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Original article

Prevalence of Multidrug-Resistant *Staphylococcus aureus* among Medical Students in Comparison to Healthcare Workers in Benghazi City

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Abstract
Multidrug-resistant *Staphylococcus aureus* (MDR-SA), particularly methicillin-resistant strains (MRSA), represents a major public health challenge due to its ability to cause a variety of infections and withstand multiple antibiotics. This descriptive cross-sectional study aimed to figure out the prevalence and antibiotic resistance patterns of *Staphylococcus aureus* among medical students (community-acquired, CA) and healthcare workers (hospital-acquired, HA) in Benghazi, Libya. Between May and November 2020, a total of 146 nasal swabs were collected: 100 from hospital participants (25 physicians, 25 nurses, 25 workers, and 25 patients) and 46 from medical students. *S. aureus* was detected in 44% of hospital samples and 17% of community samples, with the highest colonization observed among nurses (39%), followed by doctors (27%), workers (18%), and patients (16%). All isolates were resistant to cefotaxime. Methicillin resistance was observed in 31.8% of HA isolates and 12.5% of CA isolates. Resistance to vancomycin, azithromycin, and meropenem was lower compared to methicillin. HA-MRSA isolates showed higher multidrug resistance, with significant associations between HA-MRSA and resistance to azithromycin and meropenem. In contrast, CA-MRSA isolates exhibited minimal resistance. These findings highlight a substantial burden of multidrug-resistant *S. aureus*, particularly in hospital settings, and emphasize the urgent need for robust infection control strategies and antibiotic stewardship programs to limit the spread of resistant strains in both healthcare and community environments in Benghazi.
Keywords. Prevalence, Multidrug-Resistant Staphylococcus aureus, Medical Students, Healthcare Workers, Benghazi City.

Introduction

Multidrug-resistant organisms (MDROs), including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and certain gram-negative bacilli (GNB), have important infection control implications that either have not been addressed or received only limited consideration in previous isolation guidelines (1). Increasing experience with these organisms is improving understanding of the routes of transmission and effective preventive measures. Although transmission of MDROs is most frequently documented in acute care facilities, all healthcare settings are affected by the emergence and transmission of antimicrobial-resistant microbes (1,2).

Staphylococcus aureus is the most commonly isolated bacterial pathogen in humans and is a compelling cause of skin and soft-tissue infections (SSTIs), endovascular infections, pneumonia, septic arthritis, endocarditis, osteomyelitis, foreign-body infections, and sepsis (2).

Many of the MRSA isolates are becoming multidrug resistant, and they are susceptible only to glycopeptide antibiotics such as vancomycin. A low-level resistance, even to vancomycin, is emerging. A prolonged hospital stay, the indiscriminate use of antibiotics before hospitalization, etc., are the common factors of the MRSA infections, which occur globally. Infected patients constitute a significant reservoir for nosocomial transmission and may act as asymptomatic carriers, thereby posing additional challenges to antimicrobial therapy and infection control practices (3).

Methicillin resistance in *S. aureus* was first identified in the 1960s, primarily among hospitalized patients. Since that time, MRSA has become a predominant cause of *S. aureus* infections in both healthcare and community settings (4). There is limited data about the potential transmission of MRSA in the healthcare and community settings in Libya (5). Therefore, this study aimed to investigate the prevalence of community-associated MRSA (CA-MRSA) and hospital-associated MRSA (HA-MRSA) infections and to determine the sensitivity pattern of isolated Staphylococcus aureus in Benghazi, Libya.

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Methods

Study Design

This study was a descriptive cross-sectional design carried out at the Microbiology and Immunology Department, Libyan International Medical University (LIMU), in the period from May to November 2020. Ethical clearance was obtained from the university research center, and the official letter was submitted to the hospital manager for approval. Informed consent was obtained from all participants after explaining the study's objectives and procedures. A total of 146 nasal swabs were collected. Out of them, 100 swabs were collected from Benghazi Medical Center (BMC) hospital (25 physicians, 25 patients, 25 nurses, and 25 workers) for hospital-acquired isolates; the remaining 46 were collected from medical students of LIMU and represent community-acquired isolates. Participants were selected based on the inclusion criteria: Medical students with no recent history of hospitalization or antibiotic use. Medical practitioners with close contact with healthcare centers (e.g., ICU physicians). Exclusion criteria included individuals not meeting the above requirements. Full history was taken from each participant and patient, including age, gender, and residence. Patients enrolled in our study were those who had been admitted to the hospital for two or three days.

