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ORIGINAL RESEARCH

Factors Associated with Unplanned 28-Day Index-Hospital Readmission After Open Heart Valve Surgery: A Retrospective Cohort Study

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Background: Unplanned readmission after cardiac surgery indicates the quality of discharge preparation and transitional care. Evidence after open heart valve surgery in Thailand is limited.

Objective: To determine the rate of, and factors associated with, unplanned index-hospital readmission within 28 days of discharge after open heart valve surgery.

Methods: This retrospective cohort study included adults who underwent open heart valve surgery with cardiopulmonary bypass at a tertiary cardiac referral center in northeastern Thailand from 2021 to 2025, with one operation per patient. Patients who died before discharge, were discharged against medical advice, or were transferred elsewhere were excluded. Readmissions were identified in the hospital information system of the study center; readmissions to other hospitals were not captured. Covariates were selected on clinical grounds, without reference to bivariable significance, and Firth penalized logistic regression was used.

Results: Of 1,543 operation records, 1,336 patients were analyzed. Unplanned readmission within 28 days occurred in 97 patients (7.26%; 95% confidence interval [CI], 5.93–8.79). Anticoagulation-related problems were the most frequent documented reason (24.7%), followed by heart failure (18.6%) and arrhythmia (13.4%). After adjustment, readmission was associated with a mechanical prosthesis compared with repair without a replacement prosthesis (adjusted odds ratio [aOR], 3.98; 95% CI, 1.97–8.25), acute kidney injury defined by creatinine criteria (aOR, 2.00; 95% CI, 1.10–3.53), and longer cardiopulmonary bypass time (aOR per 30 minutes, 1.16; 95% CI, 1.03–1.29). Odds were also higher with a mechanical than with a bioprosthetic valve (aOR, 2.95; 95% CI, 1.65–5.32). Results were consistent in six sensitivity analyses.

Conclusion: About 1 in 14 patients had an unplanned index-hospital readmission within 28 days, a figure that may underestimate overall readmission. A mechanical prosthesis, acute kidney injury, and longer bypass time were associated with readmission. Targeted discharge preparation and anticoagulation follow-up for these patients are candidates for evaluation.

Plain Language Summary:

What is already known

- Unplanned hospital readmission is an important quality indicator after cardiac surgery and may reflect complications, discharge preparedness, and gaps in transitional and post-discharge care.
- Readmission after cardiac surgery is multifactorial, involving patient characteristics, pre-existing clinical conditions, surgical factors, postoperative complications, and continuity of care. However, evidence on predictors following open-heart valve surgery remains inconsistent.
- Most existing evidence comes from high-income countries and commonly uses a 30-day readmission timeframe. Evidence on unplanned 28-day readmission after open-heart valve surgery in Thailand, particularly in the context of nursing care and transitional care, remains limited.

What does this paper add

- This study provides contemporary evidence on unplanned inpatient readmission within 28 days after open-heart valve surgery using data from 1,336 patients at a tertiary cardiac referral center in northeastern Thailand.

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- Approximately one in 14 patients experienced unplanned readmission. Anticoagulation-related complications were the most common reason for readmission, followed by heart failure and arrhythmia.
- Acute kidney injury during the index admission, mechanical prosthesis implantation, and longer cardiopulmonary bypass time were independently associated with increased odds of readmission, providing clinically relevant targets for risk screening, discharge preparation, anticoagulation education, and early post-discharge follow-up.

Keywords: patient readmission, heart valve prosthesis implantation, cardiac surgical procedures, risk factors, continuity of patient care, Thailand

Introduction

Cardiovascular disease remains a leading cause of death worldwide, with valvular heart disease (VHD) contributing substantially to morbidity and mortality, particularly among aging populations.[1,2] Global Burden of Disease 2021 data estimated 54.8 million cases of rheumatic heart disease, 13.3 million cases of nonrheumatic calcific aortic valve disease, and 15.5 million cases of nonrheumatic degenerative mitral valve disease worldwide.[3] The burden increases markedly with age; among adults aged 70 years and older, the age-standardized prevalence was 1,803.6 per 100,000 for calcific aortic valve disease and 2,148.9 per 100,000 for degenerative mitral valve disease.[3] VHD can lead to disability, hospitalization, heart failure, arrhythmia, and premature death if severe lesions remain untreated.[2,4] The four cardiac valves maintain unidirectional blood flow, and stenosis or regurgitation can cause progressive pressure or volume overload, ventricular remodeling, pulmonary congestion, and ultimately symptomatic heart failure.[5–7]

Open-heart valve surgery, including valve repair and replacement performed under cardiopulmonary bypass, remains an important definitive treatment for severe VHD and can improve survival, symptoms, and quality of life.[4,8] However, recovery extends beyond hospitalization and requires wound care, symptom monitoring, gradual resumption of activity, and, for patients with mechanical prostheses, lifelong anticoagulation.[7] The early post-discharge period is particularly vulnerable to complications. In a prospective 10-center cohort of 5,059 adult cardiac surgical patients that recorded all-cause readmissions within 65 days of surgery, 18.3% of patients undergoing isolated valve surgery were readmitted; infection, arrhythmia, and volume overload were the most common causes of first readmissions within 30 days.[9] Other complications, including decompensated heart failure, anticoagulation-related bleeding, surgical site infection, and acute kidney injury, may also result in an unplanned return to the hospital.[10]

Unplanned hospital readmission is therefore an important outcome after cardiac surgery. It is widely used as an indicator of healthcare quality, reflecting the adequacy of discharge preparation, continuity of care, and health service delivery.[11,12] Readmission also increases healthcare expenditure, bed occupancy, clinical workload, and patient burden, with studies of coronary artery bypass grafting demonstrating additional costs associated with individual postoperative complications.[13] Conversely, structured transitional care that prepares patients and caregivers for post-discharge self-management has been shown in a randomized controlled trial to reduce rehospitalization among older adults.[14] In Thailand, cardiovascular disease similarly remains among the leading causes of death.[1] VHD reflects both the continuing burden of rheumatic heart disease, historically a dominant cause in the region and still substantial in lower socio-demographic index settings, and the increasing contribution of age-related degenerative valve disease as the population ages.[2,3,15] In Thailand, unplanned readmission within 28 days of discharge is one of the nursing quality indicators monitored by the Nursing Division of the Ministry of Public Health.[16]

Readmission following cardiac surgery is multifactorial and may reflect patient, clinical, operative, postoperative, and health service factors. Reported patient-related factors include age, sex, and body mass index. In contrast, clinical factors include preoperative heart failure, reduced left ventricular ejection fraction, pulmonary hypertension, atrial fibrillation, chronic kidney disease, and diabetes mellitus.[10] Operative factors include procedure type, prosthesis type, cardiopulmonary bypass duration, and intensive care unit length of stay. At the same time, postoperative bleeding, infection, arrhythmia, and acute kidney injury may further increase the risk of readmission.[9] Health service factors, particularly post-discharge follow-up, may also influence outcomes.[9,10] In a multicenter analysis of 38,532 patients who underwent valve surgery at 219 hospitals, 7.8% were readmitted to the index hospital within one month and 12.8% within three

months; the strongest predictors were units of packed red blood cells transfused, end-stage renal disease, type of valve surgery, emergency admission, and hospital length of stay.[10] A single-center retrospective study of 357 patients undergoing open heart surgery reported a 30-day readmission rate of 8.7%, with a history of atrial fibrillation as the only significant predictor.[17] Readmission following aortic valve replacement has also been examined in a systematic review.[18] At the same time, body mass index has been investigated as a determinant of cardiac surgical outcomes in a nationwide study accompanied by a systematic review and meta-analysis.[19] However, findings remain inconsistent, and much of the available evidence originates from high-income countries with healthcare systems, time of readmission definition (30 compared to 28 days), case mixes, discharge planning, follow-up services, travel requirements, and anticoagulation self-management practices that may differ from those in Thailand. Studies also differ in whether they count all unplanned readmissions or only those judged to be related to cardiac disease or surgery, which limits comparison of reported rates.

