

Mortality and Clinical Outcomes in Infective Endocarditis According To Management Strategy: From Conventional Treatment To Structural Intervention

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Abstract

Background: Infective endocarditis (IE) is a heterogeneous and potentially fatal cardiovascular infection in which treatment decisions depend on infection control, valve or structural damage, hemodynamic consequences, embolic risk, and operative or interventional feasibility.

Objective: To compare mortality and major clinical outcomes among patients with IE managed medically, surgically, or by transcatheter intervention, and to compare major clinical and echocardiographic outcomes across the management groups.

Methods: This prospective, single-center analytical cohort included patients with possible or definitive IE presenting to Cairo University Hospitals between May 2023 and February 2025. Patients were classified according to the management strategy ultimately received: medical management (Group 1), surgical management (Group 2), or transcatheter intervention management (Group 3). The transcatheter intervention pathway was reserved for selected patients with an IE-related hemodynamically significant lesion considered suitable for percutaneous correction, together with high surgical risk or refusal of surgery, and without an urgent or emergent surgical indication. Clinical, echocardiographic, anatomical, and outcome data were compared across the three groups.

Results: The final cohort comprised 120 patients: 62 managed medically, 38 surgically, and 20 by transcatheter intervention. Mortality was 0%, 55.3%, and 10.0%, respectively ($P < 0.001$). Heart failure occurred in 46.8%, 52.6%, and 65.0% ($P = 0.362$), major embolization in 30.6%, 21.1%, and 55.0% ($P = 0.030$), and acute kidney injury in 32.3%, 34.2%, and 45.0% ($P = 0.579$). Important differences were also observed in atrial fibrillation, previous IE, prosthetic-valve IE, intravenous drug use, right-sided IE, and tricuspid involvement.

Conclusion: Mortality and clinical phenotype differed substantially among the three management groups. The observed mortality gradient should not be interpreted as evidence of treatment superiority because treatment allocation was clinically determined and the groups differed markedly in baseline characteristics. The findings support individualized multidisciplinary management and provide hypotheses for larger studies with more robust adjustment for baseline risk.

Keywords: Infective Endocarditis, Mortality, Cardiac Surgery, Management Strategy, Transcatheter Intervention, Prosthetic-Valve Endocarditis, Intravenous Drug Use.

Introduction

Infective endocarditis is a heterogeneous cardiovascular infection that continues to carry substantial morbidity and mortality. Its contemporary clinical profile has changed with population aging, increasing comorbidity, prosthetic material, health-care exposure, and the persistent importance of *Staphylococcus aureus*. A 2025 systematic review and meta-analysis of 133 studies involving 132,584 patients demonstrated considerable short-term mortality and marked heterogeneity in the presentation and microbiology of modern IE [1-3]. Management of IE now relies on coordinated decisions about antimicrobial treatment, multimodality imaging, embolic risk, and the timing and feasibility of intervention. The 2023 European Society of Cardiology (ESC) guideline places the Endocarditis Team at the center of this process and identifies heart failure, uncontrolled infection, and prevention of embolic complications as major determinants of surgical decision-making [4]. Surgery remains an essential component of treatment when established indications are present. At the same time, patients who undergo surgery often have a more severe clinical profile than those treated conservatively. A 2024 meta-analysis of patients with a formal surgical indication found lower mortality among surgically treated patients, while also illustrating why crude comparisons between treatment groups can be misleading when baseline risk differs substantially [5-6]. Transcatheter treatment,

including Transcatheter Aortic valve replacement in the center, has become an additional option for carefully selected patients, particularly in healed IE cases when conventional surgery is considered high risk or unsuitable [7]. Therefore, we conducted the present study to compare patients with IE managed medically, surgically, or via a transcatheter strategy. We examined differences in clinical phenotype, echocardiographic findings, microbiology, major complications, and mortality. We explored factors associated with death while taking into account the non-random nature of treatment selection and the limited number of outcome events.

Methods

Study design and setting

This was a prospective, single-center analytical cohort study conducted at Cairo University Hospitals from May 2023 to February 2025. Patients presenting during the study period with possible or definitive infective endocarditis were considered for inclusion. The study protocol was approved by the relevant research ethics committees of Kasr Al Ainy and Cairo University. Verbal consent was obtained from participants, and written consent was obtained for enrolment in the IE database, the agreed management strategy, and the relevant procedure. Information was provided by the investigator in language and at a level of complexity understandable to the participant before consent was obtained.

