Original paper

Clinical predictors of adverse outcomes in patients with infective endocarditis undergoing surgery: a retrospective analysis

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Abstract

Introduction: Infective endocarditis (IE) remains a challenging condition with high mortality despite advances in diagnostics and treatment.
Aim of the research: This study aimed to assess clinical, laboratory, and microbiological predictors of early postoperative complications in patients undergoing surgery for IE.
Material and methods: Medical records of consecutive adult patients with confirmed IE requiring cardiac surgery treated surgically between 2017 and 2018 were retrospectively analysed, including preoperative clinical profile, complications and up to 1-year mortality (based on hospital records from the outpatient clinic).
Results: The cohort (N = 31) was predominantly male (66%) with a mean age of 55 years and a high prevalence of comorbidities including hypertension, chronic kidney disease (CKD), and diabetes mellitus. *Staphylococcus aureus* was the most frequently identified pathogen. Major postoperative complications were common and included new-onset atrial fibrillation (58%), acute kidney injury (AKI), bleeding, cardiac tamponade, and conduction disturbances requiring permanent pacemaker implantation. Predictors of mortality included CKD, elevated creatinine, lower glomerular filtration rate, staphylococcal infection, and higher EuroSCORE II. AKI was significantly associated with male gender, diabetes, and elevated NT-proBNP. Bleeding and cardiac tamponade were more frequent in patients with older age, renal dysfunction, anaemia, and higher surgical risk. De novo atrial fibrillation was more common in patients with older age and pre-existing coronary artery disease. Conduction disturbances were significantly more frequent in patients with prior cardiac surgery, alcohol dependence, and structural valve complications.
Conclusions: These findings underscore the importance of identifying high-risk patients using clinical, laboratory, and echocardiographic parameters to guide perioperative management and improve outcomes in surgical IE.

Introduction

Infective endocarditis (IE) is a life-threatening infection of the endothelium of the heart, typically affecting heart valves. Its annual incidence is estimated at 3–10 cases per 100,000 individuals, with in-hospital mortality approaching 30% despite advances in diagnosis and treatment [1, 2]. Prognosis varies widely and is influenced by host characteristics, pathogen virulence, and the presence of complications. High-risk patients often present with advanced age, prosthetic valve involvement, or significant comorbidities such as chronic kidney disease (CKD), diabetes mellitus (DM), or malignancy [2, 3]. Infections caused by virulent microorganisms, including *Staphylococcus aureus*, fungi, and certain non-HACEK Gram-negative organisms are linked to worse outcomes [2, 3].

The clinical presentation of IE is heterogeneous and ranges from non-specific systemic symptoms, such as fever, malaise, and weight loss, to embolic events and organ dysfunction [2, 4, 5]. Over recent decades, IE epidemiology has shifted, with increasing incidence among older adults, intravenous drug users, patients with cardiovascular implantable electronic devices, and those with healthcare-associated infections [2, 6]. *Staphylococcus aureus* is now the most common pathogen responsible for approximately 26.6% of IE cases and is linked to poor outcomes due to its high virulence [5, 7].

Current clinical guidelines advocate for multidisciplinary management, integrating cardiologists, infectious disease specialists, anaesthesiologists, and cardiac surgeons to ensure timely diagnosis, treatment, and surgical decision-making [8, 9]. Surgery is required in 40–50% of IE cases, often due to heart failure, persistent infection, abscess, and risk of embolism [9]. However, not all patients are surgical candidates. Advanced age, frailty, and comorbidities can increase perioperative risk and impact survival [10, 11]. Despite improvement in diagnostics, antimicrobial therapy, and surgical techniques, postoperative complications remain frequent and severe [6, 9, 12]. These complications stem

from systemic infection, pre-existing organ dysfunction, and the complexity of the surgical procedures. Acute kidney injury (AKI) is among the most common, affecting up to 59% of surgical patients. Approximately 10% of those with AKI require renal replacement therapy, with a 15% in-hospital mortality rate [13]. Sepsis or septic shock affects 13–22% of patients and is associated with poor outcomes [14]. Other important complications include reoperation for bleeding (8–12%), respiratory failure requiring mechanical ventilation (6–24%), and stroke (2–11%), typically diagnosed via computed tomography or magnetic resonance imaging. Conduction disturbances are also common, often necessitating permanent pacemaker implantation (2–13%) [15]. Despite their high frequency and impact, predictors of these complications remain poorly defined, especially in surgically managed patients. Most existing data come from small or heterogeneous populations emphasizing the need for robust, centre-specific studies to clarify perioperative risks and outcomes [6, 16].