A previous study at a tertiary cardiac excellence center serving patients with complex cardiac conditions across northeastern Thailand included 272 patients undergoing combined valve repair and replacement. Although the study reported a mean hospital stay of 14.07 ± 8.00 days, it did not examine post-discharge readmission or factors associated with readmission.[20] In 2025, a quality report of the study center recorded 80 readmissions within 28 days of discharge among 345 patients who underwent valve surgery (23%); this count included both planned and unplanned readmissions. Commonly documented reasons included postoperative infection, abnormal surgical wounds, acute kidney injury, arrhythmia, and anticoagulation-related problems. These data had not been formally analyzed, and the factors associated with unplanned 28-day readmission remain unclear. Generating local evidence on readmission rates and determinants is therefore important for strengthening risk assessment, discharge planning, nursing care, and continuity of care, and for developing targeted strategies to reduce potentially preventable readmissions.

Accordingly, this study aimed to determine the rate of and factors associated with unplanned readmission to the index hospital within 28 days of discharge among patients undergoing open-heart valve surgery in northeastern Thailand. The findings may provide context-specific evidence to support early identification of high-risk patients, optimize discharge preparation and transitional care, and inform clinical risk management and service improvement to reduce potentially preventable readmissions.

Materials and Methods

Study Design and Setting

We conducted a retrospective cohort study using secondary data from medical records and the electronic hospital information system. We retrospectively identified patients who met the eligibility criteria and classified them into two groups based on the study outcome. We defined the readmission group as those who had an unplanned inpatient readmission within 28 days of discharge, and the non-readmission group as those who did not. We then compared the two groups by patient, clinical, surgical, postoperative, and continuity-of-care factors. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[21]

The study was conducted in northeastern Thailand at a tertiary cardiac referral and excellence center that provides cardiac surgical services to patients referred from provinces throughout the region. The hospital performs approximately 345 open-heart valve operations annually. Postoperative care is delivered in a dedicated cardiac intensive care unit followed by a cardiac surgical ward, and patients are scheduled for outpatient follow-up after discharge.

Population and Sample

The population comprised adult and older adult patients diagnosed with valvular heart disease, including both valvular stenosis and valvular regurgitation, who underwent open-heart valve surgery at the study center. The sample comprised all such patients treated between January 1, 2021 to January 28, 2026 who met the eligibility criteria.

Inclusion and Exclusion Criteria

Patients were included if they were aged between 18 and 90 years; had a physician-confirmed diagnosis of valvular heart disease and underwent open-heart valve surgery, either valve repair or valve replacement, under cardiopulmonary bypass;

received treatment at the study center between January 1, 2021 to January 28, 2026; and had a discharge status recorded in the hospital information system.

Patients were excluded if they died during the index admission, were discharged against medical advice, or were transferred directly to another hospital for continued inpatient care, because readmission after transfer could not be traced in the records of the study center. Records were also excluded if they were duplicates, lacked a discharge status, or were incomplete. For patients who underwent more than one valve operation during the study period, only the first operation was analyzed, so that each patient contributed one observation. Patients with a planned readmission was not counted as an outcome event.

Sample Size

The study protocol estimated the minimum sample size with the events-per-variable rule of at least 10 outcome events per candidate variable.[22] With 18 candidate variables and an anticipated readmission proportion of 20%, the formula n = 10K/P gave 900 patients, or 948 after allowing 5% for incomplete records [900/(1 − 0.05)]. The 20% figure came from the 2025 quality report of the study center, which counted planned and unplanned readmissions together; the proportion of unplanned readmissions observed in this study was 7.26%. Because the events-per-variable rule alone is not an adequate basis for sample size,[23,24] we also assessed the final model against the criteria proposed by Riley et al.[24] With an institutional volume of approximately 345 valve operations annually, all eligible patients treated during the five-year period were included.

Variables and Operational Definitions

The outcome was unplanned readmission to the index hospital within 28 days of discharge, recorded as a binary variable. It was defined as any inpatient admission to the study center within 28 days of discharge from the index admission that had not been scheduled in advance.[12] Planned admissions, including scheduled procedures, planned reoperations, admissions for diagnostic investigation, routine follow-up admissions, and rehabilitation admissions, were not counted as events. Unplanned readmissions were counted regardless of cause, and no readmission was excluded as unrelated to the cardiac condition or the surgery; the outcome therefore corresponds to all-cause unplanned readmission. A patient with more than one readmission within 28 days was counted once. The planned or unplanned status and the primary reason for each readmission were taken from the documentation of the readmission episode by the research team; no independent adjudication was performed. Readmissions to other hospitals could not be identified. The hospital information system was searched for readmissions on January 1, 2021 to January 28, 2026. We used a 28-day window because unplanned readmission within 28 days of discharge is the indicator used for nursing quality monitoring by the Thai Ministry of Public Health.[16]

We examined 21 candidate variables across five domains. The patient domain comprised age, sex, and body mass index. The clinical domain comprised New York Heart Association functional class, left ventricular ejection fraction, pulmonary hypertension, atrial fibrillation, chronic kidney disease, and diabetes mellitus. The surgical domain comprised urgency of surgery, previous cardiac surgery, type of procedure, type of prosthesis, concomitant procedures, cardiopulmonary bypass time, intraoperative blood loss greater than 500 mL, and intensive care unit length of stay. The in-hospital postoperative domain comprised infection, rhythm disturbance, and acute kidney injury, each assessed during the index admission. The continuity-of-care domain comprised attendance at the day-7 outpatient follow-up visit. Valve position and the number of valves operated on were derived from the operative description. Operational definitions are listed in Supplementary Table S1.

Valvular heart disease was defined as a physician-confirmed diagnosis of stenosis or regurgitation of the mitral, aortic, tricuspid, or pulmonary valve.[2] Open heart valve surgery was defined as valve repair or valve replacement performed under cardiopulmonary bypass.[4] Heart failure and pulmonary hypertension were taken from the physician diagnosis recorded in the medical record.[25–27] Chronic kidney disease was defined as a preoperative estimated glomerular filtration rate below 60 mL/min/1.73 m^2 (n = 273) or a physician diagnosis of chronic kidney disease (n = 11), and diabetes mellitus as a physician diagnosis recorded in the medical record. Type of prosthesis referred to valve replacement prostheses only; annuloplasty rings were not counted as prostheses. The 11 patients who received both a mechanical and

a bioprosthetic valve were grouped with mechanical prostheses because both require lifelong anticoagulation. Intraoperative blood loss greater than 500 mL was taken from the anesthetic record. Postoperative infection was recorded when any infection was documented during the index admission, without distinction of site. Postoperative rhythm disturbance was recorded for any documented rhythm abnormality of any type during the index admission, including atrial fibrillation present before surgery. These definitions are broader than standard definitions of perioperative bleeding, sternal wound infection, and postoperative atrial fibrillation;[28–31] therefore, the three variables are described as recorded and are not interpreted as conventional complications. For the primary analysis, acute kidney injury was defined by the serum creatinine criterion of the Kidney Disease: Improving Global Outcomes guideline,[32,33] as a postoperative creatinine of at least 1.5 times the preoperative value or an absolute increase of at least 0.3 mg/dL. The preoperative creatinine served as baseline, and the comparison used the single postoperative value recorded on the extraction form, the timing of which was not standardized. Stages 2 and 3 were assigned for increases of 2.0–2.9 and at least 3.0 times baseline. Urine output, renal replacement therapy, and renal function at discharge were not recorded. The acute kidney injury variable originally extracted, which also included cases diagnosed by a physician that did not meet these creatinine thresholds, was examined in a sensitivity analysis.[34,35]

Data Sources and Measurement

The research team extracted data using a structured data extraction form. The form comprised two parts. The first recorded the study identifier and baseline characteristics, including age, sex, weight, height, and comorbid conditions such as diabetes mellitus, pulmonary hypertension, heart failure, atrial fibrillation, and chronic kidney disease. The second set of recorded illness and treatment data included the admission date, diagnosis, type of operation, type of prosthetic valve, cardiopulmonary bypass time, operative time, intensive care unit length of stay, postoperative complications, New York Heart Association functional class, ejection fraction, serum albumin, glycated hemoglobin, reoperation, discharge date, readmission date, and post-discharge follow-up. We prepared a codebook to convert extracted values into numerical codes for statistical analysis. We obtained data from inpatient medical records, the electronic hospital database, operative reports, anesthetic records, intensive care unit records, and the hospital patient registry and readmission database. Discharge and readmission dates were included in the form but were not available in the extracted dataset; therefore, the interval between discharge and readmission could not be analyzed.

