Accepted Manuscript online: 2024-03-05 Article published online: 2024-04-16

Recent Outcomes of Surgical Redo Aortic Valve Replacement in Prosthetic Valve Failure

Yoonjin Kang[1,*] Nazla Amanda Soehartono[2,*] Jae Woong Choi[1] Kyung Hwan Kim[1] Ho Young Hwang[1] Joon Bum Kim[3] Hong Rae Kim[3] Seung Hyun Lee[4] Yang Hyun Cho[5]

[1] Department of Thoracic and Cardiovascular Surgery, Seoul National University Hospital, Seoul National University College of Medicine, Seoul, Republic of Korea
[2] Department of Thoracic and Cardiovascular Surgery, Seoul National University College of Medicine, Jongno-gu, Seoul, Republic of Korea
[3] Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Republic of Korea
[4] Division of Cardiovascular Surgery, Severance Cardiovascular Hospital, Yonsei University College of Medicine, Republic of Korea
[5] Department of Thoracic and Cardiovascular Surgery, Heart Stroke Vascular Institute, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea

Address for correspondence Jae Woong Choi, MD, PhD, Department of Thoracic and Cardiovascular Surgery, Seoul National University Hospital, Seoul National University College of Medicine, Seoul 101, Republic of Korea (e-mail: cjw01@snu.ac.kr).

Thorac Cardiovasc Surg

Abstract

Background As redo surgical aortic valve replacement (AVR) is relatively high risk, valve-in-valve transcatheter AVR has emerged as an alternative for failed prostheses. However, the majority of studies are outdated. This study assessed the current clinical outcomes of redo AVR.

Methods and Results This study enrolled 324 patients who underwent redo AVR due to prosthetic valve failure from 2010 to 2021 in four tertiary centers. The primary outcome was operative mortality. The secondary outcomes were overall survival, cardiac death, and aortic valve-related events. Logistic regression analysis, clustered Cox proportional hazards models, and competing risk analysis were used to evaluate the independent risk factors. Redo AVR was performed in 242 patients without endocarditis and 82 patients with endocarditis. Overall operative mortality was 4.6% (15 deaths). Excluding patients with endocarditis, the operative mortality of redo AVR decreased to 2.5%. Multivariate analyses demonstrated that endocarditis (hazard ratio [HR]: 3.990, $p = 0.014$), longer cardiopulmonary bypass time (HR: 1.006, $p = 0.037$), and lower left ventricular ejection fraction (LVEF) (HR: 0.956, $p = 0.034$) were risk factors of operative mortality. Endocarditis and lower LVEF were independent predictors of overall survival.

Conclusion The relatively high risk of redo AVR was due to reoperation for prosthetic valve endocarditis. The outcomes of redo AVR for nonendocarditis are excellent. Our findings suggest that patients without endocarditis, especially with acceptable LVEF, can be treated safely with redo AVR.

Keywords
- aortic valve
- aortic valve replacement
- prosthesis

[*] *These authors are the co-first author of the manuscript.*

received
September 24, 2023
accepted after revision
February 27, 2024
accepted manuscript online
March 5, 2024

DOI https://doi.org/10.1055/a-2281-1897.
ISSN 0171-6425.

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

Introduction

Aortic valve replacement (AVR) is one of the most frequently performed open heart surgeries.[1] With the increase in patients undergoing AVR, patients who require redo AVR due to structural valve degeneration (SVD), prosthetic valve endocarditis, paravalvular leak or thrombosis/pannus formation are also increasing. With the increase in the number of patients using aortic valve bioprostheses and recent advances in valve-in-valve transcatheter aortic valve implantation (ViV-TAVI), an increase in the number of patients with failing bioprostheses is to be expected.

In previous studies, the in-hospital mortality rate of redo AVR after surgical AVR ranged from 2 to 18%, averaging around 5%.[2,3] However, these studies are outdated, and their study populations were heterogeneous with various surgical indications. Therefore, the present study evaluated recent clinical outcomes of redo AVR after surgical AVR for failing prostheses.

Patients and Methods

Patient Enrollment

The study protocol was reviewed by our Institutional Review Board and approved as a minimal risk retrospective study (Approval Number: H-2202–061–1299) that did not require individual consent on February 18, 2022. From January 2010 to December 2021, 392 consecutive patients underwent redo AVR after surgical AVR in four tertiary centers. None of the patients had underwent coronary artery bypass grafting as a primary procedure. Of these patients, 66 who had severe mitral or tricuspid valve disease and 2 who underwent intended concomitant coronary artery bypass graft were excluded. Thus, this study enrolled 324 patients (62.1 ± 13.8 years; 145 males and 179 females).

The indications for redo SVR were (1) non-SVD ($n = 84$), (2) SVD ($n = 151$), (3) prosthetic valve endocarditis ($n = 82$), and (4) thrombosis ($n = 7$).

