Surgical redo mitral valve replacement in high-risk patients: The real-world experience

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Abstract
Introduction: Redo surgical mitral valve replacement (SMVR) remains the gold standard treatment in patients with a history of mitral valve surgery presenting with recurrent mitral valve pathologies. Whilst this procedure is demanding, it is an inevitable intervention for some indications, such as infective endocarditis, thrombosis, or multivalve procedures. In this study, we aim to evaluate our institutional experience with SMVR on a real-life cohort, identifying the factors that contribute to poor surgical outcomes whilst avoiding selection bias.

Methods: Between March 2012 and November 2020, 58 consecutive high-risk patients underwent a redo SMVR at our institution. The primary endpoints of this study were 30-day and 1-year mortality. The secondary endpoint was the development of any postoperative adverse events. We analyzed and compared the survival in patients undergoing an isolated SMVR and in those that required at least one concomitant procedure.

Results: The overall operative, 30-day, and 1-year mortality were 3.4%, 22.4%, and 25.9%, respectively. The mortality in patients undergoing isolated SMVR was significantly lower than in patients requiring concomitant procedures. The multivariable regression model showed that NYHA Class IV, infective endocarditis, and postoperative dialysis were significantly associated with 30-day mortality. Society of Thoracic Surgeons Score, infective endocarditis, concomitant procedures, and mechanical valve implantation appeared to predict long-term mortality.

Conclusion: This study illustrates that SMVR after prior mitral valve surgery presents a demanding procedure with high operative risk, significant mortality, and...
morbidity. Whilst this procedure is inevitable for some indications, a careful patient selection and risk stratification provides acceptable surgical results in this cohort.

**KEYWORDS**

mitral valve, redo procedure, redo SMVR

1 | INTRODUCTION

Redo mitral valve (MV) surgery remains the gold standard treatment in patients with a history of MV surgery presenting with recurrent mitral valve pathologies. In the growing era of transcatheter valve implantation techniques, there is a distinct paradigm shift towards the implantation of biological valve prostheses with the intention of subsequent transcatheter valve implantation if necessary. Moreover, the bleeding and embolic complication arising from mechanical valves' anticoagulation regimen has been associated with a significant decline in their deployment over the last years. The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery, published in 2019, illustrated that mechanical valves implantation constituted only 6% of the surgical mitral valve replacement (SMVR) procedures carried out during that year. However, the preceding report published in 2015 outlined that the utilization of mechanical MV prostheses represented 8.4% of the total number of SMVRs. Therefore, it would be appropriate to expect a rise in the number of patients requiring a redo surgery in the future, mainly due to degenerated bioprosthetic MV, failed MV-annuloplasty, and infective endocarditis among other reasons. Vohra et al. report that 35% of patients with a history of mitral valve surgery will require another MV procedure. Accordingly, Mehaffey et al. demonstrated a yearly increase in redo mitral valve surgeries of 10% over the past 15 years in the state of Virginia (USA) with a population of over 8 million people. The high mortality and morbidity risk related to redo mitral valve procedures, especially in patients presenting with multiple comorbidities have been previously described by various research groups. Nonetheless, through careful risk stratification and patient selection, these procedures can be performed safely and present acceptable surgical risks. Indeed, the success rate of repair in patients presenting with a history of previous surgical MV repair remains controversial, ranging between 36% and 85% of the procedures, with the threshold for redo SMVR at many institutions being relatively low. Moreover, MV re-repair is often not feasible in patients with infective endocarditis, severe degenerative valve disease, MV stenosis, and complex bileaflet prolapse. Therefore, the aim of this study was to evaluate our institutional experience with surgical redo mitral valve replacement on a real-life cohort of patients (with no selection bias) presenting with a history of mitral valve surgery and to identify the factors contributing to poor surgical outcomes.

2 | MATERIALS AND METHODS

2.1 | Study design and population

This retrospective study included 58 consecutive high-risk patients, who between March 2012 and November 2020 underwent a surgical redo mitral valve replacement at our institution. All patients prior underwent a surgical mitral valve procedure (repair or replacement) and presented with recurrent mitral valve disease.