Data Collection Procedure

After obtaining ethical approval, we submitted a formal request to the Director of the tertiary cardiac center for permission to access the hospital information system and medical records. Once permission was granted, the Information Technology Unit extracted records for patients who underwent valve surgery during the study period. We checked the extracted dataset for completeness and obtained variables that could not be retrieved electronically, including comorbid conditions, operative time, New York Heart Association functional class, ejection fraction, postoperative complications, and post-discharge follow-up, through manual review of the corresponding medical records. A second member of the research team checked the extracted data against the medical records, and the data were de-identified before analysis.

Validity, Reliability, and Rigor

We developed the data extraction form from the literature and the operational definitions specified in the study protocol, and experts in cardiac surgical nursing, anesthesiology, and nursing research reviewed it for content validity; we revised it based on their recommendations. The same operational definitions were applied in all study years. We extracted data using a standardized form and codebook, and a second team member verified the extracted values against the source records. Records were not independently re-extracted; therefore, inter-rater agreement was not calculated. We checked data for completeness, internal consistency, implausible values, and date logic before analysis. We recorded the number and reasons for exclusion at each stage to construct the participant flow diagram. Missing values were few: body mass index (n = 2, recalculated from recorded weight and height), left ventricular ejection fraction (n = 1, a typing error corrected from the source record), intensive care unit length of stay (n = 3, set to the cohort median of 4 days), atrial fibrillation (n = 5), diabetes mellitus (n = 4), and previous cardiac surgery (n = 1), which were coded as absent when not

documented, chronic kidney disease (n = 1), and serum creatinine (n = 2). The two patients without creatinine values were not included in the primary model (Supplementary Table S2).

Statistical Analysis

We summarized baseline characteristics using descriptive statistics. We present categorical variables as frequencies and percentages, and continuous variables as medians with interquartile ranges (IQRs) because their distributions were skewed. We report the rate of unplanned readmission within 28 days as a proportion with its 95% confidence interval.

We compared patients with and without readmission using the chi-square test (with continuity correction for 2×2 tables), or the Fisher exact test when an expected cell count was below five, for categorical variables, and the Mann–Whitney *U*-test for continuous variables. Crude odds ratios were estimated by univariable logistic regression with Wald 95% confidence intervals; because these intervals and the group-comparison p-values come from different tests, the two can disagree near the 0.05 threshold. The multivariable analysis aimed to estimate associations, not to develop a prediction model. Covariates were therefore selected before model fitting on clinical grounds, not by bivariable p-values.[36,37] The primary model included age, preoperative atrial fibrillation, chronic kidney disease, previous cardiac surgery, valve position (mitral, aortic, mitral and aortic, or tricuspid or pulmonary only), type of prosthesis (no replacement prosthesis, bioprosthetic, or mechanical), cardiopulmonary bypass time, and acute kidney injury, giving 11 parameters for 97 events. Age, previous surgery, valve position, and atrial fibrillation were included because they may influence both the choice of prosthesis and the risk of readmission, and chronic kidney disease and bypass time because they may influence both acute kidney injury and readmission. Intensive care unit length of stay was not included because it is partly a consequence of the exposures of interest, and the recorded blood loss, rhythm disturbance, and infection variables were not included because their broad definitions gave little contrast between groups. To reduce small-sample bias, the model was fitted by Firth penalized logistic regression with profile penalized-likelihood 95% confidence intervals.[38] A direct comparison of mechanical with bioprosthetic valves was obtained by changing the reference category. Linearity of age and bypass time was examined with restricted cubic splines with three knots, and multicollinearity with generalized variance inflation factors. The optimism-corrected c-statistic and calibration slope from 1,000 bootstrap samples are reported to describe the model,[39] not to support individual risk prediction.

We conducted six sensitivity analyses: (S1) acute kidney injury as originally extracted, including physician-diagnosed cases (n = 1,336); (S2) the primary model without acute kidney injury, because acute kidney injury may lie on the pathway between bypass time and readmission; (S3) addition of sex, diabetes mellitus, and year of operation; (S4) exclusion of seven patients whose operative description and prosthesis code could not be reconciled; (S5) a model selected by bivariable screening at $p < 0.20$, comprising atrial fibrillation, chronic kidney disease, diabetes mellitus, previous cardiac surgery, bypass time, intensive care unit length of stay, postoperative infection, rhythm disturbance, acute kidney injury as originally extracted, and prosthesis type; and (S6) age modeled with a restricted cubic spline. Day-7 follow-up attendance was not included in any model, because it was measured after the outcome window began: a patient readmitted before day 7 could not attend, and attendance therefore partly reflects the outcome itself. Discharge dates were not available for a landmark analysis restricted to patients who were alive and not readmitted on day 7. All analyses were performed in R version 4.6.1; regression analyses used the logistf package (version 1.26.1), rms (version 8.2.0), and pROC (version 1.19.1) packages. A two-sided p-value below 0.05 was considered statistically significant.

Results

Participant Flow

During the study period, 1,543 operation records of patients aged 18 to 90 years who underwent open heart valve repair or replacement under cardiopulmonary bypass were identified at the study center. Of these, 193 records were excluded: 109 patients were transferred to another hospital immediately after the index admission, 45 died before discharge, 16 were discharged against medical advice, 14 had no discharge status recorded, 5 records were duplicates, and 4 medical records were incomplete. A further 14 records were repeat operations in patients already included, and only the first operation was retained. The analysis therefore included 1,336 unique patients, of whom 97 were readmitted and 1,239 were not (Figure 1). Excluded and included patients were

