GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

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Epidemiology and antibiotic resistance of *Staphylococcus aureus* at the Avicenne Military Hospital, Marrakesh (2017–2024)

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GSC Biological and Pharmaceutical Sciences, 2025, 32(01), 246-254

Publication history: Received on 07 June 2025; revised on 15 July 2025; accepted on 17 July 2025

Article DOI: https://doi.org/10.30574/gscbps.2025.32.1.0287

Abstract

Background: *Staphylococcus aureus* is a Gram-positive coccus responsible for a variety of infections ranging from mild skin and soft tissue infections to severe invasive diseases. The emergence and spread of methicillin-resistant *Staphylococcus aureus* (MRSA) has become a significant public health concern, complicating treatment and infection control efforts worldwide.

Methods: We performed a retrospective descriptive study at the microbiology department of the Avicenne Military Hospital of Marrakesh over a seven-year period from July 2017 to December 2024. We included every *Staphylococcus aureus* strains isolated from all clinical specimens of hospitalized patients and outpatients. Bacterial identification and antibiotic susceptibility testing were performed using standard microbiological techniques, including automated systems and diffusion methods, following CASFM/EUCAST guidelines. Data were analyzed using Microsoft Excel 2019.

Results: Among 7738 specimen collected *Staphylococcus aureus* represented 8.1% (n=626). MRSA accounted for 11.41% of isolates. Surgical departments made up the majority of isolates (37%). Pus and related specimens were the most frequent sample types (43%). As for antibiotic resistance, MRSA strains exhibited 100% resistance to penicillin and cefoxitin, and high resistance rates to tetracycline (48%), macrolides (42%) and aminoglycosides (up to 45%) while retaining full susceptibility to vancomycin and 96% susceptibility to linezolid. On the other hand, MSSA strains demonstrate a 92% resistance rate to penicillin while mostly conserving susceptibility to other antibiotics.

Conclusion: Our study underlines the continuing burden of *Staphylococcus aureus* particularly MRSA strains. To limit the spread of such resistant strains a continued surveillance with strict infection control practices and rational antibiotic use are critical.

Keywords: *Staphylococcus aureus;* Epidemiology; MRSA; Antibiotic resistance; Marrakesh

1. Introduction

Staphylococcus aureus is a ubiquitous Gram-positive coccus part of the commensal flora of human skin and mucosa it colonizes around 30% of the general population [1]. And it is the main cause of a myriad of infections whether community or hospital acquired infections. The clinical manifestations range from benign infections such as skin and soft tissue infections to life threatening infections such as bacteremia, endocarditis, pneumonia, osteoarticular infections and toxic shock syndrome [2]. The severity of staphylococcal infections is linked to the production of toxins such as superantigens and exotoxins associated with the cell wall in addition to its ability to develop various antibiotic resistance mechanisms [2]. The treatment of *Staphylococcus aureus* infections is becoming increasingly difficult due to

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the emergence of methicillin-resistant *Staphylococcus aureus* (MRSA), which confers MRSA strains with a combined resistance to all betalactamases a results of the production of a low affinity penicillin binding protein (PLAP2a) [3]. MRSA infections were originally nosocomial infections but the spread of these strains started including community acquired infections starting 1990s [4]. The emergence of these multiresistant strains represents a serious public health issue and calls for the establishment of rigorous infection control protocols, the instauration of effective treatment strategies and epidemiological surveillance to contain the spread of these strains. [5]

With this study we aim to determine the epidemiological profile and evolutionary aspects of Staphylococcus aureus infections and the antibiotic resistance profiles of isolated strains at the Avicenne Military Hospital in Marrakesh.

2. Materials and Methods

2.1. Ethical considerations

The study was carried out without any interaction with individuals, making informed consent unnecessary. Anonymity and confidentiality were respected for all personal data collected.

2.2. Study population and setting

We conducted a retrospective descriptive study over a period of 6 years and 7 months from July 1st, 2017 to December 31st, 2024. Data was collected from the registers of the microbiology laboratory of the Avicenne Military Hospital in Marrakech.

We included in this study all strains of Staphylococcus aureus isolated from diagnostic samples received at the microbiology laboratory from hospitalized patients in the various departments of our hospital or outpatients coming in during the study period. Samples were sent by various departments namely: the intensive Care Unit, the Emergency department, the surgical departments and the medical departments. We excluded from our research all samples taken as part of an epidemiological investigation and all redundant strains from the same patient.