Operative Strategy

The procedures were performed using various approaches, including median sternotomy ($n = 303$), upper partial sternotomy ($n = 19$), or right anterior thoracotomy ($n = 2$). One-hundred and twenty of the patients underwent redo AVR with a mechanical valve, and the other 204 patients underwent bioprosthetic redo AVR. Two different types of rapid deployment/sutureless valve were used (Sorin Perceval [$n = 3$] and Edwards Intuity [$n = 5$]). The surgical approach and type of prosthesis were selected at the discretion of the attending surgeon.

Evaluation of Early and Long-Term Clinical Outcomes

Operative mortality was defined as death within 30 days of operation or during the same hospitalization period. Postoperative low cardiac output syndrome was defined as the need for mechanical or inotropic support to maintain systolic blood pressure >90 mm Hg after correcting reversible factors.

Regular (3- to 6-month intervals) postoperative follow-up was performed at the outpatient clinic. The patient's condition was checked via telephone if they did not attend the scheduled clinic visit. Cardiac death was defined as any death of a cardiac origin, including sudden death. Aortic valve-related events (AVREs) were defined as following; (1) cardiac death, (2) congestive heart failure, (3) reoperation for aortic valve, (4) thromboembolism,[5] major bleeding that caused death, hospitalization, or need for a transfusion, (5) prosthetic aortic valve endocarditis, and (6) permanent pacemaker implantation following AVR.

The clinical follow-up period ended on April 30, 2022. The median follow-up duration was 51 months (interquartile range: 16.8–79.0 months). The completeness of follow-up was 94.1% (305 out of 324) for overall survival and other long-term clinical outcomes.

Statistical Analysis

Statistical analyses were performed using R version 4.0.3 (R Foundation for Statistical Computing) and SAS (version 9.4; SAS institute, Cary, North Carolina, United States). The two groups were compared using the Chi-square test or Fisher's exact test and Student's *t*-test for categorical and continuous variables, respectively. Survival rates were estimated using the Kaplan–Meier method.

Logistic regression analysis was performed to evaluate the factors associated with operative mortality. Risk factors for longitudinal data were analyzed using a multivariate Cox proportional hazards model.

The patients were divided into subgroups according to the presence of preoperative endocarditis. The cumulative incidences of cardiac death and AVRE were estimated with noncardiac death as a competing risk for the events. The cumulative incidences of composite of thromboembolism and bleeding were estimated with all-cause death as a competing risk for the events. The cumulative incidences of the two groups for each event were compared using the Fine–Gray test. Variables with a p-value <0.10 in the univariate analyses were entered into multivariate models. A p-value <0.05 was considered statistically significant.

To balance the patients for differences in baseline characteristics, inverse probability of treatment weight (IPTW) analysis was used. The following preoperative variables were entered into the logistic regression model: age, sex, body surface area, hypertension, diabetes mellitus, history of stroke, chronic kidney disease, coronary artery disease, dyslipidemia, atrial fibrillation, and left ventricular ejection fraction (LVEF). A clustered Cox regression analysis of overall survival based on the IPTW analysis was performed.

Results

Patient Characteristics and Operative Data

The baseline patients characteristics are presented in ►**Table 1**. Redo AVR was performed in 242 patients for reasons other than prosthetic valve endocarditis (nonendocarditis group) and the other 82 patients underwent redo AVR due to endocarditis (endocarditis group). Patients in the

Table 1 Preoperative and operative data of the study patients before and after inverse probability of treatment weighting (IPTW)

		Before IPTW, *n* (%)			IPTW-adjusted, %		
Variables	All	Nonendocarditis group (*n* = 242)	Endocarditis group (*n* = 82)	*p*-Value	Nonendocarditis group (*n* = 242)	Endocarditis group (*n* = 82)	*p*-Value
Age (y)	62.1 ± 13.8	60.9 ± 14.1	65.8 ± 12.2	0.005	62.1 ± 14.1	60.6 ± 14.4	0.195
Female, *n* (%)	145 (44.8%)	81 (33.3%)	64 (79.0%)	<0.001	44.2	43.0	0.754
Body surface area (m^2)	1.8 ± 1.6	1.7 ± 1.2	2.0 ± 2.4	0.268	1.7 ± 1.2	1.8 ± 1.3	0.607
Risk factors, *n* (%)							
Hypertension	115 (35.5%)	81 (33.5%)	34 (42.0%)	0.203	36.0	31.8	0.246
Diabetes mellitus	63 (19.4%)	37 (15.2%)	26 (32.1%)	0.002	18.3	17.8	0.863
History of stroke	50 (15.5%)	26 (10.7%)	24 (29.6%)	<0.001	15.1	18.8	0.099
Chronic kidney disease[a]	54 (16.7%)	37 (15.2%)	17 (21.0%)	0.302	18.0	22.7	0.116
Coronary artery disease	20 (6.2%)	12 (4.9%)	8 (9.9%)	0.110	6.9	6.0	0.793
Dyslipidemia	54 (16.7%)	44 (18.1%)	10 (12.3%)	0.228	42.5	12.9	0.569
Atrial fibrillation	100 (30.9%)	83 (34.3%)	17 (20.7%)	0.031	31.1	23.8	0.163
LVEF	60.9 ± 10.4	61.6 ± 9.8	58.7 ± 11.9	0.055	61.1 ± 9.7	60.7 ± 9.7	0.527
CPB time (min)	197.5 ± 91.6	189.5 ± 87.4	221.6 ± 99.6	0.006	177.8 ± 81.7	260.7 ± 92.0	<0.001
ACC time (min)	133.3 ± 68.0	126.6 ± 62.3	153.3 ± 80.1	0.007	124.0 ± 62.5	201.5 ± 79.0	<0.001
Concomitant procedure, *n* (%)							
Mitral valve procedure	68 (21.0%)	50 (20.7%)	18 (22.0%)	0.095	27.6	42.1	0.030
Tricuspid valve procedure	56 (17.3%)	52 (21.5%)	4 (4.9%)	0.008	23.8	7.9	0.380
Aorta procedure[b]	38 (11.7%)	30 (12.4%)	8 (9.8%)	0.728	8.2	10.5	0.533
Arrhythmia surgery	12 (3.7%)	10 (4.1%)	2 (2.4%)	0.732	1.7	0.0	<0.001
CABG	2 (0.6%)	1 (0.4%)	1 (1.2%)	>0.999	0.0	0.0	0.249