Preoperative evaluation of patients and all decisions on the indications were performed by the interdisciplinary Heart Team at our institution. Postoperative echocardiographic evaluation of the implanted valve prosthesis function was performed at our institution at hospital discharge and again at follow-up by referring cardiologists. Data was collected prospectively as a part of our institutional database, including detailed information on patients’ demographics; baseline clinical characteristics; laboratory, echocardiographic, and hemodynamic parameters; intraoperative variables; and postoperative outcomes. The study was conducted according to the Declaration of Helsinki (as revised in 2013). The ethical board of our institution approved the study protocol and data gathering and waived the patients’ individual informed consent. All patients signed the informed consent on follow-up at hospital admission.

2.2 | Surgical technique

The thorax was accessed via redo median sternotomy. Cardiopulmonary bypass (CPB) was initiated with the direct cannulation of the ascending aorta and bivacal cannulation of the right atrium. Moderate hypothermic cardiac arrest at 32°C was performed for all procedures. Myocardial protection was achieved with cold crystalloid cardioplegia. The mitral valve was exposed through left atriotomy via Watson's groove or through the right atriotomy and atrial septostomy if any tricuspid valve procedure had to be performed. Extensive debridement of the mitral annulus was performed under preservation of the chords if possible. The MV prosthesis (mechanical or biological) was inserted with single horizontal 4-0 Ethibond pledgeted sutures directed from the left ventricle into the left atrium. After assessment of the prosthetic valves performance and careful de-airing using transesophageal echocardiography, the patient was separated from the CPB. The anticoagulation was reversed and after securing the hemostasis, the chest was closed with steel wires in a routine fashion.
Concomitant aortic valve procedure or coronary bypass grafting was performed before the MV implantation and tricuspid valve procedures were performed after the MV procedure on the beating heart.

2.3 | Outcomes and definitions

The primary endpoints of this study were 30-day mortality and 1-year mortality. The secondary endpoint was the development of any postoperative adverse events. Additionally, we divided our cohort into two groups: Group 1 (n = 28): patients who underwent an isolated SMVR; Group 2 (n = 30): patients who underwent a redo SMVR with at least one concomitant procedure. We determined and compared 30-day and 1-year mortality between these groups.

2.4 | Statistical analysis

Statistical analysis, including regression analysis, was performed using IBM SPSS version 27 (IBM Corp.) and R software v.3.4.3 (R Foundation for Statistical Computing, Vienna, Austria). Data were tested for normality using the Shapiro–Wilk test. Continuous variables were expressed as medians (interquartile range, IQR) or as mean ± standard deviation. Categorical variables were expressed as frequencies and percentages. We divided our cohort into two groups: the first one consisted of patients who received only mitral valve replacement and the second one contained patients who besides of the mitral valve replacement received any concomitant procedure. We compared the distributions of the categorical variables using $\chi^2$ Test or Fischer Exact Test if the assumptions for the first one, were not met. The distributions of the continuous variables were compared between the groups with the t-test in cases of normal distributions and with the Mann-Whitney test if the distributions were not normal. A $p$ value of less than 0.05 was considered to indicate statistical significance. Logistic regression analysis was performed to identify independent preoperative risk factors for 30-day mortality. Multivariable Cox proportional hazards regression models were used to determine factors associated with overall survival. Variables identified by the univariate analysis with a $p$ value less than .05 were included into the multivariable models. Then, all confounding variables were excluded stepwise. Assumptions for both final regression models (logistic and Cox) were checked, and they are met. We used the Aalen model, which allows the time-dependent coefficients to check the time-variability of cumulative hazards. To construct the Aalen model, we used the same variables that are in the Cox model. The time-variability was checked with Kolmogorov–Smirnov and Cramer von Mises tests. The $p$ values of these tests less than .05 mean, that the effect of the variable on the outcome within the follow up is time-dependent. For plotting the survival curves and for computing the midterm mortality we used the Kaplan–Meier method. The cumulative survivals of both analyzed groups were compared with the log-rank test.

2.5 | Statement of responsibility

The authors had full access to the data and take full responsibility for its integrity. All authors have read and agreed to the manuscript as presented.