2.3. Bacterial isolates

We isolated *Staphylococcus aureus* from different samples mainly: urine samples, blood cultures, pus, catheter, sputum, drains and osteosynthesis material, cerebrospinal fluid, ascites fluid and pleural fluid.

Culture was performed on blood agar and chocolate agar with polyvitex plates, Chapman agar with BHI inoculation for paucibaterial sites. Plates were incubated for 48 hours at 37°C under aerobic conditions except for blood and chocolate agar which was incubated in a 5% CO_2-enriched atmosphere.

Identification was carried out via automated methods with the help of the BD PHOENIX M50 system (BECTON DICKINSON) or when unavailable using manual biochemical identification with the help of API® STAPH (BIOMERIEUX).

2.4. Antimicrobial susceptibility testing

Antibiotic susceptibility testing was performed either by automated CMI testing by BD PHOENIX M50 system (BECTON DICKINSON) and/or qualitative antibiotic disk diffusion on Mueller Hinton agar according to the European Committee on Antimicrobial Susceptibility Testing (EUCAST) guidelines [26]. (Last access on 31st January 2025).

The list of the antibiotics tested with their critical concentrations and diameters was determined according to the EUCAST guidelines [26]. All of our strains were tested for: Penicillin G, Cefoxitin, Vancomycin, Linezolid, Kanamycin, Tobramycin, Gentamycin, Tetracycline, Levofloxacin, Ciprofloxacin, Erythromycin, Clindamycin, Fusidic Acid and Trimethoprim sulfamethoxazole.

Detection of methicillin resistance was tested by a cefoxitin disk, if the diameter was≥ 22mm the strain was characterized susceptible for methicillin. If the diameter was < 22mm the strain was characterized resistant to methicillin.

2.5. Statistical analysis

All data were analyzed and processed using Microsoft Excel 2019 software.

3. Results

3.1. Epidemiological aspects of *Staphylococcus aureus* infections

3.1.1. Prevalence of *Staphylococcus aureus* infections

Out of the 7738 germs isolated between 2017 and 2924, 626 isolates were identified as *Staphylococcus aureus* wich represented 8.1% of all isolates. (Figure 1)

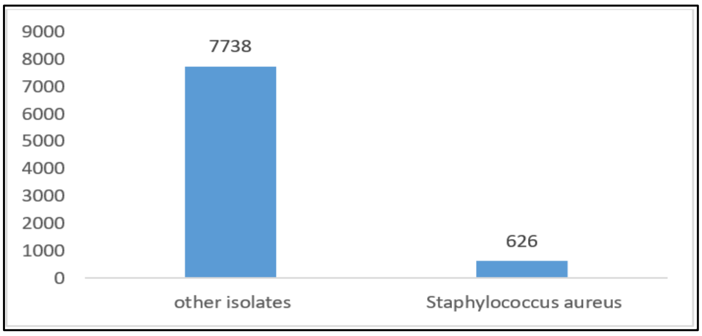

Figure 1 Prevalence of *Staphylococcus aureus* isolates**.**

3.1.2. Prevalence of *Staphylococcus aureus* by year from 2018 to 2024:

We observed a decline in the prevalence of *Staphylococcus aureus* over the past 7 years with the lowest percentage being recorded in 2021 with 7.54% and a peak in 2024 with 18.8%. (Figure 2)

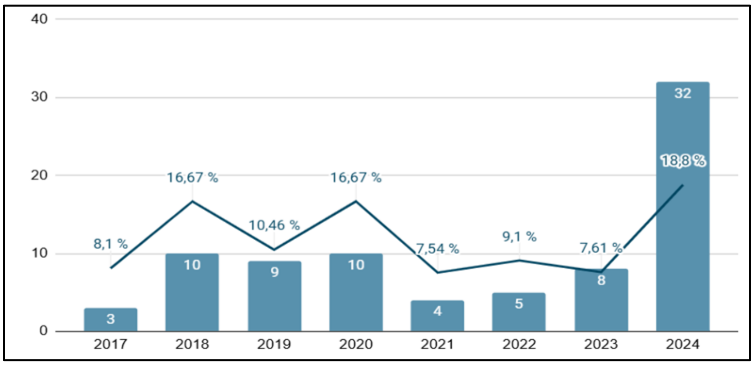

Figure 2 Prevalence of *Staphylococcus aureus* isolates by year from 2018 to 2024

3.1.3. Gender distribution

We noted a male predominance with 494 isolates which represents 79% The M/F sex ratio was: 3, 7 (Figure 3).

