

A Comparison of Mortality, Readmissions, and Outcomes in Injection Drug Use-Associated Infective Endocarditis Caused by Methicillin-Resistant Versus Methicillin-Susceptible *Staphylococcus aureus*

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Purpose: This study aimed to compare mortality and outcomes among patients with injection drug use (IDU)-associated infective endocarditis (IE) caused by MRSA (methicillin-resistant *Staphylococcus aureus*) versus MSSA (methicillin-susceptible *Staphylococcus aureus*).

Patients and Methods: A single-center retrospective cohort study was performed on adult patients (≥ 18 years old) at a large academic medical center in the Mid-Southern United States of America between January 2013 and January 2020 to compare the mortality and outcomes of initial cases of IDU-associated IE due to MRSA and MSSA. All cases were confirmed using the Duke criteria for IE.

Results: A total of 175 IE patients were divided into two groups based on the causative agent: MRSA and MSSA. A total of 25 patients (14.3%) died during the index hospitalization, while 34 (19.4%) died within one year of index hospitalization. We observed no statistically significant differences between MRSA IE and MSSA IE in terms of mortality, intensive care unit admissions, hospital readmission rates, IE recurrence, or surgical intervention. The major difference between the two groups was the significantly higher rate of septic pulmonary emboli in the MRSA IE group than in the MSSA IE group ($p = 0.0012$). This was supported by the increased rate of tricuspid valve vegetation in MRSA IE patients (72.7%).

Conclusion: Our study affirms the overall severity and high mortality rate of *Staphylococcus aureus* IE, independent of methicillin resistance status, even in the presence of appropriate antimicrobial therapy. With the increasing prevalence of IE caused by MRSA and MSSA, these challenging infections will continue to require aggressive intervention and treatment.

Keywords: injection drug use, infective endocarditis, MRSA, MSSA

Introduction

Over the last few decades, the prevalence of infective endocarditis (IE) cases in the United States of America has increased at a rate of 2.4% per year, with more than half of the cases occurring in patients without previously diagnosed heart disease.^{1,2} The most common pathogen associated with IE was identified as *Staphylococcus aureus* (*S. aureus*) at 49%, with over half of *S. aureus* IE cases caused by methicillin-resistant *S. aureus* (MRSA) strains.³ Over the last decade, the nationwide prevalence of *S. aureus*-associated IE has increased from 21% to 30%, while the past five decades have witnessed a rising proportion of cases associated with coagulase-negative *Staphylococcus* strains.²

The current opioid epidemic and the increasing national incidence of injection drug use (IDU) have contributed to the rise in IE hospitalizations.⁴ For example, the proportion of IE hospitalizations related to IDU increased from 7% to 12% by 2013, with 42% being in younger people, 15–34 years of age.^{3,5} *S. aureus* is the most commonly isolated organism in this population.^{6,7} The increased mortality and perioperative adverse events associated with *S. aureus* IE, together with the increased incidence of IDU-associated IE and the frequency of recurrent IE due to relapse, pose significant challenges to our hospital systems and treatment decisions.^{8,9}

Regardless of methicillin resistance status, *S. aureus* IE is associated with increased mortality rates and complications such as persistent bacteremia and metastatic infection requiring intensive care unit (ICU) admission or surgical intervention.^{1,6,7,10} With the rising incidence of *S. aureus* IE in the setting of the current opioid epidemic, it is imperative that we continue to assess the outcomes of IE related to MRSA and methicillin-sensitive *S. aureus* (MSSA).

Several previous studies attempting to compare IE due to MRSA and MSSA have demonstrated conflicting outcomes regarding mortality, need for surgery, and complications, although they have been limited largely by their small sample sizes.^{11–13} A larger multicenter prospective observational study demonstrated a higher 30-day mortality rate with MRSA IE than with MSSA IE, with MRSA cases demonstrating nearly twofold higher odds of death compared to MSSA.¹⁴ A recent retrospective analysis also revealed a trend of higher mortality in MRSA IE (50.0%) than in MSSA IE (9.1%) ($p = 0.019$).¹⁵ Two other studies with larger sample sizes found no difference in mortality between MRSA IE and MSSA IE: in one, methicillin resistance was not associated with higher IE-related mortality (49.7 vs 43.1%, $p = 0.32$), while in the other, there was no statistically significant increase in mortality as well (29.8 vs 23.3%, $p = 0.14$).^{16,17}