Specimens Collection

Specimens were obtained using sterile swabs from both nares of participants, transferred immediately into enrichment broth, and cultured aseptically on blood and mannitol salt agar plates at 37°C for 24 h. Colonies were confirmed to be *S. aureus* microscopically using Gram stain and biochemically using catalase, coagulase, β-hemolysis, and sugar fermentation tests. Colonies of *Staphylococcus aureus* were identified and subsequently cultured on Mueller-Hinton agar to assess antibiotic sensitivity.

Antibiotic Susceptibility Testing

Sensitivity testing was conducted for the following antibiotics: oxacillin, vancomycin, cefotaxime, azithromycin, and meropenem. Results were interpreted according to the Clinical and Laboratory Standards Institute (CLSI) guidelines (M100, 30th Edition, 2020).

Statistical analysis

Data analysis was performed using IBM SPSS version 19.0. Descriptive statistics were used to summarize the prevalence of *Staphylococcus aureus* and methicillin-resistant *Staphylococcus aureus* (MRSA) isolates. The frequency analysis is presented as percentages with 95% confidence intervals (CIs) where applicable. The categorical variables, such as the distribution of *S. aureus* isolates among different groups (e.g., healthcare workers, medical students), were compared using the Chi-square test (x^2) to assess associations. Statistical significance was set at P-value < 0.05. All tests were two-tailed, and missing data were excluded from the analyses.

Results

In this study, 52 (35.5%) of the bacterial isolates were confirmed as *S. aureus*, 44 (44%) out of 100 cases studied were positive for *S. aureus* and represent HA-*S. aureus* isolates. However, 8 (17%) out of 46 cases studied were positive for *S. aureus* and considered as CA-S. aureus isolates (Table 1).

Table 1. Distribution of Staphylococcus aureus isolates among the sample population.

Source	Staphylococcus aureus isolates		Total
	Negative (%)	Positive (%)	
Hospital	56 (56)	44 (44)	100
Community	38 (83)	8 (17)	46

Table 2. Distribution of Staphylococcus aureus isolates among hospital workers and patients.

Hospital	Staphylococcus aureus isolates		Total
	Negative (%)	Positive (%)	
Doctor	13 (52)	12 (27)	25
Nurse	8 (32)	17 (39)	25
Patient	18 (72)	7 (16)	25
Worker	17 (68)	8 (18)	25

Regarding the job, the highest prevalence rates of *Staphylococcus aureus* were found in the nurse group (39%), followed by doctors (27%) and workers (18%). Also, the number of patients colonized with *S. aureus* at hospitals was 16% (Table 2).

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Table 3. Distribution of Staphylococcus aureus resistance isolates to antimicrobial discs.

Antibiotic	Staphylococcus aureus resistance isolates		P-value
	Hospital Acquired	Community Acquired	
	n= 44 (%)	n= 8 (%)	
MET	14 (31.8)	1 (12.5)	0.51
VA	2 (4.5)	1 (12.5)	
CTX	44 (100)	8 (100)	
AZR	8 (18.2)	1 (12.5)	
MEM	3 (6.8)	0 (0)	

Among the 44 HA-S. *aureus* isolates, the highest resistance rate was shown in CTX 44 (100%), followed by MET 14 (31.8%), AZR 8 (18.2%), MEM 3 (6.8%), and VA 2 (4.5%). MRSA was detected in 31.8% of HA-*Staphylococcus aureus* isolates. On the other hand, CA- *S. aureus* isolates show an equal prevalence rate of resistance 1(12.5%) for each of MET, VA, and AZR. 100% of CTX-resistant Staphylococcus aureus isolates were recorded in all HA and CA *Staphylococcus aureus* isolates (Table 3). There were no statistically significant differences between HA-S. *aureus* isolates or CA- *S. aureus* isolates and the selected antibacterial discs (P-value = 0.51).