Abbreviations: ACC, aortic cross clamp; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; LVEF, left ventricular ejection fraction.
[a]Chronic kidney disease was defined as the definition of chronic kidney disease by The Kidney Disease: Improving Global Outcomes Work Group.
[b]Aorta procedure was defined as ascending aorta replacement or reduction plasty.

nonendocarditis group were younger, more likely to be male, and have diabetes mellitus, a history of stroke, and atrial fibrillation than the endocarditis group (►**Table 1**). There were no significant differences in preoperative characteristics between the two groups after IPTW adjustment. The aortic cross clamp time was longer and tricuspid valve procedures were performed more frequently in the endocarditis group after IPTW adjustment (►**Table 1**).

Early Results

Operative mortality occurred in 15 patients (4.6%) overall. Excluding the patients with endocarditis, the operative mortality of redo AVR decreased to 2.5% (6 of 242 patients), whereas that of redo AVR in patients with endocarditis increased to 11.0% (9 of 82 patients). In the nonendocarditis group, the operative mortality was 1.3% (2 of 151 patients) for SVD, and 4.8% (4 of 84 patients) for non-SVD. The operative mortality was significantly higher in the endocarditis group (11.0% vs. 2.5%, $p = 0.004$).

►**Table 2** summarizes the postoperative complications. There were significant differences in the operative mortality rate and incidences of postoperative acute kidney injury, stroke, and respiratory complications between the two groups (►**Table 2**). After applying the IPTW procedure, the endocarditis group also had significantly worse clinical outcomes in operative mortality and postoperative acute kidney injury than the nonendocarditis group, whereas the other postoperative outcomes were comparable.

The results of the univariate and multivariate logistic regression analyses for operative mortality are shown in ►**Table 3**. Independent risk factors of operative mortality were the presence of preoperative endocarditis (hazard ratio [HR]: 3.990; 95% confidence interval [CI]: 1.343–12.580; $p = 0.014$), longer cardiopulmonary bypass time (HR: 1.006; 95% CI: 1.000–1.011; $p = 0.037$), and lower LVEF (HR: 0.956; 95% CI: 0.918–0.998; $p = 0.034$).

Long-Term Survival

Late death occurred in 53 patients including 10 cardiac deaths. The 1- and 5-year overall survival rates were 93.4 and 83.5%, respectively (►**Fig. 1A**). In the nonendocarditis group, the overall survival at 1- and 5-years was 96.2 and 88.2%, respectively (►**Fig. 1B**). Kaplan–Meier curves showed that the overall survival was higher in the nonendocarditis group ($p < 0.001$). The freedom from cardiac death at 1- and 5-years was 98.1 and 96.2%, respectively (►**Fig. 2A**). In the nonendocarditis group, the freedom from cardiac death at 1- and 5-years was 100.0 and 98.8%, respectively (►**Fig. 2B**). Kaplan–Meier curves showed that the freedom from cardiac death was higher in the nonendocarditis group ($p = 0.010$). Multivariate analysis showed that age and the presence of endocarditis and LVEF were significantly associated with overall survival (►**Table 4**). In the competing risk analysis for cardiac death, the endocarditis group was associated with increased risk (HR: 10.260, 95% CI: 2.137–49.268; $p = 0.004$, ►**Table 4**). After IPTW, the clustered Cox regression also revealed that the endocarditis group had poorer overall survival (HR: 2.238; 95% CI: 1.161–4.314; $p = 0.016$; ►**Supplementary Table S1** and ►**Supplementary Fig. S1** [available in the online version]).

Aortic Valve-Related Events

During follow-up, AVRE occurred in 65 patients including cardiac death in 10, congestive heart failure in 20, reoperation for the aortic valve in 11, and prosthetic AV endocarditis in 9 patients.

