes	05	62.5	42	17.4	47	18.8	7.9	1.8–34.5	10.3	0.001
	No	03	37.5	200	82.6	203	81.2				
History of surgery	Yes	04	50.0	50	20.7	54	21.6	3.8	0.9–15.8	3.9	0.04
	No	04	50.0	192	79.3	196	78.4				
Antibiotic uses	Yes	02	25.0	22	9.1	24	9.6	3.3	0.6–17.5	2.2	0.13
	No	06	75.0	220	90.9	226	90.4				

4. DISCUSSION

S. aureus is commonly found on human skin and in the nasal cavity as part of the normal flora, typically without causing any harm. However, when the skin is broken due to cuts or abrasions, it can enter the body and lead to severe infections. Among its strains, MRSA has become a major global concern since the late 1970s because of its ability to resist multiple antibiotics [16]. *Staphylococcus aureus* is a prominent bacterial pathogen implicated in infections acquired in healthcare facilities and within the community. The emergence of resistant strains, particularly MRSA and VRSA, poses a critical threat to public health. These organisms have been classified as high-priority pathogens because of their capacity to cause severe outcomes, including extended hospital stays, recurrent episodes of septicemia, and elevated mortality rates when effective treatment options are not developed [17]. Consequently, MRSA and VRSA are prevalent in hospital settings and surrounding environments, making early detection essential for initiating robust strategies aimed at preventing and controlling their transmission [18].

Vancomycin is the first-choice antibiotic for treating MRSA infections. However, its widespread use in

Table[4]: Antibiotic patterns between MRSA and VRSA among clinical samples.

Antibiotic pattern		*Staphylococcus aureus* VRSA n=8		MRSA n=242		Total		χ^2	p
		No.	%	No.	%	No.	%		
Azithromycin	S	01	14.3	66	37.7	67	37.7	1.6	0.1
	R	06	85.7	109	62.3	115	62.3		
Clindamycin	S	02	25.0	120	49.6	122	48.8	1.9	0.2
	R	06	75.0	122	50.4	128	51.2		
Erythromycin	S	01	14.3	70	40.0	71	40.0	1.9	0.2
	R	06	85.7	105	60.0	111	60.0		
Nitrofurantoin	S	00	0.0	60	89.6	60	88.2	1.4	0.2
	R	01	100.0	07	10.4	08	11.8		
Minocycline	S	03	43.0	128	73.1	131	72.0	1.7	0.1
	R	04	57.0	47	26.9	51	28.0		
Rifampin	S	04	50.0	219	90.5	223	89.2	9.0	0.002
	R	04	50.0	23	9.5	27	10.8		
Teicoplanin	S	03	37.5	189	78.1	192	76.8	7.1	0.007
	R	05	62.5	53	21.9	58	23.2		
Trimethoprim/ Sulfamethoxazole	S	02	25.0	169	69.8	171	68.4	7.2	0.007
	R	06	75.0	73	30.2	79	31.6		
Linezolid	S	08	100.0	240	99.2	248	99.2	0.1	0.8
	R	00	0.0	02	0.8	02	0.8		

humans over the past few decades has led to the emergence of vancomycin-resistant strains, including vancomycin-resistant *Enterococcus* (VRE) and vancomycin-resistant *Staphylococcus aureus* (VRSA), further complicating treatment strategies [19]. Empiric therapy for nosocomial *Staphylococcus* infections was changed to vancomycin for MRSA, and VRSA emerged due to increased vancomycin use [3].

In this study, 242 (96.8%) of the 250 clinical samples were MRSA. Similar findings were reported in Hodeidah, Yemen, where MRSA was 86% [20]. In several other countries worldwide, including Iraq (80.7%) [21], India (80.73%) [18], and Australia (84.9%) [22], in contrast to the present study findings, a lower prevalence rate of MRSA was found in Taiz, Yemen (55%) [23]. In addition, low prevalence rates were also found in several studies reported in Sana'a city (17.6%, 19.3%, 23%, and 34.1%) [24–27]. Furthermore, low prevalence rates have been reported in other countries worldwide, such as Albania (38.5%) [18], Nepal (34.7% and 55%) [18, 28], Tanzania (41.2%), Pakistan (58.3%), Egypt (52.4%), Iran (52.3%) [18], the USA (71%) [29], and Japan (79%) [30].

This variation in the findings for MRSA isolates in different studies may be attributed to several factors, including the sample size, geographical location, antibiotic strategies used, which can differ from country to country, the type of samples, time period of the examination, and the methodology employed [18].

