Infection and Drug Resistance

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ORIGINAL RESEARCH

Antimicrobial Susceptibility Profile of Methicillin-Resistant *Staphylococcus Aureus* Isolated from Clinical Samples at Bac Ninh Provincial General Hospital, Vietnam

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Purpose: *Staphylococcus aureus*, including methicillin-resistant *Staphylococcus aureus* (MRSA) strain, can become resistant to all classes of clinically available antibiotics and causes skin infections and severe infections in the lungs, heart, and bloodstream. The study aimed to evaluate antimicrobial susceptibility patterns and MRSA exhibiting multidrug resistance obtained through a microbiological culture of clinical specimens at Bac Ninh Provincial General Hospital in Bac Ninh Province, Vietnam.

Methods: We employed a cross-sectional analysis at Bac Ninh Provincial General Hospital in Vietnam. 15,232 clinical samples from inpatients were examined. *S. aureus* isolates were identified using established protocols and tested for MRSA and antibiotic susceptibility. Data was analyzed using R software, with statistical calculations to assess associations between variables.

Results: *Staphylococcus aureus* was isolated from 417 samples (2.7%), with 77.2% being MRSA and 22.8% methicillin-susceptible *Staphylococcus aureus* (MSSA). Significant sources of MRSA were wounds (64.6%) and the surgical unit (50%) according to sample types and hospital wards, respectively. *S. aureus* showed high resistance rates, the highest being azithromycin (83.2%), and was fully susceptible to vancomycin. Among 294 multidrug-resistant (MDR) strains, the prevalence was 82.0% in MRSA and 18.0% in MSSA.

Conclusion: The study highlights widespread antimicrobial resistance among MRSA isolates from a provincial hospital in Vietnam, emphasizing the urgent need for antibiotic surveillance, formulation of antibiotic policies, and preventive measures to tackle the increasing prevalence of multidrug-resistant MRSA.

Keywords: *Staphylococcus aureus*, antibiotic resistance, MRSA, MDR, Vietnam

Received: 9 July 2024
Accepted: 11 September 2024
Published: 20 September 2024

Introduction

Staphylococcal infections remain a significant health concern globally despite advancements in antimicrobial therapies. *Staphylococcus* genus encompasses several pathogenic species, with *Staphylococcus aureus* being the most virulent, leading to a broad spectrum of infections, including community-associated and hospital-acquired infections.[1] This bacterium is a primary cause of pneumonia, bloodstream infections, soft tissue infections, and surgical site infections in healthcare settings.[2]

Alterations in its antibiogram patterns have exacerbated the challenge of treating *S. aureus* infections.[3–5] A notable example is the rise of MRSA strains shortly after methicillin was introduced.[6] Methicillin resistance in *S. aureus* can be mediated by the mec (A or C) genes. The mobile genetic element staphylococcal chromosomal cassette mec (SCCmec) carries both the mecA or mecC gene, encoding for a novel specific penicillin-binding protein (PBP2a), and site-specific recombinase genes ccrAB or/and ccrC.[7] MRSA can easily transmit across the hospital system and has mostly gained resistance to medications called beta-lactamases. This enzyme destroys the cell wall of beta-lactam antibiotics resulting in resistance against that respective antibiotic. Daptomycin, linezolid and vancomycin were previously used to treat MRSA infections.[8] Healthcare-associated MRSA strains frequently resist several antibiotics, including erythromycin, clindamycin, and fluoroquinolones. Conversely, community-associated MRSA strains typically resist β-lactam antibiotics, erythromycin, and occasionally fluoroquinolones.[9,10] MRSA's ability to spread rapidly in hospitals and its difficulty in eradication once established pose significant challenges for healthcare systems.[11] The predominance of MRSA is a severe therapeutic problem and differs widely among hospitals and countries.[12]