The 1- and 5-year rates of freedom from AVRE were 91.4 and 76.8%, respectively (►**Fig. 3A**). The 5-year rates of freedom from AVRE in the nonendocarditis and endocarditis groups were 93.8 and 79.7%, respectively (►**Fig. 3B**). Although there were significant differences in AVRE between the two groups in the log-rank test ($p = 0.010$), there was no significant difference in AVRE after IPTW adjustment. The multivariate analyses showed that the endocarditis was not an independent risk factor for AVRE (HR: 1.456; 95% CI: 0.792–2.710; $p = 0.236$). Instead, the presence of chronic kidney disease was associated with AVRE (►**Table 5**).

Comment

This study demonstrated three main findings. First, the clinical outcomes of redo AVR for nonendocarditis were excellent with 2.5% operative mortality. In particular, the mortality of redo AVR for SVD was very low at 1.5%. Second, endocarditis, prolonged cardiopulmonary bypass time, and low LVEF were independent risk factors in redo AVR. Third, redo AVR was associated with better overall survival and lower risk of cardiac death in younger patients with an acceptable LVEF without endocarditis.

As the proportion of patients undergoing bioprosthetic AVR is increasing,[4] increasing numbers of patients are expected to require redo AVR.[5,6] Based on reports of a relatively high risk of redo surgical AVR with around 5% operative mortality,[1] ViV-TAVI has been increasingly used. Although some previous observational studies found that ViV-TAVI was associated with lower early mortality than redo AV,[7,8] those were not randomized controlled trials. In addition, those studies were based on the administrative hospital-discharge database, which has limited information about the existing bioprosthetic valve size. In patients with smaller bioprostheses, surgery may be preferred over intervention due to patient–prosthesis mismatch; however, the reoperation of smaller existing prostheses can be technically more demanding due to the possible need for annular enlargement.[9] Moreover, compared with our patients, the patients in those studies tended to undergo previous coronary artery bypass grafting more frequently (~3% vs. 15–20%), which can confer a relatively higher risk for redo surgery.[10,11] In addition, Deharo et al included patients with previous endocarditis.[7]

Recent meta-analyses that directly compared ViV-TAVI and surgery showed that the early[12] and mid-term[13] all-cause mortalities were comparable. There has been concern regarding the mid- and long-term results of ViV-TAVI because of the higher postoperative pressure gradient compared with surgery.[14,15] Regarding that, ViV-TAVI is

Table 2 Early clinical outcomes

		Before IPTW, *n* (%)			IPTW-adjusted, %		
Variables	All	Nonendocarditis group ($n = 242$)	Endocarditis group ($n = 82$)	*p*-Value	Nonendocarditis group ($n = 242$)	Endocarditis group ($n = 82$)	*p*-Value
Operative mortality	15(4.6%)	6 (2.5%)	9(11.0%)	0.004	3.0	10.2	0.013
For nonstructural valve dysfunction ($n = 84$)		4 (4.8%)					
For structural valve degeneration ($n = 151$)		2 (1.3%)					
For thrombosis ($n = 7$)		0 (0%)					
Complications, *n* (%)							
Low cardiac output syndrome	28 (8.6%)	18 (7.4%)	10 (12.3%)	0.171	7.6	11.1	0.330
Bleeding	16 (4.9%)	10 (4.1%)	7 (7.3%)	0.559	4.6	3.6	>0.999
Acute kidney injury	48 (14.8%)	26 (10.7%)	22 (26.8%)	0.001	11.6	23.2	0.011
New-onset AF	44 (13.6%)	36 (14.9%)	8 (9.8%)	0.326	14.9	9.4	0.217
Mediastinitis	2 (0.7%)	1 (0.5%)	1 (1.4%)	0.438	0.3	0.8	0.432
Stroke	16 (4.9%)	8 (3.3%)	8 (9.8%)	0.042	2.9	7.0	0.175
CAVB	9 (2.8%)	7 (2.9%)	2 (2.4%)	0.823	3.9	1.8	0.461
PPM insertion	13 (4.0%)	9 (3.7%)	4 (4.9%)	0.891	3.8	3.2	>0.999
Respiratory	2 (0.6%)	24 (9.9%)	16 (9.5%)	0.037	10.6	12.9	0.072
Infective endocarditis	2 (0.6%)	2 (0.8%)	0 (0.0%)	0.992	1.6	0.0	0.576

Abbreviations: AF, atrial fibrillation; CAVB, complete atrioventricular block; IPTW, inverse probability of treatment weighting; PPM, permanent pacemaker.

Table 3 Logistic regression analysis for factors associated with operative mortality

Factors associated with operative mortality				
Variables[a]	Univariate analysis		Multivariable analysis	
	HR [95% CI]	*p*-Value	HR [95% CI]	*p*-Value
Endocarditis group	4.849 [1.693–14.895]	0.004	3.990 [1.343–12.580]	0.014
CPB time	1.006 [1.001–1.011]	0.011	1.006 [1.000–1.011]	0.037
LVEF	0.946 [0.911–0.987]	0.007	0.956 [0.918–0.998]	0.034

Abbreviations: CPB, cardiopulmonary bypass, LVEF, left ventricular ejection fraction.
[a]All variables in ►**Table 1** were analyzed and factors that entered into the multivariable analysis were shown.