This prior conflicting data regarding the relative outcomes of MRSA IE and MSSA IE, the increasing incidence of *S. aureus* IE in the setting of prior IDU, and the absence of a microbiologic basis beyond methicillin resistance for the reported increase in MRSA virulence warrant further studies to compare the mortality and outcomes in MSSA IE and MRSA IE.¹⁸ Therefore, the objective of this study was to directly compare the mortality, readmissions, and complications of IDU-associated IE caused by MRSA versus MSSA in a large academic medical center.

Materials and Methods

Study Design

This single-center retrospective cohort study was performed at an academic Level I trauma and regional referral center in the Mid-Southern United States of America, which is considered a center of excellence for cardiovascular care. All patients in this study were evaluated and treated by an infectious disease physician and received guideline-directed intravenous antibiotic therapy; however, detailed stratification of specific antibiotic regimens by MRSA versus MSSA groups was not systematically captured. Similarly, while indications for surgical versus percutaneous interventions were recorded, we did not capture the precise timing or decision-making factors that may have differed between the two groups.

Patient Population

All cases in our study represented the initial IE diagnoses. If an individual met the eligibility criteria over multiple admissions, only the initial admission was used. Included were patients ≥ 18 years of age between January 2013 through January 2020 with confirmed community acquired *S. aureus* bacteremia complicated by IE, as confirmed by echocardiography and by meeting the Duke criteria definition for definite IE, while episodes of *S. aureus* bacteremia that did not meet the Duke criteria and cases with polymicrobial infections were excluded.¹⁹ Patients with prosthetic valves, prosthetic joints, catheters, or intracardiac devices were also excluded from this study. None of the enrolled patients tested positive for HIV or hepatitis B.

Outcomes Measured

The primary outcome was mortality within one year of the index hospitalization. Secondary outcomes included time from hospital discharge to readmission within one year of index discharge, recurrence of IE, indications for surgical interventions, ICU admission/length of stay, and degree of metastatic infection. Readmissions were classified into 1-, 3-, 6-, and 12-month time periods. Recurrence of IE was defined as patient survival during index hospitalization and

readmission for *S. aureus* IE with the same sensitivity and resistance profile. Surgical interventions were further classified as open versus percutaneous interventions. Metastatic infections were defined as the presence of septic pulmonary emboli, splenic emboli, intracranial emboli/hemorrhage, mycotic aneurysm, vertebral osteomyelitis, or epidural abscesses. All patients were followed at our institution, and a thorough review of the electronic medical record (EMR) for readmission and mortality was conducted, with a wider review of the EMR shared by all the hospitals in the area to confirm admission/mortality at other local hospitals.

Data Collection and Statistical Analysis

Clinical characteristics and patient demographics were collected via manual chart review. Death was confirmed through electronic health records and last date of medication refills in our outpatient pharmacy database. The normal distribution of variables was assessed using the Shapiro–Wilk normality test. Continuous variables are expressed as mean values $\pm$ standard deviation (SD), and categorical variables are expressed as proportions and percentages. The differences between continuous variables were analyzed using one-way ANOVA, and the differences between categorical variables were analyzed using the chi-square or Fisher’s exact test. Statistical significance was set at $p < 0.05$. To rule out any confounding factors that might invalidate our findings, we performed multivariate analysis of the variance and correlation coefficients of the variables.

Results

Our study included 175 adult patients (aged ≥ 18 years) who met the inclusion criteria. The subjects were further categorized into MRSA IE and MSSA IE groups. Baseline characteristics and outcomes were evaluated in each group, and the results were compared.

Baseline Characteristics

Baseline characteristics of each group are presented in Table 1. The mean age of the patients was 35 years, and the sex distribution was 45.1% male and 54.9% female. All patients were confirmed to be injection drug users and 97.6% were diagnosed with hepatitis C infection. Other chronic comorbidities at the time of diagnosis included diabetes mellitus (5.1%), end-stage renal disease (ESRD) 2.6%, and liver cirrhosis (2.6%).

