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Reoperative Aortic Root Replacement in Patients with Previous Aortic Root or Aortic Valve Procedures

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Background: Generalization of standardized surgical techniques to treat aortic valve (AV) and aortic root diseases has benefited large numbers of patients. As a consequence of the proliferation of patients receiving aortic root surgeries, surgeons are more frequently challenged by reoperative aortic root procedures. The aim of this study was to evaluate the outcomes of redo-aortic root replacement (ARR). **Methods:** We retrospectively reviewed 66 patients (36 male; mean age, 44.5±9.5 years) who underwent redo-ARR following AV or aortic root procedures between April 1995 and June 2015. **Results:** Emergency surgeries comprised 43.9% (n=29). Indications for the redo-ARR were aneurysm (n=12), pseudoaneurysm (n=1), or dissection (n=6) of the residual native aortic sinus in 19 patients (28.8%), native AV dysfunction in 8 patients (12.1%), structural dysfunction of an implanted bioprosthetic AV in 19 patients (28.8%), and infection of previously replaced AV or proximal aortic grafts in 30 patients (45.5%). There were 3 early deaths (4.5%). During follow-up (median, 54.65 months; quartile 1–3, 17.93 to 95.71 months), there were 14 late deaths (21.2%), and 9 valve-related complications including reoperation of the aortic root in 1 patient, infective endocarditis in 3 patients, and hemorrhagic events in 5 patients. Overall survival and event-free survival rates at 5 years were 81.5%±5.1% and 76.4%±5.4%, respectively. **Conclusion:** Despite technical challenges and a high rate of emergency conditions in patients requiring redo-ARR, early and late outcomes were acceptable in these patients.

Key words: 1. Aorta
2. Aorta, Thoracic
3. Aortic valve
4. Reoperation

Introduction

Bentall and de Bono [1] introduced the initial standardized procedure for aortic root replacement (ARR) in 1968, and since then, technical improvements, surgical modifications, and development of new materials during the last 3 decades have made this procedure safer and more reproducible.

In the current era, reported surgical outcomes following ARR are very favorable in elective cases with hospital mortality rates of less than 5% [2-4]. With an increase in cases undergoing aortic root procedures, the number of patients who require redo-ARR has increased as well. Redo-ARR is regarded as technically challenging, and related with high morbidity and mortality rates especially in emergency settings [5-7]. In the interest of reviewing outcomes of redo-ARR in the current era, we sought to evaluate the

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Table 1. Baseline characteristics

Characteristic	Value
No. of patients	66
Age (yr)	45.2±12.8
Male gender	36 (54.5)
Body mass index (kg/m^2)	21.83±4.67
Diabetes mellitus	6 (9.1)
Hypertension	15 (22.7)
History of cerebrovascular accident	5 (7.6)
Atrial fibrillation	1 (1.5)
Chronic renal failure	5 (7.6)
Marfan syndrome	8 (12.1)
Behcet's disease	9 (13.6)
Takayasu's arteritis	6 (9.1)
Emergency	29 (43.9)
Estimated glomerular filtration rate (mL/min/1.73 m^2)	72.9±22.3
No. of previous operations through sternotomy	
1	53 (80.3)
2	11 (16.7)
3	1 (1.5)
4	1 (1.5)
Echocardiographic data	
Left atrial dimension (mm)	38.9±9.5
Left ventricular ejection fraction (%)	54.3±12.3
Peak TR pressure gradient (mmHg)	26.2±10.3
TR	
None-to-trace	14 (21.2)
Grade I	40 (60.6)
Grade II	8 (12.1)
Grade III	3 (4.5)
Grade IV	1 (1.5)

Values are presented as mean±standard deviation or number (%).
TR, tricuspid regurgitation.

Table 2. Previous aortic root procedures (N=66)

Variable	Value
AV procedures	
Isolated AVP	3 (4.5)
Isolated AVR	28 (42.4)
AVP+supra-coronary ascending aortic replacement	3 (4.5)
AVR+supra-coronary ascending aortic replacement	3 (4.5)
Aortic root procedure	
Aortic root remodeling	6 (9.1)
Complete root replacement	11 (16.7)
Supra-coronary ascending aortic replacement	5 (7.6)
Supra-coronary ascending aortic replacement+arch replacement	4 (6.1)
Other procedures	3 (4.5)

Values are presented as number (%).
AVP, aortic valve repair; AVR, aortic valve replacement.

early and late outcomes of redo-ARR in our institution.