Aim of the research

This study aims to analyse clinical, laboratory, and microbiological factors related with major perioperative complications, especially bleeding, cardiac tamponade, AKI, and permanent pacemaker implantation, in patients undergoing surgery for infective endocarditis.

Material and methods

This retrospective, observational, single-centre study was conducted at the 2nd Department of Cardiology and the Department of Cardiac Surgery of the Central Clinical Hospital in Lodz – a specialist tertiary centre covering population of 2.5 million citizens. Medical histories of consecutive adult patients diagnosed with IE who underwent surgical treatment between 2017 and 2018 were analysed.

This analysis included assessment of comorbidities (arterial hypertension, history of myocardial infarction, history of heart failure, atrial fibrillation, CKD, chronic obstructive pulmonary disease, diabetes mellitus) and other risk factors such as: alcohol dependence, intravenous drug use, smoking, history of previous cardiac surgery, congenital heart defects, history of previous infective endocarditis, New York Heart Association (NYHA) functional class, and overall hemodynamic status. Transthoracic and/or transoesophageal echocardiography data were used to assess vegetations, valve involvement, and left ventricular ejection fraction (EF). Electrocardiographic findings were reviewed retrospectively. Laboratory parameters, including complete blood count, renal and liver function markers, inflammatory markers such as C-reactive protein (CRP) and procalcitonin (PCT), and cardiac biomarkers such as N-terminal pro–B-type natriuretic peptide (NT-proBNP) and troponin, as well as above-mentioned clinical data (including body temperature, blood pressure and heart rate) were recorded at the time of admission to the hospital, before transfer for cardiac surgery. The diagnosis of IE was established according to the European Society of Cardiology (ESC) guidelines in effect at the time of patient inclusion. Decisions regarding surgical intervention were made by a multidisciplinary Heart Team, comprising the attending cardiologist, echocardiography specialist, interventional cardiologist, and cardiac surgeon. Microbiological evaluation was based on blood cultures obtained prior to the initiation of antibiotic therapy. Identified pathogens were categorized as staphylococci, streptococci, or enterococci. Cases with no identifiable organism were classified as culture-negative endocarditis.

Intraoperative and early postoperative data were collected, including the requirement for transfusion of red blood cells or platelets, and the occurrence of complications such as bleeding, cardiac tamponade, AKI, de novo atrial fibrillation (AF), and the need for permanent pacemaker implantation or reoperation. Bleeding was defined as requiring surgical intervention or transfusion of two or more units of red blood cells. AKI was defined according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria. Cardiac tamponade was confirmed by echocardiographic evidence of pericardial effusion with hemodynamic compromise, requiring surgical drainage. De novo AF was defined as new-onset atrial fibrillation occurring during hospitalization. The indication for permanent pacemaker implantation was based on standard electrophysiological criteria, including advanced atrioventricular block or symptomatic bradyarrhythmias. Reoperation was defined as the need for an additional cardiac surgical procedure during the same hospitalization. Patients were followed for up to one year after discharge to assess the incidence of death, recurrence of infective endocarditis, cardiac surgery due to recurrent infective endocarditis, and the timing of any post-discharge cardiac surgery.

This study was conducted in accordance with the principles of the Declaration of Helsinki (1989). As a retrospective observational study using anonymized patient data, it did not require informed consent.

Statistical analysis

Statistical analyses were conducted using PQStat v.1.8.6. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on distribution, and compared using Student's *t*-test or Mann–Whitney *U* test, as appropriate. Categorical variables were presented as frequencies and percentages and compared using the χ^2 test or Fisher's exact test. A two-sided *p*-value of less than 0.05 was considered statistically significant.