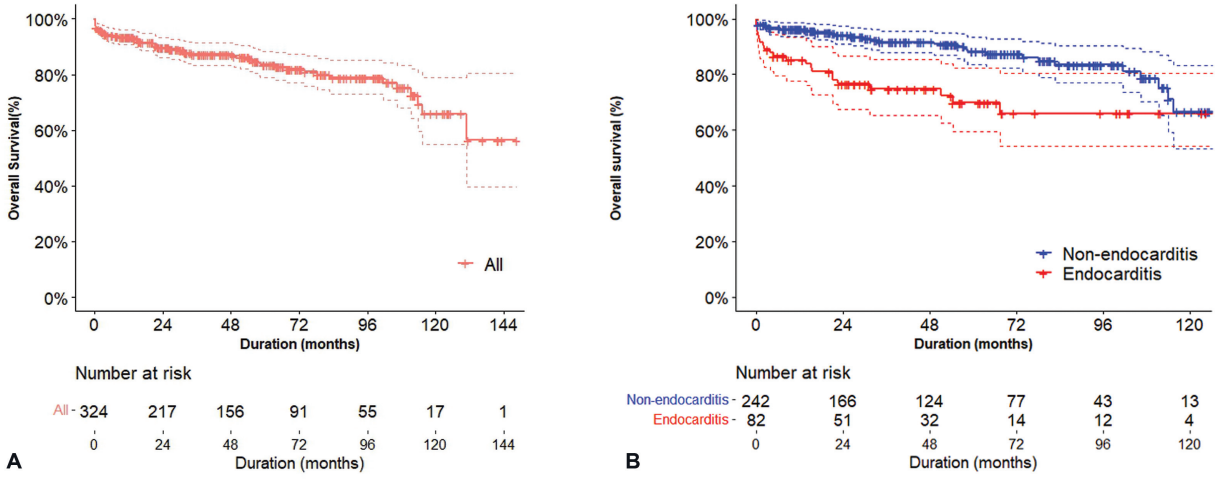

Fig. 1 Kaplan–Meier curve (unweighted) for overall survival (**A**) in all patients and (**B**) according to the presence of preoperative prosthetic valve endocarditis.

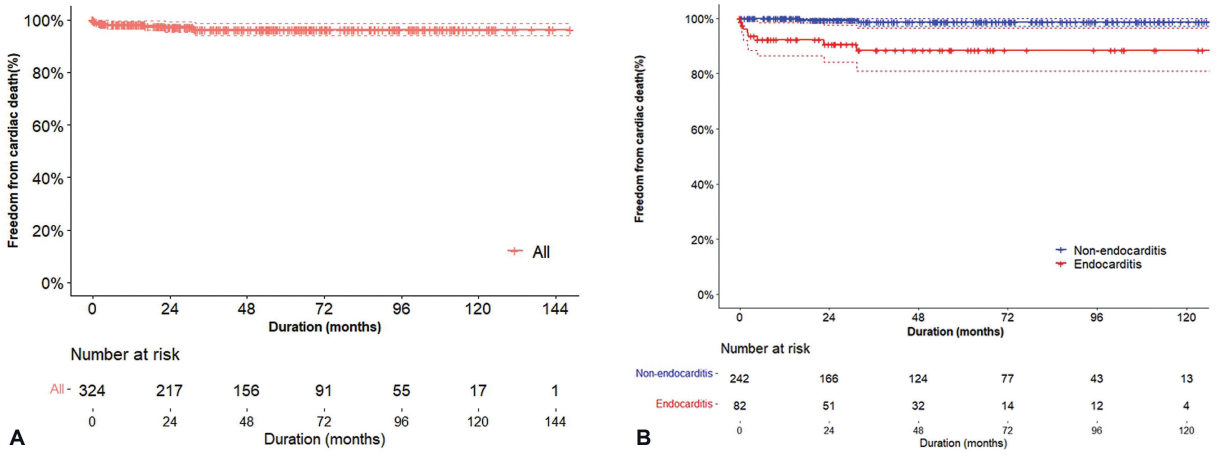

Fig. 2 Kaplan–Meier curve (unweighted) for cardiac death (**A**) in all patients and (**B**) according to the presence of preoperative prosthetic valve endocarditis.

challenging in patients with small bioprostheses (<21 mm) in terms of hemodynamic performance[16] and Asians are tend to implant smaller bioprostheses at the index procedure. In our study, 290 patients (89.5%) had bioprostheses less than or equal to 21 mm. Hawkins et al[17] have also emphasized that patients with life expectancy longer than the duration of TAVI valve and unsuitable anatomy for ViV-TAVI should be considered as a surgical AVR candidate. Regarding reported mortality rates of 12 and 29–32% at 1 and 3 years after ViV TAVI,[18,19] we observed relatively high 1- and 5-year overall survival rates of redo AVR (96.2 and 88.2%) in the non-endocarditis group. In addition, early studies suggested high rates of device malposition, elevated transvalvular gradients, and coronary obstruction.[20,21]