Table 1 Clinical Characteristics of Patients

Characteristics ^a	All (n = 175)	MRSA IE (n = 121)	MSSA IE (n = 54)
Age (years)	35 $\pm$ 14.1	35 $\pm$ 12.3	35 $\pm$ 10.2
Sex			
Male	79 (45.1%)	54 (44.6%)	25 (46.3%)
Female	96 (54.9%)	67 (55.4%)	29 (53.7%)
Medical history			
Body mass index	25.5 $\pm$ 5.67	25.2 $\pm$ 5.78	24.5 $\pm$ 5.66
Diabetes mellitus	10 (5.7%)	5 (4.1%)	3 (5.6%)
End-stage renal disease	15 (8.6%)	13 (10.7%)	2 (3.7%)
Cirrhosis	5 (2.9%)	5 (4.1%)	0 (0%)
Hepatitis C	156 (89.1%)	117 (96.7%)	39 (72.2%)

Notes: ^aVariables are expressed as n (%) or mean $\pm$ standard deviation.

Abbreviations: IE, infective endocarditis; MSSA, methicillin-sensitive *Staphylococcus aureus*; MRSA, methicillin-resistant *Staphylococcus aureus*.

Outcomes

The mortality rate within one year of diagnosis, secondary outcomes, and any surgical intervention performed are presented in Table 2. A total of 25 patients (14.3%) died during the index hospitalization, while 34 (19.4%) died within one year of index hospitalization. There was no difference between MRSA IE and MSSA IE when comparing rates of mortality, ICU admission, acute kidney injury (AKI), splenic infarct, epidural abscess, intracerebral hemorrhage (ICH), or mycotic aneurysm. The major difference between the two groups was the higher rate of septic pulmonary emboli in the MRSA IE group, which was statistically significant ($p = 0.0012$). This was supported by an increased rate of tricuspid valve vegetation in MRSA IE patients (72.7%). We did not find a difference in hospital readmission rates at the 3-, 6-, and 12-month intervals or in recurrence rates at the 1-, 3-, 6-, and 12-month intervals.

Nor did we find a statistically significant difference between MSSA and MRSA IE in the need for surgical intervention, which occurred in 45 patients (25.7%) with the largest factors leading to intervention being persistent bacteremia (35.6%) and ≥ 1 embolic event during the first two weeks of therapy (31.1%). Surgical procedures were

Table 2 Outcomes

Characteristics ^a	All (n = 175)	MRSA IE (n = 121)	MSSA IE (n = 54)	Odds Ratio	p-value
Primary outcome					
In-hospital mortality	25 (14.3%)	17 (14.0%)	8 (14.8%)	0.9808	0.9544
One-year mortality	34 (19.4%)	24 (19.8%)	10 (18.5%)	1.0887	0.839
Secondary outcome					
ICU admission	87 (49.7%)	63 (52.1%)	24 (44.4%)	1.3578	0.3523
Readmission, 3 months	26 (14.9%)	16 (13.2%)	10 (18.5%)	0.6545	0.3453
Readmission, 6 months	41 (23.4%)	29 (24.0%)	12 (22.2%)	1.0956	0.8198
Readmission, 12 months	33 (18.9%)	25 (20.7%)	8 (14.8%)	1.5032	0.3668
IE recurrence, 1 month	5 (2.9%)	1 (0.83%)	4 (7.4%)	–	0.7053
IE recurrence, 3 months	8 (4.6%)	5 (4.13%)	3 (5.6%)	–	0.6115
IE recurrence, 6 months	14 (8.0%)	9 (7.4%)	5 (9.3%)	–	0.4758
IE recurrence, 12 months	7 (4.0%)	4 (3.3%)	3 (5.6%)	–	0.5457
Clinical outcomes					
AKI	102 (58.3%)	68 (56.2%)	34 (63.0%)	0.9399	0.8937
Septic pulmonary emboli	132 (75.4%)	100 (82.6%)	32 (59.3%)	3.2738	0.0012*
Splenic infarction	23 (13.1%)	14 (11.6%)	9 (16.7%)	0.6542	0.3591
Epidural abscess	29 (16.6%)	19 (15.7%)	10 (18.5%)	0.8196	0.6439
ICH	28 (16.0%)	16 (13.2%)	12 (22.2%)	0.5333	0.1375
Mycotic aneurysm	8 (4.6%)	5 (4.1%)	3 (5.6%)	0.7328	0.6782
Surgical interventions	45 (25.7%)	35 (28.9%)	10 (18.5%)	1.7907	0.1489
Open intervention	34 (75.5%)	28 (80.0%)	6 (60.0%)	–	–
Percutaneous intervention	11 (24.4%)	7 (20.0%)	4 (40.0%)	–	–

(Continued)

Table 2 (Continued).

