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Impact of Anesthetic Strategy and the Institutional Learning Curve on Outcomes After Transcatheter Aortic Valve Implantation

ABSTRACT

Background: As transcatheter aortic valve implantation (TAVI) has become a standard treatment for severe aortic stenosis, the optimal anesthetic strategy remains debated. In addition to anesthesia choice, institutional experience may influence procedural efficiency and outcomes; however, their interplay remains unclear. This study aimed to evaluate the association between anesthetic strategy and outcomes after elective transfemoral TAVI and to assess whether these associations are modified by institutional experience.

Methods: In this retrospective observational study, consecutive patients undergoing elective transfemoral TAVI at a high-volume tertiary center between 2020 and 2025 were analyzed. To reduce selection bias, inverse probability weighting with double-robust outcome modeling was applied. The primary outcome was intensive care unit (ICU) stay duration, and in-hospital mortality was evaluated as a secondary outcome. Institutional experience was modeled as chronological case sequence, with an interaction term to assess effect modification.

Results: A total of 852 patients were included. After weighting, baseline characteristics were well balanced between conscious sedation (CS) and general anesthesia (GA) groups. General anesthesia utilization decreased from 71% in 2020 to 13% in 2025. Conscious sedation was associated with shorter ICU stay compared with GA (21.0 vs. 23.0 hours; $P < .001$). In adjusted analysis, GA remained independently associated with longer ICU stay (rate ratios = 1.46, $P < .001$, 95% CI: 1.28-1.66). Anesthetic strategy was not associated with in-hospital mortality (OR = 1.14, $P = .667$, 95% CI: 0.62-2.10), and no significant interaction with case sequence was observed.

Conclusion: Conscious sedation was associated with shorter ICU stay, while no significant differences were observed in mortality outcomes.

Keywords: Aortic stenosis, conscious sedation, general anesthesia, learning curve, length of stay, transcatheter aortic valve implantation

ORIGINAL INVESTIGATION

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INTRODUCTION

Transcatheter aortic valve implantation (TAVI) has become an established treatment for patients with symptomatic severe aortic stenosis, with indications continuing to expand across a broad range of risk profiles.[1] Advances in device technology and procedural techniques have led to substantial improvements in clinical outcomes, reinforcing the role of TAVI as a minimally invasive and widely adopted intervention.[2] As procedural success rates improve, attention has increasingly shifted toward optimizing perioperative management to enhance recovery, reduce complications, and improve resource utilization.[3]

The optimal anesthetic strategy for TAVI remains an area of ongoing debate. Historically, most procedures were performed under general anesthesia (GA) to ensure airway control and facilitate intraprocedural imaging. However, there has been a progressive transition toward conscious sedation (CS), driven by the development of minimalist TAVI approaches. Observational studies and randomized trials have suggested that CS may be associated with shorter procedure duration, reduced need for vasoactive support, and faster postprocedural recovery. Recent

single-center data have also demonstrated favorable hemodynamic safety with dexmedetomidine-fentanyl sedation during TAVI.[4] Nevertheless, GA continues to be preferred in selected cases, particularly in more complex anatomies or when procedural control and imaging are prioritized, and a uniform consensus has not yet been established.[3]

In addition to anesthetic strategy, procedural outcomes in TAVI are strongly influenced by institutional and operator experience. The learning curve has been shown to affect procedural efficiency, complication rates, and overall outcomes, particularly during the early phases of program development.[5] However, the relationship between anesthetic strategy and institutional experience has not been fully clarified. Specifically, it remains uncertain whether the benefits attributed to conscious sedation are consistent across different stages of the learning curve, or whether they are partly driven by increasing procedural proficiency over time.[6,7]

In this study, the authors aimed to evaluate the association between anesthetic strategy and clinical outcomes in patients undergoing elective transfemoral TAVI at a high-volume tertiary center, while accounting for institutional experience. Using inverse probability weighting (IPW) and a double-robust analytical approach, the authors assessed intensive care unit (ICU) stay duration as the primary outcome and in-hospital mortality as a secondary outcome. In addition, the authors examined the interaction between anesthetic strategy and case sequence, modeled as a surrogate of the institutional learning curve, to determine whether the effect of anesthesia strategy varies with increasing procedural experience.

METHODS

Study Design and Population

This retrospective observational study was conducted at a tertiary heart center in Türkiye and designed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[8] The study population consisted of consecutive adult patients (≥18 years) who underwent elective transfemoral TAVI between January 1, 2020, and November 30, 2025. The study database was locked on November 30, 2025; therefore, procedural volumes reported for 2025 represent a partial calendar year and should not be interpreted as the institution's full annual TAVI volume. Patients were identified through the hospital's electronic medical records.

Patients were eligible for inclusion if they had undergone transfemoral TAVI at the study center during the specified study period, were aged 18 years or older, had a clearly documented anesthesia strategy (conscious sedation or general anesthesia), and had available data on ICU stay duration, in-hospital mortality, and baseline clinical, laboratory, and echocardiographic parameters.

Patients were excluded if they underwent emergency TAVI procedures, had preprocedural hemodynamic instability (including cardiogenic shock or requirement for vasopressor/inotropic or mechanical circulatory support), required emergency surgical intervention, were intubated and mechanically ventilated prior to the procedure, or had missing key clinical, laboratory, echocardiographic, or procedural data.

The study protocol was approved by the Local Ethics Committee (approval number: 2026/05/1401; approval date: March 10, 2026) and was conducted in accordance with the principles of the Declaration of Helsinki.

Data Collection and Variables

Comprehensive clinical data were extracted from the institutional database. Baseline characteristics, including demographic features, comorbidities, and preprocedural medications, were recorded.

Laboratory parameters (hematological and biochemical markers) were collected at baseline and during the early postoperative period. Acute kidney injury was defined as an absolute increase in serum creatinine of ≥0.3 mg/dL or a ≥1.5-fold increase from baseline within 72 hours after the procedure.[9]

Transthoracic echocardiography was performed before and after the procedure to assess valvular function, ventricular dimensions, and hemodynamic parameters.

Anesthesia Strategy and Learning Curve

Patients were categorized into 2 groups based on the primary anesthetic technique: general anesthesia (GA) or conscious sedation (CS). The choice of anesthesia was determined by the attending anesthesiologist in accordance with the heart team's decision. Conscious sedation was administered using a standardized institutional protocol combining intravenous midazolam and fentanyl, titrated to achieve adequate sedation while maintaining spontaneous ventilation and verbal contact. General anesthesia was performed using total intravenous anesthesia with endotracheal intubation. Intraprocedural transesophageal echocardiography was not routinely used during transfemoral TAVI procedures; when clinically indicated, it was performed preprocedurally for anatomical assessment and procedural planning. Patients requiring intraprocedural conversion from conscious sedation to general anesthesia were excluded from the study cohort.

HIGHLIGHTS

- Conscious sedation (CS) was associated with significantly shorter intensive care unit (ICU) stay compared with general anesthesia (GA) in transfemoral transcatheter aortic valve implantation.
- General anesthesia independently increased ICU stay duration by 46% in double-robust inverse probability weighting (IPW)-adjusted analysis.
- No significant differences were observed between CS and GA in in-hospital mortality or major complications.
- The benefit of CS on ICU stay remained consistent across different stages of the institutional learning curve.
- Covariate balance was successfully achieved using IPW, strengthening the validity of the findings.

Institutional experience was assessed using the chronological case sequence, defined as the order in which each TAVI procedure was performed during the study period. Case sequence was treated as a continuous variable and used as a surrogate marker of the institutional learning curve. Although institutional learning curves are inherently multidimensional, chronological case sequence has been widely used in TAVI research as a pragmatic surrogate of cumulative institutional experience, reflecting procedural maturation, increasing operator familiarity, and organizational development over time.[10,11]

Outcome Measures

The primary outcome was the duration of ICU stay (hours). Secondary outcomes included in-hospital mortality. Additionally, postoperative clinical events—including cerebrovascular accidents, new permanent pacemaker requirements, acute kidney injury, and access-site complications—were documented. Intensive care unit discharge was guided by standardized clinical criteria throughout the study period, including hemodynamic stability without vasopressor support, absence of significant arrhythmia requiring continuous monitoring, adequate respiratory function, and stable renal function. These criteria remained consistent across the study period.

Procedural Success

Procedural success was defined based on the Valve Academic Research Consortium-3 criteria.[12] It was characterized by the successful implantation of the valve in the proper anatomical position, with intended performance (mean aortic gradient < 20 mm Hg and absence of moderate or severe paravalvular leak) and without immediate procedure-related mortality or major complications including stroke and conversion to surgery. Postoperative valvular functions were assessed via transthoracic echocardiography performed prior to discharge.

Statistical Analysis

Continuous variables were assessed for normality using the Shapiro–Wilk test and visual inspection of histograms. Normally distributed variables are expressed as mean ± SD and compared using Student's *t*-test. Non-normally distributed continuous variables are presented as median and interquartile range (IQR) and compared using the Mann–Whitney *U*-test. Categorical variables are reported as frequencies and percentages, and comparisons were performed using the Pearson chi-square test or Fisher's exact test, as appropriate.