Table 4. Distribution of Staphylococcus aureus resistance isolates among the antimicrobial agents in patients and hospital workers.

Antimicrobial agents	Staphylococcus aureus resistance isolates				P-value
	Doctors n=25(%)	Nurses n=25(%)	Patients n=25(%)	Workers n=25(%)	
MET	2 (8)	4 (16)	5 (20)	3 (12)	0.739918
VA	1 (4)	1 (4)	0 (0)	0 (0)	
CTX	0 (0)	0 (0)	0 (0)	0 (0)	
AZR	2 (8)	1 (4)	3 (12)	2 (8)	
MEM	0 (0)	0 (0)	2 (8)	1 (4)	

Among the MRSA isolates, the highest prevalence rate was detected in patients, followed by nurses, workers, and doctors, and was 5 (20%), 4 (16%), 3 (12%), 2 (8%), respectively. Regarding the resistant isolates to AZR, the highest prevalence rate was detected in patient 3 (12%) and the lowest one was detected in nurse 1 (4%), while the doctors and workers showed the same prevalence rate 2(8%). VR shows a low prevalence rate among HA-*Staphylococcus aureus* isolates, which was only detected in both doctors and nurses at 1(4%). We did not find any resistant strain to CTX between patients and health care workers. Only 2 (8%) of MEM resistance isolates were detected in patients and 1 (4%) in workers. The p-value for overall resistance differences among groups is 0.739918. This indicates no statistically significant difference in antibiotic resistance rates of *Staphylococcus aureus* between the groups studied ($p > 0.05$).

Table 5. Correlation between HA-MRSA and CA-MRSA isolates and antimicrobial-resistant agents

Resistance to antimicrobial agents	MRSA isolates		Association Cramer's V	P-value
	HA-MRSA n=14 (%)	CA-MRSA n=1 (%)		
VA	0 (0)	1 (7)	0.008	0.957
CTX	14 (93)	1 (7)	-	-
AZR	6 (40)	0 (0)	0.408	0.026*
MEM	3 (20)	0 (0)	0.381	0.009*

**: Significantly correlated (P value= < 0.05).*

In this study, a total of 15 MRSA isolates were identified. Of the 14 confirmed HA-MRSA isolates, 14 (93%) were resistant to CTX, 6 (40%) were resistant to AZR, and 3 (20%) were resistant to MEM. There was a significant association between HA-MRSA isolates and AZR (P=0.026) and MEM resistance (P=0.009). Screening of CA-MRSA isolates showed that only two isolates were resistant to antibacterial discs VA 1 (7%) and CTX 1 (7%), while the remaining were sensitive to AZR and MEM. There was no significant difference between the CA-MRSA isolates and these antimicrobial agents (Table 5).

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Discussion

This study identified *Staphylococcus aureus* isolates, with 44% of hospital-acquired (HA-*S. aureus*) and 17% of community-acquired (CA-*S. aureus*), emphasizing the higher prevalence in healthcare settings compared to community environments (Figure 1).

In Egypt, HA-*S. aureus* prevalence ranges from 67.3% to 91.8%, significantly higher than this study's findings, probably due to differences in infection control practices and antibiotic resistance concerns, particularly methicillin resistance (6,7). Sudanese studies highlight poor infection control and limited diagnostic tools as contributors to high HA-*S. aureus* rates, though specific prevalence data remains sparse (8,9). Tunisian studies report HA-S. aureus prevalence at 20% and CA-S. aureus at 7%, consistent with this study's observations (9). In the UK, stringent hygiene protocols have reduced MRSA prevalence to <5%, contrasting with the higher rates observed here (7,10). The USA reports significant HA-*S. aureus* burdens, especially MRSA, but CA-*S. aureus* prevalence (<1%) is lower than the 17% observed in this study, potentially reflecting regional differences in healthcare access and environmental factors (6,8. These findings underscore the need for improved infection control strategies and antibiotic stewardship globally to address *S. aureus* infections effectively.