Results

Thirty-one consecutive adults with definite IE constituted the study cohort. The mean age was 55 years and two-thirds of the patients were male. Arterial hypertension (52%), established cardiovascular disease (CAD) (39%), congenital structural heart disease (including bicuspid aortic valve, ventricular septal defect, patent foramen ovale) (42%), CKD (35%), current or former smoking (35%) and DM (29%) were the most prevalent comorbidities. A history of intravenous drug use or previous IE was uncommon but recognised in a small subset of patients, both constituting major predisposing factors for the IE episode. Staphylococcal species represented the dominant microbiological aetiology, followed by enterococci and streptococci; nevertheless, blood cultures remained negative in > 30% of cases. Two-thirds of patients presented febrile (> 38°C) and the median symptom-to-admission interval was about 3 weeks. Most patients were haemodynamically compensated but functionally limited, with the large majority classified as NYHA class III on admission. A new cardiac murmur was documented in approximately three quarters. Electrocardiography revealed sinus rhythm in the vast majority. Inflammatory (CRP, procalcitonin) and cardiac injury/strain biomarkers (high-sensitivity troponin T, NT-proBNP) were markedly elevated. IE most frequently affected native aortic valves (~40%), followed by native mitral valves and combined aorto-mitral disease; tricuspid and prosthetic-valve infections were less common. Echocardiography demonstrated large vegetations (> 10 mm) in the vast majority of cases, and severe valvular regurgitation was likewise frequent. Peripheral embolism, AKI and new or worsening congestive heart failure each complicated approximately one third of episodes. Among patients with peripheral embolism, 30% (3/10) had neurological embolic events. Structural valvular destruction, especially perforation or aneurysm, was common, whereas peri-valvular extension (abscess, pseudo-aneurysm or fistula) occurred in a smaller but clinically significant proportion. High-grade atrioventricular block, although infrequent, represented an important conduction disturbance directly attributable to the infection.

Post-operative outcomes in patients undergoing surgery for IErevealed a high burden of complications (Table 1). Arrhythmias were especially prominent, with new-onset AF emerging as the most frequent, affecting over half of patients. Conduction disturbances requiring temporary or permanent pacemaker implantation were also significant, underscoring the vulnerability of the cardiac conduction system in this population. Bleeding and fluid-related complications, including AKI and pleural effusion, were common and contributed to prolonged recovery. A considerable proportion of patients required reoperation for cardiac tamponade, indicating the complexity of surgical management and postoperative haemodynamics. Neurological and neuropsychiatric complications, although less frequent, were clinically significant and included stroke and transient mental disturbances. In-hospital mortality approached 16.13%, aligning with the high-risk profile indicated by a median EuroSCORE II of 7.1% (Table 1).

Predictors of mortality and complications

In our cohort, 5 (16.1%) patients died during hospitalization. Several factors were significantly more frequent in the group of deceased patients (Table 2). CKD was present in 80% of the deceased patients compared to 26.9% of survivors ($p = 0.044$). This was accompanied by markedly higher creatinine levels (209.0 vs. 76.5 µmol/l, $p = 0.026$) and significantly lower glomerular filtration rates (GFR) (25.0 vs. 75.9 ml/min/1.73 m^2, $p = 0.016$). Staphylococcal infection was also significantly more frequent among patients who died (80.0% vs. 26.9%, $p = 0.044$). The average EuroSCORE II, which estimates surgical risk, was significantly higher in non-survivors (25.7 vs. 6.9, $p = 0.026$), indicating a greater burden of comorbidities and operative risk. Additional factors more frequently observed in deceased patients included undergoing only vegetation removal without valve replacement and postoperative complications such as bleeding, cardiac tamponade, and the need for reoperation. These features reflect both the severity of the disease and the complexity of surgical management in these cases. Other variables, including age, sex, body mass index (BMI), inflammatory markers (such as CRP and procalcitonin), and the type of affected valve, did not show statistically significant differences between survivors and non-survivors.

Despite the limited number of patients, several clinically plausible and statistically significant associations were identified between specific complications and patient characteristics in the cohort with IE. AKI, both preoperatively and postoperatively, was significantly more common in male patients (preoperative: 66.7% vs. 15.8%, $p = 0.007$; postoperative: 66.7% vs. 11.1%, $p = 0.0041$). Additionally, type 2 diabetes mellitus was more prevalent among those who developed postoperative AKI (50.0% vs. 11.1%, $p = 0.0342$). Patients with AKI had significantly higher levels of NT-proBNP both before (19,016 pg/ml vs. 1,776 pg/ml, $p = 0.0111$) and after surgery (19,016 pg/ml vs. 1,785 pg/ml, $p = 0.0165$), suggesting that cardiac strain may contribute to the development of renal complications. Postoperative bleeding complications were more frequent in patients with older age (68.0 vs. 53.0 years, $p = 0.0041$), impaired renal function (creatinine: 126.0 vs. 75.2 µmol/l, $p = 0.0481$; GFR: 49.9 vs. 99.7 ml/min/1.73 m^2, $p = 0.0076$), and elevated NT-proBNP (20,762 pg/ml vs. 1,717 pg/ml, $p = 0.0067$). The EUROSCORE II was also significantly higher in this group (16.9% vs.