To minimize potential selection bias and achieve balanced baseline covariates between anesthesia strategies (GA vs. CS), IPW was employed. Propensity scores were calculated using a logistic regression model incorporating age, sex, hypertension, diabetes, coronary artery disease, heart failure, chronic obstructive pulmonary disease (COPD), chronic kidney disease, atrial fibrillation, baseline left ventricular ejection fraction (LVEF), aortic mean gradient, and case sequence (representing the institutional learning curve). Average Treatment Effect weights were utilized for the IPW process. Covariate balance was assessed using Standardized Mean Differences (SMD), with an SMD < 0.1 considered indicative of successful balancing between groups. The improvement in covariate balance following IPW is illustrated in Figure 1, confirming adequate overlap between groups.

For the analysis of clinical outcomes, a "Double-Robust" estimation approach was adopted, combining IPW weighting with multiple regression within the same model to enhance the reliability of the estimates. Due to the right-skewed distribution of the ICU stay duration (hours), a Gamma Generalized Linear Model with a log-link function was applied. Coefficients from the Gamma model were exponentiated to provide Rate Ratios (RRs) for ease of interpretation. In-hospital mortality was analyzed using a logistic regression model with a quasibinomial distribution, and results are presented as odds ratios (ORs) with 95% CIs.

The impact of the institutional learning curve was accounted for by including the case sequence as a continuous covariate in the outcome models. Furthermore, an interaction term between the anesthesia strategy and case sequence was included to evaluate whether the effect of the anesthetic choice on ICU duration varied over time. A 2-sided $P < .05$ was considered statistically significant.

Long-term all-cause mortality was defined as death occurring at any time after the index TAVI procedure during the available follow-up period. Survival time was calculated from the date of the TAVI procedure to death from any cause or censoring at the last follow-up contact. Patients alive at the end of the study period were right-censored at their last recorded contact date. In-hospital deaths were included in the survival analysis as early events.

To maintain methodological consistency with the primary analysis, an IPW-weighted multiple Double-Robust Cox proportional hazards model was constructed by applying propensity score-derived IPW weights within the Cox framework using the survey package in R, while simultaneously adjusting for all prespecified baseline covariates. Results are presented as adjusted HR with 95% CIs. To assess whether the association between anesthetic strategy and long-term mortality was modified by institutional experience, a cross-product interaction term between anesthetic strategy and chronological case sequence was additionally tested in a separate model. Kaplan–Meier survival curves were generated using IPW-weighted data, and survival differences between groups were evaluated within the Cox modeling framework.

All statistical analyses were performed using R software (version 4.4.3; R Foundation for Statistical Computing, Vienna, Austria) utilizing the "WeightIt," "cobalt," "survey," "survival," and "ggeffects" packages.

RESULTS

Study Population and Baseline Characteristics

A total of 852 patients who underwent elective transfemoral TAVI were included in the final analysis. The median age was 78 years (IQR 74-83), and 55.3% of the study population were male. Comorbidity burden was substantial, with high

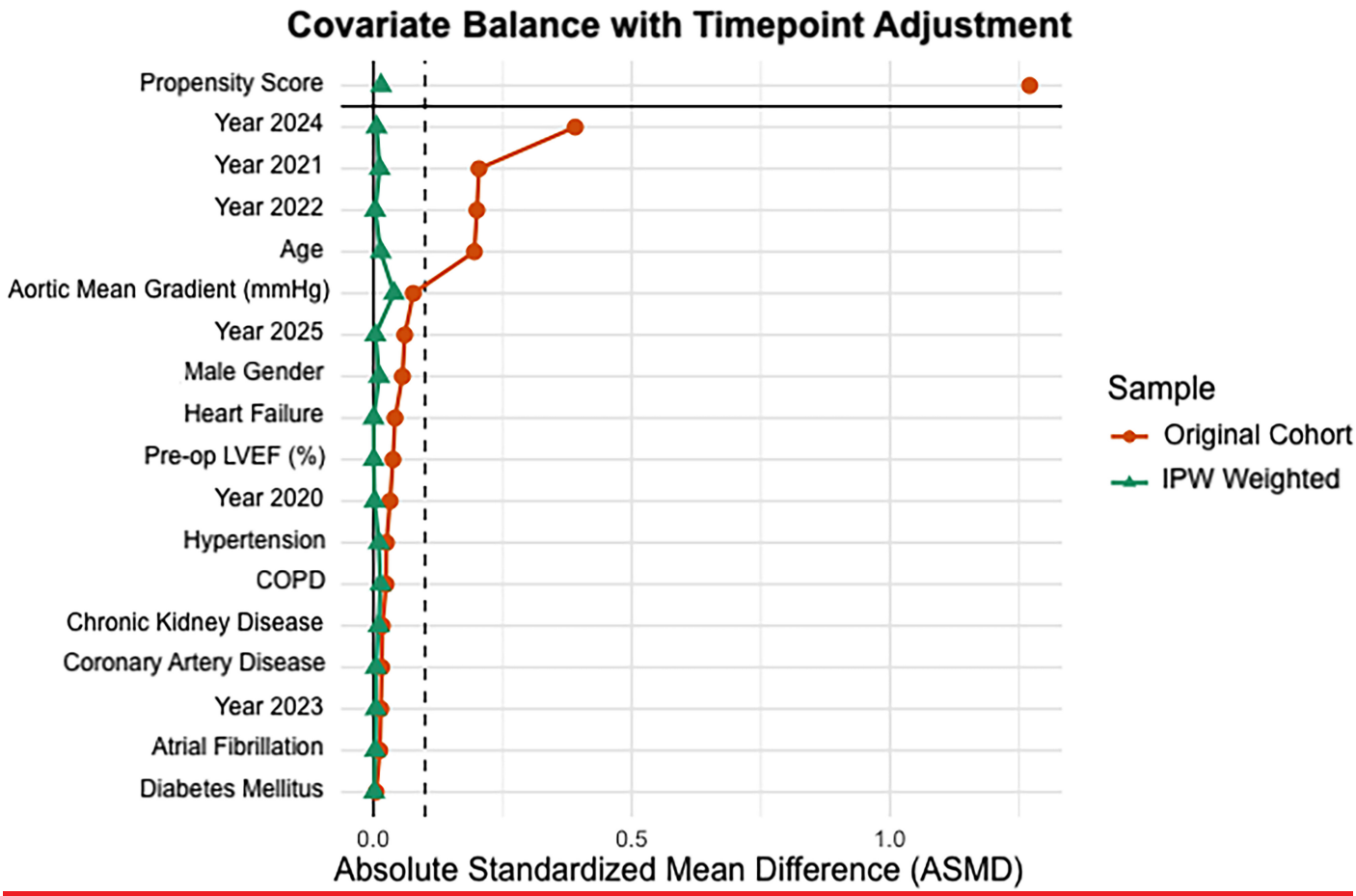

Figure 1. Covariate balance before and after inverse probability weighting (IPW). Standardized mean differences (SMDs) for baseline covariates between the general anesthesia (GA) and conscious sedation (CS) groups are shown before and after weighting. The dashed vertical line represents the predefined threshold for acceptable balance (SMD < 0.1). After IPW, all covariates achieved adequate balance, indicating successful adjustment for baseline differences.

prevalences of hypertension (81.6%), coronary artery disease (52.1%), diabetes mellitus (32.9%), atrial fibrillation (29.5%), and chronic kidney disease (19.5%).

Baseline demographic, clinical, laboratory, echocardiographic, and procedural characteristics according to anesthesia strategy are summarized in Table 1. In the unadjusted comparison, some differences were observed between the CS and GA groups, particularly with respect to age, procedural year distribution, selected laboratory parameters, and tricuspid regurgitation severity. The median aortic valve area was 0.7 cm^2 (IQR 0.5-0.8), the median preprocedural peak aortic gradient was 72.0 mm Hg (IQR 62.8-82.2), and the median LVEF was 65.0% (IQR 50.0-65.0). The distribution of transcatheter heart valve platforms is presented in Supplementary Table 1. After inverse probability weighting, all prespecified covariates achieved adequate balance, with standardized mean differences below 0.1 (Figure 1).

Temporal Trends, Procedural Findings, and Early Clinical Outcomes

A marked temporal change in anesthetic practice was observed during the study period. The proportion of procedures performed under GA progressively decreased from 71% in 2020 to 13% in 2025, whereas the use of CS increased accordingly (Figure 2).

Postprocedural echocardiographic findings were generally comparable between the 2 groups. Postprocedural LVEF, peak and mean aortic gradients, and severe paravalvular leak rates were similar in patients treated with CS and GA. Although the overall distribution of paravalvular aortic regurgitation grades differed between groups, the incidence of severe PVL remained low and did not differ significantly.

Among early clinical outcomes, acute kidney injury occurred less frequently in the CS group than in the GA group (7.0% vs. 11.4%, $P = .028$). In contrast, no statistically significant differences were observed between groups with respect to cerebrovascular events, permanent pacemaker implantation, or femoral access-site complications (Table 1).