Consistent with other studies,[1,22,23] the operative mortality of redo AVR in our study was 4.6%. Mortality around 5%

Table 4 Cox proportional hazards models for factors associated with overall survival and competing risk analysis for factors associated with cardiac death

Factors associated with overall survival				
Variables[a]	Univariate analysis		Multivariable analysis	
	HR [95% CI]	*p*-Value	HR [95% CI]	*p*-Value
Age (y)	1.069 [1.039–1.099]	<0.001	1.065 [1.035–1.095]	<0.001
Endocarditis group	2.654 [1.539–4.577]	<0.001	2.107 [1.198–3.709]	0.010
LVEF	0.967 [0.946–0.989]	<0.001	0.961 [0.940–0.984]	<0.001
Factors associated with cardiac death				
Variables[a]	Univariate analysis		Multivariable analysis	
	HR [95% CI]	*p*-Value	HR [95% CI]	*p*-Value
Age	1.078 [1.010–1.151]	0.024	1.087 [1.012–1.167]	0.023
Endocarditis group	12.800 [2.717–60.310]	0.001	10.260 [2.137–49.268]	0.004
LVEF	0.927 [0.890–0.967]	<0.001	0.918 [0.874–0.964]	<0.001

Abbreviations: AF, atrial fibrillation; LVEF, left ventricular ejection fraction.
[a]All variables in ►**Table 1** were analyzed and factors that entered into the multivariable analysis were shown.

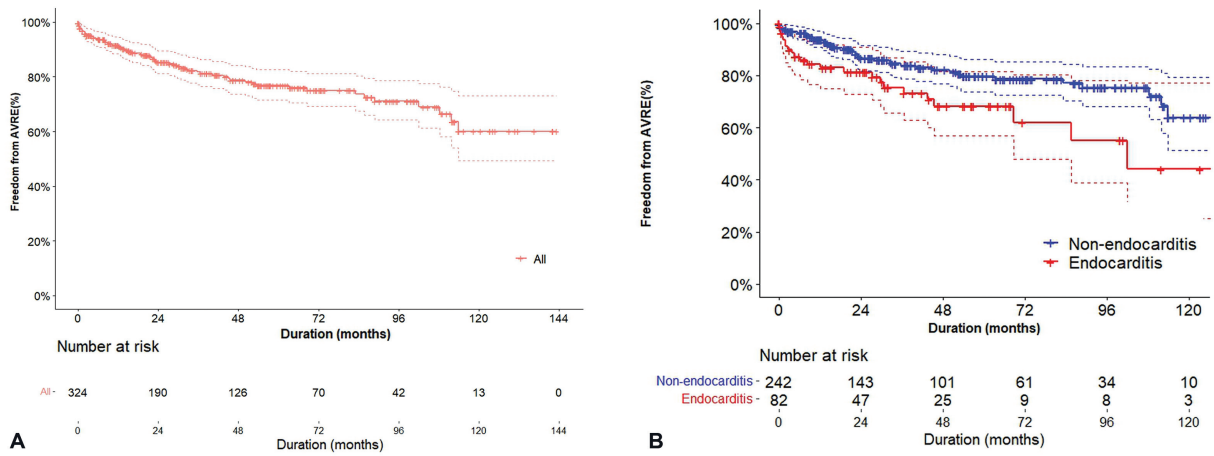

Fig. 3 Kaplan–Meier curve (unweighted) for aortic valve-related events (**A**) in all patients and (**B**) according to the presence of preoperative prosthetic valve endocarditis.

Table 5 Competing risk analysis for factors associated with aortic valve-related event (AVRE)

Factors associated with AVRE				
Variables[a]	Univariate analysis		Multivariable analysis	
	HR [95% CI]	*p*-Value	HR [95% CI]	*p*-Value
CKD	2.050 [1.220–3.450]	0.007	2.030 [1.183–3.480]	0.010
LVEF	0.977 [0.955–0.998]	0.035	0.978 [0.956–1.000]	0.067
Endocarditis group	1.790 [1.080–2.990]	0.024	1.456 [0.782–2.710]	0.236
Male gender	1.690 [1.030–2.750]	0.036	1.280 [0.713–2.300]	0.408
History of stroke	1.670 [0.934–2.970]	0.084	1.291 [0.698–2.390]	0.415

Abbreviations: CKD, chronic kidney disease; LVEF, left ventricular ejection fraction.
[a]All variables in ►**Table 1** were analyzed and factors that entered into the multivariable analysis were shown.

was observed with heterogeneous surgical patients, including reoperation involving aortic surgery[22,23] and various surgical indications.[1] Moreover, most of those studies were published before 2010. After excluding the patients with prosthetic valve endocarditis, the operative mortality in our study fell to 2.5%, and decreased further to 1.5% for the patient with SVD. Our data show that the operative mortality of prosthetic aortic valve endocarditis is up to 11.0%.