Table 1. Baseline characteristics of the study group

Patients' characteristics	Results
Age [years], mean ± SD	55.48 ±17.21
Gender (male) *n* (%)	21 (67.74)
Body-mass index (BMI), mean ± SD	25.24 ±4.48
Hypertension, *n* (%)	16 (51.61)
Coronary artery disease (CAD), *n* (%)	12 (38.71)
History of myocardial infarction (MI), *n* (%)	4 (12.90)
Heart failure with reduced ejection fraction (HFrEF), *n* (%)	3 (9.68)
Atrial fibrillation (AF), *n* (%)	5 (16.13)
Chronic kidney disease (CKD), *n* (%)	11 (35.48)
Chronic obstructive pulmonary disease (COPD), *n* (%)	5 (16.13)
Diabetes mellitus (DM), *n* (%)	9 (29.03)
Alcohol dependence, *n* (%)	4 (12.90)
Drug use1, *n* (%)	3 (9.68)
Smoking, *n* (%)	11 (35.48)
History of cardiac surgery, *n* (%)	7 (22.58)
Congenital heart defect, *n* (%)	13 (41.94)
History of infective endocarditis (IE), *n* (%)	2 (6.45)
Infective endocarditis	
Aetiology – blood cultures, *n* (%)	
Staphylococcus (total)	11 (35.48)
Methicillin-sensitive *Staphylococcus aureus*	5 (16.13)
Methicillin-resistant *Staphylococcus aureus*	4 (12.90)
Streptococcus	2 (6.45)
Enterococcus (*e.g., E. faecalis*)	6 (19.35)
Negative cultures	11 (35.48)
Fever > 38°C, *n* (%)	21 (67.74)
Duration of symptoms before admission to hospital, median (IQR)	20 (11–26.5)
NYHA functional class at admission, *n* (%)	
Class I	0 (0)
Class II	8 (25.81)
Class III	20 (64.52)
Class IV	3 (9.68)
New heart murmur, , *n* (%)	23 (74.19)
ECG findings, *n* (%):	
Sinus rhythm	27 (87.09)
Atrial fibrillation/flutter	3 (9.68)
Pacemaker rhythm	1 (3.22)
C-reactive protein (CRP) [mg/l] median (IQR)	72.8 (35.75–107.65)
Procalcitonin (PCT) [ng/ml] median (IQR)	0.28 (0.12–0.495)
NT-proBNP [pg/ml] [< 125 N], mean ±SD	12732.39 ±13329.15

Table 1. Cont.

Patients' characteristics	Results
Troponin T [ng/l] median (IQR)	33.0 (17.5–67.0)
Involved valve (native), *n* (%)	
Aortic	12 (38.71)
Mitral	7 (22.58)
Tricuspid	4 (12.90)
Aortic + Mitral	5 (16.13)
Prosthetic valve	5 (16.13)
Infective endocarditis complications, *n* (%)	
Peripheral embolism	10 (32.26)
Atrioventricular (A-V) block	6 (19.35)
Acute kidney injury (AKI)	12 (38.71)
Congestive heart failure (CHD)	11 (35.48)
Cariogenic or septic shock	2 (6.45)
Vegetation > 10 mm	28 (90.32)
Perivalvular abscess/pseudoaneurysm/fistula	4 (12.90)
Valve perforation/aneurysm	13 (41.94)
New paravalvular leak in the prosthetic valve	2 (6.45)
Severe regurgitation (affected valve)	24 (77.42)
Post-operative IE complications, *n* (%)	
Cerebrovascular accident (CVA)/stroke/transient ischemic attack (TIA)	1 (3.23)
Temporary mental disorders/hallucinations	7 (22.58)
New-onset atrial fibrillation (AF)	18 (58.06)
Temporary complete A-V block (3rd degree)	4 (12.90)
Need for pacemaker (PM)	9 (29.03)
Permanent A-V block (3rd degree)	2 (6.45)
Permanent PM implantation	2 (6.45)
Postoperative bleeding	15 (48.39)
Cardiac tamponade	7 (22.58)
Reoperation due to tamponade during hospitalization	8 (25.81)
Acute kidney injury (AKI)	12 (38.71)
Pleural effusion	12 (38.71)
Sternal wound infection	1 (3.23)
Sudden cardiac arrest	5 (12.90)
Asystole	1 (20)
Ventricular fibrillation (VF)	4 (80)
In-hospital mortality, *n* (%)	5 (16.13%)
Total length of hospital stay [days], mean ± SD	43.06 ±16.79
EuroSCORE II [%], median (IQR)	7.1% (4.7–19.4)
Long-term observation, *n* (%)	
Mortality within 1 year	1 (3.23%)
Recurrence of infective endocarditis	3 (9.68%)

[1]*Aamphetamine, heroin, novel psychoactive substances (including iv use).*

Table 2. The comparison of the group of patients who survived with those who died during hospitalization