Intensive Care Unit Stay Duration and In-Hospital Mortality

Intensive care unit stay duration was significantly shorter in the CS group compared with the GA group (21.0 [IQR 17.0-24.0] vs. 23.0 [IQR 20.0-31.2] hours, $P < .001$) (Table 1). In the double-robust inverse probability weighted gamma regression model, GA remained independently associated

Table 1. Baseline Characteristics, Procedural Data, and Clinical Outcomes According to Anesthesia Strategy (Sedation vs. General Anesthesia)

Variables	Overall (n = 852)	Sedation (n = 511)	General Anesthesia (n = 341)	*P*
Demographics and comorbidities				
Age, years	78.0 (74.0-83.0)	78.0 (73.0-82.0)	79.0 (75.0-83.0)	.003*
Male sex, n (%)	471 (55.3)	271 (53.0)	200 (58.7)	.122
Hypertension, n (%)	695 (81.6)	422 (82.6)	273 (80.1)	.4
Diabetes mellitus, n (%)	280 (32.9)	169 (33.1)	111 (32.6)	.933
Coronary artery disease, n (%)	444 (52.1)	263 (51.5)	181 (53.1)	.696
Congestive heart failure, n (%)	176 (20.7)	97 (19.0)	79 (23.2)	.164
Chronic obstructive pulmonary disease, n (%)	120 (14.1)	77 (15.1)	43 (12.6)	.363
Cerebrovascular disease, n (%)	70 (8.2)	47 (9.2)	23 (6.7)	.25
Atrial fibrillation, n (%)	251 (29.5)	148 (29.0)	103 (30.2)	.754
Chronic kidney disease, n (%)	166 (19.5)	96 (18.8)	70 (20.5)	.589
Procedural year				<.001*
2020, n (%)	21 (2.5)	6 (1.2)	15 (4.4)	
2021, n (%)	93 (10.9)	14 (2.7)	79 (23.2)	
2022, n (%)	125 (14.7)	34 (6.7)	91 (26.7)	
2023, n (%)	225 (26.4)	132 (25.8)	93 (27.3)	
2024, n (%)	342 (40.1)	285 (55.8)	57 (16.7)	
2025, n (%)	46 (5.4)	40 (7.8)	6 (1.8)	
Medications				
Beta-blocker, n (%)	482 (56.6)	288 (56.4)	194 (57.0)	.932
ACE inhibitor, n (%)	501 (58.9)	299 (58.6)	202 (59.3)	.923
Statin, n (%)	310 (36.5)	211 (41.4)	99 (29.1)	.089
SGLT2 inhibitor, n (%)	101 (11.9)	73 (14.3)	28 (8.1)	.246
MRA, n (%)	124 (14.6)	84 (16.5)	40 (11.6)	.418
Furosemide, n (%)	318 (37.4)	180 (35.3)	138 (40.7)	.511
Preprocedural laboratory parameters				
Hemoglobin, g/dL	11.7 ± 1.9	11.9 ± 1.9	11.6 ± 1.9	.022*
Platelets, $\times 10^3/\mu L$	227.0 (184.0-274.0)	228.0 (182.5-271.0)	224.0 (186.0-280.0)	.384
WBC, $\times 10^3/\mu L$	7.3 (6.0-9.1)	7.3 (5.9-8.9)	7.3 (6.1-9.4)	.144
Monocytes, $\times 10^3/\mu L$	0.6 (0.5-0.7)	0.5 (0.4-0.7)	0.6 (0.5-0.8)	<.001*
Lymphocytes, $\times 10^3/\mu L$	1.6 (1.1-2.0)	1.6 (1.2-2.0)	1.6 (1.1-1.9)	.311
Neutrophils, $\times 10^3/\mu L$	4.8 (3.8-6.2)	4.7 (3.7-6.0)	4.9 (3.8-6.4)	.149
Creatinine, mg/dL	1.0 (0.8-1.3)	0.9 (0.8-1.2)	1.0 (0.8-1.3)	.43
AST, U/L	20.0 (16.0-27.0)	21.0 (16.2-27.0)	19.6 (15.3-26.3)	.029*
ALT, U/L	14.0 (10.6-20.3)	14.5 (11.1-21.0)	13.5 (10.0-19.0)	.008*
Albumin, g/dL	4.0 (3.7-4.2)	3.9 (3.7-4.1)	4.0 (3.7-4.2)	.055
Total bilirubin, mg/dL	0.5 (0.4-0.8)	0.6 (0.4-0.8)	0.5 (0.4-0.8)	.521
BNP, pg/mL	621.0 (241.0-1765.0)	565.0 (223.5-1434.0)	751.5 (278.8-2490.5)	.012*
CRP, mg/L	5.1 (2.0-14.4)	5.0 (2.0-13.9)	5.4 (2.0-15.1)	.285
Troponin, ng/L	0.1 (0.0-18.0)	0.1 (0.0-15.2)	0.1 (0.0-22.8)	.445
Preprocedural echocardiographic and tomography parameters				
LVEF, %	65.0 (50.0-65.0)	60.0 (50.0-65.0)	65.0 (50.0-65.0)	.882
LVEDD, cm	4.7 (4.4-5.1)	4.7 (4.4-5.1)	4.7 (4.4-5.1)	.697
LVESD, cm	3.0 (2.6-3.5)	3.0 (2.6-3.5)	2.9 (2.5-3.5)	.542
Aortic max gradient, mm Hg	72.0 (62.8-82.2)	71.0 (62.0-81.0)	74.0 (63.0-84.0)	.091
Aortic mean gradient, mm Hg	44.0 (40.0-51.0)	43.0 (40.0-50.0)	44.0 (40.0-52.0)	.238
Aortic valve area, cm^2	0.7 (0.5-0.8)	0.7 (0.6-0.8)	0.7 (0.5-0.8)	.215
LVOT diameter, cm	2.0 (1.8-2.1)	1.9 (1.8-2.1)	2.0 (1.8-2.1)	.542
TAPSE, cm	2.0 (1.8-2.1)	2.0 (1.8-2.2)	2.0 (1.7-2.1)	.059
PASP (echo), mm Hg	35.0 (30.0-50.0)	35.0 (30.0-45.8)	35.0 (30.0-50.0)	.623
Mitral regurgitation severity				.16
Grade 1, n (%)	386 (45.4)	236 (46.3)	150 (44.0)	
Grade 2, n (%)	315 (37.0)	195 (38.2)	120 (35.2)	
Grade 3, n (%)	85 (10.0)	48 (9.4)	37 (10.9)	
Grade 4, n (%)	4 (0.5)	3 (0.6)	1 (0.3)	

(*Continued*)

Table 1. Baseline Characteristics, Procedural Data, and Clinical Outcomes According to Anesthesia Strategy (Sedation vs. General Anesthesia) (*Continued*)

Variables	Overall (n = 852)	Sedation (n = 511)	General Anesthesia (n = 341)	*P*
Aortic regurgitation severity				.487
Grade 1, n (%)	407 (47.8)	243 (47.6)	164 (48.1)	
Grade 2, n (%)	197 (23.1)	127 (24.9)	70 (20.5)	
Grade 3, n (%)	32 (3.8)	19 (3.7)	13 (3.8)	
Grade 4, n (%)	4 (0.5)	3 (0.6)	1 (0.3)	
Tricuspid regurgitation severity				.010*
Grade 1, n (%)	429 (50.4)	266 (52.2)	163 (47.8)	
Grade 2, n (%)	247 (29.0)	159 (31.2)	88 (25.8)	
Grade 3, n (%)	88 (10.3)	46 (9.0)	42 (12.3)	
Grade 4, n (%)	15 (1.8)	7 (1.4)	8 (2.3)	
LFLG AS, n (%)	106 (12.5)	64 (12.5)	42 (12.3)	.92
Paradoxical LFLG AS, n (%)	63 (7.4%)	39 (7.6)	24 (7.1)	.852
Agatston score	2955.0 (2039.5-4271.0)	2991.0 (2012.0-4226.0)	2904.0 (2088.5-4347.0)	.816
Postprocedural laboratory parameters				
Creatinine, mg/dL	1.0 (0.8-1.2)	0.9 (0.7-1.2)	1.0 (0.8-1.3)	.125
Troponin, ng/L	0.5 (0.1-120.8)	0.6 (0.2-123.5)	0.3 (0.1-110.7)	.7
BNP, pg/mL	321.0 (113.0-1036.5)	274.5 (84.5-762.2)	381.0 (126.0-1296.0)	.016*
Postprocedural echocardiographic parameters				
LVEF, %	65.0 (50.0-65.0)	65.0 (50.0-65.0)	60.0 (50.0-65.0)	.496
Aortic max gradient, mm Hg	15.0 (12.0-20.0)	15.0 (12.0-20.0)	16.0 (12.0-20.5)	.236
Aortic mean gradient, mm Hg	8.0 (6.0-11.0)	8.0 (6.0-11.0)	8.0 (6.0-11.8)	.452
TAPSE, cm	2.0 (1.7-2.0)	2.0 (1.8-2.1)	1.9 (1.7-2.0)	.069
PASP (echo), mm Hg	35.0 (25.0-45.0)	30.0 (25.0-41.0)	35.0 (30.0-45.0)	.051
Mitral regurgitation severity				.891
Grade 1, n (%)	460 (56.9)	282 (57.6)	178 (56.0)	
Grade 2, n (%)	202 (25.0)	117 (23.9)	85 (26.7)	
Grade 3, n (%)	44 (5.4)	28 (5.7)	16 (5.0)	
Grade 4, n (%)	2 (0.2)	1 (0.2)	1 (0.3)	
Tricuspid regurgitation severity				.155
Grade 1, n (%)	434 (53.7)	277 (56.5)	157 (49.4)	
Grade 2, n (%)	190 (23.5)	104 (21.2)	86 (27.0)	
Grade 3, n (%)	61 (7.5)	33 (6.7)	28 (8.8)	
Grade 4, n (%)	12 (1.5)	6 (1.2)	6 (1.9)	
Paravalvular aortic regurgitation severity				.031*
Grade 0, n (%)	485 (59.9)	313 (63.7)	172 (53.9)	
Grade 1, n (%)	246 (30.4)	136 (27.7)	110 (34.5)	
Grade 2, n (%)	69 (8.5)	38 (7.7)	31 (9.7)	
Grade 3, n (%)	10 (1.2)	4 (0.8)	6 (1.9)	
Severe PVL, n (%)	10 (1.2)	4 (0.8)	6 (1.9)	.204
Outcomes and procedural complications				
ICU stay, hours	22.0 (18.2-25.0)	21.0 (17.0-24.0)	23.0 (20.0-31.2)	<.001*
Acute kidney injury, n (%)	73 (8.8)	35 (7.0)	38 (11.4)	.028*
Cerebrovascular accident, n (%)	9 (1.1)	3 (0.6)	6 (1.8)	.159
Femoral complication, n (%)	30 (3.5)	18 (3.5)	12 (3.5)	.93
Permanent pacemaker, n (%)	36 (4.2)	19 (3.7)	17 (5.0)	.378
In-hospital mortality, n (%)	70 (8.2)	32 (6.3)	38 (11.1)	.011*