In Vietnam, several independent studies of antimicrobial resistance (AMR) prevalence have been conducted in individual hospitals. Still, these may not provide a comprehensive picture due to limited resources and variations in testing practices. More precise and readily available data on MRSA is needed to ensure adequate identification and treatment in clinical settings. Failure to adequately monitor MRSA prevalence can have serious consequences for both individual patients and public health. Without accurate MRSA surveillance data, healthcare providers may not suspect MRSA infections early, leading to delayed diagnosis and inappropriate initial antibiotic treatment. This delay can worsen patient outcomes and increase the risk of complications. Treating MRSA infections is often more challenging and expensive due to the need for more potent, and often more expensive, antibiotics. Inadequate surveillance might lead to the use of inappropriate antibiotics initially, delaying effective treatment and increasing costs. Furthermore, without proper monitoring, resistant strains can spread more easily within hospitals and into the community. This can lead to more widespread infections that are difficult to treat, contributing to the growing public health threat of antibiotic resistance.[13–15] Therefore, tracking MRSA prevalence, especially in low- and middle-income countries like Vietnam, is crucial for public health. This study aims to assess the prevalence of MRSA isolated at Bac Ninh General Hospital in Bac Ninh, Vietnam. We focus on their antibiogram profiles and MDR to common antibiotics, providing valuable insights for better clinical management of MRSA infections.

Materials and Methods

Methodology and Setting

We employed a cross-sectional design at the Department of Central Laboratory, Bac Ninh Provincial General Hospital, for three years, from 2021 to 2023. This is a provincial general level I hospital located in Bac Ninh province, Vietnam, with a scale of 1130 planned beds, 38 departments, rooms, and centers. The hospital provides treatment for about 200.000 outpatients and 50.000 inpatients per year. It offers therapeutic, restorative, and educational services and delivers a range of healthcare services to prevent illness and promote well-being among patients throughout the province and neighboring areas.

Sample Size and Sample Collection

The study encompassed 15,232 clinical samples collected from hospitalized patients spanning all age demographics submitted to the Department of Central Laboratory. Samples were collected for *S. aureus* screening from various sources including blood, urine, wounds, and samples obtained from the lower respiratory tract, including coughed-up mucus

(sputum), secretions directly aspirated from the airways (tracheal/bronchial secretions), and fluid used to wash the lungs (bronchial lavage fluid). Duplicated isolates from the same patients were excluded. Data used in the study were *S. aureus*, patient age, year of isolation, sample types, hospital wards, and antimicrobial susceptibility testing.

S. aureus Isolation and Antimicrobial Susceptibility Testing (AST)

Blood culture and urine were inoculated on brilliance UTI Clarity agar and blood agar (Oxoid, England). The other samples were inoculated onto MacConkey, chocolate, and blood agar (Oxoid, England). All isolates underwent morphological and biochemical characterization employing standard laboratory methods.[15] Cultures with suspected bacterial growth for *Staphylococcus* genus on blood agar and chocolate agar underwent further analysis to identify *Staphylococcus aureus*. This included examining the pattern of red blood cell breakdown around colonies (beta-hemolysis on blood agar), Gram staining to confirm Gram-positive cocci, and a catalase test to differentiate from *Streptococcus* species. The presence of *Staphylococcus aureus* was further confirmed by a positive tube coagulase test. Phenotypic testing was conducted using the API 20 Staph ID test kit (bioMérieux, Durham, NC). Antimicrobial susceptibility testing (AST) uses the Kirby–Bauer disc diffusion method (gentamycin, azithromycin, ciprofloxacin, levofloxacin, tetracycline, doxycycline, vancomycin, clindamycin, trimethoprim/sulfamethoxazole, chloramphenicol) following guidelines of the updated Clinical and Laboratory Standards Institute.[16] MRSA is defined as resistant to cefoxitin using the disc diffusion methods. Multidrug resistance describes a situation where bacteria were resistant to antibiotics from at least three different classes.[16,17] *S. aureus* ATCC 25923 was used as a quality control strain in bacterial culture and AST.

Statistical Analysis

Statistical analysis was conducted to interpret the data using R software version 4.3.3, and statistical calculations were conducted to evaluate associations between the variables under study. P- value was set under 0.05 for a statically significant.