In this study, the prevalence rates of *Staphylococcus aureus* colonization among different hospital populations (Table 2) varied and showed the highest rate with nurses (39%), followed by doctors (27%), workers (18%), and patients (16%). These findings align with several international studies but also reveal some notable differences:

The overall prevalence among healthcare workers (HCWs) in this study (18-39%) is lower than reported rates in Egypt (67.3-91.8%) (11), suggesting potentially better infection control practices. The higher colonization rate among nurses compared to other groups is consistent with findings from a US study, where nurses had the highest MRSA prevalence (10.5%) among HCWs (12). The patient colonization rate (16%) is higher than reported rates in some UK studies, where MRSA prevalence alone has been reported at up to 6.7% in hospital settings (13). The prevalence among HCWs in this study is almost higher than reported rates in Tunisia (20% for HA-S. aureus) (14), indicating potential regional variations in colonization patterns. While specific data for Sudan was not available, the overall prevalence in this study appears to be lower than general reports from other African countries, suggesting possible differences in infection control measures or reporting practices (15). These comparisons highlight the importance of context-specific infection control strategies and the need for standardized surveillance methods across different healthcare settings and geographical regions.

This study demonstrated high resistance rates among *Staphylococcus aureus* isolates, with 100% resistance to cefotaxime (CTX) observed in both hospital-acquired (HA) and community-acquired (CA) isolates (Table 3). Methicillin resistance (MET) was detected in 31.8% of HA isolates and 12.5% of CA isolates, while lower resistance was recorded for azithromycin (AZR), meropenem (MEM), and vancomycin (VA). These findings align with global trends of antimicrobial resistance but reveal regional differences when compared to other studies.

HA-MRSA prevalence in this study (31.8%) is lower than Egypt's reported rates of up to 63%, where widespread misuse of antibiotics has contributed to higher resistance levels. Vancomycin resistance in Egyptian MRSA strains is reported at 9%, exceeding the 4.5% observed here, reflecting differences in clinical practices and drug availability (16). Sudanese studies report significant resistance to erythromycin (100%) and tetracycline (97.1%), which are higher than the azithromycin resistance rate observed here (18.2%). The prevalence of MRSA in Sudan also aligns with this study's findings, suggesting similar challenges with infection control and antimicrobial stewardship (17). Tunisian studies highlight HA-MRSA prevalence as high as 54% in burn units, surpassing this study's rate of 31.8%. Resistance to pristinamycin and other antibiotics has been documented, but vancomycin resistance remains low, consistent with this study (18). MRSA rates in UK hospitals are typically lower (<5%) due to stringent infection control measures, contrasting sharply with the findings here. In the USA, MRSA prevalence is higher in healthcare settings, with vancomycin resistance reaching 9%, exceeding this study's rates. However, CA-MRSA strains in the USA often exhibit lower multidrug resistance profiles due to effective surveillance programs (19,20).

This study highlights the antimicrobial resistance patterns of *Staphylococcus aureus* isolates among patients and hospital workers (Table 4). Among the MRSA isolates, the highest prevalence rate was detected in patients, followed by nurses, workers, and doctors, at 5 (20%), 4 (16%), 3 (12%), and 2 (8%), respectively. Regarding the resistant isolates to AZR, the highest prevalence rate was detected in patients (12%) and the lowest in nurses (4%), while doctors and workers both showed a prevalence of 8%. VR showed low prevalence among HA-*Staphylococcus aureus* isolates and was only detected in doctors and nurses (4% each). No resistant strains to CTX were found among patients or healthcare workers. Only 2 (8%) of MEM-resistant isolates were detected in patients and 1 (4%) in workers. The p-value for overall resistance differences among groups is 0.739918, indicating no statistically significant difference in antibiotic resistance rates of *Staphylococcus aureus* between the groups studied ($p > 0.05$). These findings are consistent with reports from Egypt, Tunisia, and Sudan, where MRSA prevalence among healthcare workers and patients ranges from 15% to 40% and vancomycin resistance remains rare, but contrast with lower MRSA rates (below 10%)

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and similarly low vancomycin resistance in the USA and UK, likely due to stricter infection control measures in those countries (21–26). These findings emphasize the need for targeted antimicrobial stewardship programs and infection control strategies tailored to specific hospital roles to mitigate *S. aureus* transmission risks globally.