Values are presented as mean ± SD or median (IQR) for continuous variables and n (%) for categorical variables. Data are presented as mean ± SD, median (IQR), or n (%), as appropriate.
ACE, angiotensin-converting enzyme; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BNP, B-type natriuretic peptide; CRP, C-reactive protein; ICU, intensive care unit; LFLG AS, low-flow low-gradient aortic stenosis; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end-systolic diameter; LVOT, left ventricular outflow tract; MRA, mineralocorticoid receptor antagonist; PASP, pulmonary artery systolic pressure; PVL, paravalvular leak; SGLT2, sodium-glucose cotransporter-2; TAPSE, tricuspid annular plane systolic excursion; WBC, white blood cell.
*Statistically significant difference ($P < .05$).

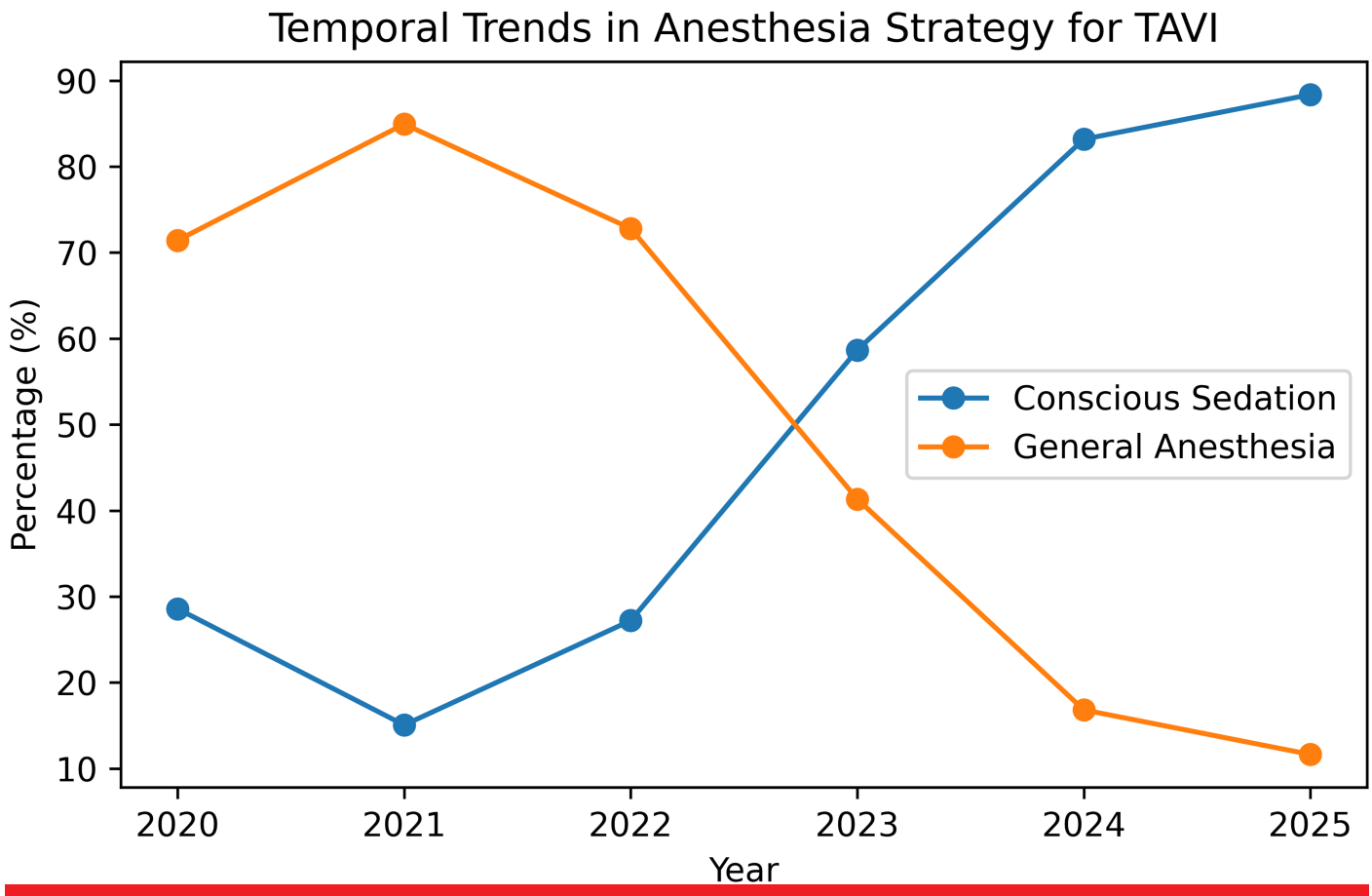

Figure 2. Temporal evolution of anesthetic strategy during transfemoral transcatheter aortic valve implantation (TAVI). The proportion of TAVI procedures performed under conscious sedation (CS) and general anesthesia (GA) according to calendar year. The progressive adoption of CS and decline in GA illustrate the temporal evolution of institutional practice patterns and the transition toward a minimalist TAVI approach during program maturation.

with prolonged ICU stay (RR = 1.46, $P < .001$, 95% CI: 1.28-1.66) (Table 2). In addition to anesthesia strategy, male sex (RR = 1.19, $P = .012$, 95% CI: 1.04-1.37) and chronic kidney disease (RR = 1.43, $P < .001$, 95% CI: 1.16-1.78) were also independently associated with longer ICU stay.

Adjusted marginal estimates derived from the model demonstrated a predicted ICU stay of 23 hours in the CS group and 34 hours in the GA group (Figure 3A-B).

In-hospital mortality was numerically lower in the CS group in the unadjusted analysis (6.3% vs. 11.1%, $P = .011$). However, in the double-robust logistic regression model, anesthesia strategy was not independently associated with in-hospital mortality (OR = 1.14, $P = .667$, 95% CI: 0.62-2.10) (Table 3). Although mortality was evaluated as a secondary outcome, greater institutional experience, expressed as case sequence per 100 procedures, was independently associated with lower in-hospital mortality (OR = 0.85, $P = .029$, 95% CI: 0.73-0.98). Chronic kidney disease was also strongly associated with in-hospital mortality (OR = 3.42, $P < .001$, 95% CI: 1.88-6.22), whereas atrial fibrillation was inversely associated with mortality in the adjusted model (OR = 0.44, $P = .020$, 95% CI: 0.22-0.88). Given the limited number of mortality events, these findings should be interpreted as exploratory and hypothesis-generating.

Long-Term Mortality

Over a median follow-up of 596 days (IQR 409-813) in the CS group and 971 days (IQR 530-1379) in the GA group, all-cause mortality occurred in 52 patients (10.2%) in the CS group and 77 patients (22.6%) in the GA group.

Inverse probability weighting-weighted Kaplan–Meier analysis suggested higher long-term survival among patients treated with conscious sedation compared with those treated with general anesthesia (weighted log-rank $P = .0016$) (Figure 4). Estimated 1-year survival rates were 91.6% and 82.9% in the CS and GA groups, respectively, whereas corresponding 2-year survival rates were 89.9% and 80.3%.

In the IPW-weighted double-robust Cox proportional hazards model, general anesthesia was independently associated with higher long-term mortality compared with conscious sedation (adjusted HR = 2.18, $P = .037$, 95% CI: 1.05-4.55) (Table 4, Figure 5). Older age (HR = 1.07, $P = .021$, 95% CI: 1.01-1.12), COPD (HR = 2.80, $P = .007$, 95% CI 1.32-5.94), and atrial fibrillation

Table 2. Double-Robust Inverse Probability Weighted (IPW) Gamma Regression Analysis of Factors Independently Associated with ICU Stay Duration Following TAVI.