3 | RESULTS

3.1 | Baseline characteristics

A total of 58 consecutive high-risk patients with multiple comorbidities were enrolled in the study. The mean age was 63.6 ± 12.5 years. Baseline characteristics and demographics are shown in Tables 1 and 2. Overall, patients showed a high-risk profile with a mean logistic EuroSCORE-I of 36.9 ± 24.4%, a median EuroSCORE-II of 13.1 (IQR 6.5–27.1) and a median Society of Thoracic Surgeons (STS) Score of 4.8% (IQR 2.4–10.1), and 72.4% (n = 42) patients were at admission in NYHA functional Class III or IV. All patients previously underwent at least one mitral valve procedure via median sternotomy, and 22.4% (n = 13) presented with a history of two sternotomies. A total of 29 patients (50%) showed a preoperative impaired renal function.

3.2 | Procedure

The median time from the last mitral valve procedure in our cohort was 3.62 (IQR 0.74–12.3) years. More than half of the patients 56.9% (n = 33) prior underwent a SMVR and the remaining 44.8% (n = 26) presented with a history of mitral valve repair. In the majority of cases, the thorax was accessed via median sternotomy 96.6% (n = 56), whereas two patients (3.4%) underwent an endoscopic redo procedure via right lateral thoracotomy. The overall operating time averaged 254.2 min and the median aortic cross-clamp time was 84.7 min. A total of seven patients (12.5%) required re-exploration for bleeding and another three patients (5.2%) suffered postoperative AV-Block III°, requiring permanent pacemaker implantation. We observed no postoperative myocardial infarction or stroke in our cohort. Acute kidney injury requiring temporary dialysis occurred in 26.8% (n = 15) of the patients. Intraoperative characteristics and postoperative outcomes are presented in Tables 3 and 4.

3.3 | Survival

Within the entire patient cohort, the intraoperative, 30-day, and one-year mortality, were 3.4%, 22.4%, and 25.9%, respectively. In patients that underwent an isolated redo mitral valve replacement, the intraoperative, 30-day, and one-year mortality were 0%, 10.7%, and 18%, respectively. In patients with at least one concomitant procedure, the intraoperative, 30-day, and 1-year mortality were 6.7%, 33%, and 33%, respectively (Table 4). At 1 year, the mortality was
significantly lower in the first group \( (p = .023) \) (Figure 1). The median follow-up time was 2.85 (IQR 0.34–4.9) years. The mortality rate for all patients was 72% at 1 year and 48% at 4 years. The Kaplan–Meier overall survival curve is given in Figure 2.

### 3.4 Regression analysis

To evaluate independent predictors of 30-day mortality, a logistic regression model was constructed. Several univariate indicators were found to predict 30-day mortality. The multivariable regression model showed that NYHA Class IV (odds ratio [OR], 20.79; 95% confidence interval [CI], 2.3–506.31; \( p = .02 \)), infective endocarditis (OR, 10.85; 95% CI, 1.27–194.77, \( p = .05 \)), and postoperative acute kidney failure (OR, 15.69; 95% CI, 2.25–231.33, \( p = .01 \)) were significantly associated with 30-day mortality. Operating time was also near-significantly associated with 30-day mortality with (OR, 1.01; 95% CI, 1.00–1.02, \( p = .06 \) (Figure 3). Cox proportional analysis showed that STS Score, active infective endocarditis, concomitant procedures, and implantation of mechanical valve prostheses had a direct effect on survival (Figure 4). Moreover, we applied the Aalen model for the presentation of the variability of the effects of the