Methods

From the institutional prospective cardiac surgical database, we identified 66 consecutive adult patients (>17 years old) who underwent reoperative complete ARR following surgery for the aortic valve (AV) or an aortic root procedure between April 1995 and June 2015. The ARR was defined by complete replacement of the AV and aortic sinus by valved conduits using mechanical protheses, bio-prostheses, or a homograft. All subject patients underwent coronary reattachment to a new aortic sinus using the coronary button technique. Retrospective medical chart reviews were conducted to collect information on prior aortic root surgeries, baseline demographic and clinical profiles, details on redo-ARR surgeries, and postoperative outcomes. Major early adverse events included stroke, renal failure that required new dialysis, bleeding control surgery, pericardial effusion, surgical site wound problems, and permanent pacemaker insertion. Primary outcomes of interest were death and valve-related complications that included hemorrhagic complications secondary to anticoagulation therapy, thromboembolic events, requirement for surgery in the operated aortic root, and infective endocarditis [4].

Emergency surgery was defined as an operation before the beginning of the next working day after the decision to operate based on the new EuroSCORE II guidelines. Early death was defined as occurring within 30 days following surgery or during index hospitalization.

Categorical variables were expressed as percentages or frequencies, and continuous variables were expressed as mean±standard deviation or median with range. Kaplan-Meier curves were formulated to delineate the overall survival and event-free survival rates. Differences in these rates between the groups were assessed using the log-rank test. To identify the predictors of primary adverse outcomes (death and valve-related complications), Cox-proportional hazard models were used. Covariates listed in Tables 1, 2, and 3 were evaluated in univariable Cox models, and those with p-values of less than 0.1 in the univariable

Table 3. Indications of redo-aortic root replacement

Variable	Value
Diseases of aortic sinus	
Aneurysm of the sinus	12 (18.2)
Pseudo-aneurysm formation	1 (1.5)
Aortic dissection	6 (9.1)
Diseases of AV	
Severe dysfunction of native AV	8 (12.1)
Bioprosthetic SVD	16 (24.2)
Bioprosthetic SVD+aortic root aneurysm	3 (4.5)
Infectious conditions	
Prosthetic valve endocarditis	13 (19.7)
Prosthetic graft infection	2 (3.0)
Prosthetic valve+graft infection	2 (3.0)
Native valve endocarditis (after AV repair)	3 (4.5)

Values are presented as number (%).
AV, aortic valve; SVD, structural valve dysfunction.

Table 4. Operative profiles and outcomes

Variable	Value
Types of implanted aortic valves	
Mechanical	49 (74.2)
Homograft	8 (12.1)
Bioprosthetic	9 (13.6)
Concomitant procedures	
Arch repair	14 (21.2)
Hemi arch	9 (13.6)
Total arch	5 (7.6)
Mitral valve surgery	6 (9.0)
Repair	3 (4.5)
Replacement	3 (4.5)
Tricuspid repair	1 (1.5)
Coronary artery bypass grafting	9 (13.6)
Cardiopulmonary bypass time (min)	274.8±110.9
Cardiac ischemic time (min)	164.0±50.0
Total circulatory arrest	25 (37.9)

Values are presented as number (%) or mean±standard deviation.

models were candidates for multivariable Cox-hazard models. The multivariable analyses involve a step-wise backward elimination technique and variables with p-values of less than 0.1 were used in the final Cox-hazard model.

Statistical analyses were performed using IBM SPSS Statistics for Windows ver. 21.0 software (IBM Co., Armonk, NY, USA). This study was approved by the Asan Medical Center Ethics Committee/Review Board (S2016-1344-0001), who waived the need for patient consent.

Results

1) Baseline characteristics

The mean age of subject patients in this study was 45.2±12.8 years (range, 35.3 to 55 years) and 29 cases (43.9%) were emergency procedures. Fifteen patients (22.7%) presented with systemic vasculitis syndrome such as Behcet disease (n=9) and Takayasu arteritis (n=6). Among the patients, 53 patients (80.3%) had undergone 1 previous cardiac operation, 11 (16.7%) had undergone 2, and 2 (3.0%) had undergone 3 or more operations. Further details on baseline characteristics of patients are shown in Table 1.