Variables	Estimate (log)	RR	95% CI (for RR)	*P*
Anesthesia (General)	0.38	1.46	(1.28-1.66)	<.001*
Case sequence (per 100 cases)	−0.011	0.98	(0.95-1.01)	.46
Age	−0.002	0.99	(0.98-1.01)	.641
Sex (Male)	0.178	1.19	(1.04-1.37)	.012*
Hypertension	0.13	1.13	(0.99-1.30)	.052
Diabetes mellitus	−0.041	0.96	(0.84-1.09)	.543
Coronary artery disease	−0.02	0.97	(0.85-1.12)	.775
Heart failure	0.071	1.07	(0.95-1.20)	.242
Chronic obstructive pulmonary disease	−0.029	0.97	(0.81-1.15)	.739
Chronic kidney disease	0.363	1.43	(1.16-1.78)	<.001*
Atrial fibrillation	−0.067	0.93	(0.83-1.05)	.267
Preoperative left ventricular ejection fraction (%)	0.003	1	(0.99-1.01)	.31
Aortic mean gradient	0.001	1	(0.99-1.00)	.561

Estimates are presented as log-transformed coefficients from gamma regression models. The RRs were obtained by exponentiating the log estimates. The CIs are reported for RR. A double-robust IPW approach was used to adjust for potential confounding. Case sequence was modeled per 100 procedures. A *P*-value <.05 was considered statistically significant.
IPW, inverse probability weighting; RR, rate ratios.
*Statistically significant values are indicated with an asterisk.

(HR = 2.11, *P* = .034, 95% CI: 1.06-4.20) were also independently associated with increased long-term mortality.

The interaction between anesthesia strategy and case sequence was not statistically significant (*P* for interaction = .669), suggesting that the association between anesthesia strategy and long-term mortality remained broadly consistent across different stages of institutional experience (Supplementary Table 2). Given that the study was not originally designed or statistically powered to evaluate long-term survival outcomes, and that follow-up duration differed substantially between groups, these findings should be interpreted as exploratory and hypothesis-generating.

Learning Curve and Interaction Analysis

To account for institutional experience, case sequence was incorporated into the regression models as a continuous variable representing the chronological order of procedures. In the ICU stay model, case sequence itself was not independently associated with ICU duration (RR = 0.98, *P* = .460, 95% CI: 0.95-1.01). However, in the mortality model, increasing case sequence was associated with lower in-hospital mortality, suggesting a favorable effect of accumulated institutional experience on this secondary outcome.

Importantly, the interaction between anesthesia strategy and case sequence was not statistically significant (*P* for interaction > .05), indicating that the association between CS and shorter ICU stay did not materially vary across different stages of the institutional learning curve (Figure 6).

DISCUSSION

The authors' findings demonstrate that CS is independently associated with a significantly shorter duration of ICU

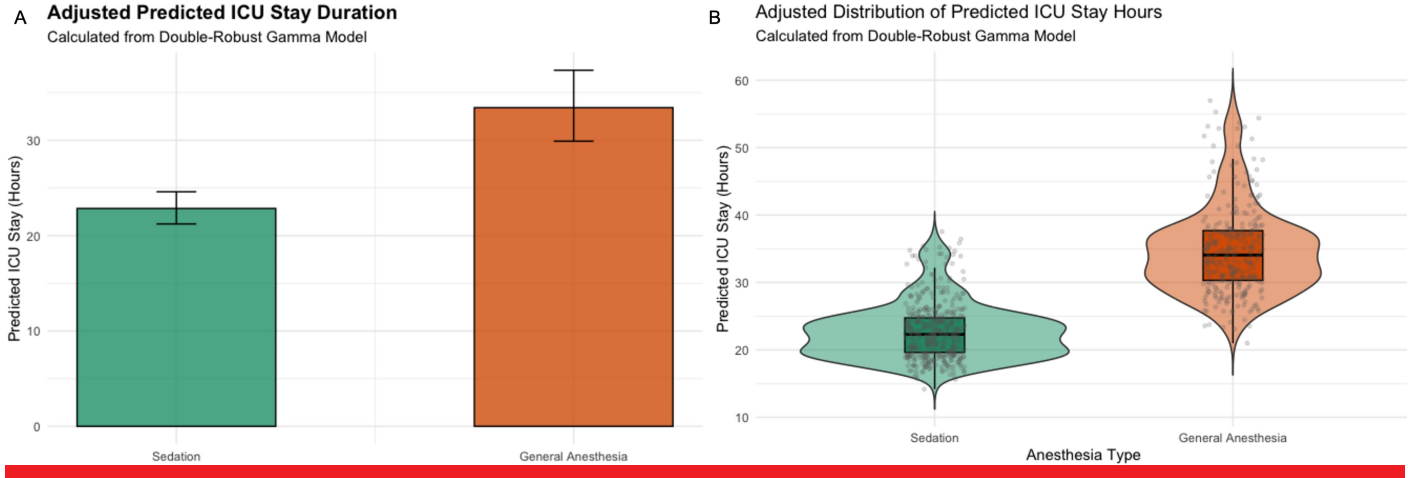

Figure 3. Adjusted predicted intensive care unit (ICU) stay duration according to anesthesia strategy. (A) Adjusted marginal estimates of ICU stay duration. (B) Distribution of predicted ICU stay duration derived from the double-robust gamma regression model.

Table 3. Double-Robust Logistic Regression Analysis for In-Hospital Mortality Following TAVI.

Variables	OR	95% CI	*P*
Anesthesia (General vs. sedation)	1.14	(0.62-2.10)	.667
Case sequence (per 100 cases)	0.85	(0.73-0.98)	.029*
Age	1.01	(0.96-1.06)	.833
Sex (Male)	1.75	(0.84-3.65)	.136
Hypertension	0.83	(0.36-1.94)	.673
Diabetes mellitus	0.93	(0.50-1.74)	.822
Coronary artery disease	0.78	(0.43-1.43)	.425
Heart failure	1.45	(0.81-2.60)	.212
Chronic obstructive pulmonary disease	0.43	(0.18-1.02)	.055
Chronic kidney disease	3.42	(1.88-6.22)	< .001*
Atrial fibrillation	0.44	(0.22-0.88)	.020*
Preoperative left ventricular ejection fraction (%)	0.97	(0.95-1.00)	.076
Aortic mean gradient	1	(0.98-1.02)	.862

The ORs and 95% CIs were derived from a double-robust logistic regression model adjusted using IPW to account for potential confounding. Case sequence was modeled per 100 procedures. A *P*-value <.05 was considered statistically significant.
IPW, inverse probability weighting; OR, odds ratio.
*Statistically significant values are indicated with an asterisk.

stay compared to GA. Crucially, by utilizing double-robust estimation to account for the institutional learning curve, the authors observed that the resource-saving benefits associated with this minimalist approach remained consistent after adjustment for institutional learning curve and procedural experience. While no significant difference

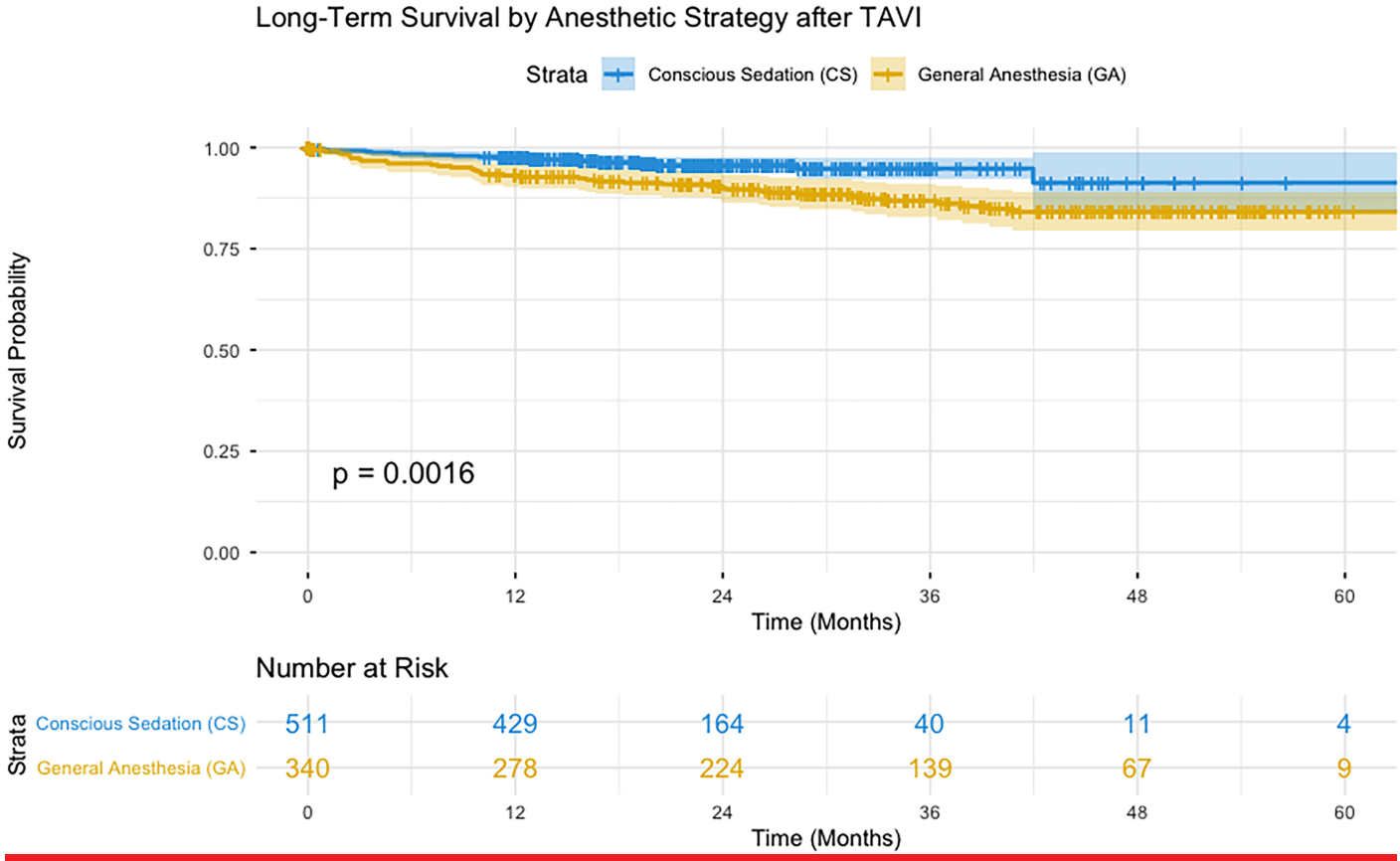

Figure 4. Inverse probability weighting (IPW)-weighted Kaplan–Meier analysis of long-term survival according to anesthetic strategy. Inverse probability-weighted Kaplan–Meier survival curves comparing long-term all-cause mortality between patients undergoing transcatheter aortic valve implantation (TAVI) under conscious sedation (CS) and general anesthesia (GA). The curves suggest higher long-term survival among patients treated with CS (weighted log-rank *P* = .0016). Shaded areas represent 95% CIs. Numbers at risk are displayed below the survival curves.