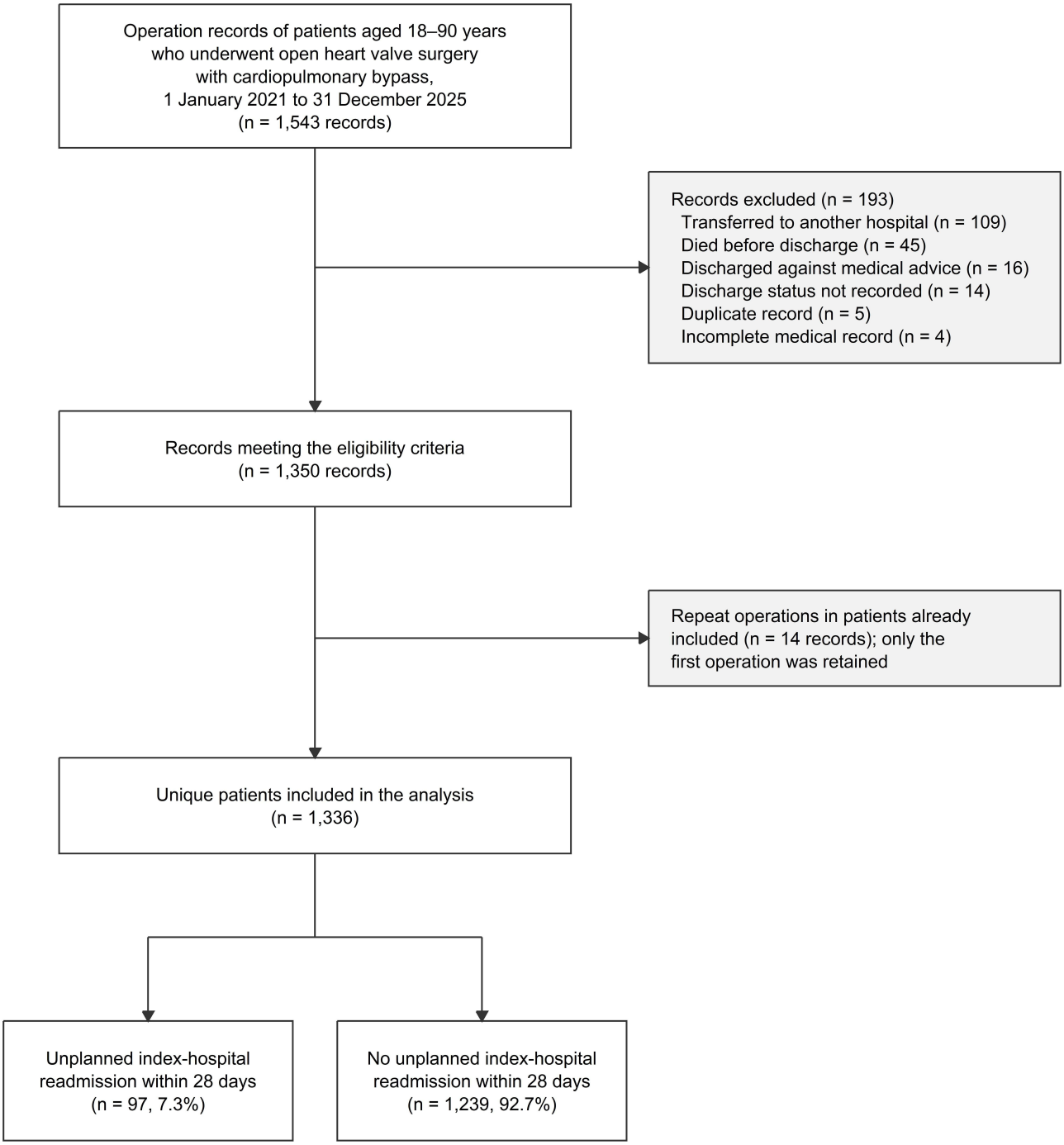


Figure 1 Flow diagram of operation records and patients. Records were excluded at the record level; repeat operations in patients already included were removed so that each patient contributed one observation.

of similar age; however, excluded patients had previous cardiac surgery more often (20.8% compared to 13.4%, p = 0.008), and patients transferred to other hospitals were more often men (69.7%). Operative and postoperative variables were not extracted for excluded records; therefore, further comparison was not possible (Supplementary Table S4).

Baseline Characteristics

The median age was 60.0 years (IQR 53.0–67.0), and 618 patients (46.3%) were women. Most patients were in New York Heart Association functional class II (699, 52.3%) or class III (550, 41.2%), and the median left ventricular

ejection fraction was 63.2% (IQR 53.1–71.8). Atrial fibrillation was present in 535 patients (40.0%), pulmonary hypertension in 603 (45.1%), chronic kidney disease in 284 (21.3%), and diabetes mellitus in 269 (20.1%). Valve replacement alone was performed in 578 patients (43.3%), repair alone in 380 (28.4%), and combined repair and replacement in 378 (28.3%); 357 patients (26.7%) received a mechanical prosthesis and 604 (45.2%) a bioprosthetic valve. The operation involved the mitral valve in 637 patients (47.7%), the aortic valve in 328 (24.6%), both the mitral and aortic valves in 253 (18.9%), and only the tricuspid or pulmonary valve in 118 (8.8%). The diagnosis recorded the etiology in 214 patients (16.0%), including rheumatic disease in 112 (8.4%). After correction of 15 operation-type codes against the operative description, procedure and prosthesis categories agreed in 1,329 of 1,336 patients (Supplementary Table S3). The median cardiopulmonary bypass time was 140.0 minutes (IQR 108.0–184.0), and the median intensive care unit stay was 4.0 days (IQR 3.0–7.0). Acute kidney injury by the creatinine criterion occurred in 130 of 1,334 patients (9.7%; stage 1, 99; stage 2, 26; stage 3, 5), and the originally extracted acute kidney injury variable was positive in 232 (17.4%). Table 1 shows baseline characteristics overall and by readmission status.

Table 1 Baseline Characteristics of Patients Undergoing Open Heart Valve Surgery, Overall and by Unplanned Index-Hospital Readmission Status Within 28 Days After Discharge, with Crude Odds Ratios from Bivariable Analysis

Characteristic	Total (n = 1,336)	Readmission (n = 97)	No Readmission (n = 1,239)	Crude OR (95% CI)	p-value
Patient characteristics					
Age (years), median (IQR)	60.0 (53.0–67.0)	60.0 (51.0–69.0)	60.0 (53.0–67.0)	1.00 (0.98–1.02)	0.901[a]
Sex, n (%)					0.730[b]
Male	718 (53.7)	50 (51.5)	668 (53.9)	1.00 (reference)	
Female	618 (46.3)	47 (48.5)	571 (46.1)	1.10 (0.73–1.66)	
Body mass index (kg/m^2), median (IQR)	22.6 (20.3–25.2)	23.0 (20.3–26.2)	22.6 (20.3–25.2)	1.04 (0.99–1.10)	0.180[a]
Clinical characteristics					
NYHA functional class, n (%)					0.487[c]
Class I	19 (1.4)	0 (0.0)	19 (1.5)	Not estimable	
Class II	699 (52.3)	46 (47.4)	653 (52.7)	1.00 (reference)	
Class III	550 (41.2)	46 (47.4)	504 (40.7)	1.30 (0.85–1.98)	
Class IV	68 (5.1)	5 (5.2)	63 (5.1)	1.13 (0.43–2.94)	
Left ventricular ejection fraction (%), median (IQR)	63.2 (53.1–71.8)	63.4 (54.0–72.0)	63.1 (53.1–71.8)	1.00 (0.98–1.01)	0.978[a]
Pulmonary hypertension, n (%)	603 (45.1)	47 (48.5)	556 (44.9)	1.15 (0.76–1.75)	0.565[b]
Atrial fibrillation, n (%)	535 (40.0)	48 (49.5)	487 (39.3)	1.51 (1.00–2.29)	0.063[b]
Chronic kidney disease[d], n (%)	284 (21.3)	30 (30.9)	254 (20.5)	1.74 (1.10–2.73)	0.022[b]
Diabetes mellitus, n (%)	269 (20.1)	27 (27.8)	242 (19.5)	1.59 (1.00–2.53)	0.067[b]
Surgical characteristics					
Urgency of surgery, n (%)					0.212[b]
Elective	1265 (94.7)	95 (97.9)	1170 (94.4)	1.00 (reference)	
Emergency	71 (5.3)	2 (2.1)	69 (5.6)	0.36 (0.09–1.48)	
Redo cardiac surgery, n (%)	172 (12.9)	20 (20.6)	152 (12.3)	1.86 (1.10–3.13)	0.027[b]
Type of procedure[e], n (%)					0.138[b]
Valve repair	380 (28.4)	20 (20.6)	360 (29.1)	1.00 (reference)	
Valve replacement	578 (43.3)	43 (44.3)	535 (43.2)	1.45 (0.84–2.50)	
Repair and replacement	378 (28.3)	34 (35.1)	344 (27.8)	1.78 (1.00–3.15)	
Prosthesis type[f], n (%)					0.002[b]
No replacement prosthesis	375 (28.1)	18 (18.6)	357 (28.8)	1.00 (reference)	
Bioprosthetic	604 (45.2)	39 (40.2)	565 (45.6)	1.37 (0.77–2.43)	
Mechanical	357 (26.7)	40 (41.2)	317 (25.6)	2.50 (1.41–4.45)	
Valve position, n (%)					0.095[b]
Mitral	637 (47.7)	47 (48.5)	590 (47.6)	1.00 (reference)	
Aortic	328 (24.6)	15 (15.5)	313 (25.3)	0.60 (0.33–1.09)	
Mitral and aortic	253 (18.9)	25 (25.8)	228 (18.4)	1.38 (0.83–2.29)	
Tricuspid/pulmonary only	118 (8.8)	10 (10.3)	108 (8.7)	1.16 (0.57–2.37)	

(*Continued*)

Table 1 (Continued).