The most common prior surgical procedure was an isolated aortic valve replacement (AVR; n=28, 42.4%), followed by a complete ARR (n=11, 16.7%), and aortic root remodeling (n=6, 9.1%). Other previous aortic root procedures are further detailed in Table 2.

Indications for the redo-ARR were aneurysm (n=12), pseudoaneurysm (n=1), or dissection (n=6) of the residual native aortic sinus in 19 patients (28.8%), native AV dysfunction in 8 patients (12.1%), structural dysfunction of an implanted bioprosthetic AV in 19 patients (28.8%), and infection of a previously replaced AV or previously placed proximal aortic grafts in 30 patients (45.5%) (Table 3). The mean interval between previous aortic root procedures and index redo-ARR was 65.3±14.7 months.

Most patients received mechanical valved-conduits for redo-ARR (74.2%) while homograft and bioprosthetic valved conduits were used in 12.1% and 13.6% of patients, respectively. Concomitant arch repair was undertaken in 14 patients (21.2%), while an additional 11 patients required circulatory arrest during redo-ARR with a mean duration of 17.4±4.2 minutes. Details of concomitant cardiac procedures, and durations of cardiopulmonary bypass (CPB) and cardiac ischemia during procedures are summarized in Table 4.

2) Outcomes

There were 3 early deaths (4.5%, all of which occurred in emergency operations), in which the indications for redo-ARR were residual aortic dissection in which the indications for redo-ARR were as follows; a dissection of residual native aorta in 1

patient and infective endocarditis of prosthetic AV in 2 patients. No patients died following elective procedures. The former mortality case received redo-ARR due to severe aortic regurgitation caused by residual aortic dissection in the native aortic root followed by supra-coronary aortic replacement in the setting of acute type A aortic dissection. The patient died of multi-organ failure despite redo-ARR and postoperative extracorporeal membrane oxygenation support. The latter two mortality cases required emergency operations due to aggravation of infective endocarditis in prosthetic AV. However, septic shock followed by multi-organ failure led to death in these two patients. Overall, 18 patients (27.3%) experienced major early complications, details of which are shown in Table 5.

Table 5. Adverse outcomes (N=66)

Variable	Value
Early death	3 (4.5)
No. of patients with early major morbidity	18 (27.3)
Stroke	4 (6.1)
Requirement for new dialysis	3 (4.5)
Surgical bleeding requiring re-exploration	8 (12.1)
Pericardial effusion	1 (1.5)
Surgical site wound problem	1 (1.5)
Permanent pacemaker implantation	3 (4.5)
Requirement for extracorporeal membrane oxygenation	3 (4.5)
Multiple organ failure	2 (3.0)
Prolonged ventilator support (>24 hr)	9 (13.6)
Late death	14 (21.2)
Secondary outcomes	
Anticoagulation-related bleeding	5 (7.6)
Aortic root reoperation	1 (1.5)
Infective endocarditis	3 (4.5)
All clinical endpoints	20 (30.3)

Values are presented as number (%).

During follow-up (median, 54.65 months; quartile 1–3, 17.93 to 95.71 months), there were 14 late deaths (21.2%), 9 valve-related complications including reoperation of the aortic root in 1 patient, infective endocarditis in 3 patients, and hemorrhagic events in 5 patients (Table 5). There was 1 case of reoperation of the reoperated aortic root: trido Bentall operation was conducted to treat recurred infective endocarditis.

Overall survival at 5 and 10 years were 81.5%±5.1% and 57.6%±9.3%, respectively. Event-free survival rates at 5 and 10 years were 76.4%±5.4% and 41.1%±11.7%, respectively (Fig. 1).

Five-year survival and event-free survival rates according to the baseline presentations were as follows: (1) emergency group (n=29);, 74.9%±8.2%, 68.2%±9.8%, (2) vasculitis (Behcet, Marfan, Takayasu) group (n=23); 85.8%±7.6%, 76.5%±11.5%, and (3) AV only AVP or AVR (AVP: aortic valve repair, AVR: Aortic valve replacement) group (n=31); 85.8%±9.4%, 84.6%±10.0%, respectively (Fig. 2). There was no statistical difference in overall survival according to the baseline settings of the patients (Fig. 2). The emergency group had a lower event-free survival