Among the 14 MRSA isolates identified (Table 5), HA-MRSA demonstrated pronounced resistance patterns with 93% to cefotaxime (CTX), 40% to aztreonam (AZR), and 20% to meropenem (MEM), with significant associations between HA-MRSA and AZR (P=0.026) or MEM resistance (P=0.009). In contrast, community-acquired MRSA (CA-MRSA) isolates exhibited minimal resistance, with only 7% resistant to vancomycin (VA) and CTX, and no significant associations with AZR or MEM. In a similar regional study by Ali et al. (2019), the resistance patterns of MRSA isolates from skin and soft tissue infections were examined, revealing significant resistance to common antibiotics, including cephalosporins and beta-lactams, which aligns with the findings of pronounced resistance to cefotaxime (CTX) and aztreonam (AZR) in hospital-acquired MRSA (HA-MRSA) in our study. (27) Comparing these findings globally, Egypt reports MRSA prevalence as high as 52%, while Tunisia saw an increase from 16% to 41% between 2002 and 2007, reflecting similarly high resistance rates in Sudan and other Middle Eastern countries (28-31). In the UK and USA, MRSA prevalence varies but is generally lower due to robust surveillance systems (32). These results highlight the regional differences in MRSA epidemiology and resistance patterns, emphasizing the need for tailored strategies to address antimicrobial resistance effectively in different settings.

Conclusion

In conclusion, the study reveals a notable prevalence of multidrug-resistant *Staphylococcus aureus*, particularly among healthcare workers in hospital settings compared to medical students in the community. High resistance rates, especially to cefotaxime and methicillin, were observed, with nurses being the most affected group. The findings underscore the urgent need for enhanced infection control measures and antibiotic stewardship to mitigate the spread of resistant *S. aureus* strains in both healthcare and community environments in Benghazi.

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الملخص

تُمثل المكورات العنقودية الذهبية المقاومة للأدوية المتعددة (MDR-SA) وخاصةً السلالات المقاومة للميثيسيلين(MRSA) ، تحديًا صحيًا عامًا كبيرًا نظرًا لقدرتها على التسبب في مجموعة متنوعة من العدوى ومقاومة العديد من المضادات الحيوية. هدفت هذه الدراسة الوصفية المقطعية إلى معرفة انتشار المكورات العنقودية الذهبية وأنماط مقاومتها للمضادات الحيوية بين طلاب الطب (المكتسبة من المجتمع، CA) والعاملين في مجال الرعاية الصحية (المكتسبة من المستشفى، HA)، في بنغازي، ليبيا. بين مايو ونوفمبر 2020، تم جمع ما مجموعه 146 مسحة أنفية: 100 من المشاركين في المستشفى (25 طبيبًا و25 ممرضة و25 عاملًا و25 مريضًا) و46 من طلاب الطب. تم الكشف عن المكورات العنقودية الذهبية في 44٪ من عينات المستشفيات و17٪ من عينات المجتمع، مع ملاحظة أعلى استعمار بين الممرضات (39٪)، يليه الأطباء (27٪) والعمال (18٪) والمرضى (16٪). أظهرت جميع العزلات مقاومة للسيفوتاكسيم. ولوحظت مقاومة الميثيسيلين في 31.8% من عزلات HA و12.5% من عزلات CA. وكانت مقاومة الفانكومايسين والأزيثروميسين والميروبينيم أقل مقارنةً بالميثيسيلين. وأظهرت عزلات HA-MRSA مقاومة أعلى للأدوية المتعددة، مع وجود ارتباطات مهمة بين HA-MRSA ومقاومة الأزيثروميسين والميروبينيم. في المقابل، أظهرت عزلات CA-MRSA مقاومة ضئيلة. تُسلط هذه النتائج الضوء على العبء الكبير الذي تُشكله بكتيريا S. aureus المقاومة للأدوية المتعددة، لا سيما في المستشفيات، وتُؤكد على الحاجة المُلحة لاستراتيجيات فعّالة لمكافحة العدوى وبرامج إدارة المضادات الحيوية للحد من انتشار السلالات المقاومة في كل من بيئات الرعاية الصحية والمجتمع في بنغازي.

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