Characteristics ^a	All (n = 175)	MRSA IE (n = 121)	MSSA IE (n = 54)	Odds Ratio	p-value
Indication for surgery					
Large vegetation (10 mm)	7 (15.6%)	4 (11.43%)	3 (30%)	–	–
≥1 embolic event	14 (31.1%)	11 (31.4%)	3 (30%)	–	–
Valvular insufficiency	4 (8.9%)	2 (5.7%)	2 (20%)	–	–
Decompensated HF	4 (8.9%)	4 (11.43)	–	–	–
Perivalvular abscess	0	–	–	–	–
New heart block	0	–	–	–	–
Persistent bacteremia	16 (35.6%)	14 (40.0%)	2 (20%)	–	–

Notes: ^aVariables are expressed as n (%); *value is statistically significant ($p < 0.05$).

Abbreviations: AKI, acute kidney injury; HF, heart failure; ICH, intracerebral hemorrhage; ICU, intensive care unit; IE, infective endocarditis; MSSA, methicillin-sensitive *Staphylococcus aureus*; MRSA, methicillin-resistant *Staphylococcus aureus*.

further classified as open versus percutaneous interventions, with the majority being open surgical interventions (75.5%). The main reason for percutaneous intervention was a large (>10 mm) vegetation size in the setting of tricuspid valve IE.

The most common cardiac valves involved in IE due to MRSA and MSSA were the tricuspid valve (MRSA IE, 72.7%; MSSA IE, 55.6%) and the mitral valve (MRSA IE, 15.7%; MSSA IE, 22.2%), as shown in Table 3. Despite the frequency of tricuspid valve endocarditis and degree of septic pulmonary emboli, there was only one documented case of pulmonic valve endocarditis, which occurred in the MRSA subgroup. Seven cases of each group had no visible vegetation on transthoracic echocardiography but still met the Duke criteria for definite IE.

As shown in Table 4, when an ANOVA framework (analysis of variance) was used to compare variances inside the groups and between the groups for comorbidities and outcomes, hepatitis C status was found to differ significantly between MRSA versus MSSA groups ($p = 0.02$). Other than that, there was no confounding factor with any of the other variables in the study. Also, long-term readmission (12 months) differed significantly between MRSA and MSSA patients. The negative correlation suggests higher readmission is associated with the MRSA group ($p = 0.01$). In terms of complications seen, intracranial hemorrhage shows significant variation between groups, with a slight negative association with MRSA ($p = 0.02$). Figure 1 demonstrates correlation between all variables in the study.

Discussion

Our study found that overall mortality rates were similar between MRSA and MSSA IE patients using injection drugs. Despite appropriate antimicrobial therapy, the in-hospital mortality rate for all IE cases in our cohort was 14.3% with

Table 3 Valvular Involvement of *Staphylococcus aureus* IE Patients

Valve Involved	MRSA n (%)	MSSA n (%)	Odds Ratio	95% CI	z-statistic	p-value
Tricuspid	88 (72.7%)	30 (55.6%)	2.1333	1.0922–4.1668	2.218	0.0265
Pulmonic	1	0	–	–	–	–
Mitral	19 (15.7%)	12 (22.2%)	0.6520	0.2909–1.4613	1.039	0.2989
Aortic	6 (5.0%)	5 (9.3%)	0.5113	0.1490–1.7546	1.066	0.2863

Abbreviations: CI, confidence interval; MSSA, methicillin-sensitive *Staphylococcus aureus*; MRSA, methicillin-resistant *Staphylococcus aureus*.