| Variables                  | SMVR, \( n \) (%) | Isolated SMVR, \( n \) (%) | Combined SMVR, \( n \) (%) | \( p \) |
|----------------------------|-------------------|---------------------------|---------------------------|-------|
| Age, years                 | 63.6 ± 12.5       | 65.4 (IQR 55.0–73.2)      | 67.3 (IQR 57.6–76.3)      | .45   |
| Female sex                 | 60.3% (\( n = 35 \)) | 60.7% (\( n = 17 \))      | 60.0% (\( n = 18 \))      | .96   |
| BMI, kg/m²                 | 26.1 ± 4.6        | 25.8 (IQR 22.3–29.1)      | 25.1 (IQR 23.3–26.8)      | .83   |
| NYHA Class                 |                   |                           |                           |       |
| II                         | 27.6% (\( n = 16 \)) | 35.7% (\( n = 10 \))      | 20.0% (\( n = 6 \))       | .18   |
| III                        | 46.6% (\( n = 27 \)) | 46.4% (\( n = 13 \))      | 46.7% (\( n = 14 \))      | .99   |
| IV                         | 25.9% (\( n = 15 \)) | 17.9% (\( n = 5 \))       | 33.3% (\( n = 10 \))      | .18   |
| Infective endocarditis     | 37.9% (\( n = 22 \)) | 42.9% (\( n = 12 \))      | 33.3% (\( n = 10 \))      | .45   |
| Coronary artery disease    | 20.7% (\( n = 12 \)) | 32.1% (\( n = 9 \))       | 10.0% (\( n = 3 \))       | .05   |
| Prior PCI                  | 6.9% (\( n = 4 \)) | 3.6% (\( n = 1 \))        | 10.0% (\( n = 3 \))       | .61   |
| Cerebral arterial disease  | 13.8% (\( n = 8 \)) | 10.7% (\( n = 3 \))       | 16.7% (\( n = 5 \))       | .71   |
| History of stroke          | 24.1% (\( n = 14 \)) | 21.4% (\( n = 6 \))       | 2.7% (\( n = 8 \))        | .64   |
| Prior TIA                  | 1.7% (\( n = 1 \)) | 0                          | 3.3% (\( n = 1 \))        | 1.0   |
| Peripheral arterial disease| 5.2% (\( n = 3 \)) | 7.1% (\( n = 2 \))        | 3.3% (\( n = 1 \))        | .61   |
| COPD                       | 17.2% (\( n = 10 \)) | 14.3% (\( n = 4 \))       | 20.0% (\( n = 6 \))       | .73   |
| Arterial hypertension      | 87.9% (\( n = 51 \)) | 85.7% (\( n = 24 \))      | 90.0% (\( n = 27 \))      | .61   |
| Pulmonary hypertension     | 55.2% (\( n = 32 \)) | 50.0% (\( n = 14 \))      | 60.0% (\( n = 18 \))      | .44   |
| Chronic kidney injury      | 50% (\( n = 29 \)) | 46.4% (\( n = 13 \))      | 53.3% (\( n = 16 \))      | .60   |
| Preoperative dialysis      | 6.9% (\( n = 4 \)) | 7.1% (\( n = 2 \))        | 6.7% (\( n = 2 \))        | 1.0   |
| Preoperative ICU           | 18.9% (\( n = 11 \)) | 21.4% (\( n = 6 \))       | 16.7% (\( n = 5 \))       | .64   |
| Creatinine                 | 1.2 (IQR 0.9–1.6)  | 1.04 (IQR 0.85–1.7)       | 1.24 (IQR 1.0–1.5)        | .53   |
| GFR                        | 53.5 (IQR 35.5–65.3) | 65.0 (IQR 31.5–66.5)      | 51.5 (IQR 36.75–65.3)     | .52   |
| Diabetes                   | 17.2% (\( n = 10 \)) | 17.9% (\( n = 5 \))       | 16.7% (\( n = 5 \))       | .90   |
| Atrial fibrillation        | 62.1% (\( n = 36 \)) | 50.0% (\( n = 14 \))      | 73.3% (\( n = 22 \))      | .07   |

**Risk Scores**

| Score                  | SMVR, (IQR) | Isolated SMVR, (IQR) | Combined SMVR, (IQR) | \( p \) |
|------------------------|-------------|----------------------|----------------------|-------|
| EuroSCORE I            | 32.3 (IQR 14.4–59.1) | 28.6 (IQR 12.05–55.7) | 38.8 (IQR 15.9–60.2) | .42   |
| EuroSCORE II           | 13.1 (IQR 6.5–27.1)  | 10.5 (IQR 5.0–22.5)   | 15.4 (IQR 9.9–46.3)  | .02   |
| STS PROM               | 4.8 (IQR 2.4–10.1)   | 3.7 (IQR 1.65–7.5)    | 5.9 (IQR 2.8–14.0)   | .09   |

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease; GFR, glomerular filtration rate; ICU, intensive care unit; IQR, interquartile range; PCI, percutaneous coronary intervention; SMVR, surgical mitral valve replacement; STS PROM, Society of Thoracic Surgeons Score; TIA, transient ischemic attack.
variable which are in the Cox model, over time (Figure 5 and Table 5). We found out, that the risk associated with the STS Score, active infective endocarditis and concomitant procedures varies over time. It is high directly after the surgery and lowers over time (steep curves are becoming flatter). Only the effect of mechanical prosthesis implantation is relatively constant over time (p = .16, the curve on the graph has a relatively constant slope).