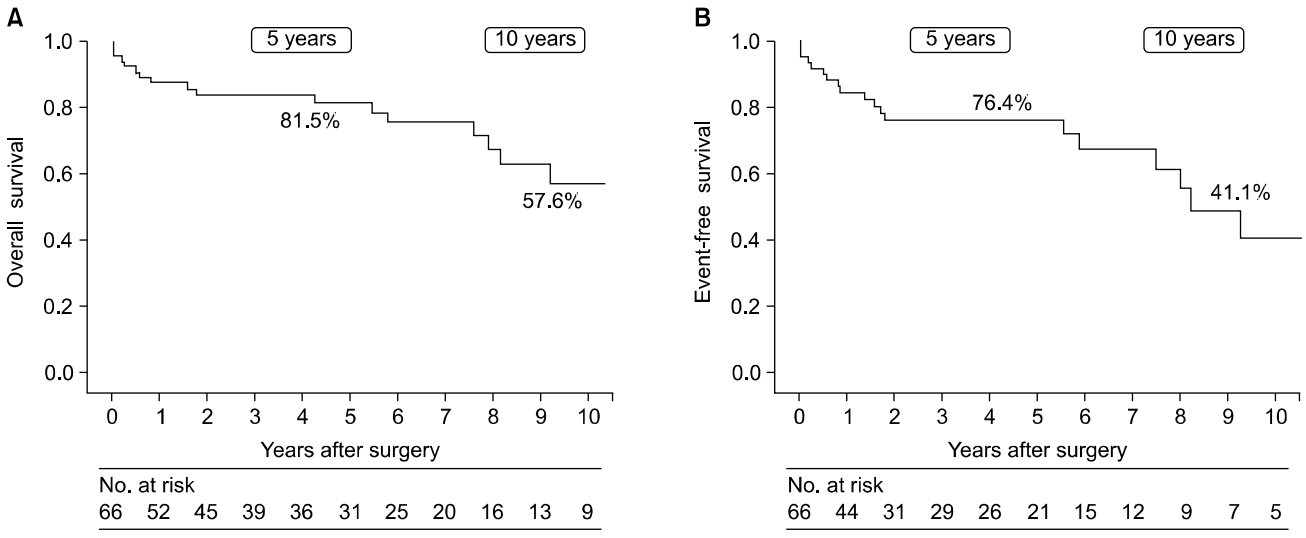

Fig. 1. Kaplan-Meier plots for (A) overall and (B) event-free survival.