Results

Prevalence of *S. aureus*

The proportion of the study group that tested positive for *S. aureus*, spanning from 2021 to 2023, included 15,232 participants, among whom 417 isolates (2.7%) were identified as *S. aureus*. The year of isolation did not show a significant association with any of the age groups (Table 1).

Prevalence of MRSA

Table 1 illustrates the correlation between MRSA isolation and different demographic factors, clinical specimens, and hospital wards. Out of the 417 recovered *S. aureus* strains, 322 (77.2%) were identified as MRSA, while the remaining 95 (22.8%) were MSSA. A higher number of MRSA isolates were found in 2023 (127; 39.4%) compared to 2022 (105; 32.6%) and 2021 (90; 28%). The age group 41–65 had the greatest number of MRSA cases (157), accounting for 48.8% of all MRSA cases identified in the study, followed by those above 66 years (88; 27.3%), 16–40 years (61; 18.9%), 0–15 years (16; 5%). The primary sources of MRSA were wounds (208; 64.6%), respiratory tract (57; 17.7%), and blood (57; 17.7%). MRSA was not detected in urine samples. Wounds (44; 46.3%) had a greater percentage of MSSA, followed by blood (35; 36.8%), respiratory tract (15; 15.8%), and urine (1; 1.1%). A statistically significant association was found between the isolation rate of MRSA and clinical sample types (p=0.0002). According to the hospital ward, MRSA was found in the surgical unit (161; 50%), followed by internal medicine (124; 38.5%), ICU (28; 8.7%), and infectious diseases (9; 2.8%). MSSA was observed with the highest percentage in internal medicine (51; 53.7%), the second-highest percentage was in the surgical unit (31; 32.6%), and the lowest rate was in infectious diseases (5; 5.3%). The association between MRSA and the hospital ward was statistically significant (p=0.0172).

Table 1 Demographic and Distribution of Staphylococcus aureus Strains Isolated from Hospitalized Patients in Bac Ninh Provincial General Hospital

	MRSA		MSSA		Total		P
	N	%	N	%	N	%	
Year							
2021	90	28	29	30.5	119	28.5	0.2733
2022	105	32.6	37	38.9	142	34.1	
2023	127	39.4	29	30.5	156	37.4	
Total	322	100	95	100	417	100	
Hospital ward							
ICU	28	8.7	8	8.4	36	8.6	0.0172
Infectious disease	9	2.8	5	5.3	14	3.4	
Internal medicine	124	38.5	51	53.7	175	42	
Surgical	161	50	31	32.6	192	46	
Total	322	100	95	100	417	100	
Sample type							
Respiratory	57	17.7	15	15.8	72	17.3	0.0002
Wounds	208	64.6	44	46.3	252	60.4	
Blood	57	17.7	35	36.8	92	22.1	
Urine	0	0	1	1.1	1	0.2	
Total	322	100	95	100	417	100	
Age group							
0–15	16	5	4	4.2	20	4.8	0.9822
16–40	61	18.9	17	17.9	78	18.7	
41–65	157	48.8	47	49.5	204	48.9	
≥ 66	88	27.3	27	28.4	115	27.6	
Total	322	100	95	100	417	100	

Note: P-value was calculated by the Chi-square test.
Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*; N, number of isolates.

Antimicrobial Susceptibility Profile of MRSA

Table 2 presents the antibiogram of MRSA and MSSA against various antimicrobial agents. All *S. aureus* isolates in this study exhibited AMR (resistance to at least one drug). MRSA demonstrated a greater resistance rate to numerous drugs. Notably, 89.8% of MRSA isolates were resistant to azithromycin, followed by 76.8% resistant to clindamycin, 72.3% resistant to tetracycline, 44.9% resistant to doxycycline, 33.1% resistant to gentamycin, 27.6% resistant to ciprofloxacin, 27.3% resistant to levofloxacin. All tested isolates were sensitive to vancomycin, and a low rate of resistance was detected to chloramphenicol (15.9%) and trimethoprim/sulfamethoxazole (13.0%). Conversely, 61.1% of MSSA exhibited resistance to azithromycin. The probability of resistance or susceptibility to methicillin was notably correlated with