4 | DISCUSSION

In the growing era of transcatheter valve implantation, conventional surgical methods remain the gold standard in reoperative mitral valve procedures. Redo SMVR is a high-risk procedure with high morbidity and mortality. There are several single- and multicentre studies describing the outcomes after redo-SMVR in various patient cohorts, but due to selection bias present in these cohorts, the results are very heterogenous and mostly not comparable. In the present study we present a real-life cohort of patients with a history of either SMVR or mitral valve repair who underwent a redo SMVR. To be able to present a real-world cohort with its' actual risks and outcomes, we aimed not to exclude the patients presenting with valve prosthesis endocarditis, mechanical valve thrombosis, and patients with concomitant pathologies. Despite the massive developments in transcatheter techniques over the last decade, there remain various indications where the utilization of transcatheter methods is impossible. It is, therefore, crucial to evaluate the risks of redo SMVR in cohorts such as ours.
The available literature reports different 30-day mortality rates after redo SMVR ranging between 1.3% and 17.4%. In those studies, the cohorts were heterogeneous, making it unfeasible to conduct a qualitative meta-analysis and sufficient cross-study comparisons. The 30-day mortality of our cohort for all the procedures without exclusion was relatively high, standing at 22.4%. The following result could be explained through a high portion of patients presenting with infective endocarditis (37.9%) and 51.7% of patients requiring at least one concomitant procedure. Both procedures initially carry higher risks when compared with isolated redo SMVR. To present the discrepancy in the outcomes, we divided our cohort (as previously mentioned) into two groups and analyzed their separate mortality rates. Patients who underwent an isolated redo SMVR showed 30-day mortality of 10.7%, while the patients with at least one additional concomitant procedure presented with significantly higher mortality of 33%, which could be explained through the complexity of the procedure and the comorbidities of the patients. It is of crucial importance to note that in most published reports, those patients would form part of the exclusion criteria of studies. The overall 30-day mortality in our cohort was overestimated by the EuroSCORE I and underestimated by the EuroSCORE II.

Similarly, to the other groups, we have also demonstrated various complications to be of significant importance, including re-thoracotomy for bleeding (12.5%), new pacemaker implantation (5.2%), acute kidney injury requiring dialysis (26.8%), and new-onset atrial fibrillation (32.1%). Our findings correlate with the ones of current literature, although we did not report any cerebrovascular accidents or myocardial infarction in our cohort.

Zeng et al. emphasized the effects of the cardioplegic solution on the postoperative myocardial infarction rate, suggesting that the crystalloid cardioplegic solution is inferior to blood cardioplegia. In our study, we used crystalloid cardioplegia in all patients and did not experience this much-feared complication. Nevertheless, we did report a relatively high postoperative incidence of septic and cardioigenic shock (10.3%), mainly due to the fact that we did not exclude the patients with acute endocarditis and multivalvular concomitant procedures.

The median time until reoperation in our study was 3.62 (IQR 0.74–12.3) years, which is much shorter than what was reported by