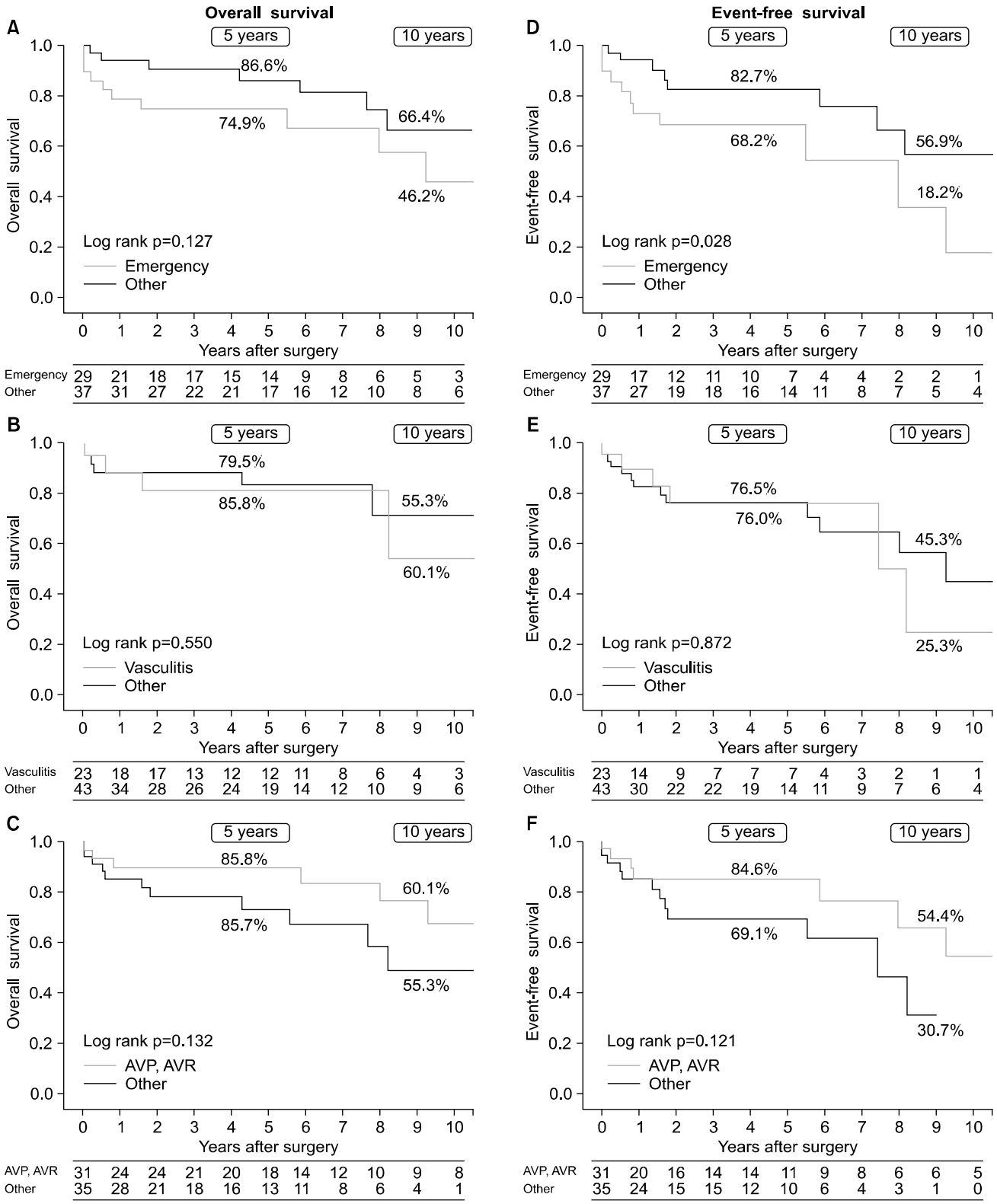

Fig. 2. Kaplan-Meier plots for overall survival in (A) emergency, (B) vasculitis, and (C) AVP or AVR groups vs. other groups. Kaplan-Meier plots for event-free survival in (D) emergency, (E) vasculitis, and (F) AVP or AVR groups vs. other groups. AVP, arginine vasopressin; AVR, aortic valve replacement.

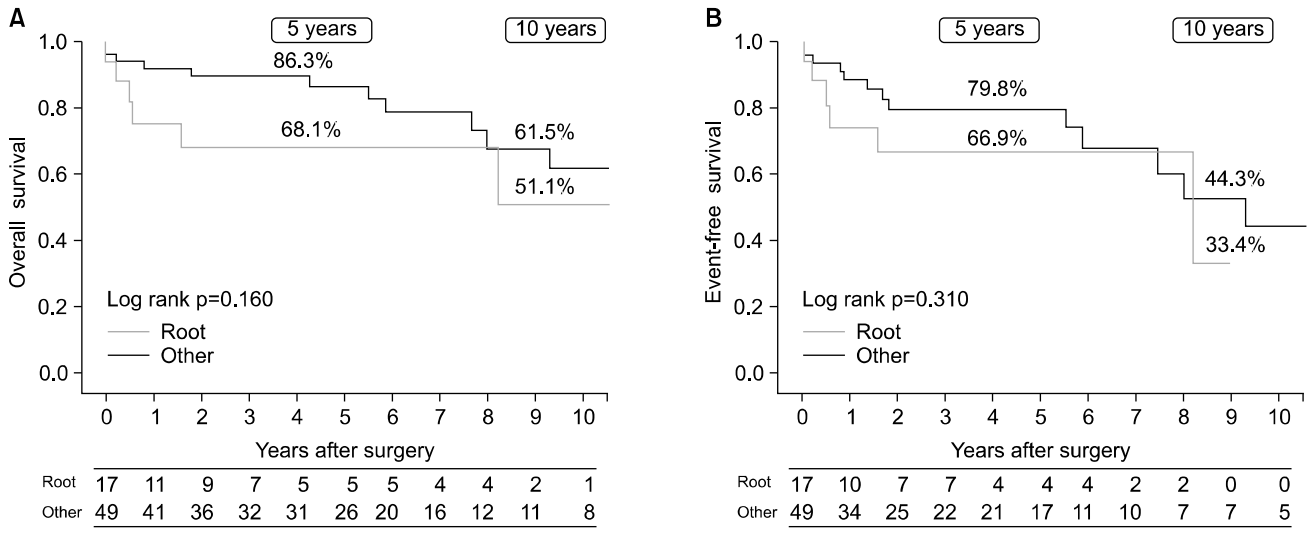

Fig. 3. Kaplan-Meier plots for (A) overall and (B) event-free survival in previous ARR followed redo-ARR patients vs. other patients. ARR, aortic root replacement.

rate than that of non-emergency group (p-value= 0.028).