Table 2 Antimicrobial Resistance Patterns Between MSSA and MRSA Strains Isolated from Hospitalized Patients in Bac Ninh Provincial General Hospital in Vietnam from 2021 to 2023

Antimicrobials Class	Antimicrobial Agents	MSSA		MRSA		Total		P
		N	%R	N	%R	N	%R	
Aminoglycosides	Gentamicin	95	48.4	320	33.1	415	36.6	0.0066
Macrolides	Azithromycin	95	61.1	322	89.8	417	83.2	< 0.0001
Fluoroquinolones	Ciprofloxacin	93	33.3	315	27.6	408	28.9	0.2861
	Levofloxacin	83	36.1	286	27.3	369	29.3	0.1183
Tetracyclines	Tetracycline	94	47.9	321	72.3	415	66.7	< 0.0001
	Doxycycline	49	38.8	187	44.9	236	43.6	0.4411
Glycopeptides	Vancomycin	NA	NA	8	0	8	0	NA
Lincosamides	Clindamycin	90	54.4	310	76.8	400	71.7	< 0.0001
Folate pathway antagonists	Trimethoprim/sulfamethoxazole	82	14.6	276	13.0	358	13.4	0.7109
Phenicols	Chloramphenicol	95	15.8	321	15.9	416	15.9	0.9816

Note: P-value was calculated by the Chi-square test.
Abbreviations: N, number of tested isolates; R, Resistance; NA, Not applicable; MSSA, Methicillin-susceptible *Staphylococcus aureus*; MRSA, Methicillin-resistant *Staphylococcus aureus*.

azithromycin, tetracycline, and clindamycin ($p < 0.0001$). Tables 3–5 demonstrated the susceptibility profile of MRSA to various antimicrobial agents concerning year of isolation, hospital ward, and sample types. It was noted that the resistance pattern of MRSA isolates had only a significant chance of being resistant/susceptible to azithromycin, tetracycline, and clindamycin with specific clinical sample types ($p<0.0001$). While the clindamycin-resistance pattern of MRSA isolates was particular to the year of isolation ($p<0.0001$), azithromycin and tetracycline-resistance patterns of MRSA isolates were found to be specific to any hospital ward ($p=0.0084$ and $p=0.0101$). Figure 1 presents the status of

Table 3 Antimicrobial Resistance Patterns of MRSA Strains Isolated from Hospitalized Patients in Bac Ninh Provincial General Hospital in Vietnam from 2021 to 2023

Antimicrobials Class	Antimicrobial Agents	2021		2022		2023		Total		
		N	%R	N	%R	N	%R	N	%R	P
Aminoglycosides	Gentamicin	90	30.0	103	37.9	127	31.5	320	33.1	0.4509
Macrolides	Azithromycin	90	86.7	105	91.4	127	33.1	322	89.8	0.5116
Fluoroquinolones	Ciprofloxacin	90	27.8	99	30.3	126	25.4	315	27.6	0.7156
	Levofloxacin	90	26.7	104	29.8	92	25.0	286	27.3	0.7433
Tetracyclines	Tetracycline	90	72.2	105	76.2	126	69.0	321	72.3	0.4823
	Doxycycline	14	64.3	98	42.9	75	44.0	187	44.9	0.3141
Glycopeptides	Vancomycin	1	0.0	NA	NA	7	0.0	8	0.0	0.0339
Lincosamides	Clindamycin	89	84.3	99	87.9	122	62.3	310	76.8	< 0.0001
Folate pathway antagonists	Trimethoprim/sulfamethoxazole	90	5.6	105	12.4	81	22.2	276	13.0	0.0052
Phenicols	Chloramphenicol	90	17.8	104	16.3	127	14.2	321	15.9	0.7648

Note: P-value was calculated by the Chi-square test.
Abbreviations: N, number of tested isolates; R, Resistance; MRSA, Methicillin-resistant *Staphylococcus aureus*; NA, Not applicable.