Characteristic	Total (n = 1,336)	Readmission (n = 97)	No Readmission (n = 1,239)	Crude OR (95% CI)	p-value
Etiology stated in the diagnosis, n (%)					0.005[c]
Not stated in diagnosis	1122 (84.0)	74 (76.3)	1048 (84.6)	1.00 (reference)	
Rheumatic	112 (8.4)	17 (17.5)	95 (7.7)	2.53 (1.44–4.47)	
Infective endocarditis	68 (5.1)	2 (2.1)	66 (5.3)	0.43 (0.10–1.79)	
Degenerative/bicuspid	34 (2.5)	4 (4.1)	30 (2.4)	1.89 (0.65–5.50)	
Concomitant procedure, n (%)					0.303[c]
Valve only	1114 (83.4)	82 (84.5)	1032 (83.3)	1.00 (reference)	
Valve and CABG	180 (13.5)	15 (15.5)	165 (13.3)	1.14 (0.64–2.03)	
Valve and aneurysm repair	37 (2.8)	0 (0.0)	37 (3.0)	Not estimable	
Valve, CABG and aneurysm repair	5 (0.4)	0 (0.0)	5 (0.4)	Not estimable	
Cardiopulmonary bypass time (min), median (IQR)	140.0 (108.0–184.0)	151.0 (120.0–211.0)	139.0 (108.0–182.0)	1.05 (1.02–1.09)	0.011[a]
Intensive care unit stay (days), median (IQR)	4.0 (3.0–7.0)	5.0 (4.0–10.0)	4.0 (3.0–6.0)	1.07 (1.03–1.11)	<0.001[a]
Intraoperative blood loss >500 mL[g], n (%)	1306 (97.8)	96 (99.0)	1210 (97.7)	2.30 (0.31–17.07)	0.719[c]
In-hospital postoperative factors, as recorded					
Infection, any site[g], n (%)	341 (25.5)	31 (32.0)	310 (25.0)	1.41 (0.90–2.20)	0.165[b]
Rhythm disturbance, any type[g], n (%)	1155 (86.5)	89 (91.8)	1066 (86.0)	1.81 (0.86–3.79)	0.153[b]
Acute kidney injury, as originally extracted[h], n (%)	232 (17.4)	36 (37.1)	196 (15.8)	3.14 (2.02–4.87)	<0.001[b]
Acute kidney injury, KDIGO creatinine criterion[i] (n = 1,334), n (%)					<0.001[c]
No AKI	1204 (90.3)	77 (79.4)	1127 (91.1)	1.00 (reference)	
Stage 1	99 (7.4)	11 (11.3)	88 (7.1)	1.83 (0.94–3.57)	
Stage 2	26 (1.9)	7 (7.2)	19 (1.5)	5.39 (2.20–13.22)	
Stage 3	5 (0.4)	2 (2.1)	3 (0.2)	9.76 (1.61–59.27)	
Continuity of care					
Day-7 follow-up[j], n (%)					0.603[b]
Attended	1120 (83.8)	79 (81.4)	1041 (84.0)	0.83 (0.49–1.42)	
Did not attend	216 (16.2)	18 (18.6)	198 (16.0)	1.00 (reference)	

Notes: Data are n (%) for categorical variables and median (interquartile range) for continuous variables. Crude odds ratios are from univariable logistic regression with Wald 95% confidence intervals (per 10 minutes for cardiopulmonary bypass time and per day for intensive care unit stay); p-values come from the group-comparison tests indicated and may differ from inference based on the confidence intervals near the 0.05 threshold. a = Mann–Whitney *U*-test. b = Chi-square test (with continuity correction for 2×2 tables). c = Fisher exact test. d = Preoperative estimated glomerular filtration rate <60 mL/min/1.73 m^2 or physician diagnosis. e = After correction of 15 operation-type codes against the operative description. f = Valve replacement prostheses only; 11 patients with both mechanical and bioprosthetic valves are grouped with mechanical. g = As recorded; blood loss was taken from the anesthetic record, and infection and rhythm disturbance include any site or type, including pre-existing atrial fibrillation. h = Laboratory criterion or physician diagnosis. i = Postoperative creatinine ≥1.5 times or ≥0.3 mg/dL above the preoperative value; two patients without creatinine values are excluded. j = Measured after the outcome window began; patients readmitted before day 7 could not attend.

Abbreviations: AKI, acute kidney injury; CABG, coronary artery bypass grafting; CI, confidence interval; IQR, interquartile range; KDIGO, Kidney Disease: Improving Global Outcomes; NYHA, New York Heart Association; OR, odds ratio.

Rate of Unplanned Readmission Within 28 days

Unplanned inpatient readmission within 28 days of discharge occurred in 97 of 1,336 patients, a rate of 7.26% (95% CI 5.93–8.79). The annual rate ranged from 4.53% (95% CI 2.43–7.62) in 2025 to 10.26% (95% CI 6.68–14.88) in 2023 and showed no statistically significant difference across the five years (chi-square = 7.62, df = 4, p = 0.106); rates by year are shown in Table 2. The study was not designed to detect trends over time.

A documented primary reason was available for all 97 readmissions (Table 3). Anticoagulation-related problems accounted for 24 readmissions (24.7%): 22 for an international normalized ratio outside the target range without documented bleeding, and 2 for an abnormal international normalized ratio with another documented problem (heart failure in one patient and pleural effusion in one). Readmissions with bleeding symptoms, such as gum bleeding, epistaxis, or blood in the stool, were classified as bleeding, including one patient with over-anticoagulation and bleeding; one patient with hemopericardium and over-anticoagulation was classified as pericardial effusion or hemopericardium. Of the 24 anticoagulation-related readmissions, 19 occurred in patients with a mechanical prosthesis, 4 with a bioprosthetic, and 1 after repair, and 12 patients had preoperative atrial fibrillation (Supplementary Table S8). Heart failure (18, 18.6%), arrhythmia (13, 13.4%), surgical site or prosthetic valve infection (9, 9.3%), pericardial effusion or

Table 2 Rate of Unplanned Index-Hospital Readmission Within 28 Days After Discharge Following Open Heart Valve Surgery, Overall and by year

Year	Patients Analyzed, n	Readmissions Within 28 Days, n	Readmission Rate, % (95% CI)
2021	271	16	5.90 (3.41–9.41)
2022	254	20	7.87 (4.88–11.90)
2023	234	24	10.26 (6.68–14.88)
2024	290	24	8.28 (5.37–12.06)
2025	287	13	4.53 (2.43–7.62)
Total	1,336	97	7.26 (5.93–8.79)

Notes: Confidence intervals are exact (Clopper-Pearson). Chi-square test across years: $\chi^2 = 7.62$, $df = 4$, $p = 0.106$.
Abbreviations: CI, confidence interval; df, degrees of freedom.