Among 66 patients, 17 had undergone previous ARR either by valve-sparing or by valve-replacement, followed by redo-ARR. There were no significant differences between those who had undergone ARR and those who had undergone other procedures in overall survival (p=0.160) and event-free survival (p=0.310) (Fig. 3).

On multivariable Cox-proportional hazard models, emergency surgery (hazard ratio [HR], 2.80; 95% confidence interval [CI], 1.12 to 7.00; p=0.027) was the only significant and independent predictor of the major adverse outcomes (death and valve-related complications) while the baseline hemoglobin level was a marginally significant factor associated with the adverse outcomes (HR, 0.80; 95% CI, 0.63 to 1.03 by 1 g/dL increment; p=0.079).

Discussion

Due to the progress in surgical techniques, reoperation in cardiac surgery is increasingly performed [8]. Re-operative aortic root, ascending aorta, or both are challenging reoperations associated with high mortality rate [5-7]. Due to great diversity among these operations, however, the reported mortality and morbidity have been highly variable among studies. In addition, there have been only a few studies that specifically evaluated clinical outcomes of redo-ARR. The present study aimed to evaluate a homogeneous cohort who underwent redo-ARR following AV or aortic root procedures.

Although redo-ARR had been reported to carry a high postoperative mortality in older studies, more recent series have demonstrated early mortality of 3% to 7% [9,10]. Our data showed similar outcomes with an in-hospital mortality rate of 4.5% (n=3). Interestingly, these outcomes are very similar to those for an elective primary ARR procedure, which varies from 4.5% to 7.5% [11,12].

As the number of repeat-sternotomies increases, surgical risks of cardiac procedures are also reportedly increased with a strong positive association. In this study, the number of repeat sternotomies was not associated with any early or late adverse outcomes. Of note, 13 patients (19.7%) had more than three cardiac operations in this study. Safe re-entry into the chest is thought to be the most important factor for favorable outcomes [9]. Advances in surgical strategies for re-exploration of the sternum promoted by the use of modern computed tomography imaging are believed to have contributed favorable results during re-entry into the chest [9,13,14]. Once high-risk patients have been identified with CT, utilization of CPB through other sites like the femoral or axillary vessels could be an option for safe re-entry into the sternum.

Previous studies identified risk factors of in-hospital mortality, which were age of the patient (≥75 years), preoperative New York Heart Association functional class IV, emergency presentation, prior cardiac surgery, unplanned coronary artery bypass grafting, prolonged CPB time, and postoperative renal failure [5-7,9,10,13-17]. In our study, emergency surgery was the only significant and independent predictor of the primary adverse outcomes (HR, 2.80; 95% CI, 1.12 to 7.00; p=0.027). Among 66 patients, 29 patients had redo-ARR in emergency presentation. In subgroup analysis, event-free survival rate was significantly lower (log rank p-value=0.028) in the emergency group than in that of the non-emergency group.

Due to very limited numbers of early mortality cases (n=3 out of 66), as well as late adverse outcomes, studies on a larger cohort are needed to determine risk factors of redo-ARR.

In the present study 3 patients died in the early period, of which 2 patients died of acute prosthetic valve endocarditis (PVE). Both patients had undergone a previous ARR followed by the current redo-ARR due to acute PVE. A PVE is known as a catastrophic complication, which carries operative mortality of 25% to 60% [18,19]. In this study, 13 patients presented with PVE and 2 of them died, constituting 15.4% of the early mortality rate for PVE, which seemed encouraging considering the challenging nature of such a condition.

1) Limitations

This study has several major limitations including the retrospective nature of the analyses and the small sample size. In addition, results are those of a high-volume tertiary academic center; therefore, they may not be generalizable to other settings.

2) Conclusions

Despite technical challenges and a high rate of emergency conditions in patients requiring redo-ARR, early and late outcomes following the procedure were acceptable in these patients.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

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