Table 4 Antimicrobial Resistance Patterns of MRSA Strains Isolated from Hospitalized Patients According to Hospital Wards in Bac Ninh Provincial General Hospital from 2021 to 2023

Antimicrobials Class	Antimicrobial Agents	ICU		Infectious Disease		Internal Medicine		Surgical		Total		P
		N	%R	N	%R	N	%R	N	%R	N	%R	
Aminoglycosides	Gentamicin	28	42.9	9	22.2	123	30.1	160	34.4	320	33.1	0.5111
Macrolides	Azithromycin	28	82.1	9	66.7	124	87.1	161	94.4	322	89.8	0.0084
Fluoroquinolones	Ciprofloxacin	28	39.3	8	37.5	120	24.2	159	27.7	315	27.6	0.3897
	Levofloxacin	26	38.5	9	33.3	110	24.5	141	27.0	286	27.3	0.5265
Tetracyclines	Tetracycline	28	53.6	9	55.6	123	68.3	161	79.5	321	72.3	0.0101
	Doxycycline	16	31.2	7	42.9	67	34.3	97	54.6	187	44.9	0.0468
Glycopeptides	Vancomycin	NA	NA	1	0	2	0	5	0.0	8	0.0	0.1969
Lincosamides	Clindamycin	25	76.0	8	62.5	122	73.8	155	80.0	310	76.8	0.4854
Folate pathway antagonists	Trimethoprim/sulfamethoxazole	25	20.0	9	22.2	107	9.3	135	14.1	276	13.0	0.3689
Phenicols	Chloramphenicol	28	25.0	9	11.1	123	15.4	161	14.9	321	15.9	0.5668

Note: P-value was calculated by the Chi-square test.
Abbreviations: N, number of tested isolates; R, Resistance; ICU, Intensive care unit; MRSA, Methicillin-resistant *Staphylococcus aureus*; NA, Not applicable.

Table 5 Antimicrobial Resistance Patterns of MRSA Strains Isolated from Hospitalized Patients According to Sample Types in Bac Ninh Provincial General Hospital from 2021 to 2023

Antimicrobials Class	Antimicrobial Agents	Respiratory		Wound		Blood		Total		P
		N	%R	N	%R	N	%R	N	%R	
Aminoglycosides	Gentamicin	57	29.8	208	33.7	55	34.5	320	33.1	0.8367
Macrolides	Azithromycin	57	91.2	208	92.8	57	77.2	322	89.8	0.0025
Fluoroquinolones	Ciprofloxacin	54	25.9	205	26.8	56	32.1	315	27.6	0.6995
	Levofloxacin	50	22.0	184	27.7	52	30.8	286	27.3	0.5946
Tetracyclines	Tetracycline	57	66.7	208	79.3	56	51.8	321	72.3	0.0001
	Doxycycline	26	34.6	127	50.4	34	32.4	187	44.9	0.0896
Glycopeptides	Vancomycin	NA	NA	7	0.0	1	0.0	8	0.0	0.0339
Lincosamides	Clindamycin	55	72.7	202	82.7	53	58.5	310	76.8	0.0008
Folate pathway antagonists	Trimethoprim/sulfamethoxazole	53	15.1	177	11.9	46	15.2	276	13.0	0.7389
Phenicols	Chloramphenicol	57	17.5	207	16.4	57	12.3	321	15.9	0.6988

Note: P-value was calculated by the Chi-square test.
Abbreviations: N, number of tested isolates; R, Resistance; MRSA, Methicillin-resistant *Staphylococcus aureus*: NA, Not applicable.

MDR *S. aureus* according to MRSA and MSSA. An increasing number of drug-resistant MRSA isolates was observed. Among MDR isolates, the prevalence of MDR in MRSA was notably higher, at 81.9% (241/294) and MSSA 18.0% (53/294), respectively.