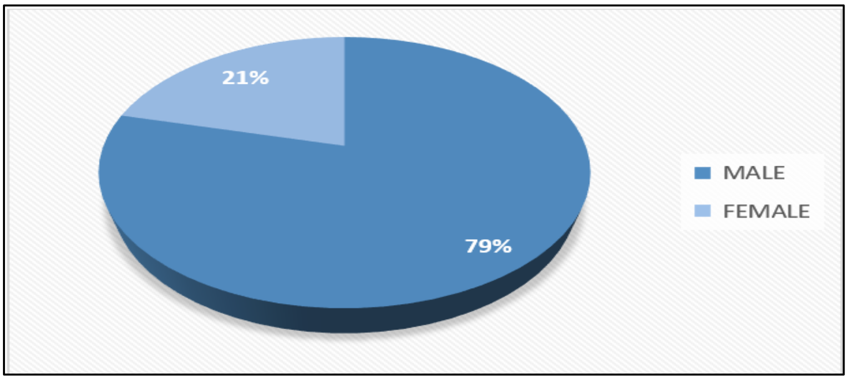

Figure 3 Gender distribution of *Staphylococcus aureus* isolates

3.1.4. Distribution according to hospital department:

Specimens were received from all hospital departments; *Staphylococcus aureus* isolates were found primarily in specimens related to the surgical departments which accounted for of 33,5% isolates (n = 210). They were followed by the intensive care unit with 31,1% of isolates (n = 195) and medical departments with 17,9%of isolates (n = 112). The remainder of isolates came from outpatients at the HMA emergency department 17.5% (n=119). (Figure 4)

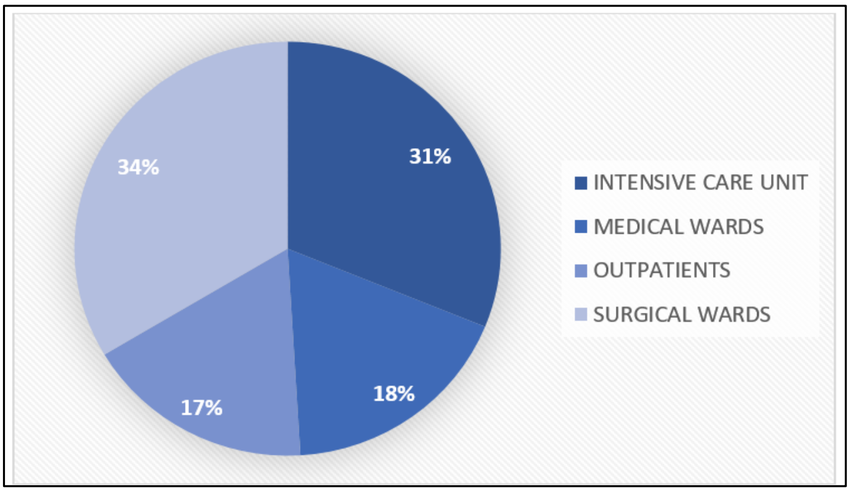

Figure 4 Distribution of *Staphylococcus aureus* isolates by hospital department

3.1.5. Distribution according to specimen type

The distribution of *Staphylococcus aureus* isolates by specimen type revealed a predominance of pus and pus-derived specimens, accounting for 36,4%, n = 231 of cases. These were followed by respiratory samples 25%, n=156 then blood cultures with 13,4%, n = 84 and urinalysis with 8% (n = 50). (Figure 5)