Table 4. IPW-Adjusted Multiple Double-Robust Cox Proportional Hazards Model Predicting Long-Term Mortality After TAVI.

Variables	Regression Coefficient (β)	Adjusted HR	95% CI	*P*
Anesthesia strategy (General vs. CS)	0.781	2.184	1.048-4.552	.037
Age (per year)	0.063	1.065	1.010-1.124	.021
Sex (Male vs. female)	0.421	1.524	0.753-3.085	.242
Hypertension	−0.422	0.656	0.305-1.412	.281
Coronary artery disease	0.607	1.835	0.916-3.676	.087
Diabetes mellitus	0.084	1.088	0.545-2.171	.812
Heart failure	0.103	1.108	0.320-3.834	.871
Chronic obstructive pulmonary disease	1.03	2.802	1.323-5.935	.007
CVA	0.198	1.22	0.447-3.326	.698
Atrial fibrillation	0.745	2.107	1.057-4.201	.034
Chronic kidney disease	0.688	1.99	0.966-4.100	.062
Preoperative LVEF (%)	−0.033	0.967	0.924-1.012	.153
Aortic mean gradient (mm Hg)	0.003	1.003	0.972-1.035	.861
Institutional learning curve (per 100 cases)	−0.092	0.912	0.782-1.064	.24

CS, conscious sedation; CVA, cerebrovascular accident; HR, hazard ratio; LVEF, left ventricular ejection fraction.

was observed in in-hospital mortality, the shorter ICU stay associated with conscious sedation remained robust after adjustment for baseline characteristics and institutional experience. Collectively, the results suggest that the advantages of a minimalist anesthetic approach are not solely attributable to increasing institutional experience over time.

The observed reduction in ICU stay duration in the CS group (predicted 23 hours vs. 34 hours for GA) aligns with

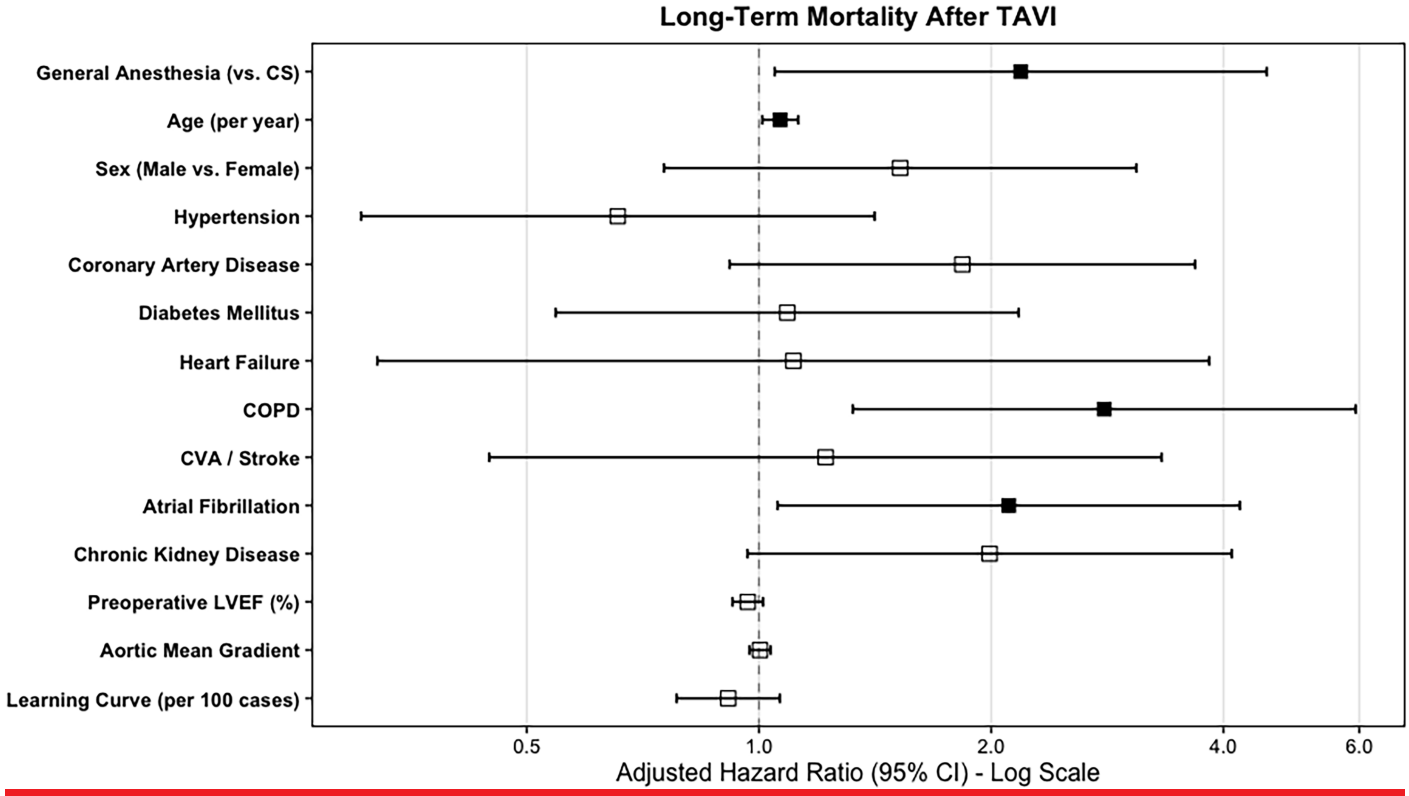

Figure 5. Inverse probability-weighted double-robust Cox proportional hazards model for long-term mortality. Forest plot displaying adjusted hazard ratios (HRs) and 95% CIs derived from the IPW double-robust Cox proportional hazards model for long-term all-cause mortality after TAVI. The model included demographic, clinical, echocardiographic, and procedural covariates, including institutional experience expressed as chronological case sequence. Hazard ratios greater than 1 indicate increased mortality risk. The vertical dashed line denotes the null value (HR = 1.0).