Study population and management groups

Patients of either sex or any age with possible or definitive IE were eligible for consideration. For the present analysis, patients were categorized according to the management strategy received: medical management (Group 1, n=62), surgical management (Group 2, n=38), or transcatheter intervention (Group 3, n=20). The transcatheter intervention group represented patients enrolled in the planned intervention pathway. This pathway was considered for patients with an IE-related hemodynamically significant lesion requiring intervention, when the lesion was judged technically suitable for percutaneous correction by the structural heart intervention team and the patient had either a Society of Thoracic Surgeons (STS)-estimated combined morbidity and mortality risk greater than 8% or declined surgery. Patients managed outside this pathway constituted the conventional group and were subsequently classified according to whether their definitive management was medical or surgical.

Eligibility and exclusion criteria

IE was diagnosed according to the 2023 Duke-ISCVID criteria and contemporary ESC recommendations. The 2023 Duke-ISCVID framework has subsequently undergone external and clinical validation, supporting its use for contemporary IE classification. [4] Eligibility for the planned transcatheter intervention pathway required an IE-related hemodynamically significant lesion, such as severe valvular regurgitation, perforation, peri-annular complications, or selected congenital lesions requiring intervention, together with technical feasibility for percutaneous correction and high surgical risk or refusal of surgery. Patients were not included in the planned transcatheter intervention pathway if they indicated urgent or emergent surgery, if the lesion was considered unsuitable for transcatheter intervention, or if they declined the proposed treatment or study participation.

Clinical and laboratory assessment

Baseline assessment included demographic and social characteristics, predisposing factors, comorbidities, previous antibiotic exposure, medication history, previous cardiac surgery, presenting features, and clinical signs of IE and heart failure.

Imaging assessment

Echocardiography formed the principal imaging modality. Comprehensive transthoracic echocardiography was performed at baseline and during follow-up as clinically indicated, with transoesophageal echocardiography used when required for diagnostic clarification, assessment of complications, and procedural planning. Additional multislice CT/CT angiography was performed when further anatomical definition was required. In patients being considered for delayed transcatheter intervention, 18F-FDG PET/CT was used as part of the protocol to assess for persistent metabolically active infection before the procedure.

Management pathway and follow-up

All patients were managed according to contemporary IE guidance and the local IE working-group protocol. Antibiotic therapy was initiated after initial clinical assessment, with duration determined by the type of IE, prosthetic material, and clinical course. Patients selected for the planned transcatheter intervention pathway underwent continued clinical, echocardiographic, and laboratory follow-up. Transcatheter intervention was

undertaken when the clinical condition was suitable, and the lesion remained appropriate for correction. Development of an urgent or emergent surgical indication, or loss of transcatheter intervention feasibility, prompted referral for surgery.

Statistical analysis

Continuous variables were analyzed as non-parametric variables and are therefore presented as median (interquartile range [IQR]). The three-group comparison was performed using the Kruskal–Wallis test. Categorical variables were expressed as number and percentage and compared using Pearson chi-square testing. When the overall comparison was significant, pairwise comparisons were performed using Mann–Whitney U. Spearman correlation was used for continuous-variable relationships. Mortality was compared across the three management groups as a categorical outcome. A two-sided $P < 0.05$ was considered statistically significant.

Results

Patient groups and echocardiographic characteristics

The final analyzed cohort comprised 120 patients enrolled in the prospective cohort: 62 in the medical group, 38 in the surgical group, and 20 in the Transcatheter intervention group. The three groups differed in several clinical and anatomical characteristics, which is important when interpreting outcome comparisons. No significant difference was detected between the three groups regarding age. LVES differed significantly between groups, with the highest level in the transcatheter intervention group. Post-hoc analysis showed that LV end-systolic dimension differed between the medical and transcatheter intervention groups ($P = 0.036$), while TAPSE also differed between these two groups ($P = 0.015$).