| Table 3 | Intraoperative characteristics |

| Variables                              | SMVR, n (%) | Isolated SMVR, n (%) | Combined SMVR, n (%) | p    |
|----------------------------------------|-------------|----------------------|----------------------|------|
| Surgical approach                      |             |                      |                      |      |
| Median sternotomy                      | 96.6% (n = 56) | 96.4% (n = 27)       | 96.7% (n = 29)       | .96  |
| Lateral thoracotomy                    | 3.4% (n = 2) | 3.6% (n = 1)         | 3.3% (n = 1)         | 1.0  |
| Prosthesis type                        |             |                      |                      |      |
| mechanical mitral valve                | 17.2% (n = 10) | 17.9% (n = 5)        | 16.7% (n = 5)        | .90  |
| biological mitral valve                | 82.2% (n = 48) | 82.1% (n = 23)       | 83.3% (n = 25)       | .90  |
| Mean prosthesis size, mm               | 28.5 ± 2.2  | 29.0 (IQR 27.0–29.0) | 29.0 (IQR 27.0–31.0) | .41  |
| Concomitant procedure                  |             |                      |                      |      |
| CABG                                   | 51.7% (n = 30) | 0                    | 100% (n = 30)        | 1.0  |
| Aortic valve replacement               | 1.7% (n = 1) | 0                    | 3.3% (n = 1)         | 1.0  |
| Tricuspid valve repair                 | 15.5% (n = 9) | 0                    | 30.0% (n = 9)        | .03  |
| Tricuspid valve replacement            | 36.2% (n = 21) | 0                   | 70.0% (n = 21)       | <.001|
| Exprocorporal life support             | 5.2% (n = 3) | 0                    | 10.0% (n = 3)        | .24  |
| MAZE                                   | 3.8% (n = 2) | 0                    | 6.7% (n = 2)         | .49  |
| Operating time, min                    | 254.2 ± 101.2 | 210.0 (IQR 168.5–246.0) | 243 (IQR 208.75–315.5) | .05  |
| CPB-time, min                          | 140.4 ± 62.4 | 107.0 (IQR 85.0–134.25) | 136.5 (IQR 112.5–190.25) | .005 |
| Cross-clamp time, min                  | 84.7 ± 44.4  | 59.5 (IQR 50.0–73.5)  | 88.0 (IQR 68.25–114.25) | .001 |
| Blood transfusion, Units               | 2.0 (IQR 0–4.00) | 2.5 (IQR 0.25–4.0) | 2.0 (IQR 0–4.00) | .77  |

Abbreviations: CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; IQR, interquartile range; SMVR, surgical mitral valve replacement.
### TABLE 4  
Postoperative outcomes and survival

| Variables                        | SMVR, n (%) | Isolated SMVR, n (%) | Combined SMVR, n (%) | p  |
|----------------------------------|-------------|----------------------|----------------------|----|
| Intraprocedural death            | 3.4% (n = 2) | 0                    | 6.7% (n = 2)         | .49|
| MVmean gradient                  | 3.8 ± 1     | 3.75 (IQR 3.0–4.4)   | 4.0 (IQR 3.0–4.15)   | .92|
| Paravalvular leakage             | 0           | 0                    | 0                    |    |
| Rethoracotomy                    | 12.5% (n = 7)| 14.3% (n = 4)        | 10.7% (n = 3)        | 1.0|
| Stroke                           | 0           | 0                    | 0                    |    |
| Re-intubation                    | 12.5% (n = 7)| 10.7% (n = 3)        | 14.3% (n = 4)        | 1.0|
| Myocardial infarction            | 0           | 0                    | 0                    |    |
| AKI on dialysis                  | 26.8% (n = 15)| 25.0% (n = 7)       | 28.6% (n = 8)        | .76|
| Wound infection                  | 1.7% (n = 1) | 3.6% (n = 1)         | 0                    | 1.0|
| New-onset Afib                   | 32.1% (n = 18)| 39.3% (n = 11)      | 25.0% (n = 7)        | .25|
| Pacemaker implantation           | 5.2% (n = 3) | 10.7% (n = 3)        | 0                    | .24|
| Shock                            | 24.1% (n = 14)| 17.9% (n = 5)       | 30.0% (n = 9)        | .21|
| Cardiogenic                      | 10.3% (n = 6) | 7.1% (n = 2)         | 13.3% (n = 4)        | .67|
| Septic                           | 10.3% (n = 6) | 7.1% (n = 2)         | 13.3% (n = 4)        | .67|
| Hemorrhagic                      | 3.4% (n = 2)  | 3.6% (n = 1)         | 3.3% (n = 1)         | 1.0|
| ICU-stay, days                   | 3.5 (IQR 2.0–7.6)| 4.0 (IQR 2.0–9.0)  | 3.0 (IQR 2.0–6.0)   | .18|
| Time on ventilator, days         | 1.0 (IQR 1.0–2.8)| 1.0 (IQR 0.5–5.25) | 1.0 (IQR 1.0–1.25)  | .81|
| Hospital-stay, days              | 12.4 ± 11.6 | 11.0 (IQR 7.25–16.0)| 10.0 (IQR 7.0–14.0) | .26|
| Prolonged ventilation > 24 h     | 20.7% (n = 12)| 25.0% (n = 7)       | 16.7% (n = 5)        | .52|
| 30-day mortality                 | 22.4% (n = 13)| 10.7% (n = 3)       | 33.3% (n = 10)       | .06|
| One-year mortality               | 25.9%       | 18%                  | 33.3%                | .023|
| Three-year mortality             | 25.9%       | 18%                  | 33.3%                | .023|
| Follow-up time, years            | 2.85 (IQR 0.34–4.9)| 2.65 (IQR 0.68–4.83)| 3.14 (IQR 0.03–5.2) | .51|
| Follow-up time, days             | 1040.5 (IQR 126–1783.7)| 971.0 (IQR 248.25–1764.24)| 1149.5 (IQR 9.5–1899.75)| .51|