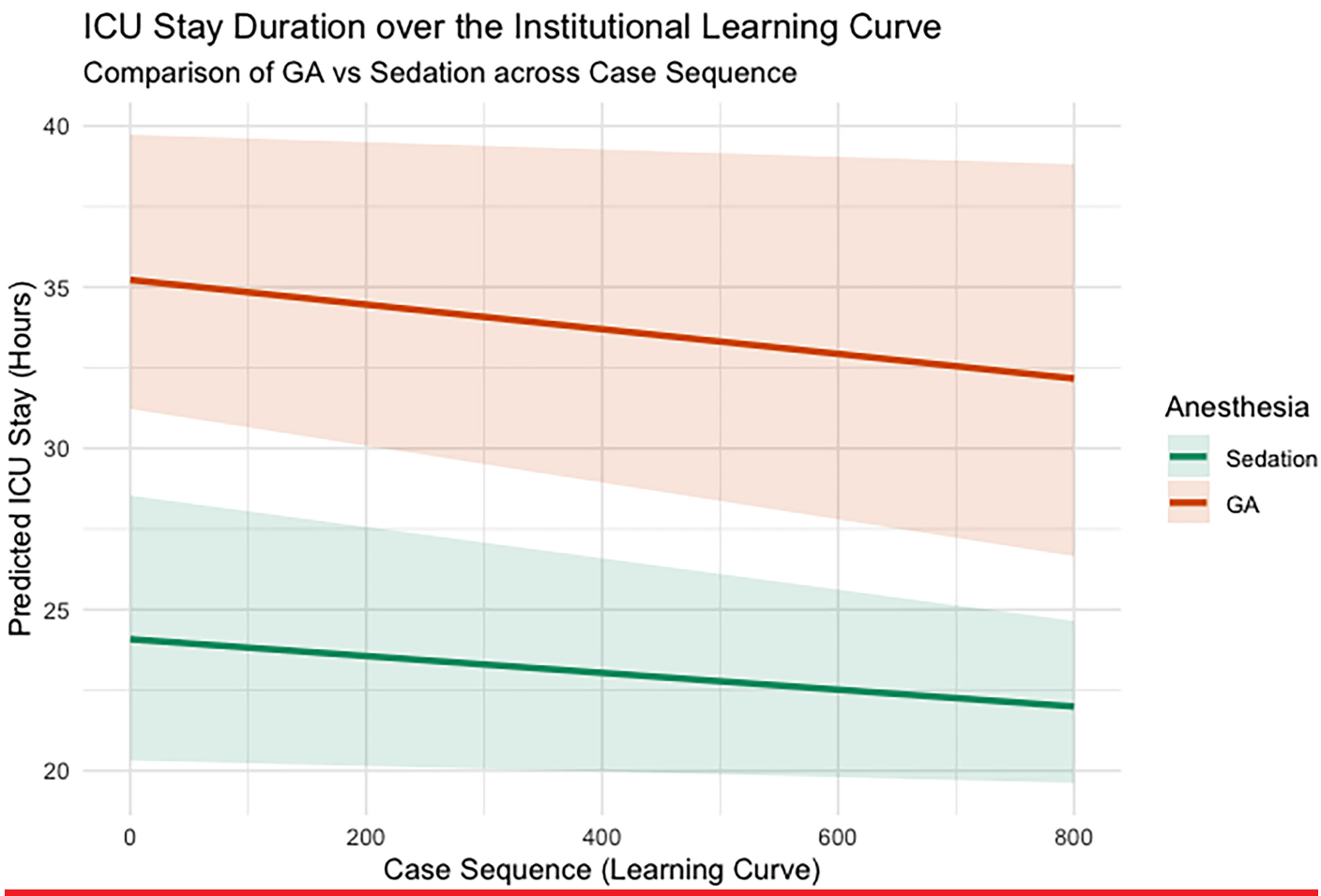

Figure 6. Interaction between anesthesia strategy and institutional learning curve for intensive care unit (ICU) stay duration. Predicted ICU stay duration according to anesthesia strategy across the institutional learning curve. The interaction term between anesthesia strategy and case sequence was not statistically significant, indicating that the association between conscious sedation and shorter ICU stay remained consistent throughout different stages of institutional experience. Shaded areas represent 95% CIs.

contemporary multicenter registries and randomized controlled trials.[13,14] Recent evidence suggests that avoiding GA is a cornerstone of the minimalist TAVI approach, facilitating faster hemodynamic stabilization and earlier mobilization compared with traditional approaches.[7] The authors' findings are consistent with clinical trials demonstrating that a sedation-first strategy supports safe next-day discharge protocols without compromising patient safety.[7,15,16] The prolonged ICU duration observed in the GA group may be attributed to the residual pharmacological effects of anesthetic agents, a higher incidence of transient intraprocedural hypotension requiring vasopressor support, and the inherent delays in recovery associated with airway management.[17,18] Consistent with this mechanistic perspective, prior studies have demonstrated higher rates of procedural hypotension and increased vasopressor/inotrope use under GA, which may contribute to delayed recovery and prolonged ICU monitoring.[19,20] Furthermore, recent large-scale studies have highlighted that standardized procedural simplification centered around CS is key to optimizing healthcare resource utilization in high-volume centers.[13,16] By utilizing double-robust estimation, the authors minimized the selection bias inherent in retrospective cohorts, providing more robust evidence that CS is associated with a more efficient recovery profile. The greater difference observed in adjusted marginal estimates compared with crude ICU stay durations likely reflects correction for baseline clinical differences and temporal imbalances between groups, including the progressive transition from general anesthesia to conscious sedation during institutional maturation.

Consistent with findings from major randomized trials and large-scale sub-analyses, the authors observed no significant differences in in-hospital mortality or major postoperative complications between the 2 anesthetic strategies.[21,22] These findings suggest that while GA offers a highly controlled environment and may facilitate high-quality transesophageal imaging, CS represents a safe and clinically feasible alternative. Furthermore, the stability of the outcomes following IPW suggests that even after rigorous adjustment for baseline risks, the choice of anesthesia does not inherently alter the safety profile of the procedure in a

high-volume setting. Notably, although the primary analytical framework was designed to evaluate ICU length of stay, exploratory analyses also suggested an association between institutional procedural experience (case sequence per 100 cases) and in-hospital mortality. This secondary observation should be interpreted cautiously, yet it may reflect the broader impact of cumulative team experience on clinical outcomes rather than a direct effect of anesthetic strategy.

Beyond the primary endpoint of ICU stay duration, exploratory long-term survival analyses suggested a potential association between anesthetic strategy and all-cause mortality. In the IPW-weighted double-robust Cox model, general anesthesia was associated with higher long-term mortality compared with conscious sedation. However, these findings should be interpreted with considerable caution. The study was not originally designed or statistically powered to evaluate long-term survival outcomes, and substantial differences in follow-up duration existed between groups due to the temporal evolution of anesthetic practice. Although adjustment for baseline characteristics, institutional experience, and follow-up time was performed, residual temporal confounding cannot be completely excluded. Therefore, these observations should be regarded as exploratory and hypothesis-generating rather than evidence of a causal survival benefit of conscious sedation.

An unexpected finding in the adjusted in-hospital mortality model was the inverse association between atrial fibrillation and mortality risk. This counterintuitive result may reflect residual confounding, survivor bias, or peri-procedural selection effects that cannot be completely eliminated in observational studies. Patients with pre-existing atrial fibrillation may have undergone closer monitoring and more intensive perioperative management, potentially influencing short-term outcomes. Importantly, atrial fibrillation emerged as an independent predictor of increased mortality in the exploratory long-term survival analysis, a finding that is substantially more consistent with the established literature. This divergence between short- and long-term associations underscores the complexity of atrial fibrillation as a prognostic variable in TAVI populations and warrants further investigation.

A unique contribution of this study is the granular analysis of the interaction between the anesthetic strategy and the institutional learning curve. Because the transition from GA to CS strongly correlated with chronology, a major challenge in this study was disentangling the true effect of the anesthetic technique from the natural improvements in procedural efficiency and postoperative care over time. By incorporating case sequence as a continuous covariate and evaluating its interaction with the anesthesia strategy, the authors demonstrated that the shorter ICU stay associated with CS was stable and consistent throughout the study period. These findings suggest that the shorter ICU stay associated with conscious sedation is unlikely to be explained solely by temporal improvements in procedural experience, institutional maturation, or postoperative care pathways. Nevertheless, residual temporal confounding cannot be completely excluded, and therefore the observed associations should be interpreted within the context of the study's observational design.

As TAVI indications continue to expand toward younger and lower-risk populations, the optimization of hospital resource utilization has become a clinical and administrative priority. The reduction in ICU stay by a predicted average of 11 hours per patient, as demonstrated in the regression models, carries important implications for institutional throughput and healthcare expenditures. Such a decrease in intensive care occupancy may enhance bed turnover, potentially alleviating capacity constraints often encountered in high-volume tertiary centers. These findings support a sedation-first strategy as a key component of a streamlined TAVI pathway, offering a scalable approach to improving procedural efficiency without compromising the quality of care or patient safety.

Study Limitations

Despite the application of robust statistical methods to mitigate selection bias, several limitations of this study must be acknowledged. First, its retrospective and single-center design may limit the generalizability of the findings to different clinical settings or healthcare systems.

Second, due to the retrospective and non-randomized nature of this study, the choice between CS and GA was left to the discretion of the multidisciplinary heart team. Consequently, patients perceived as clinically more fragile, anatomically more complex, or procedurally more challenging may have preferentially received general anesthesia, introducing the potential for confounding by indication. Although the authors applied inverse probability weighting and double-robust adjustment to balance measured baseline characteristics and account for the institutional learning curve, residual confounding from unmeasured factors cannot be completely excluded.

Third, the authors' representation of the institutional learning curve as a continuous chronological case sequence is an operational surrogate. In a tertiary academic center, learning curves are inherently multifactorial, driven by operator experience, structural team optimization, and iterations in valve technologies. While isolating each component was technically unfeasible, cumulative case sequence serves as an established and well-validated proxy in structural heart research, effectively encapsulating the global evolution of institutional proficiency and technological adaptation over time. Nevertheless, this measure may not fully capture operator-specific expertise, technological advancements, device iterations, workflow optimization, or changes in multidisciplinary team organization over time. Chronological case sequence has previously been used as a pragmatic surrogate of cumulative institutional experience in TAVI learning-curve studies.

Fourth, total hospital length of stay and other recovery-related outcomes were not systematically available and therefore could not be evaluated. Consequently, the authors were unable to determine whether the observed reduction in ICU stay translated into shorter overall hospitalization. In

addition, although ICU discharge was guided by standardized clinical criteria throughout the study period, administrative factors such as bed availability and institutional workflow may have influenced discharge timing and cannot be completely excluded.

Fifth, detailed data regarding intraprocedural vasopressor and inotrope administration were not systematically recorded throughout the study period and therefore could not be incorporated into the current analyses. Because these factors may influence hemodynamic stability, peri-procedural recovery, and ICU utilization, their potential confounding effects cannot be completely excluded.

Finally, although both in-hospital and long-term mortality were evaluated, mortality outcomes should be interpreted cautiously. In-hospital mortality was a prespecified secondary endpoint and the absolute number of events was limited, reducing statistical power to detect modest between-group differences. Post-hoc power analysis demonstrated approximately 71% statistical power for detecting differences in in-hospital mortality between groups, supporting the possibility of a type II error. Furthermore, long-term mortality analyses were exploratory in nature and may have been influenced by residual temporal confounding, differential follow-up duration between groups, and the evolving institutional learning curve despite statistical adjustment. Therefore, both short- and long-term survival findings should be considered hypothesis-generating and require confirmation in prospective multicenter studies with standardized follow-up.