Table 4 Variance and Correlation Coefficient for Each of the Study Variables

	Variable	Variance within Groups	Variance Between Groups	Separation	p-value	Correlation Coefficient
V2	Sex, 0=female, 1=male	0.25	0.37	1.46	0.23	−0.09
V3	Age	105.36	25.49	0.24	0.62	0.04
V4	BMI	35.58	2.62	0.07	0.79	0.02
V5	DM	0.056	0.002	0.04	0.84	−0.02
V6	ESRD	0.029	0.06	1.93	0.17	0.11
V7	Cirrhosis	0.029	0.06	1.93	0.17	0.11
V8	Hepatitis C	0.070	0.36	5.13	0.02*	0.17
V9	Temperature on arrival	4.08	9.97	2.44	0.12	0.12
V10	WBC count on arrival	59.32	18.23	0.31	0.58	−0.04
V11	AKI	0.25	0.033	0.14	0.71	−0.03
V12	Septic pulmonary emboli	0.14	0.29	2.03	0.16	0.11
V13	Mycotic aneurysm	0.045	0.10	2.20	0.14	−0.11
V14	Intracranial hemorrhage	0.15	0.84	5.56	0.02*	−0.18
V15	Epidural abscess	0.15	0.16	1.01	0.32	−0.08
V16	Splenic infarct	0.11	0.12	1.06	0.30	−0.08
V17	In-hospital mortality	0.11	0.05	0.45	0.50	−0.05
V18	One-year mortality	0.21	0.17	0.81	0.37	−0.07
V19	ICU admission	0.25	0.10	0.41	0.52	0.05
V20	ICU LOS	26.35	0.17	0.01	0.94	−0.01
V21	Readmission, 1 month	1.73	0.15	0.087	0.77	−0.02
V22	Readmission, 3 months	1.74	1.77	1.02	0.31	−0.08
V23	Readmission, 6 months	1.77	2.31	1.30	0.26	−0.09
V24	Readmission, 12 months	1.89	13.61	7.19	0.01*	−0.20
V25	TTE results	0.26	1.34	5.16	0.02*	−0.17
V26	TEE results	0.51	0.001	0.002	0.96	−0.003
V27	Tricuspid valve	0.21	0.13	0.63	0.43	0.06
V28	Pulmonic valve	0.006	0.002	0.37	0.54	0.05
V29	Mitral valve	0.15	0.38	2.54	0.11	−0.12
V30	Aortic valve	0.06	0.12	1.97	0.16	−0.11
V31	Surgery	0.14	0.29	2.03	0.16	−0.11

Notes: *Value is statistically significant ($p < 0.05$).

Abbreviations: AKI, Acute kidney injury; BMI, Body mass index; DM, Diabetes mellitus; ESRD, End-stage renal disease; LOS, Length of stay; TEE, Transesophageal echocardiogram; TTE, Transthoracic echocardiogram; WBC, white blood cells.

a one-year mortality rate of 19.4%. The main difference between the two groups was that patients with MRSA endocarditis had an increased rate of septic pulmonary emboli and an increased incidence of tricuspid valve IE. This is consistent with the known increased frequency of right-sided endocarditis associated with injection drug use (IDU), although IE is not an exclusively right-sided heart disease, as left heart and left heart valves can also be infected.²⁰ These right-sided IE patients also exhibit a larger vegetation size and are at increased risk of pulmonary thromboembolism.^{6,7} We did not observe a difference between the two groups in readmission rates, ICU admissions, recurrence of IE, or surgical interventions. Complication rates, including AKI, ICH, mycotic aneurysm, splenic infarcts, and epidural abscess, were also similar between the two groups. In addition, our study focused on IDU-associated IE while excluding healthcare-associated factors such as prosthetic valves or catheters minimizing confounding and ensuring the outcomes compared between MRSA and MSSA reflect the IDU population rather than mixed etiologies.