Table 1: Age and gender of the studied groups

Variable	Medical (n=62)	Surgical (n=38)	Transcatheter intervention (n=20)	P value
Age, years	35.0 (27.2–44.0)	32.5 (25.2–43.8)	42.0 (32.2–55.2)	0.155
Gender	24 (38.7%)	14 (36.8%)	11 (55.0%)	0.363

Continuous variables are presented as median (IQR) because non-parametric analysis was used; Kruskal–Wallis test for the overall three-group comparison

Baseline clinical and anatomical characteristics

Several clinically important characteristics differed among management groups. Atrial fibrillation was most frequent in the transcatheter intervention group (60.0%) and least frequent in the medical group (12.9%; $P < 0.001$). Previous IE occurred in 8.1% of medically managed patients compared with 13.2% of surgical and 55.0% of transcatheter intervention patients ($P < 0.001$). Prosthetic-valve IE was common in both transcatheter intervention and surgical groups (75.0% and 86.8%, respectively) but absent from the medical group ($P < 0.001$). Intravenous drug use was recorded in 60.5% of medically treated patients and in none of the other groups ($P < 0.001$). Right-sided IE also differed significantly, occurring in 34.2% of surgical and 30.6% of medical patients but in none of the transcatheter intervention group ($P = 0.012$).

Table 2: Clinical and echocardiographic characteristics of the studied groups

Variable	Medical (n=62)	Surgical (n=38)	Transcatheter intervention (n=20)	P value
Diabetes	7 (11.3%)	7 (18.4%)	6 (30.0%)	0.140
Hypertension	13 (21.0%)	10 (26.3%)	7 (35.0%)	0.441
CKD	13 (21.0%)	5 (13.2%)	3 (15.0%)	0.577
Atrial fibrillation	8 (12.9%)	12 (31.6%)	12 (60.0%)	<0.001
Thyroid disease	2 (3.2%)	2 (5.3%)	4 (20.0%)	0.030
Chronic liver disease	6 (9.7%)	10 (27.0%)	6 (30.0%)	0.034
Anemia	51 (82.3%)	29 (76.3%)	17 (85.0%)	0.668
Smoking	22 (35.5%)	14 (36.8%)	2 (10.0%)	0.073

Fever	52 (83.9%)	38 (100.0%)	16 (80.0%)	0.023
Previous IE	5 (8.1%)	5 (13.2%)	11 (55.0%)	<0.001
Prosthetic-valve IE	0 (0.0%)	33 (86.8%)	15 (75.0%)	<0.001
IV drug use	23 (60.5%)	0 (0.0%)	0 (0.0%)	<0.001
Rheumatic heart disease	0 (0.0%)	9 (23.7%)	1 (5.0%)	<0.001
Right-sided IE	19 (30.6%)	13 (34.2%)	0 (0.0%)	0.012
Left-sided IE	40 (64.5%)	24 (63.2%)	18 (90.0%)	0.196
LVEDD, cm	4.7 (4.3–5.8)	5.0 (4.5–5.4)	5.2 (5.0–5.8)	0.210
LVES, cm	3.1 (2.8–3.8)	3.2 (2.8–3.9)	3.7 (3.3–4.2)	0.036
EF, %	62.0 (58.0–65.0)	60.0 (55.0–67.0)	57.0 (53.5–62.2)	0.082
TAPSE, mm	21.5 (20.0–25.8)	21.0 (18.2–24.0)	19.0 (17.0–21.0)	0.023

Valve involvement

Mitral-valve involvement was similar across groups (46.8%, 42.1%, and 45.0%; $P=0.901$), whereas tricuspid involvement differed significantly, being absent in the transcatheter intervention group and present in 34.2% of surgical and 29.0% of medical patients ($P=0.013$). Aortic and pulmonary valve involvement did not differ significantly between groups.

Table 3: Valve involvement among the three groups

Variable	Medical	Surgical	Transcatheter intervention	P value
Mitral valve	29 (46.8%)	16 (42.1%)	9 (45.0%)	0.901
Tricuspid valve	18 (29.0%)	13 (34.2%)	0 (0.0%)	0.013
Aortic valve	19 (30.6%)	11 (28.9%)	11 (55.0%)	0.097
Pulmonary valve	2 (3.2%)	2 (5.3%)	0 (0.0%)	0.568

Clinical outcomes and mortality

Heart failure occurred in 46.8% of medical, 52.6% of surgical, and 65.0% of transcatheter intervention patients, without a significant overall difference ($P=0.362$). Major embolization differed in the overall comparison (30.6%, 21.1%, and 55.0%; $P=0.030$). Acute kidney injury was also similar (32.3%, 34.2%, and 45.0%; $P=0.579$). Mortality showed the largest difference, with no deaths among 62 medical patients, 21 among 38 surgical patients, and 2 deaths among 20 transcatheter intervention patients ($P<0.001$).