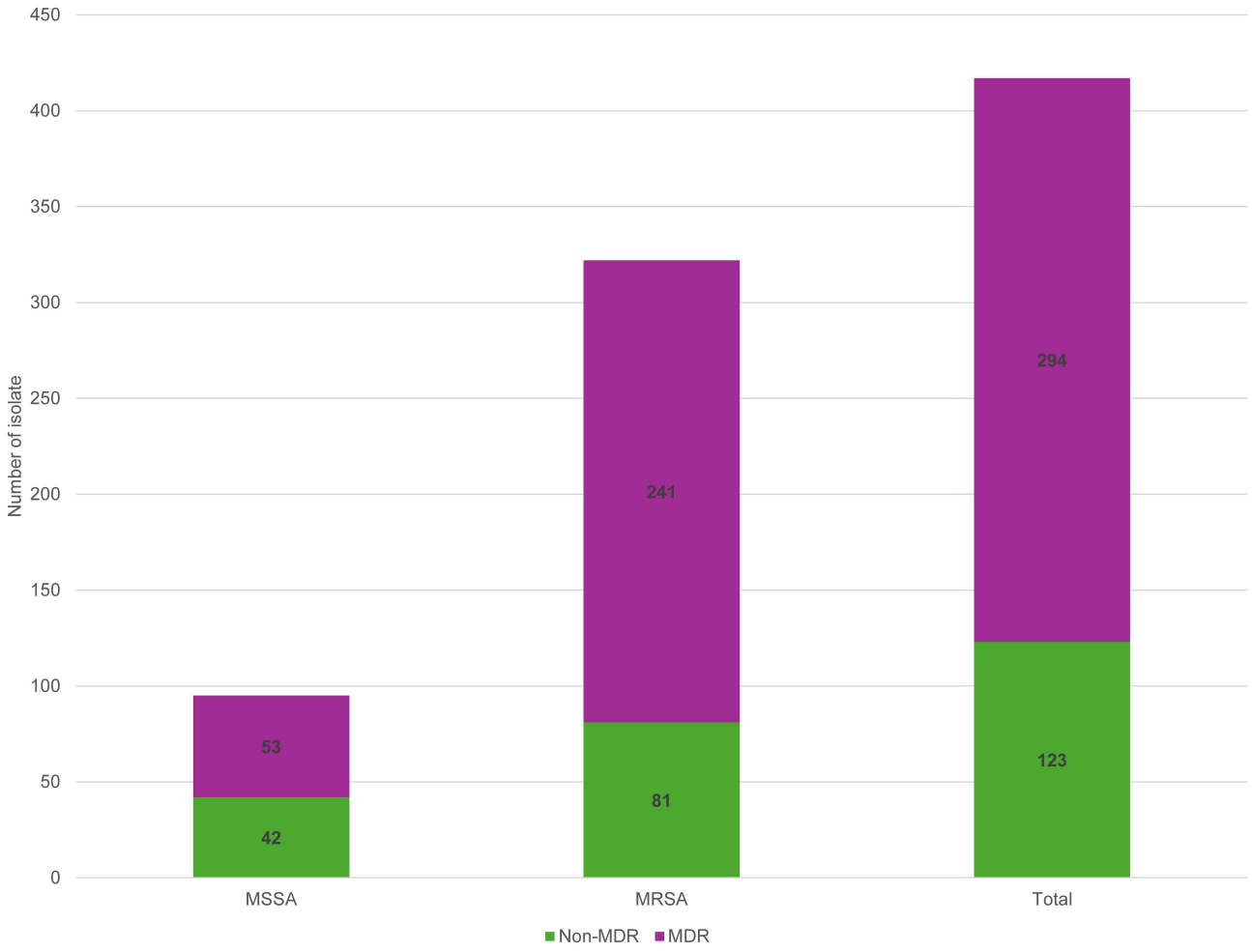

Figure 1 Distribution of multidrug-resistant *Staphylococcus aureus* according to MRSA and MSSA.
Abbreviations: MDR, multidrug-resistant; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*.