Variable	Patients who survived (*N* = 26)	Patients who deceased (*N* = 5)	*P*-value
Age [years] median (IQR)[M]	59.5 (39.5–66.8)	73.0 (59.0–77.0)	0.112
Gender (male), *n* (%)[F]	15 (65.38)	3 (60.00)	0.845
Overweight/obesity, *n* (%)[F]	11 (42.3)	3 (60.0)	0.636
Arterial hypertension, *n* (%)[F]	12 (46.2)	4 (80.0)	0.333
Coronary artery disease (CAD), *n* (%)[F]	9 (34.6)	3 (60.0)	0.341
History of myocardial infarction (MI), *n* (%)[F]	2 (7.7)	2 (40.0)	0.112
HFrEF (EF < 40%), *n* (%)[F]	2 (7.7)	1 (20.0)	0.431
Atrial fibrillation on admission (AF), *n* (%)[F]	3 (11.5)	0 (0.0)	1.000
Chronic kidney disease (CKD) on admission, *n* (%)[F]	7 (26.9)	4 (80.0)	**0.044**
Chronic obstructive pulmonary disease (COPD), *n* (%)[F]	3 (11.5)	2 (40.0)	0.173
Type 2 diabetes mellitus (DM), *n* (%)[F]	7 (26.9)	2 (40.0)	0.589
Congenital heart disease (CHD), *n* (%)[F]	11 (42.3)	2 (40.0)	0.949
Fever on admission, *n* (%)[F]	18 (69.2)	3 (60.0)	0.704
NYHA, *n* (%)[F]:			
II	7 (26.9)	1 (20.0)	0.813
III	17 (65.4)	3 (60.0)	0.821
IV	2 (7.7)	1 (20.0)	0.482
Staphylococcus spp., *n* (%)[F]	7 (26.9)	4 (80.0)	**0.044**
Streptococcus MSSA/ MRSA, *n* (%)[F]	5 (19.2)	4 (80.0)	**0.017**
Enterococcus, *n* (%)[F]	5 (19.2)	1 (20.0)	0.928
Negative culture, *n* (%)[F]	11 (42.3)	0	0.080
Creatinine [µmol/l], (IQR)[M]	76.5 (70.6–134.1)	209.0 (111.0–254.5)	**0.026**
GFR [ml/min/1.73 m^2], (IQR)[M]	75.9 (53.4–105.9)	25.0 (19.1–47.0)	**0.016**
CRP [mg/l], (IQR)[M]	65.9 (35.4–100.8)	95.0 (72.0–118.0)	0.480
PCT [ng/ml], (IQR)[M]	0.28 (0.12–0.49)	0.12 (0.06–3.40)	0.856
NT-proBNP [pg/ml], (IQR)[M]	4047.0 (1436.0–22550.0	17270.0 (12281.0–21407.0)	0.404
Troponin [ng/], (IQR)[M]	29.5 (17.2–48.2)	165.0 (24.0–829.0)	0.144
EUROSCORE II [%] (IQR)[F]	6.9 (4.4–12.5)	25.7 (24.2–26.6)	**0.003**
Affected valve: aortal, *n* (%)[F]	10 (35.8)	2 (40.0)	0.939
Affected valve: mitral, *n* (%)[F]	5 (19.2)	2 (40.0)	0.374
Affected valve: tricuspid, *n* (%)[F]	4 (15.4)	0 (0)	0.475
Affected valve: artificial, *n* (%)[F]	5 (19.2)	0	0.387
EF [%], median (IQR)	53.5 (45.8–60.0)	53.0 (52.0–62.0)	0.808
Vegetation >10 mm, *n* (%)[F]	23 (88.5)	5 (100.0)	0.578
Abscess/pseudoaneurysm/fistula, *n* (%)[F]	4 (15.4)	0 (0.0)	0.379
Perforation of the valve or aneurysm, *n* (%)[F]	10 (38.5)	3 (60.0)	0.396
New paravalvular leak in the prosthesis, *n* (%)[F]	2 (7.7)	0 (0.0)	0.570
Severe regurgitation (affected valve), *n* (%)[F]	21 (80.8)	3 (60.0)	0.335
Hemodynamically significant stenosis on coronary angiography, *n* (%)[F]	3 (11.5)	2 (40.0)	0.129

Table 2. Cont.