Table 4: Clinical outcomes and mortality rates according to management strategy

Outcome	Medical	Surgical	Transcatheter intervention	P value
Heart failure	29 (46.8%)	20 (52.6%)	13 (65.0%)	0.362
Major embolization	19 (30.6%)	8 (21.1%)	11 (55.0%)	0.030
Acute kidney injury	20 (32.3%)	13 (34.2%)	9 (45.0%)	0.579
Mortality	0 (0.0%)	21 (55.3%)	2 (10.0%)	<0.001

Correlation analyses

Across all 120 patients, LV end-diastolic dimension correlated strongly with LV end-systolic dimension ($\rho=0.860$, $P<0.001$), while LV end-diastolic dimension correlated inversely with ejection fraction ($\rho=-0.437$, $P<0.001$). LV end-systolic dimension also correlated inversely with ejection fraction ($\rho=-0.699$, $P<0.001$) and weakly with TAPSE ($\rho=-0.220$, $P=0.016$). Ejection fraction correlated positively with TAPSE ($\rho=0.246$, $P=0.007$). Age was not significantly correlated with any of the echocardiographic variables.

Table 6: Correlations between different variables

Variable 1	Variable 2	Spearman rho	P value
Age	LV end-diastolic dimension	0.090	0.329

Age	LV end-systolic dimension	0.118	0.198
Age	Ejection fraction	-0.078	0.397
Age	TAPSE	0.036	0.699
LV end-diastolic dimension	LV end-systolic dimension	0.860	<0.001
LV end-diastolic dimension	Ejection fraction	-0.437	<0.001
LV end-diastolic dimension	TAPSE	-0.088	0.340
LV end-systolic dimension	Ejection fraction	-0.699	<0.001
LV end-systolic dimension	TAPSE	-0.220	0.016
Ejection fraction	TAPSE	0.246	0.007

Discussion

Taken together, the present findings support a clinically individualized interpretation of the three management pathways. The medical, surgical, and transcatheter intervention groups were formed through clinical decision-making rather than random allocation, and therefore the observed differences in mortality, echocardiographic measurements, atrial fibrillation, previous IE, prosthetic-valve status, and embolization cannot be interpreted as comparative treatment effects. Larger prospective studies with predefined management pathways and standardized follow-up are needed to clarify the role of transcatheter intervention in selected patients with residual structural disease after IE and to better define how baseline anatomy, ventricular function, surgical risk, and treatment timing influence outcomes. Major embolization occurred in 30.6% of medical, 21.1% of surgical, and 55.0% of transcatheter intervention patients (overall $P=0.030$), whereas heart failure and acute kidney injury did not differ significantly. The higher embolization rate in the transcatheter intervention group should not be interpreted as a procedural effect because the groups differed substantially in baseline anatomy and clinical phenotype. Current evidence continues to support early multidisciplinary assessment of embolic risk and surgical indications in complicated IE, with timing individualized according to heart failure, embolic risk, neurological status, and anatomical complications. [4,9,15] The absence of a significant difference in heart failure or acute kidney injury in our cohort further suggests that the principal between-group differences were driven by the underlying clinical composition of the groups rather than by a uniform difference in complications. The distribution of prosthetic-valve IE and right-sided disease further illustrates the heterogeneity of the management pathways. Prosthetic-valve IE was present in 86.8% of surgical patients and 75.0% of transcatheter intervention patients but was absent in the medical group, while right-sided IE was present in the medical and surgical groups but absent from the transcatheter intervention group. Contemporary studies of prosthetic-valve IE continue to report substantial morbidity and mortality and emphasize that management decisions depend on valve type, anatomical complications, surgical risk, and timing of intervention. [10] Thus, the markedly different anatomical profiles in our cohort should be regarded as important characteristics of the groups rather than as effects caused by the management strategy itself. Atrial fibrillation and previous IE also differed markedly among the groups. Atrial fibrillation was present in 12.9% of medical patients, 31.6% of surgical patients, and 60.0% of transcatheter intervention patients, while previous IE occurred in 8.1%, 13.2%, and 55.0%, respectively (both $P<0.001$). These differences demonstrate that the three groups were not clinically interchangeable before treatment. The high frequency of previous IE in the transcatheter intervention group is particularly relevant because transcatheter intervention after healed IE has generally been considered in patients with substantial structural disease and high surgical risk. The international transcatheter intervention infective endocarditis literature also demonstrates that infection involving prosthetic valves is associated with substantial clinical complexity, reinforcing the need for careful patient selection and longitudinal follow-up [7, 10-11]. The echocardiographic findings also provide clinically relevant descriptive information. LV end-systolic dimension and TAPSE differed between groups at the unadjusted level, although the corresponding FDR q-values were 0.087 and 0.073. The pairwise analysis identified differences between the medical and transcatheter intervention groups. These findings should not be interpreted as evidence that transcatheter intervention or medical treatment improves ventricular function, because echocardiographic measurements were obtained in groups with substantially different baseline clinical characteristics. Contemporary reviews emphasize that echocardiography is central to the assessment of IE, including evaluation of valve dysfunction, ventricular response, complications, and procedural planning [14-15]. The present results therefore support the value of integrating structural and functional echocardiographic parameters into the clinical description of IE, while avoiding causal interpretation of isolated