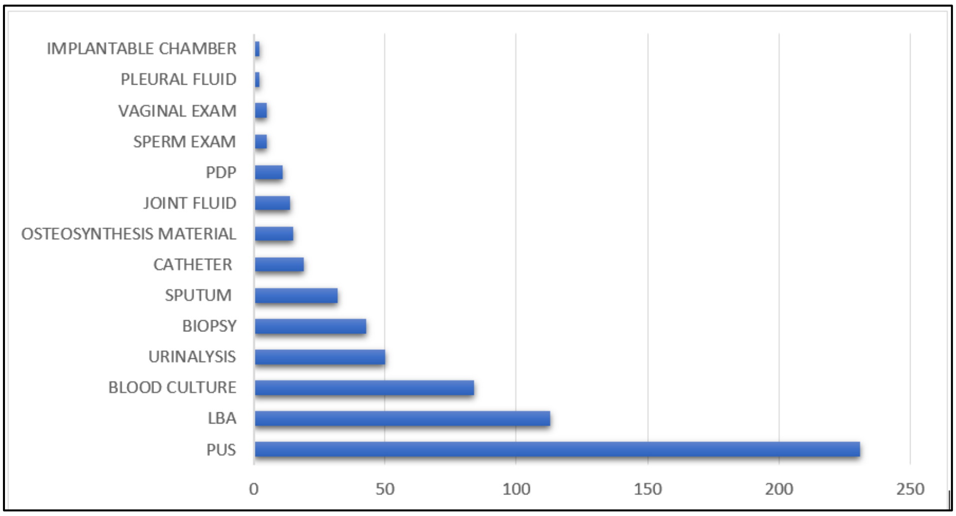

Figure 5 Distribution of *Staphylococcus aureus* strains by sample type

3.2. Epidemiology of resistance to antibiotics

3.2.1. Methicillin-sensitive Staphylococcus aureus (MSSA) antibiotic resistance profile:

Of all the isolated strains studied, MSSA strains accounted for 87.1%, with a resistance profile characterized by an extremely high resistance rate to penicillin G at 95%. A relatively high resistance rate to tetracycline was also noted with 31% resistant strains. As for aminosides and macrolides we observed a moderate resistant rate with 17% resistance rate to gentamycin and 17% erythromycin. Low resistance rate to fusidic acid (9%), to trimethoprim/sulfamethoxazole (5%) and to fluoroquinolones (8%) was observed. However, 98% of isolated strains retained their sensitivity to linezolid and 100% were susceptible to Vancomycin. (Figure 6)

3.2.2. Methicillin-resistant Staphylococcus aureus (MRSA) antibiotic resistance profile:

Among the 626 isolated 81 strain exhibited a resistance to methicillin which makes the prevalence of MRSA in our study of 12.9%. We observed total resistance to penicillin G and cefoxitin as a result of resistance to methicillin. High resistance to tetracycline was also noted in MRSA strains (48%) as well as high levels of resistance to Kanamycin (48%), Tobramycin (42%), Gentamycin (31%), Erythromycin (43%) and Fusidic acid (46%). Moderate resistance rates was observed for fluoroquinolones (33%) and trimethoprim/sulfamethoxazole (29%). All of our MRSA strains remained susceptible to Vancomycin, 94% were susceptible to Linezolid and 86% to clindamycin. (Figure 6)

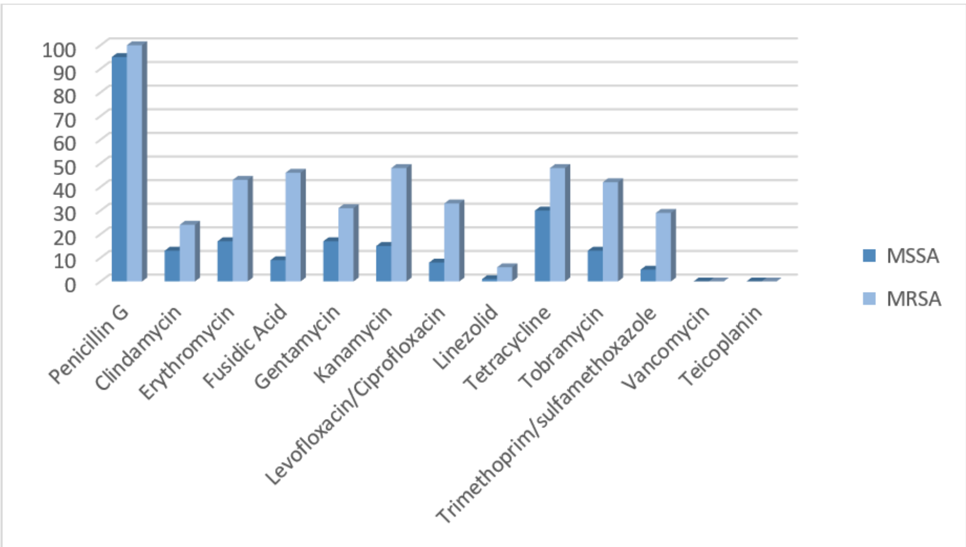

Figure 6 MSSA and MRSA antibiotic resistance profile

4. Discussion

4.1. Epidemiology of *Staphylococcus aureus* at HMA between 2017 and 2024

During the study period, *Staphylococcus aureus* strains accounted for 8.1% of all bacteria isolated within the HMA laboratory. This rate is relatively low compared with that reported by Sapkota et al, in a study carried out in Nepal, which was 19.96% [6]. Another study carried out by Islah et al, at the CHU IBN Tofail in Marrakech also reported a rate of 15.8% [7]. The highest rates were reported by CANWARD Pathogens in Canada, with a rate of 21.1% [8]. Our results concur with those of a study by Mao et al in China, who reported a rate of 7.42% [9].