Table 3 Documented Primary Reasons for Unplanned Index-Hospital Readmission Within 28 Days After Discharge (n = 97)

Reason for Readmission	n	%
Anticoagulation-related complication[a]	24	24.7
Heart failure	18	18.6
Arrhythmia	13	13.4
Surgical site or prosthetic valve infection	9	9.3
Pericardial effusion or hemopericardium[b]	8	8.2
Bleeding or anemia[c]	8	8.2
Prosthetic valve dysfunction or thrombus	4	4.1
Other infection	4	4.1
Respiratory complication	4	4.1
Myocardial ischemia	3	3.1
Renal or electrolyte disorder	2	2.1
Total	97	100.0

Notes: n, number of readmissions; each patient was counted once. Reasons are the primary reason documented for the readmission episode, without independent adjudication. a = International normalized ratio outside the target range without documented bleeding (n = 22) or with another documented problem (heart failure, n = 1; pleural effusion, n = 1); 19 of the 24 patients had a mechanical prosthesis. b = Includes one patient with hemopericardium and over-anticoagulation. c = Readmissions with bleeding symptoms such as gum bleeding, epistaxis, or blood in the stool; includes one patient with over-anticoagulation and bleeding.

hemopericardium (8, 8.2%), and bleeding or anemia (8, 8.2%) were the next most frequent reasons. The interval between discharge and readmission could not be determined.

Factors Associated with Unplanned Readmission (Bivariable Analysis)

In bivariable analysis (Table 1), readmission was associated at $p < 0.05$ with acute kidney injury by either definition, prosthesis type, intensive care unit length of stay, cardiopulmonary bypass time, chronic kidney disease, and previous cardiac surgery. The crude odds of readmission increased with the stage of acute kidney injury (stage 1, odds ratio [OR] 1.83; stage 2, OR 5.39; stage 3, OR 9.76). Day-7 follow-up attendance was not associated with readmission ($p = 0.603$); however, this comparison is limited because patients readmitted before day 7 could not attend.

Factors Associated with Unplanned Readmission (Multivariable Analysis)

In the primary Firth model (n = 1,334; 97 events; 11 parameters), three factors were associated with readmission (Table 4 and Figure 2). Compared with repair without a replacement prosthesis, a mechanical prosthesis was associated with higher odds of readmission (adjusted odds ratio [aOR] 3.98, 95% CI 1.97–8.25; p < 0.001), whereas a bioprosthesis was not (aOR 1.35, 95% CI 0.71–2.61; p = 0.359). In the direct comparison, the odds of readmission were higher with a mechanical than with a bioprosthetic valve (aOR 2.95, 95% CI 1.65–5.32; p < 0.001). Acute kidney injury defined by the creatinine criterion was associated with readmission (aOR 2.00, 95% CI 1.10–3.53; p = 0.024), as was longer cardiopulmonary bypass time (aOR 1.16 per 30 minutes, 95% CI 1.03–1.29; p = 0.013; equivalent to 1.050, 95% CI 1.011–1.089, per 10 minutes). Across the interquartile range of bypass time (108 to 184 minutes), the aOR was 1.45 (95% CI 1.08–1.91). Age, atrial fibrillation, chronic kidney disease, previous cardiac surgery, and valve position were not associated with readmission at p < 0.05; the estimates for chronic kidney disease (aOR 1.42, 95% CI 0.85–2.33) and age (aOR 1.21 per 10 years, 95% CI 0.97–1.54) were imprecise.

The three associations were consistent in all sensitivity analyses (Supplementary Table S5). The aOR for a mechanical prosthesis ranged from 3.59 to 4.66, the aOR for bypass time per 30 minutes from 1.14 to 1.18, and the aOR for acute kidney injury by the creatinine criterion from 1.91 to 2.13. With acute kidney injury as originally extracted (S1), the aOR was 2.75 (95% CI 1.66–4.51). In the model selected by bivariable screening (S5), the estimates were 2.53 (95% CI 1.39–4.60) for a mechanical prosthesis, 2.57 (95% CI 1.50–4.40) for acute kidney injury as originally extracted, and 1.04 (95% CI 1.00–1.07) per 10 minutes of bypass time. Adding procedure type and body mass index to that model widened the confidence interval for a mechanical prosthesis to 0.42–12.98, because procedure type and prosthesis type were almost collinear (Supplementary Table S6).

Model Checks

The primary model had an apparent c-statistic of 0.690 (95% CI 0.636–0.744) and an optimism-corrected c-statistic of 0.652. The optimism-corrected calibration slope was 0.81, which indicates that the estimates would be expected to shrink in new data (Supplementary Table S7). For 11 parameters, the criterion of Riley et al for an expected shrinkage of at least 0.9 would have required 2,849 patients.[24] Adjusted generalized variance inflation factors ($GVIF^{1/(2df)}$) were all 1.30 or

Table 4 Factors Associated with Unplanned Index-Hospital Readmission Within 28 Days After Open Heart Valve Surgery: Primary Firth Penalized Logistic Regression Model (n = 1,334; 97 Events)

Factor	Crude OR (95% CI)	Adjusted OR (95% CI)[a]	p-value[b]
Age (per 10 years)	1.01 (0.86–1.20)	1.21 (0.97–1.54)	0.096
Preoperative atrial fibrillation	1.51 (1.00–2.29)	1.08 (0.68–1.71)	0.740
Chronic kidney disease	1.75 (1.11–2.75)	1.42 (0.85–2.33)	0.172
Redo cardiac surgery	1.87 (1.11–3.14)	1.32 (0.71–2.34)	0.372
Valve position (reference = mitral)			
Aortic	0.60 (0.33–1.10)	0.52 (0.26–1.01)	0.055
Mitral and aortic	1.38 (0.83–2.30)	0.83 (0.46–1.47)	0.523
Tricuspid or pulmonary only	1.16 (0.57–2.37)	1.93 (0.83–4.21)	0.125
Prosthesis type (reference = no replacement prosthesis)			
Bioprosthetic	1.37 (0.77–2.44)	1.35 (0.71–2.61)	0.359
Mechanical	2.50 (1.41–4.45)	3.98 (1.97–8.25)	<0.001
Mechanical vs bioprosthetic[c]	1.83 (1.15–2.90)	2.95 (1.65–5.32)	<0.001
Cardiopulmonary bypass time (per 30 min)	1.170 (1.061–1.290)	1.157 (1.032–1.291)	0.013
Acute kidney injury, KDIGO creatinine criterion	2.66 (1.57–4.52)	2.00 (1.10–3.53)	0.024

Notes: Crude odds ratios are from univariable logistic regression with Wald 95% confidence intervals. Results with maximum likelihood estimation and the sensitivity analyses are given in Supplementary Table S5. a = Firth penalized logistic regression including all variables listed, with 95% profile penalized-likelihood confidence intervals; 11 parameters. b = p-values for adjusted odds ratios. c = Same model with bioprosthetic valve as the reference category.

Abbreviations: CI, confidence interval; KDIGO, Kidney Disease: Improving Global Outcomes; OR, odds ratio.