Discussion

S. aureus can be carried by patients both before and after hospital admission. It is a common commensal of humans and animals and may colonize nares, axilla, perineum, skin, and multiple other body sites.[18,19] Approximately 15% of the population is estimated to carry *S. aureus* in the anterior nares persistently.[20] Patients entering the hospital might already be carriers of *S. aureus*. Additionally, they can acquire it during their hospital stay, especially if they undergo surgery or have other invasive procedures.[21] It has been widely known that MRSA is a dominant hospital pathogen causing significant morbidity and mortality worldwide.[22–24] MRSA colonization increases the risk of infection and contributes to healthcare-associated transmission.[25] In Vietnam, AMR surveillance efforts began in 1988 with various programs, including VINARES, a network of 16 hospitals nationwide that collected data on antimicrobial consumption, resistance patterns, and hospital-acquired infections.[26–28] In the VINARES report from 2016–2017, 73% of *S. aureus* isolates were identified as MRSA.[13] In a study by Song et al in 2011, MRSA constituted 67.4% of healthcare-associated infections.[29] The study investigating the causes of bloodstream infections in patients in Northern Vietnam revealed a methicillin resistance rate of 37% among *S. aureus* isolates.[30] Epidemic isolates of these MRSA are usually also resistant to several other antibiotics.[14] The emergence and global dissemination of these MRSA isolates pose significant therapeutic challenges for many hospitals, necessitating substantial resources to control and prevent their spread.

Various studies have reported varying prevalence rates of MRSA in different countries. Our study determined the occurrence and antibiotic susceptibility characteristics of various MRSA isolates obtained from types of samples and hospital wards in 2021–2023. Among 417 *S. aureus* strains analyzed, 77.2% were identified as MRSA, higher than 37%

in Northern Vietnam.[30] In comparison to other countries, it was greater than India (31.1%) and the Philippines (38.1%) but lower than Sri Lanka (86.5%).[29,31] Variations in the prevalence rate of MRSA may be influenced by differences in the study period's duration, sample size, types of samples collected, number of study sites involved, and laboratory methodologies utilized.[32] Consistent with national data, the MRSA rate in our study was 77.6%, similar to the reported prevalence in Korea (77.6%).[29]

Although the study identified the 41–65 age group as having the highest isolation rate of *S. aureus*, there were no significant differences in the proportion of MRSA cases among the different age groups. This result supports previous research suggesting that age itself might not be a significant factor influencing MRSA colonization.[33] This study encountered the highest MRSA rates in wound specimens and the hospital's surgical wards. These findings also agree with results in Trinidad and Tobago by Patrick et al, 2006 and Canada by Simor et al, 2001, where most patients were older adults receiving medical care in the surgical ward.[32,34] It could partly be because most wound specimens came from the hospital's surgical ward. MRSA is becoming more prevalent in surgical wards, particularly in critically ill patients who have had prolonged hospital stays, received antibiotic treatment, have underlying immune-compromised conditions, and have been exposed to hospital environments, instrumentation, and other invasive devices.[35] Over time, the increasing resistance of MRSA to existing antibiotics is a cause for concern.

All MRSA isolates showed resistance to a greater number of antibiotics compared to MSSA isolates. Gentamicin, azithromycin, tetracycline, and clindamycin showed significantly greater resistance ($p<0.001$ for all) compared to other antibiotics tested in this study. However, the difference observed in the case of ciprofloxacin ($p=0.2861$), levofloxacin ($p=0.1183$), doxycycline ($p=0.4411$), trimethoprim/sulfamethoxazole ($p=0.7109$) and chloramphenicol ($p=0.9816$) was not statistically significant. Similar results were noted for clindamycin and tetracycline resistance among MRSA isolates in Iran.[36]