Our study showed a male predominance, with a sex ratio of 3.7, which is consistent with studies by Lohan et al, and Frikh et al, who also showed a male predominance in *Staphylococcus aureus* carriage and infection [10] [11]. In our context, this may be linked to the type of recruitment in the Avicenne military hospital, which is essentially represented by a male military population.

However other studies like the ones by Pradhan et al and Rehman et al have shown contradictory results, indicating that women are more likely to be colonized by *Staphylococcus aureus* than men, with respective sex ratios of 0.96 and 0.85 [12] [13]. Results as to the association between *Staphylococcus aureus* infection and gender seem to be inconclusive. Other factors such as age, immune status and hygiene habits may play a role in susceptibility to *Staphylococcus aureus* infection. It is important to note that the results of studies may vary according to the populations studied and the methods of data collection [71].

In addition, the isolates from the surgical department were predominant accounting for 34% of all isolates which is in agreement with studies conducted by Cikman et al, and Arora et al (51%,47.9%) [14] [15].This high rate of isolation of *Staphylococcus aureus* strains in surgical departments could be explained by the fact that patients undergoing surgical procedures are particularly susceptible to Staphylococcus aureus infections due to the invasive nature of the procedures relying on catheters, drains and tubes serving as entry points. Moreover, longer hospital stays in surgical departments compared to other departments may increase the exposure to antibiotic resistant strains. [16] [17]

Our results showed that *Staphylococcus aureus* was mostly isolated from different pus specimens with a rate of 36.4% followed by respiratory samples 25%. These findings are corroborated by studies like Sogut et al (51%) and Pignataro et al (29%), who showed the predominance of S. aureus isolates in pus and miscellaneous samples [18] [19]. On the other hand, a study by Quodrati et al showed a 51% predominance of *Staphylococcus aureus* infections in blood cultures [20].

4.2. Antibiotic resistance profile status of *Staphylococcus aureus*

4.2.1. Methicillin-sensitive *Staphylococcus aureus*

In our series, penicillin resistance due to penicillinase production was 95%. This rate matched that of a study carried out at Mohamed V Military Hospital in Rabat in 2016 [10] with a penicillin resistance rate of 93%. Furthermore, the study carried out by Rehman et al in Pakistan [13] observed 100% penicillin resistance. Penicillinase production is due to a transposon located on a plasmid which can integrate other antibiotic resistance genes (aminoglycosides, macrolides) [10] [13]. With regard to aminoglycosides, the gentamicin resistance rate in our series was 17%, which is lower than that observed in the study carried out in China which had a resistance rate of 28% [9] and that of the study carried out in Italy by Pignataro et al with a resistance rate of 31% [24]. However, lower rates were observed in Iran with 4% and in Rabat with 7.3% [20] [10]. Macrolide resistance was 17% for erythromycin, which is lower than that reported by Rehman et al in Pakistan with 56%, Quodrati et al in Iran with 43% and Pignataro et al in Italy with 32% [13] [20] [24].

4.2.2. Methicillin-resistant Staphylococcus aureus between 2018 and 2024:

In our study, MRSA represented 12.9% which is the equivalent of 81 isolates out of 626. Our result is similar to that of a study by Sogut et al with an MRSA rate of 13.5% [18]. However, this prevalence remains high compared to the study carried out by Aourir et al [7] at Ibn Tofail Hospital in Marrakesh in the period between 2010 and 2019, with an MRSA rate of 7.24%. Furthermore, the MRSA rate was 6.3% in another study conducted by E. Abou Warda et al in Egypt [19]. In contrast, higher rates were found at the Ibn Tofail Hospital in Marrakesh [22] during the period 2020-2021, with a rate of 37.5%, as well as in a study conducted in Nepal by Pradhan et al, who found a rate of 57%. The rate of MRSA infection varied widely from country to country. [23] This rate varies from one facility to another, even within the same country [22] [7] [23]. Our result remains below the worldwide prevalence announced by GLASS in 2021. (figure 7)