One possible explanation for these findings is the severity of infective endocarditis caused by *S. aureus* regardless of the methicillin resistance status. There are conflicting reports in the literature regarding the differences in outcomes and mortality rates between patients with MRSA IE and MSSA IE. Previous studies that observed an increase in mortality rate attributed it to the virulence of MRSA.^{14,15} However, other studies have been unable to define a mechanism of increased virulence beyond the antibiotic resistance for which MRSA strains are named.¹⁶ Since MSSA carries its own

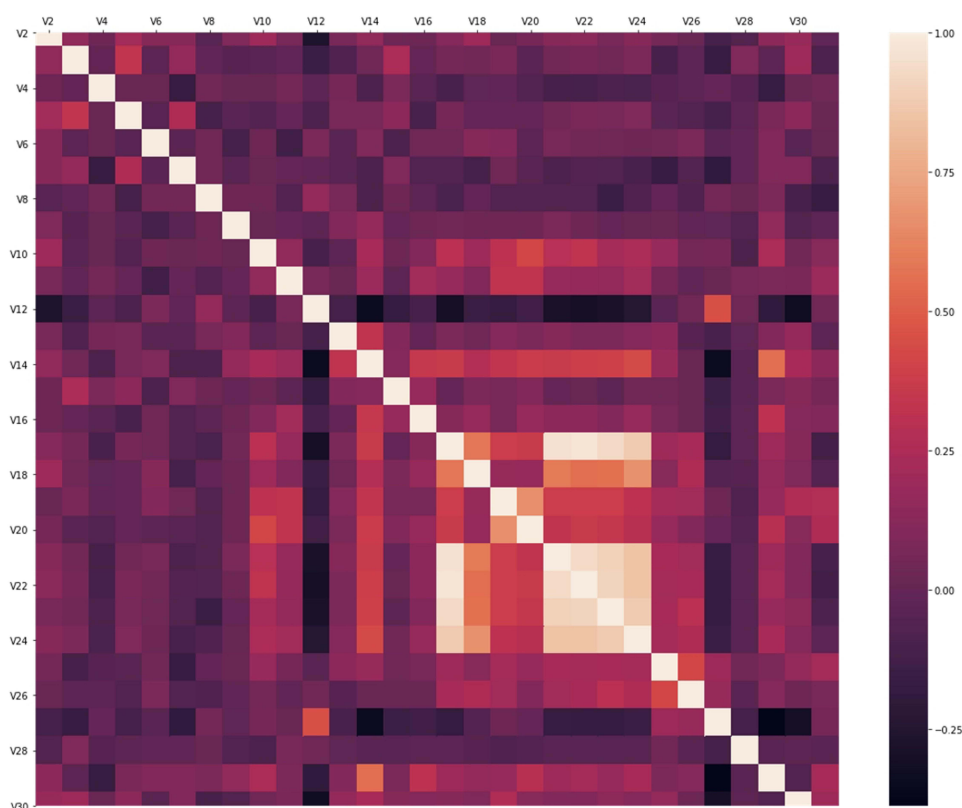


Figure 1 Heat map demonstrating correlation between all variables in the study.

virulence patterns and increased risks of inoculum effects, it would not be unreasonable to see similar mortality outcomes in the presence of adequate antimicrobial therapy.¹⁵

The findings of our study are also consistent with those of two of the largest studies that compared the mortality rates of MRSA IE and MSSA IE patients. The first study found no difference in one-year mortality between MRSA IE and MSSA IE, although it has been argued that the patient distribution in this study was disproportionate, since only 59 of the 437 patients were diagnosed with MRSA IE.¹⁶ The second study also failed to find a difference in in-hospital mortality between MRSA IE and MSSA IE, which was attributed to the overall increased mortality of IE when it was caused by *S. aureus*.¹⁷

Despite the conflicting literature comparing the mortality rate of MRSA IE versus that of MSSA IE, it is well established that the overall mortality associated with IE caused by *S. aureus* is increased.¹⁷ This increased morbidity and mortality for *S. aureus* IE is a crucial factor when considering how to treat these patients, especially as the opiate epidemic continues. With increasing restrictions on narcotic prescriptions, more people suffering from opiate addiction are turning to IDU.^{20–23} IDU is also more commonly associated with younger adults, as seen in our cohort. These younger adults typically have fewer comorbid conditions at the time of IE diagnosis, yet they carry a higher perioperative risk and lower survival rates than their non-IDU counterparts.⁸