Variable	Patients who survived (*N* = 26)	Patients who deceased (*N* = 5)	*P*-value
Peripheral embolism, *n* (%)[F]	7 (26.9)	3 (60.0)	0.203
Vegetation removal only, *n* (%)[F]	0 (0.0)	1 (20.0)	**0.028**
Valve repair + leaflet perforation closure, *n* (%)[F]	1 (3.8)	0 (0.0)	0.7257
Biological valve implantation, *n* (%)[F]	12 (46.2)	2 (40.0)	0.8275
Mechanical valve implantation, *n* (%)[F]	13 (50.0)	2 (40.0)	0.7098
Congestive heart failure (CHD), *n* (%)[F]	9 (34.6)	2 (40.0)	0.821
Cardiogenic or septic shock, *n* (%)[F]	1 (3.8)	1 (20.0)	0.323
Postoperative bleeding, *n* (%)[F]	10 (38.5)	5 (100.0)	**0.014**
Cardiac tamponade, *n* (%)[F]	3 (11.5)	4 (80.0)	**0.0051**
Reoperation during hospitalization due to tamponade, *n* (%)[F]	3 (11.5)	5 (100.0)	**0.0001**
Post-surgery acute kidney injury (AKI), *n* (%)[F]	10 (38.5)	2 (40.0)	1.000
De novo atrial fibrillation after surgery, *n* (%)[F]	15 (57.7)	(60.0)	1.000

[F]Fisher's exact test; [M]Mann–Whitney U test.

6.2%, $p = 0.0128$), indicating that patients at greater operative risk were more likely to experience bleeding. Cardiac tamponade was observed more frequently in patients with reduced renal function (GFR: 35.0 vs. 75.9 ml/min/1.73 m², $p = 0.0378$), higher NT-proBNP levels (21,407 vs. 2,471 pg/ml, $p = 0.0312$), lower haemoglobin concentrations (9.4 vs. 10.6 g/dl, $p = 0.0232$), and higher EUROSCORE II (24.2% vs. 6.6%, $p = 0.017$). This pattern suggests that tamponade may be more likely in patients with significant preoperative decompensation and fluid retention, consistent with known clinical risk factors. The development of de novo atrial fibrillation (AF) following surgery was significantly more common among patients with older age (66.5 vs. 44.0 years, $p = 0.0009$) and the presence of coronary artery disease (61.1% vs. 7.7%, $p = 0.0034$). Interestingly, CRP levels were lower in patients who developed de novo AF (47.2 vs. 100.0 mg/l, $p = 0.0291$). The higher EuroSCORE II in this group (11.8% vs. 5.7%, $p = 0.0225$) underscores the relationship between surgical risk and postoperative arrhythmias. Permanent third-degree atrioventricular (A-V) block was significantly more frequent among alcohol dependent patients (100.0% vs. 6.9%, $p = 0.0129$), those with prior cardiac surgery (100.0% vs. 17.2%, $p = 0.0452$), and the presence of a new paravalvular leak (100.0% vs. 0.0%, $p = 0.0022$).

Bacterial aetiology and clinical outcomes

Among the bacterial pathogens identified in patients with IE, only *Staphylococcus aureus* (including MSSA and MRSA) showed a statistically significant association with clinical outcomes. Specifically, *S. aureus* infection was significantly related to in-hospital mortality ($p = 0.017$). No other statistically significant associations were observed between specific pathogens (*S. aureus*, *Streptococcus* spp., or *Enterococcus faecalis*) and complications such as AKI, peripheral embolism, congestive heart failure, shock, cardiac tamponade, or postoperative conduction disturbances. Although numerically more frequent in some groups, the difference in AKI and cardiac tamponade did not reach statistical significance.

Discussion

This study provides an evaluation of the clinical presentation, complications, and outcomes of patients with definite IE, highlighting the significant burden of comorbidities, the complexity of management, and the high rate of postoperative and in-hospital complications. These findings highlight the need for vigilant post-operative monitoring and multidisciplinary care to manage the diverse and serious complications following endocarditis surgery. The characteristics of our study population, particularly the high prevalence of cardiovascular risk factors such as arterial hypertension, CAD, and CKD, are consistent with findings from other published cohorts of patients with IE. For example, a Portuguese surgical cohort reported a similar demographic profile, marked by a predominance of male patients and a high prevalence of comorbid conditions such as hypertension and CKD, both of which were independently associated with increased in-hospital mortality (reported at 13.1%) [17]. Despite advances in antimicrobial therapy and surgical techniques over the past decades, in-hospital mortality among patients undergoing surgery for IE remains consistently elevated, ranging from 15% to