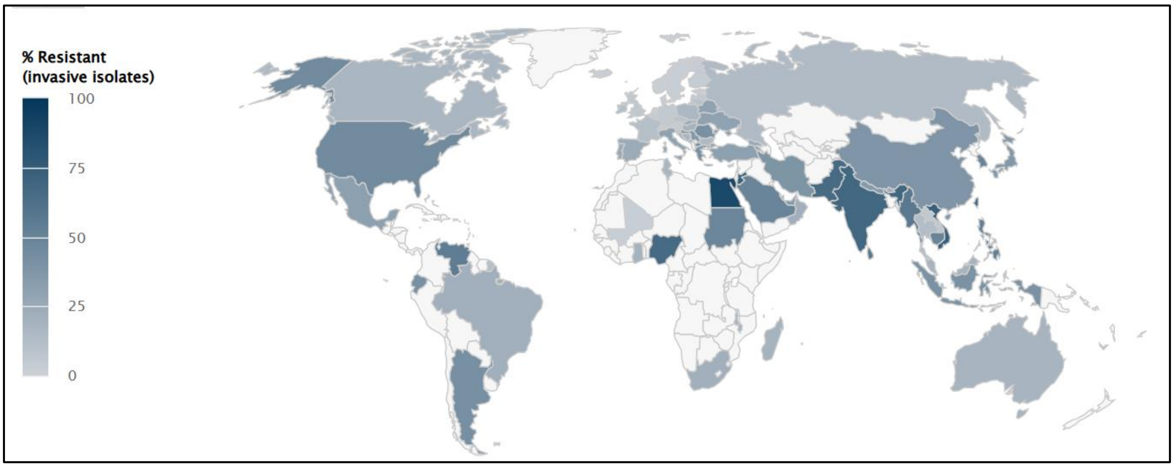

Figure 7 Global distribution of methicillin-resistant *Staphylococcus aureus* rates 2021[23]

Our study on MRSA susceptibility revealed high rates of resistance to tetracycline, with 48% resistance. This is higher than the results found at the Luigi Vanvitelli University Hospital in Italy and in Poland, which had rates of 22% and 10% respectively [25] [24]. However, the results of other studies are much higher, with rates of 67% in Rabat, 62% in Iran, and 61% in China [10] [20] [9]. As for macrolides, resistance to erythromycin was 43%. Our result seems close to that of Rabat, with 54% resistance [10]. However, it remains lower than the other study conducted at the General Hospital of China, which had 94% resistance, 89% in Iran, 77% in Poland, and 65% in Italy [9] [20] [25] [24]. With regard to glycopeptides, MRSA resistance to vancomycin was 0%. Our results are consistent with the data in the literature. Several studies have reported that the majority of strains remain sensitive to vancomycin. The frequency reported by a study conducted at HMM V in Rabat and in Iran is similar (0%) [10] [20]. The resistance rates observed in our study, particularly for tetracyclines, erythromycin, and trimethoprim-sulfamethoxazole combination could be explained by several factors. First, self-medication and the overprescription of empirical antibiotic therapy by doctors without resorting to antibiograms may contribute to the emergence of resistant strains of *Staphylococcus aureus*. The inappropriate or excessive use of antibiotics promotes the selection of resistant bacteria and reduces the effectiveness of treatments. Second, the high adaptability of *Staphylococcus aureus* plays an important role in antibiotic resistance with its ability to acquire several mechanisms of drug resistance. Overall, the rates of MRSA resistance to antibiotics in our study remain lower than those reported in most other studies.

5. Conclusion

Our study was a five-year retrospective study highlighting the importance of *Staphylococcus aureus* as a significant pathogen at the Avicenne Military Hospital of Marrakech. We demonstrated that it was predominantly isolated from surgical and intensive care units, with a male predominance among affected patients. While overall the prevalence of MRSA strains was moderate, these strains still constitute a persistent threat to patient care. Although all of our isolates remained susceptible to vancomycin and linezolid we noted a high rate of resistance to penicillin, tetracyclines and macrolides particularly among MRSA strains. These findings highlight the importance of continuous local epidemiological surveillance and strict infectious control measures. It also underlines the importance of rational antibiotic use to avoid the spread of these resistant strains. This can be achieved via regular updates of empirical therapy protocols and regular epidemiological surveillance in an effort to optimize patient outcomes and preserve antibiotic efficacy.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest regarding this paper.

Statement of informed consent

The study was carried out without any interaction with individuals, making informed consent unnecessary.

Availability of data and materials

The data and materials used to support the findings of this study are publicly available.

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