In this study, only eight (3.2%) VRSA strains were resistant to vancomycin. Similar findings have been reported in Saudi Arabia (3.1% of cases of VRSA), Iraq (2.5% and 4%), and Iran (2.9%) [30]. In addition, high prevalence rates have also been found in several studies reported in Iran (6.7%) [30], Dhamar, Yemen (7.1%) [31], and Iraq (10% and 10.3%) [30]. In contrast, lower prevalence rates were also found in several studies reported in Saudi Arabia (0%), Turkey (0%), and Iran (0.7%) [30]. Such differences in the frequency of VRSA may be due to differences in antibiotic usage policies, infection control measures, local healthcare practices, and surveillance systems implemented [18].

In this study, the highest prevalence of MRSA (58.6%) was observed in pus samples. No similar findings have been reported in other studies. In contrast, a higher rate was found in Egypt (71.8%) [18]. In contrast, lower rates were reported in Nepal (18.5%) [28], Pakistan (37.9%), and Iran (47.7%) [18]. Because most isolates were recovered from pus samples obtained from lesions that might be exposed to environmental flora, the presence of commensal *S. aureus* on the skin increases the susceptibility of wounds to infection [28].

This study showed that in the case of VRSA, a higher rate of VRSA was observed among males (62.5%). Similar results were noted in Dhamar„ Yemenwith 55.6% [31]. In this study, males were identified as a risk group, which is different from that previously reported by others in Egypt, where females showed a higher incidence of VRSA [32]. This might be due to biological and behavioral factors,

such as differences in hygiene practices, variations in immune responses, and increased exposure to bacteria due to occupational or environmental behavior [30].

This study showed the risk factors and clinical interference of VRSA, where the most common chronic diseases were diabetes and hypertension (30.4%). This result was similar to that of a study conducted in Saudi Arabia [33]. This might be attributed to several factors, including impaired immune responses, changed tissues, and elevated blood glucose levels, which collectively create an optimal environment for bacterial growth and contribute to the increased severity of infection [34]. In addition, central line, ICU stay, invasive devices, and surgery were significantly associated with VRSA isolates ($p < 0.05$). These findings are consistent with those reported in the USA [6]. This could be due to repeated handling, prolonged device use, improper sterilization, and chronic wound conditions such as diabetic foot, all of which facilitate the transmission of VRSA either between patients or from the hospital environment to patients, thereby increasing the risk of colonization and infection.

This study showed a higher rate of VRSA susceptibility pattern with high resistance to azithromycin (62.3%), erythromycin (60.0%), and clindamycin (51.2%) than the previous studies. This result was similar to those reported in Nigeria and India [3, 35]. All VRSA isolates were highly sensitive to linezolid (LZD). It has the highest clinical availability and is the only oral option with (99.2%) susceptibility rate in the current study. Similar rates have been reported in previous studies from Egypt and Iran [18]. These findings are inconsistent with those of a study conducted in Yemen and Nepal [18, 24]. This variation in resistance demonstrated that the establishment of LZD resistance had already started and had become a progressive trend over time. Although this drug is a beneficial addition to Yemen's antimicrobial options, its use should be restricted to patients who actually need them to delay the evolution of antibiotic resistance in Yemen and worldwide.

The frequency of VRSA isolates showed a significant correlation with high resistance to several antibiotics, including rifampin, teicoplanin, and trimethoprim/sulfamethoxazole, which were similar to those reported in studies conducted in Italy [36], China [37], Nepal [28], India [38], and Iran [18].

These differences in resistance levels among *Staphylococcus aureus* isolates may be attributed to variations in strain origin, antibiotic usage patterns, and local antimicrobial resistance prevalence. Treatment options are limited owing to the resistance of commonly used antibiotics. Thus, there is an urgent need to develop effective strategies for controlling infections and antimicrobial stewardship programs to limit the spread of resistant bacteria [38].

5. CONCLUSION AND RECOMMENDATIONS:

5.1. Conclusions:

This study confirmed the low prevalence of VRSA. Showed resistance to several antibiotics, with linezolid being the most effective. Most isolates were obtained from pus samples and were associated with chronic diseases. These results emphasize the need for evidence-based antibiotic use and strict infection control measures to protect public health.

5.2. Recommendation:

Effective antibiotic stewardship, limited linezolid use, enhanced VRSA surveillance, strict infection control, management of high-risk patients, and molecular studies are required to mitigate the spread of antimicrobial resistance.

Limitations of the Study

First, the study lacked molecular characterization to identify the genetic determinants of resistance, and the samples were limited to major hospitals in Sana'a, which may limit the generalizability of the findings. Consequently, future studies should include molecular analyses and a wider geographic sampling scope to obtain more representative data.

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Authors' contributions

Hadeel Al-Hammadi collected the clinical samples, performed laboratory procedures, analyzed the data, and wrote the manuscript. Prof. Dr. Saleh Bahaj supervised the study and revised the manuscript accordingly. Prof. Dr. Anwar supervised and provided scientific guidance. Dr. Aref Al-Afif performed statistical analyses. All authors have read and approved the final version of the manuscript.

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