between-group differences. The transcatheter intervention group in our cohort had 2 deaths (10.0%) and represented a highly selected population. Santos-Martínez et al. described TAVR in patients with healed aortic-valve IE and residual valvular lesions who were considered high risk for conventional surgery; among 54 patients, in-hospital mortality was 5.6% and 1-year mortality was 11.1%, although significant aortic regurgitation and heart-failure readmission remained important concerns [7]. More recent reviews have emphasized that TAVR in the setting of active aortic-valve IE remains a highly selected and incompletely established strategy, whereas its potential role after infection has healed is more clearly defined [12]. These observations are compatible with the selected nature of our transcatheter intervention pathway and support cautious interpretation of the 10.0% mortality rate. The absence of mortality in the medical group should not be interpreted as evidence that medical therapy is preferable in patients who indicate surgery. Caldonazo et al. performed a meta-analysis of reconstructed time-to-event data involving 3,003 patients with IE and a surgical indication, of whom 922 were managed conservatively and 2,081 surgically. Surgical treatment was associated with a lower mortality risk than conservative treatment (HR 0.27, 95% CI 0.24–0.31; $P < 0.001$); pooled survival at 1, 6, and 12 months was 87.6%, 74.7%, and 73.3% with surgery versus 57.6%, 34.6%, and 32.7% with conservative treatment [5]. The contrast with our crude group comparison illustrates confounding by indication: patients receiving different strategies are not necessarily comparable at baseline. Recent work on surgical timing likewise suggests that timing and referral pathways can materially affect outcomes, supporting the importance of considering the clinical pathway rather than interpreting crude group mortality in isolation [8-9]. The high mortality observed in the surgical group should therefore be interpreted in the context of disease severity and treatment selection. Jensen et al., in a Danish nationwide study of 8,804 patients with first-time IE, reported that 1,981 patients (22.5%) underwent valve surgery and that 30-day postoperative mortality varied across calendar periods. More recent surgical series have similarly emphasized that operative outcomes depend strongly on the acuity of presentation, valve type, hemodynamic compromise, and the complexity of the required procedure. Gopal et al. highlighted the substantial perioperative risk that remains in contemporary IE surgery, while Miller et al. reported improving outcomes over time in patients undergoing double-valve surgery for IE [6, 13-14]. Our surgical mortality of 55.3% is therefore higher than many contemporary postoperative series, although the endpoints, patient selection, and clinical context are not directly comparable. The principal finding of this prospective cohort was the marked difference in crude mortality among the three management groups: 0% in the medical group, 55.3% in the surgical group, and 10.0% in the transcatheter intervention group ($P < 0.001$). This cannot be interpreted as a treatment effect because treatment was not randomly assigned. In our cohort, the surgical group had a very different baseline phenotype from the medical and transcatheter intervention groups, including much higher frequencies of prosthetic-valve IE and intravenous drug use. The observed mortality therefore reflects both management and the clinical risk profile that led to each management pathway.

Strengths and limitations

A major strength of this study is the direct three-way comparison of medical, surgical, and transcatheter intervention management within a single cohort, with clinical, anatomical, echocardiographic, and outcome data considered together.

Conclusion

In this cohort of 120 patients with infective endocarditis, medical, surgical, and transcatheter intervention management groups differed substantially in baseline phenotype, anatomical distribution, and crude mortality. Surgical patients had the highest observed mortality. The transcatheter intervention group had 2 deaths (10.0%), whereas no deaths occurred in the medical group, but these findings should be considered hypothesis-generating because of major baseline differences and non-random treatment allocation.

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