The overall findings of this study indicate an alarming situation regarding antimicrobial resistance associated with *S. aureus*. The increasing prevalence of antibiotic resistance in bacteria is a cause for concern and has been identified as a significant public health threat, particularly impacting developing nations.[37] One limitation of this study was the lack of whole genome sequencing, which prevented us from comprehensively investigating the genetic mutations that cause resistance in these MRSA isolates. Understanding the origins of MRSA strains is crucial for effective infection control and treatment strategies. Although we did not investigate the specific sources of these strains in this study, likely factors such as community-acquired infections, hospital-acquired infections, colonization rates among healthcare workers, and specific surgical procedures all play a role in the prevalence of MRSA in different clinical settings. This understanding can inform the development of more effective infection control measures. Further, a more in-depth investigation into risk factors associated with MRSA infections in our hospital setting would provide valuable insights for implementing targeted interventions. The high prevalence of MRSA isolates exhibiting resistance to azithromycin, tetracycline, clindamycin, and other antibiotics suggests the limited efficacy of these agents for the treatment of MRSA infections. This finding, coupled with the fact that we did not investigate the specific sources of MRSA, highlights the need for further research to understand the factors contributing to the spread of antibiotic-resistant strains and to develop more effective treatment strategies. Vancomycin seems to be the drug of choice in treating *S. aureus* infections as it showed complete effectiveness in 8/8 tested isolates. Unlike most studies, previous reports in Pakistan, Vietnam, and Trinidad obtained a similar result for vancomycin.[4,14,32] Diekema et al (2001) reported that most MRSA isolates resist most other antibiotics.[38] Given its 100% susceptibility against MDR-MRSA isolates in this study, vancomycin could be the preferred choice for treatment. However, close monitoring of vancomycin susceptibility through regular testing remains crucial.

Implementing regular surveillance of hospital-acquired infections, including monitoring antibiograms of both MRSA and MSSA and establishing clear antibiotic treatment protocols, can contribute to reducing MRSA infections. The findings of this study can serve as a springboard for launching larger epidemiological investigations into MRSA infections. Notably, MDR patterns in our study were more prevalent in MRSA (241/322; 81.9%) than in MSSA (53/294; 18.0%). This observed resistant pattern is consistent with previous studies on Vietnam, China, and Ethiopia populations.[13,39,40] Several factors contribute to the emergence of MDR-MRSA, including extended hospitalizations, overuse of antibiotics, inadequate hygiene practices, and the use of antibiotics before admission. Hence, the emergence of MDR in MRSA strains has placed a significant burden on researchers and pharmaceutical companies in developing new antimicrobials that are effective against MDR-MRSA challenges. Treatment delays due to multidrug resistance pose

a significant public health challenge, leading to a rise in morbidity, mortality, extended hospitalizations, and substantial increases in healthcare costs.[41]

Conclusions

In conclusion, this study found a high prevalence of multidrug-resistant *Staphylococcus aureus* and MRSA in the Bac Ninh provincial hospital setting, posing significant challenges for infection control and public health. The surgical unit and wound infections emerged as primary sources of these pathogens. Notably, multidrug resistance patterns were more prevalent in MRSA isolate, with clindamycin, tetracycline, and azithromycin showing low effectiveness. While vancomycin, chloramphenicol, and trimethoprim/ sulfamethoxazole remained viable options for MDR-MRSA treatment, the growing concern revolves around the emergence of resistance to these drugs. Continued monitoring of antibiotic susceptibility patterns and implementing stricter antibiotic stewardship programs are crucial to preserve the effectiveness of existing treatments. Furthermore, limitations in our study, such as lack of molecular analysis, highlight the need for further research to comprehensively understand the spread and identify risk factors associated with MRSA infections. Overall, controlling the spread of MRSA requires a multi-pronged approach. This includes implementing hospital preventive measures, such as infection prevention and control programs, education and training, and isolation protocols. Ongoing surveillance, including monitoring, reporting, and next-generation sequencing and data analysis, is crucial. Finally, optimized antibiotic use practices, such as antimicrobial stewardship programs, guidelines and protocols, and education and awareness, are essential to combating the spread of MRSA.

Ethical Information

This study received approval from the ethics committee of Military Hospital 103 (Approval No. 46/CNChT- HĐĐĐ). Due to its retrospective nature, the ethics committee waived participants' informed consent requirements. Patient information was anonymized prior to analysis. The study adhered to the principles outlined in the Declaration of Helsinki.

Acknowledgment

We express our gratitude to the Department of Central Laboratory staff at Bac Ninh General Hospital for their valuable collaboration and contributions.

Author Contributions

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.

Funding

There is no funding to report.

Disclosure

The authors declare no competing interests in this work.

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