20% in various international studies. The mortality rate observed in our cohort (16.1%) is within this range and underlines the severity of illness and high-risk nature of these surgical interventions [18, 19]. *Staphylococcus aureus* was the most frequently isolated pathogen in our cohort, aligning with previous studies that have documented the high prevalence of *S. aureus* in IE and its strong association with adverse clinical outcomes and higher in-hospital mortality [17, 20]. It is a well-known cause of severe complications due to its aggressive nature, including rapid valve destruction, abscess formation, and systemic embolization. Blood culture-negative IE accounted for over 30% of cases in our study, a figure consistent with previous surgical cohorts in which culture negativity was reported in up to one-third of patients. This subgroup is known to be associated with diagnostic challenges and worse early outcomes, including a significantly higher early mortality rate (14.9% vs. 10.2% in culture-positive cases) [21]. Most patients in our cohort presented with features indicative of advanced disease. A majority were in NYHA functional class III, with echocardiographic findings demonstrating large vegetations (> 10 mm), severe valvular regurgitation, and structural damage. These clinical and imaging features are well-established indicators for surgical intervention and have been consistently associated with increased risk of systemic embolization, hemodynamic deterioration, and adverse outcomes. International guidelines and published surgical cohorts emphasize the importance of the vegetation size and degree of cardiac dysfunction in guiding clinical decision-making and predicting prognosis [22].

The overall complication burden observed in our study was considerable and reflects the clinical complexity commonly encountered in IE surgical populations. Perioperative complications included new-onset atrial fibrillation in over 50% of patients, as well as AKI, significant bleeding, pericardial tamponade, and disturbances in the cardiac conduction system. These findings are consistent with those reported in previous clinical cohorts of IE patients undergoing surgery and are indicative of the profound physiological stress and tissue damage characteristic of the disease and its treatment [17, 20]. In particular, our data demonstrate a high incidence of postoperative complications, including tamponade (25%) and arrhythmias (58%), which are frequently observed in the context of surgical intervention for unstable IE. The elevated incidence of renal complications, including both pre-existing CKD and postoperative AKI, reflects the complex interplay between impaired renal reserve, systemic inflammation, and hemodynamic instability. CKD impairs immune competence, predisposes to volume overload, and amplifies inflammatory responses, thereby increasing perioperative vulnerability. This relationship is supported by large-scale observational studies, where preoperative CKD was a strong independent predictor of both early and 1-year mortality following IE surgery [23]. The prolonged hospital stay likely reflects illness severity and frequent complications, underscoring the need for close postoperative monitoring and multidisciplinary care. An intermediate-to-high median EuroSCORE II highlighted the elevated operative risk in this cohort, with significantly higher scores in patients who developed postoperative bleeding. This aligns with existing evidence linking higher surgical risk, frailty, renal dysfunction, and hemodynamic instability to bleeding complications.

Our findings also demonstrated a significant burden of rhythm disturbances. New-onset atrial fibrillation was observed in over 50% of patients, a rate comparable to that seen in other cardiac surgical cohorts. Advanced age and underlying CAD are known contributors to atrial fibrillation in this patient population. Moreover, the need for permanent pacemaker implantation in our cohort was more frequent with prior cardiac surgery, alcohol dependence, and the presence of new paravalvular leaks. These observations suggest underlying structural fragility of the conduction system and potential iatrogenic injury during surgical repair. This is consistent with prior reports identifying postoperative conduction disturbances as a consequence of local valve destruction, surgical trauma, or infection-related damage to the atrioventricular node or bundle branches [17, 24]. Postoperative conduction disturbances and the subsequent requirement for pacemaker placement have been linked to structural and clinical factors including paravalvular leaks, previous surgical interventions, and substance-related tissue fragility. These findings are in alignment with previously published data that describe iatrogenic and infection-related injury to the conduction apparatus in patients undergoing IE surgery [17].

Elevated levels of NT-proBNP both before and after surgery were observed in our cohort and correlated strongly with the development of AKI and postoperative bleeding. While NT-proBNP has not been widely studied in surgical IE cohorts specifically, it is recognized in broader cardiac surgery populations as a marker of myocardial strain and neurohormonal activation. Pathophysiological mechanisms linking elevated NT-proBNP to renal injury include increased myocardial wall stress, impaired forward flow, endothelial dysfunction, and heightened inflammatory signalling, all of which are amplified in the context of systemic infection and cardiopulmonary bypass [25].