CONCLUSION

This study demonstrates that a conscious sedation strategy for transfemoral TAVI is independently associated with a significant reduction in ICU stay duration. Importantly, this association remained consistent after adjustment for baseline characteristics, temporal trends, and institutional experience, suggesting that the shorter ICU stay observed with CS was not fully explained by the institutional learning curve or increasing procedural experience. No significant differences were observed in in-hospital mortality, although mortality findings should be interpreted cautiously given the exploratory nature of these analyses.

Ethics Committee Approval: This study was approved by the Ethics Committee of Kartal Koşuyolu Training and Research Hospital (Approval No: 2026/05/1401, Date: March 10, 2026).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – İ.B., O.P.Z., D.M.; Design – İ.B., S.T.U.; Supervision – S.T.U., E.O.; Resources – N.D., Az.K..; Materials – İ.B., B.K., E.G.D; Data Collection and/or Processing – A.K., N.D., Az.K.; Analysis and/or Interpretation – B.K., D.M.; Literature Search – A.K., N.D., Az.K.; Writing – P.Z.M, D.M., S.T.U.; Critical Review – E.G.D., E.O.

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REFERENCES

1. Beerkens FJ, Tang GHL, Kini AS, et al. Transcatheter aortic valve replacement beyond severe aortic stenosis: JACC state-of-the-art review. *J Am Coll Cardiol*. 2025;85(9):944-964. [CrossRef]
2. Arnold SV, Manandhar P, Vemulapalli S, et al. Trends in transcatheter aortic valve replacement outcomes: insights from the STS/ACC TVT registry. *JAMA Cardiol*. 2024;9(12):1115-1123. [CrossRef]
3. Ajello V, Fresilli S, D'Amico F, et al. Management of anaesthesia for transfemoral transcatheter aortic valve implantation: an Italian interdisciplinary consensus statement. *Br J Anaesth*. 2026;136(3):824-835. [CrossRef]
4. Gürsoy Çirkinoğlu G, Şahinkaya HH. Hemodynamic safety of dexmedetomidine-fentanyl sedation during TAVI. *Anatol J Cardiol*. 2026 ;30(7):443-447. [CrossRef]
5. Vemulapalli S, Carroll JD, Mack MJ, et al. Procedural volume and outcomes for transcatheter aortic-valve replacement. *N Engl J Med*. 2019;380(26):2541-2550. [CrossRef]
6. Otto CM, Kumbhani DJ, Alexander KP, et al. 2017 ACC expert consensus decision pathway for transcatheter aortic valve replacement in the management of adults with aortic stenosis: a report of the American College of Cardiology task force on clinical expert consensus documents. *J Am Coll Cardiol*. 2017;69(10):1313-1346. [CrossRef]
7. Butala NM, Chung M, Secemsky EA, et al. Conscious sedation versus General Anesthesia for transcatheter aortic valve replacement: variation in practice and outcomes. *JACC Cardiovasc Interv*. 2020;13(11):1277-1287. [CrossRef]
8. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61(4):344-349. [CrossRef]
9. van der Molen AJ, Reimer P, Dekkers IA, et al. Post-contrast acute kidney injury – Part 1: Definition, clinical features, incidence, role of contrast medium and risk factors: recommendations for updated ESUR Contrast Medium Safety Committee guidelines. *Eur Radiol*. 2018;28(7):2845-2855. [CrossRef]
10. Wassef AWA, Rodes-Cabau J, Liu Y, et al. The learning curve and annual procedure volume standards for optimum outcomes of transcatheter aortic valve replacement: findings from an international registry. *JACC Cardiovasc Interv*. 2018;11(17):1669-1679. [CrossRef]
11. Arai T, Lefèvre T, Hovasse T, et al. Evaluation of the learning curve for transcatheter aortic valve implantation via the transfemoral approach. *Int J Cardiol*. 2016;203:491-497. [CrossRef]
12. VARC-3 WRITING COMMITTEE, Généreux P, Piazza N, et al. Valve Academic Research Consortium 3: Updated endpoint definitions for aortic valve clinical research. *Eur Heart J*. 2021;42(19):1825-1857. [CrossRef]
13. Frank D, Durand E, Lauck S, et al. A streamlined pathway for transcatheter aortic valve implantation: the BENCHMARK study. *Eur Heart J*. 2024;45(21):1904-1916. [CrossRef]
14. Thiele H, Kurz T, Feistritzer HJ, et al. General versus Local anesthesia with conscious sedation in transcatheter aortic valve implantation: the randomized SOLVE-TAVI trial. *Circulation*. 2020;142(15):1437-1447. [CrossRef]
15. Tagliari AP, Taramasso M. New practices in transcatheter aortic valve implantation: how I Do it in 2023. *J Clin Med*. 2023;12(4):1342. [CrossRef]
16. Butala NM, Wood DA, Li H, et al. Economics of minimalist transcatheter aortic valve replacement: results from the 3M-TAVR

economic study. *Circ Cardiovasc Interv*. 2022;15(10):e012168. [CrossRef]
17. Villablanca PA, Mohananey D, Nikolic K, et al. Comparison of local versus general anesthesia in patients undergoing transcatheter aortic valve replacement: a meta-analysis. *Catheter Cardiovasc Interv*. 2018;91(2):330-342. [CrossRef]
18. Maier A, Hammerich B, Humburger F, et al. A logistic regression analysis comparing minimalistic approach and intubation anaesthesia in patients undergoing transfemoral transcatheter aortic valve replacement. *PLOS One*. 2020;15(2):e0227345. [CrossRef]
19. Yılmaz Ş, Zeren G, Avcı İİ, et al. Transkateter aort kapak İmplantasyonunda Uygulanan anestezi Tipinin etkisi [The effect of anesthesia type applied in transcatheter aortic valve implantation]. *Turk Kardiyol Dern Ars*. 2023;51(6):394-398. [CrossRef]
20. İzgi M, Halis A, Şener YZ, et al. Evaluation of anaesthetic approaches in transcatheter aortic Valv implantation procedures. *Turk J Anaesthesiol Reanim*. 2023;51(5):427-433. [CrossRef]
21. Feistritzer HJ, Kurz T, Stachel G, et al. Impact of anesthesia strategy and valve type on clinical outcomes after transcatheter aortic valve replacement. *J Am Coll Cardiol*. 2021;77(17):2204-2215. [CrossRef]
22. Hyman MC, Vemulapalli S, Szeto WY, et al. Conscious sedation versus General Anesthesia for transcatheter aortic valve replacement: insights from the national cardiovascular data registry Society of Thoracic Surgeons/American College of Cardiology transcatheter valve therapy registry. *Circulation*. 2017;136(22):2132-2140. [CrossRef]

Supplementary Table 1. Distribution of transcatheter heart valve types according to anesthetic strategy

Variables	Overall (n=852)	Sedation (n=511)	General Anesthesia (n=341)	*P*
Valve type, n (%)				<.001
Evolut (R/Pro/ Pro Plus)	302 (35.4%)	214 (41.9%)	88 (25.8%)	
Myval	178 (20.9%)	114 (22.3%)	64 (18.8%)	
Acurate Neo / Neo2	167 (19.6%)	100 (19.6%)	67 (19.6%)	
Portico	61 (7.2%)	13 (2.5%)	48 (14.1%)	
Allegra / Hydra	16 (1.9%)	15 (2.9%)	1 (0.3%)	
Navitor	11 (1.3%)	9 (1.8%)	2 (0.6%)	
Unclassified	105 (12.3%)	39 (7.6%)	66 (19.4%)	

Valve type was not recorded with sufficient specificity in a subset of cases (n=105), predominantly from the early study period (2020–2022), and these cases are reported as unclassified.

Supplementary Table 2. Double-Robust Cox Proportional Hazards Model with Interaction Analysis for Long-Term Mortality

Variables	Coefficient (β)	Robust SE	Adjusted Hazard Ratio (HR)	95% Confidence Interval (CI)	*P*
Anesthesia Strategy (General vs. CS)	1.006	0.689	2.734	0.708 – 10.553	.145
Institutional Learning Curve (per 100 cases)	-0.045	0.114	0.956	0.764 – 1.195	.691
Anesthesia x Learning Curve Interaction	-0.069	0.162	0.933	0.679 – 1.282	.669
Age (per year)	0.064	0.027	1.067	1.012 – 1.124	.017
Sex (Male vs. Female)	0.407	0.362	1.503	0.739 – 3.057	.261
Hypertension	-0.421	0.391	0.656	0.305 – 1.412	.281
Coronary Artery Disease	0.634	0.347	1.886	0.956 – 3.720	.067
Diabetes Mellitus	0.091	0.349	1.095	0.553 – 2.171	.794
Heart Failure	0.095	0.64	1.1	0.314 – 3.853	.882
COPD	1.03	0.382	2.802	1.326 – 5.921	.007
Cerebrovascular Accident (CVA)	0.198	0.51	1.219	0.449 – 3.311	.697
Atrial Fibrillation	0.761	0.348	2.141	1.082 – 4.236	.029
Chronic Kidney Disease	0.695	0.366	2.005	0.979 – 4.106	.057
Preoperative LVEF (%)	-0.033	0.023	0.967	0.924 – 1.013	.157
Aortic Mean Gradient (mm Hg)	0.003	0.016	1.003	0.972 – 1.035	.849