Prosthetic valve endocarditis is one of the most important indications of redo AVR and its reported mortality rate is between 5 and 17%.[24,25] In numerous previous studies, prosthetic valve endocarditis as an indication for redo AVR was a risk factor for early mortality, which is similar to our findings.[1,26,27]

The reported results after redo AVR are associated with the timing and indications of reoperation, cardiac/noncardiac risk factors, and the type of valve implanted.[26–28] In our study, the multivariate analysis showed that preoperative prosthetic valve endocarditis, prolonged cardiopulmonary bypass time, and low preoperative LVEF were independent risk factors for operative mortality. In particular, a reduced LVEF is a well-known risk factor for early mortality, which is similar to our results.[5,27] These findings show the importance of a comprehensive preoperative evaluation of the candidates for redo cardiac surgery.

As technological advances have led to the introduction of transcatheter valve implantation in selected patients who require redo cardiac surgery, a thorough understanding of the operative outcomes and risk factors of redo AVR is essential. Although redo cardiac surgery is technically demanding, surgical advances and standardized intensive care unit protocols to minimize perioperative complication help reduce the associated morbidity. Minimally invasive surgical techniques continue to be developed and new surgical devices have been introduced, including sutureless valves, rapid deployment valves, and automated suture fasteners, such as Cor-Knot.[1] Minimally invasive surgery can facilitate access to redo surgery, expanding the surgical options to make redo surgery safer. In addition, the introduction of new surgical devices can help reduce aortic cross clamp time, and avoid the dissection of a previous aortotomy site and annulus injury during hand-tying. Moreover, the postoperative cardiac intensive care protocols have been developed and standardized.[29] As a re-evaluation of recent clinical outcomes of redo AVR was needed, we conducted this study to re-assess the contemporary results of redo AVR.

Several limitations of this study must be noted. First, it was limited by its retrospective design. As the patients were not randomized to the interventions, there was selection bias. However, we applied IPTW analysis to minimize bias. Second, the indications for valve selection for redo AVR might have affected the clinical outcomes. However, due to the retrospective nature of the study, we could not delineate the precise indications for valve selection. Finally, we did not compare the clinical outcomes of redo AVR and ViV-TAVI.

In conclusion, the early and long-term clinical outcomes of redo AVR for nonendocarditis were excellent. Our findings suggest that patients without endocarditis, especially with an acceptable ejection fraction, can be treated with redo AVR safely. However, the long-term results of redo AVR and ViV-TAVI are needed to establish the superiority of redo AVR with degenerated bioprosthetic aortic valves.

Data Availability Statement

Data available on request.

Authors' Contribution

Y.K. contributed to conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, visualization, writing-original draft, writing-review and editing. N.A.S. contributed to : conceptualization, data curation, writing-original draft. J.W.C. contributed to conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, visualization, writing-original draft, writing-review and editing. K.H.K. contributed to formal analysis, investigation, supervision, validation, writing-review and editing. H.Y.H. contributed to conceptualization, data curation, formal analysis, project administration, validation, visualization, writing-review and editing. J.B.K. contributed to conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, visualization, writing-original draft, writing-review and editing. H.R.K. contributed to conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, visualization, writing-original draft, writing-review and editing. S.H.L. contributed to conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, visualization, writing-original draft, writing-review and editing; Y.H.C. contributed to conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, visualization, writing-original draft, writing-review and editing.

Conflict of Interest

None declared.

Acknowledgment

We wish to thank the Medical Research Collaborating Center, Seoul National University Hospital for statistical consultation.

References

1 Choi JW, Kim JB, Jung YJ, et al. Trends in heart valve surgery in Korea: a report from the heart valve surgery registry database. J Chest Surg 2022;55(05):388–396
2 Davierwala PM, Borger MA, David TE, Rao V, Maganti M, Yau TM. Reoperation is not an independent predictor of mortality during aortic valve surgery. J Thorac Cardiovasc Surg 2006;131(02): 329–335
3 Onorati F, Biancari F, De Feo M, et al. Mid-term results of aortic valve surgery in redo scenarios in the current practice: results from the multicentre European RECORD (REdo Cardiac Operation Research Database) initiative. Eur J Cardiothorac Surg 2015;47 (02):269–280, discussion 280
4 Woo HS, Hwang HY, Kim HJ, et al. Changes in the prosthesis types used for aortic valve replacement after the introduction of sutureless and rapid deployment valves in Korea: a nationwide population-based cohort study. J Chest Surg 2021;54(05): 369–376
5 Leontyev S, Borger MA, Davierwala P, et al. Redo aortic valve surgery: early and late outcomes. Ann Thorac Surg 2011;91(04): 1120–1126