Endothelial dysfunction, a common pathophysiological thread in aging, CKD, and sepsis, seems to contribute to both increased susceptibility to IE and adverse outcomes following surgery. The virulence of *S. aureus*, particularly its capacity for biofilm formation

and immune evasion, further exacerbates local tissue destruction and systemic embolic events, offering a biologically plausible explanation for its consistent association with poor prognosis [17, 26]. In our cohort, *S. aureus* was the only pathogen significantly associated with in-hospital mortality. The absence of significant associations for other organisms is likely attributable to sample size limitations rather than an absence of pathogenicity. Other significant predictors of mortality included pre-existing CKD, reduced glomerular filtration rate (GFR), elevated serum creatinine, and higher EuroSCORE II values. These variables are consistent with findings from large multicentre analyses. For example, Jussli-Melchers *et al.* identified chronic dialysis dependence, NYHA class IV, prosthetic valve endocarditis, and cardiogenic shock as strong predictors of 30-day mortality in surgical IE populations [26]. Risk stratification tools such as EuroSCORE II remain useful for estimating perioperative mortality. However, IE-specific prognostic models may provide superior discriminatory power by incorporating infection-related variables such as microbiological virulence and host immune competence [27]. In our cohort, complications such as pre- and postoperative sepsis, pericardial tamponade, atrial fibrillation, need for renal replacement therapy, and postoperative severe valvular regurgitation were all associated with increased mortality risk. These findings are supported by observational studies that have established the prognostic significance of such complications in surgical IE [17]. Moreover, the presence of vegetations larger than 10 mm, intracardiac abscesses, pseudoaneurysms, and fistulas has been consistently linked to adverse outcomes and poorer prognosis [28, 29]. The simultaneous occurrence of severe valve regurgitation and cardiogenic shock appears particularly deleterious and is associated with significantly higher 30-day mortality in available literature [17].

Long-term mortality following surgical treatment of IE remains considerable [30]. Contemporary data indicate a 5-year survival rate of approximately 82% among IE patients undergoing surgery and even higher in those receiving medical therapy [31]. However, this figure drops significantly in left-sided *S. aureus* IE, where reported 5-year survival rates range from 45% to 57% [32]. Major predictors of long-term mortality include age greater than 55 years, congestive heart failure, pre- and postoperative sepsis, delayed surgical intervention, residual valve dysfunction and renal complications.

From a practical perspective, our findings may help improve perioperative risk stratification in patients undergoing surgery for infective endocarditis. In particular, the coexistence of CKD, impaired renal function, elevated NT-proBNP, *Staphylococcus aureus* infection, and a higher EuroSCORE II may identify patients who require closer postoperative surveillance. Such patients may benefit from early nephrology consultation, strict haemodynamic and fluid balance monitoring (i.e. using bioimpedance based ECG monitors), continuous rhythm surveillance, and closer echocardiographic follow-up for major complications. Although these findings should be interpreted with caution because of the small sample size, they suggest that readily available preoperative variables may help anticipate postoperative risk and support multidisciplinary management.

Our single-centre, retrospective analysis is limited by a small sample size (n = 31) and low event rate, which restricts generalizability and has likely contributed to the absence of significant associations due to reduced statistical power. Although comparison with larger multicentre cohorts and meta-analyses offsets some of these limitations, residual confounding and institution-specific biases remain possible. Additionally, evolving antimicrobial and surgical practices over time could influence outcomes.

Conclusions

IE remains a high-risk condition with substantial perioperative and long-term mortality, driven by comorbidities such as CKD, *S. aureus* infection, and structural cardiac complications. Based on our findings, the most important factors affecting mortality include impaired renal function, *S. aureus* infection, elevated EuroSCORE II indicating higher operative risk, absence of valve replacement during surgery, and the occurrence of major postoperative complications such as bleeding, cardiac tamponade, and the need for reoperation. Our findings emphasize the importance of early surgical consideration, infection-specific therapy, and cautious renal and postoperative management. Integrating both host-related and pathogen-related risk factors into clinical decision-making is essential to improving outcomes in surgical IE patients.

Clinical implications

The findings from this study offer several actionable insights for the clinical management of IE:

– early, aggressive management – prompt identification of high-risk features (e.g. *S. aureus*, large vegetations, abscess) and early surgical intervention are crucial.
– kidney function monitoring – given the significant mortality impact of CKD and AKI, nephrology involvement and optimized fluid/antibiotic management should be integrated early.
– tailored follow-up – high-risk subgroups, such as those with renal disease or complex prostheses warrant prolonged post-discharge surveillance.
– pathogen-specific strategies – the aggressive nature of *S. aureus* IE supports immediate, targeted antimicrobial therapy and early surgical consultation.

– structural and conduction system complications – patients at risk for structural damage, such as paravalvular leaks or conduction system involvement, may benefit from preoperative imaging and postoperative rhythm monitoring.

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Conflict of interest

The authors declare no conflict of interest.

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