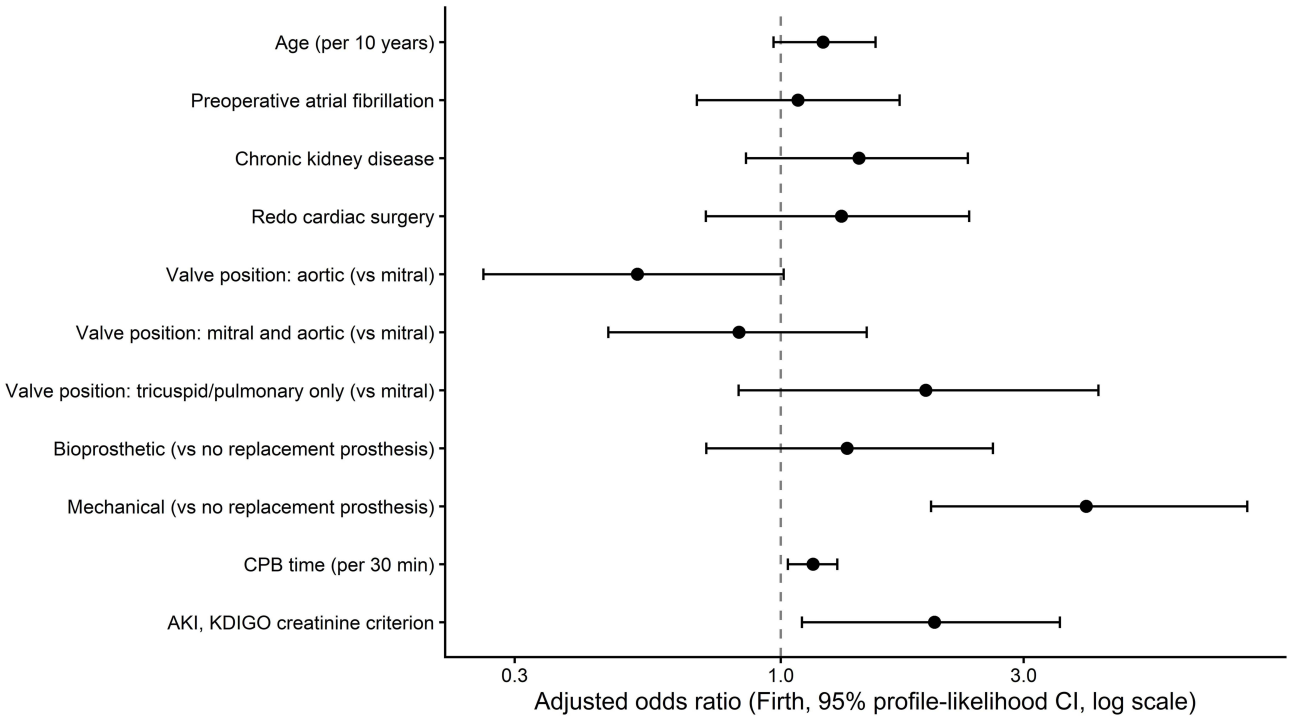


Figure 2 Adjusted odds ratios for unplanned index-hospital readmission within 28 days in the primary Firth penalized logistic regression model (n = 1,334; 97 events). Horizontal bars show 95% profile penalized-likelihood confidence intervals; the horizontal axis is on a logarithmic scale.
Abbreviations: AKI, acute kidney injury; CPB, cardiopulmonary bypass; eGFR, estimated glomerular filtration rate; KDIGO, Kidney Disease: Improving Global Outcomes.

lower. Restricted cubic splines suggested a departure from linearity for age (p = 0.027) but not for bypass time (p = 0.269); modeling age with a spline (S6) did not change the other estimates (Supplementary Table S7).

Discussion

In this five-year cohort of 1,336 patients who underwent open heart valve surgery at a tertiary cardiac referral center in northeastern Thailand, 7.26% had an unplanned readmission to the index hospital within 28 days of discharge. After adjustment for clinically selected covariates, a mechanical prosthesis, acute kidney injury during the index admission, and longer cardiopulmonary bypass time were associated with readmission. Anticoagulation-related problems, most often an international normalized ratio outside the target range, were the most frequent documented reason. These associations were consistent across six sensitivity analyses.

The observed rate should be compared with published estimates with care. Pack et al reported that 7.8% of 38,532 patients were readmitted to the index hospital within one month of valve surgery,[10] and a single-center study of open-heart surgery reported 8.7% at 30 days.[17] The 18.3% reported for isolated valve surgery by Iribarne et al included all-cause readmissions up to 65 days after surgery and is not directly comparable.[9] Our figure is limited to the index hospital. Care after valve procedures is often fragmented; in a cohort of 266 patients undergoing transcatheter aortic valve replacement, 39.1% were readmitted within 90 days to a site other than the treating center.[40] Because the study center receives referrals from a largely rural region, some patients were probably readmitted to provincial hospitals closer to home, and our rate may underestimate overall readmission. This under-ascertainment may also differ between groups. If patients who live farther from the center, or who are referred back to provincial hospitals for follow-up, differ in prosthesis type or renal function, the associations could be biased in either direction. The 28-day window, shorter than the 30-day window used in most comparator studies, would also lower the observed proportion slightly. Annual rates ranged from 4.53% to 10.26%; with 13 to 24 events per year, the absence of a statistically significant difference between years does not establish that the rate was stable.

The case mix also differs from that of the comparator cohorts. The median age was 60 years, younger than in most North American series. Thai surgical series report a high proportion of rheumatic valve disease;[41,42] however, the etiology was stated in only 16.0% of diagnoses in our records, and we therefore could not describe the cohort by etiology or adjust for it.

The association with a mechanical prosthesis was the strongest finding and remained after adjustment for valve position, age, atrial fibrillation, and previous surgery. Because the primary contrast is with repair without a replacement prosthesis, we also compared mechanical with bioprosthetic valves directly; the odds of readmission were approximately three times higher with a mechanical valve. This agrees with a propensity-matched analysis of 109,744 patients undergoing isolated surgical aortic valve replacement, in which 30-day readmission was higher after mechanical than after bioprosthetic valves (12.6% compared to 10.3%), with the excess concentrated in bleeding or coagulopathy and in effusions.[43] Most anticoagulation-related readmissions in our cohort (19 of 24) occurred in patients with a mechanical prosthesis, and most were for an international normalized ratio outside the target range without documented bleeding. Anticoagulation exposure is a plausible explanation; however, we did not measure anticoagulation intensity or time in the therapeutic range, and the study therefore cannot show that the association operates through anticoagulation. Confounding by indication is also possible, because mechanical valves may be chosen for younger patients, for patients with multivalve or rheumatic disease, or for patients already receiving anticoagulation, and these characteristics were only partly measured. Stable anticoagulation is difficult to achieve in Thai patients; after mechanical mitral valve replacement, patients in one cohort spent 54.0% of the observed time below an international normalized ratio of 2.5.[44] European guidance notes that thromboembolic risk after valve surgery is highest in the early postoperative period,[4] which overlaps the 28-day window.

Acute kidney injury by the creatinine criterion was associated with twice the odds of readmission, and the crude odds increased with stage. A multicenter registry of 2,209 cardiac surgical patients found a similar gradient, with adjusted odds ratios of 1.81, 2.39, and 3.47 for stages 1 to 3.[45] Acute kidney injury may lead to readmission directly, through fluid overload or electrolyte disturbance, or may mark hemodynamic and renal vulnerability.[34,35] The association was stronger with the originally extracted variable (aOR 2.75), which also included physician-diagnosed cases; however, that definition is harder to reproduce. Bypass time was associated with readmission whether or not acute kidney injury was in the model (aOR per 30 minutes 1.16 and 1.18). Because longer bypass may contribute to renal injury,[35] the estimate with acute kidney injury in the model represents the part of the association of bypass time that is not explained by acute kidney injury. Although the estimate per 30 minutes is modest, a patient at the 75th percentile of bypass time (184 minutes) had 1.45 times the odds of readmission of a patient at the 25th percentile (108 minutes). Similarly, the loss of statistical significance for chronic kidney disease after adjustment does not show that its effect operates through acute kidney injury; the adjusted estimate was imprecise (aOR 1.42, 95% CI 0.85–2.33).