Abbreviations: AKI, acute kidney injury; ICU, intensive care unit; IQR, interquartile range; SMVR, surgical mitral valve replacement.

FIGURE 1  
Overall survival
**FIGURE 2** Survival of the Group 1 versus Group 2, \( p = .023 \)

**FIGURE 3** Logistic regression. CI, confidence interval; OR, odds ratio

**FIGURE 4** Cox regression. CI, confidence interval; HR, hazard ratio; STS, Society of Thoracic Surgeons Score
Ejiofor et al. in their recent publication. The mean patients’ age was 63.6 ± 12.5 years and more than half of the patients (57.5%, n = 19) who underwent a previous SMVR were then treated with biological valve prostheses. It has already been established that deterioration of biological prostheses in mitral position progresses faster than in the aortic position due to the exposition to higher pressure. Also, the survival advantage of mechanical prostheses in mitral positions in younger patients is indisputable. Apart from a high portion of patients with infective endocarditis, the rapid structural deterioration of biological prostheses in younger patients was responsible for the shorter period of time between the initial and the redo procedure.

Due to the complexity and comorbidities of this patient cohort, various factors have been described which might potentially affect postoperative outcomes. Most of these factors are well-known conditions, predicting mortality also in other cardiothoracic procedures and are represented in both EuroSCORE and STS Score. Accordingly, we also report that high NYHA class, infective endocarditis, concomitant procedures, and mechanical valve implantation significantly contributed to long-term mortality in our cohort. The effect of these factors was also not diminishing over time, as presented with the Aalen model (Figure 5).

In conclusion, the current study corroborates that redo mitral valve replacement after prior mitral valve surgery presents as a demanding procedure with a high operative risk and is associated with significant mortality and morbidity. Nevertheless, the procedure is the gold standard of care and remains unavoidable in such indications as infective endocarditis, valve thrombosis, and concomitant procedures. A careful patient selection and risk stratification provide acceptable surgical results in this high-risk population. STS Score, infective endocarditis, concomitant procedures, and mechanical valve implantation seem to predict long-term mortality.

### 4.1 Study limitations

The retrospective nonrandomized nature of the study coming from a single center with a limited number of patients may have an impact on the outcomes and the study power and can leave room for bias.

**TABLE 5 Additive Aalen model—tests for time-variability of the coefficients**

| Variables                                      | p value (Kolmogorov–Smirnov test) | p value (Cramer von Mises test) |
|------------------------------------------------|-----------------------------------|---------------------------------|
| Intercept                                      | .03                               | .04                             |
| STS-Score                                      | .03                               | .03                             |
| Infective endocarditis                         | .03                               | .02                             |
| Concomitant procedures                         | .04                               | .05                             |
| Implantation of mechanical mitral valve prosthesis | .16                               | .16                             |

Abbreviation: STS, Society of Thoracic Surgeons.

**FIGURE 5** Aalen model, effect variability over time. STS, Society of Thoracic Surgeons Score
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CONFLICT OF INTERESTS
The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS
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