6 Oxenham H, Bloomfield P, Wheatley DJ, et al. Twenty year comparison of a Bjork-Shiley mechanical heart valve with porcine bioprostheses. Heart 2003;89(07):715–721
7 Deharo P, Bisson A, Herbert J, et al. Transcatheter valve-in-valve aortic valve replacement as an alternative to surgical re-replacement. J Am Coll Cardiol 2020;76(05):489–499
8 Malik AH, Yandrapalli S, Zaid S, et al. Valve-in-valve transcatheter implantation versus redo surgical aortic valve replacement. Am J Cardiol 2020;125(09):1378–1384
9 Sá MPBO, Zhigalov K, Cavalcanti LRP, et al. Impact of aortic annulus enlargement on the outcomes of aortic valve replacement: a meta-analysis. Semin Thorac Cardiovasc Surg 2021;33(02):316–325
10 Iturra SA, Greason KL, Suri RM, et al. Repeat sternotomy for surgical aortic valve replacement in octogenarian patients with aortic valve stenosis and previous coronary artery bypass graft operation: what is the operative risk? J Thorac Cardiovasc Surg 2014;148(05):1899–1902
11 Giorgio Malvindi P, Luthra S, Santarpino G, et al. Early- and mid-term outcomes of reinterventions for aortic bioprosthesis failure. Asian Cardiovasc Thorac Ann 2022;30(07):788–796
12 Takagi H, Mitta S, Ando T. Meta-analysis of valve-in-valve transcatheter versus redo surgical aortic valve replacement. Thorac Cardiovasc Surg 2019;67(04):243–250
13 Thandra A, Abusnina W, Jhand A, et al. Valve-in-valve transcatheter aortic valve replacement versus redo surgical valve replacement for degenerated bioprosthetic aortic valve: an updated meta-analysis comparing midterm outcomes. Catheter Cardiovasc Interv 2021;97(07):1481–1488
14 Smith CR, Leon MB, Mack MJ, et al; PARTNER Trial Investigators. Transcatheter versus surgical aortic-valve replacement in high-risk patients. N Engl J Med 2011;364(23):2187–2198
15 Ussia GP, Barbanti M, Petronio AS, et al; CoreValve Italian Registry Investigators. Transcatheter aortic valve implantation: 3-year outcomes of self-expanding CoreValve prosthesis. Eur Heart J 2012;33(08):969–976
16 Pingpoh C, Schroefel H, Franz T, et al. Transcatheter valve-in-valve implantation in degenerated aortic bioprostheses: are patients with small surgical bioprostheses at higher risk for unfavourable mid-term outcomes? Ann Cardiothorac Surg 2020;9(06):478–486
17 Hawkins RB, Deeb GM, Sukul D, et al. Redo surgical aortic valve replacement after prior transcatheter versus surgical aortic valve replacement. JACC Cardiovasc Interv 2023;16(08):942–953
18 Mahmoud AN, Gad MM, Elgendy IY, et al. Systematic review and meta-analysis of valve-in-valve transcatheter aortic valve replacement in patients with failed bioprosthetic aortic valves. EuroIntervention 2020;16(07):539–548
19 Webb JG, Mack MJ, White JM, et al. Transcatheter aortic valve implantation within degenerated aortic surgical bioprostheses: PARTNER 2 valve-in-valve registry. J Am Coll Cardiol 2017;69(18):2253–2262
20 Dvir D, Webb J, Brecker S, et al. Transcatheter aortic valve replacement for degenerative bioprosthetic surgical valves: results from the global valve-in-valve registry. Circulation 2012;126(19):2335–2344
21 Dvir D, Webb JG, Bleiziffer S, et al; Valve-in-Valve International Data Registry Investigators. Transcatheter aortic valve implantation in failed bioprosthetic surgical valves. JAMA 2014;312(02):162–170
22 David TE, Feindel CM, Ivanov J, Armstrong S. Aortic root replacement in patients with previous heart surgery. J Card Surg 2004;19(04):325–328
23 Kirsch EW, Radu NC, Mekontso-Dessap A, Hillion ML, Loisance D. Aortic root replacement after previous surgical intervention on the aortic valve, aortic root, or ascending aorta. J Thorac Cardiovasc Surg 2006;131(03):601–608
24 Habib G, Tribouilloy C, Thuny F, et al. Prosthetic valve endocarditis: who needs surgery? A multicentre study of 104 cases. Heart 2005;91(07):954–959
25 Lopes S, Calvinho P, de Oliveira F, Antunes M. Allograft aortic root replacement in complex prosthetic endocarditis. Eur J Cardiothorac Surg 2007;32(01):126–130, discussion 131–132
26 Tang GH, Maganti M, David TE, Feindel CM, Scully HE, Borger MA. Effect of prior valve type on mortality in reoperative valve surgery. Ann Thorac Surg 2007;83(03):938–945
27 Potter DD, Sundt TM III, Zehr KJ, et al. Operative risk of reoperative aortic valve replacement. J Thorac Cardiovasc Surg 2005;129(01):94–103
28 Vogt PR, Brunner-LaRocca H, Sidler P, et al. Reoperative surgery for degenerated aortic bioprostheses: predictors for emergency surgery and reoperative mortality. Eur J Cardiothorac Surg 2000;17(02):134–139
29 Milne B, Gilbey T, Kunst G. Perioperative management of the patient at high-risk for cardiac surgery-associated acute kidney injury. J Cardiothorac Vasc Anesth 2022;36(12):4460–4482