Day-7 follow-up attendance was not associated with readmission; however, this result provides little information on whether follow-up is effective. Attendance was measured after the outcome window had begun, and a patient readmitted before day 7 could not attend; attendance therefore partly reflects the absence of early readmission. Without discharge dates we could not perform a landmark analysis. Attendance also records only that a visit took place, not whether medication was reviewed or the international normalized ratio was checked. In a large Ontario cohort, physician follow-up within seven days of discharge after myocardial infarction, heart failure, or chronic obstructive pulmonary disease was not associated with a significant reduction in 30-day readmission,[46] and in a pragmatic trial in heart failure, 30-day readmission did not differ between early nurse or pharmacist telephone visits and physician clinic visits.[47] Structured transitional care has reduced readmission in other populations;[14,48] however, it has not been evaluated after valve surgery.

Preoperative atrial fibrillation, which predicted readmission in a single-center study of open heart surgery[17] and heart failure hospitalization after transcatheter aortic valve implantation,[49] was not associated with readmission after adjustment (aOR 1.08, 95% CI 0.68–1.71), and the confidence interval does not exclude a moderate association. Previous cardiac surgery (aOR 1.32, 95% CI 0.71–2.34) was also not associated with readmission at $p < 0.05$; with 97 events this estimate is imprecise and should not be read as evidence of no association. The discrimination of the model was modest (optimism-corrected c-statistic 0.65), and the calibration slope of 0.81 indicates overfitting relative to the number of events; most readmission prediction models in other settings also discriminate poorly.[50] The model was built to estimate associations and should not be used for individual risk prediction. Factors that may influence readmission, such as health literacy, distance from the hospital, caregiver support, and anticoagulation management after discharge, were not recorded.

The findings identify candidates for service evaluation; they do not show that any intervention reduces readmission. Patients with a mechanical prosthesis, acute kidney injury during the index admission, or prolonged bypass time can be identified before discharge from routine records, and closer monitoring of anticoagulation and renal function in the first weeks after discharge could be evaluated in this group. In nursing practice, this could take the form of a discharge checklist that identifies these patients, records the target international normalized ratio and the date and place of the first test after discharge, schedules a renal function test, and confirms that the patient and caregiver can recognize signs of bleeding and fluid overload. Because many patients live far from the center, arrangements with provincial hospitals for anticoagulation monitoring may matter as much as the content of discharge education. Pharmacist participation in warfarin management reduced bleeding in a meta-analysis,[51] and patient self-management of oral anticoagulation reduced mortality in a Cochrane review, whereas self-monitoring alone did not.[52] Neither approach has been evaluated after valve surgery in Thailand. Because readmission causes were classified from documentation without independent review, structured adjudication would be needed before the proportion of preventable readmissions can be estimated.

This study included every eligible patient operated on over five consecutive years at a high-volume tertiary cardiac center, giving a complete series rather than a sample. Patients who underwent more than one operation during the period contributed only their first operation, so each patient appears once, and the regression model's independence assumption is preserved. Variables were prespecified in the study protocol and span five domains, including continuity of care, which this literature rarely examines. A documented reason for readmission was available for all 97 readmissions, allowing the cause profile to be described without missing data. We ascertained readmission by searching the hospital information system through January 28, 2026, so every patient, including those discharged at the end of December 2025, had a complete 28-day observation window; the annual rates are therefore comparable across the five years, and the final year is not deflated by incomplete follow-up. Finally, the authors report model calibration, discrimination, and a sensitivity analysis alongside the effect estimates so readers can judge the model's stability, not just its coefficients.

Limitations

This study has several limitations. First, it was a single-center retrospective study based on routine documentation; therefore, information bias is possible, and the findings may not apply to centers with a different case mix or follow-up system. Second, readmissions to other hospitals were not captured, and deaths after discharge could not be identified; patients who died before they could be readmitted were counted as not readmitted. Both problems may lead to underestimation of the readmission rate and to bias if they differ between exposure groups. Third, 193 records were excluded, including 109 patients transferred to other hospitals; excluded patients had previous cardiac surgery more often, and operative details were not available for further comparison; therefore, selection bias cannot be excluded. Fourth, discharge and readmission dates were not available, which prevented analysis of the time to readmission and a landmark analysis of day-7 follow-up. Fifth, several variables had broad or incomplete definitions: blood loss, rhythm disturbance, and infection were recorded without severity or site, acute kidney injury was based on a single postoperative creatinine value with unstandardized timing, and valve etiology was rarely documented. Sixth, readmission causes were classified from documentation without independent adjudication, and extracted data were verified by a second team member but not independently re-extracted; therefore, inter-rater agreement could not be assessed. Seventh, with 97 events the model had 8.8 events per parameter; penalized estimation reduces small-sample bias; however, the estimates remain imprecise, and residual confounding by unmeasured factors such as socioeconomic status, health literacy, caregiver support, and travel distance is likely. Finally, the 28-day window limits direct comparison with studies that used 30 days.

Future studies should link hospital records with regional or national databases to capture readmissions and deaths outside the study center, record discharge and readmission dates, and use standardized definitions of postoperative complications and adjudicated readmission causes. Multicenter prospective data would be needed before a readmission risk assessment tool could be developed for patients recovering from open heart valve surgery in Thailand.

Conclusions

Unplanned index-hospital readmission within 28 days occurred in 7.26% of patients discharged after open heart valve surgery, a figure that may underestimate overall readmission because readmissions to other hospitals were not captured.

Acute kidney injury during the index admission, mechanical prosthesis implantation compared with repair without a replacement prosthesis or with a bioprosthetic, and longer cardiopulmonary bypass time were associated with readmission. Anticoagulation-related problems were the most frequently documented reason. These findings support evaluation of targeted discharge and anticoagulation-care strategies, while incomplete capture of external readmissions and residual confounding limit interpretation.

Generative AI Statement

The authors used Grammarly Pro (Grammarly Inc., USA) during manuscript preparation to assist with grammar, spelling, punctuation, and language clarity. In addition, Claude Opus 5.5--Claude Code (Anthropic) powered by the Opus 5.5 model, was used to review and proofread R code for statistical analyses. All AI-generated suggestions and outputs were critically reviewed and verified by the authors. The authors take full responsibility for the accuracy, integrity, and final content of the manuscript.

Data Sharing Statement

The de-identified data supporting the findings of this study are available from the corresponding author on reasonable request, subject to approval by the Center for Ethics in Human Research, Khon Kaen University, and the study center.

Ethics Approval and Informed Consent

This study was reviewed and approved by the Center for Ethics in Human Research, Khon Kaen University (Approval No. HE691384), on June 6, 2026. The ethics committee waived the requirement for informed consent at the time of approval. The study is a retrospective analysis of secondary data obtained from medical records and the electronic hospital database. It involves no direct contact with patients, no intervention, and no collection of biological specimens, and poses no more than minimal risk to participants; therefore, the researchers requested a waiver of informed consent in accordance with the ethics committee's criteria. The Director of the tertiary cardiac center provided written permission to access the hospital information system and medical records before data collection began.

Personal data were protected throughout. A study identifier replaced direct identifiers, and the analysis dataset included no name, national identification number, hospital number, telephone number, or other identifying information. The research team stored electronic data on password-protected computers accessible only to the team, and kept research data files separate from any document that could identify a patient. Results are reported only in aggregate form so no individual can be identified. The research team will retain the data for five years after the project ends, then destroy it in accordance with Khon Kaen University policy. The study was conducted in accordance with the Declaration of Helsinki principles.

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Author Contributions

All authors made a significant contribution to the work reported, whether 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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completion of the study. The funder had no role in the study design, data collection, analysis, interpretation of the data, preparation of the manuscript, or the decision to submit it for publication.

Disclosure

The authors declare that there is no conflict of interest regarding the publication of this study.

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