A growing number of IDU-associated IE cases are being managed using percutaneous mechanical vegetation debulking interventions (Penumbra® and AngioVac®), as the decision to perform valvular surgery in the IDU population can be challenging, given the risk of relapse and reinfection. Percutaneous treatment options may facilitate earlier clearance of bacteremia, lower the risk of metastatic infection, and improve mortality in high-risk patients.^{24,25}

Most patients who qualified for valvular intervention at our hospital underwent open valvular replacement; however, percutaneous mechanical vegetation debulking procedures were also utilized, with outcomes similar to those of open surgical intervention.^{7,23} All patients underwent infectious disease consultation and received proper intravenous antibiotic therapy guided by microbiological data for susceptibility in accordance with the IDSA guidelines. The average duration of antibiotic therapy was approximately six weeks.

Beyond antimicrobial therapy and surgical intervention, engagement with addiction medicine services, harm reduction programs, and medication-assisted treatment has been shown to improve long-term outcomes in this population. Because these data were not systematically collected in our study, we could not evaluate their effect on readmission or recurrence. Nonetheless, acknowledging their importance is essential to fully contextualize the medical outcomes observed.

With increased rates of IDU and *S. aureus* IE, and with the young age of the affected patients, it is prudent to continue to assess the outcomes of these patients to guide best treatment practices. Further studies aimed at identifying *S. aureus* virulence factors and antibiotic treatment options may improve the management of these challenging infections.

Limitations

Our study was not without limitations. This study was retrospective, with a small sample size, which limits the power of the study and potentially allows for unmeasured confounders. This study did not capture detailed antibiotic regimens or the precise timing of surgical versus percutaneous interventions, both of which could have influenced outcomes. This was a single-center study, which can make generalization to other institutions difficult. Our facility is also a regional referral center, which carries the risk of referral bias, as these patients often have more complex presentations and are often referred for evaluation of surgical interventions not offered at other locations. Therefore, the outcomes we report may reflect the severity of illness in this referred population rather than the full spectrum of IDU-associated infective endocarditis cases. In addition, our study did not capture social determinants of health such as engagement with addiction treatment programs, socioeconomic status, or housing stability. These factors are known to play a critical role in shaping outcomes such as adherence to therapy, hospital readmission, and recurrence of infective endocarditis in people who inject drugs. The absence of these variables limits our ability to fully contextualize the outcomes observed and highlights the importance of integrating social and behavioral data into future studies of IDU-associated IE.

Conclusion

Our study affirms the overall severity and high mortality rates of *S. aureus* IE, regardless of methicillin resistance of the causative strain, in people who inject drugs. With rising prevalence, these challenging infections will continue to require aggressive intervention and treatment.

Abbreviations

AKI, Acute Kidney Injury; ANOVA, Analysis of Variance; BMI, Body Mass Index; CI, Confidence Interval; DM, Diabetes Mellitus; EMR, Electronic Medical Record; ESRD, End-Stage Renal Disease; HF, Heart Failure; HIV, Human Immunodeficiency Virus; ICH, Intracerebral Hemorrhage; ICU, Intensive Care Unit; IDSA, Infectious Diseases Society of America; IDU, Injection Drug Use; IE, Infective Endocarditis; LOS, Length of Stay; MRSA, Methicillin-Resistant *Staphylococcus aureus*; MSSA, Methicillin-Susceptible *Staphylococcus aureus*; SD, Standard Deviation; TEE, Transesophageal Echocardiogram; TTE, Transthoracic Echocardiogram; USA, United States of America; WBC, White Blood Cells.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

As this study was a retrospective chart review approved by the University of Tennessee Graduate School of Medicine Institutional Review Board (IRB), the requirement for informed consent was waived. Authors confirm adherence to all relevant guidelines and regulations (such as the Declaration of Helsinki). Patient confidentiality was strictly maintained throughout the study. All identifying information (names, medical record numbers, addresses, etc.) was removed and replaced with coded identifiers prior to data collection and analysis. Only authorized members of the research team had access to the data, which were stored in secure, password-protected, and encrypted files. Results are reported in aggregate to ensure that no individual participant can be identified. This project adheres to all applicable HIPAA regulations and IRB requirements regarding patient privacy and confidentiality. IRB#: 4762.

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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.

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Disclosure

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