Clinical outcomes of aortic root replacement after previous aortic root replacement

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Objective: The study objective was to examine the short- and long-term outcomes of reoperative aortic root replacement after a previous aortic root replacement.

Methods: From September 1985 to February 2011, 84 consecutive patients underwent reoperative aortic root replacement. The patients' mean age was 46 ± 15 years (range, 19-80 years), and 86% were men. The main indication for reoperation was failed biological or bioprosthetic aortic valve and prosthetic valve endocarditis. Cox proportional hazard regression modeling was performed to identify risk factors that adversely affected overall survival.

Results: The operative mortality was 6% (5 patients). Perioperative morbidity included myocardial infarction in 2 patients, low cardiac output syndrome in 7 patients, sepsis in 3 patients, pulmonary complications in 7 patients, renal failure in 3 patients, reoperation for bleeding or tamponade in 5 patients, superficial sternal wound infections in 3 patients, permanent transvenous pacemaker in 8 patients, and stroke in 1 patient. Kaplan-Meier estimates for survival at 5, 10, and 12 years were $82.5\% \pm 4.7\%$, $72.5\% \pm 6.4\%$, and $65.0\% \pm 7.6\%$, respectively; the freedom from reoperation was 100%, $92.3\% \pm 5.2\%$, $92.3\% \pm 5.2\%$, respectively; and valve-related mortality was $93.1\% \pm 3.4\%$, $90.8\% \pm 4.0\%$, and $86.2\% \pm 5.8\%$, respectively. During the follow-up, valve-related deaths occurred in 7 patients. Age by increments of 5 years (hazard ratio, 1.205; 95% confidence interval, 1.036-1.401) and prosthetic valve endocarditis (hazard ratio, 2.662; 95% confidence interval, 1.054-6.724) were independent risk factors for mortality.

Conclusions: Aortic root replacement after a previous aortic root replacement is associated with a relatively low operative mortality and perioperative morbidity, but long-term survival is suboptimal. Increasing age and prosthetic valve endocarditis adversely affect survival. (*J Thorac Cardiovasc Surg* 2013;146:611-5)

In 1968, Bentall and De Bono¹ described an operation using a tubular graft and a prosthetic valve for combined replacement of the ascending aorta and aortic valve with reimplantation of the coronary arteries. Forty years later and after several technical modifications, this operation has become an essential part of the surgical armamentarium to treat patients with aortic root disease.²⁻⁵ Sioris and colleagues,⁶ from Toronto General Hospital, reported an operative mortality for the modified Bentall procedure of 4% in patients who underwent operation between 1990 and 2001, and many other series have reported similar operative mortality.⁶⁻¹⁰ However, despite extensive evidence of safety of the modified Bentall procedure as a first cardiac surgical intervention, there is limited information regarding the clinical outcomes of this operation after a previous aortic valve surgery, and in particular after a previous aortic root

replacement (ARR). In 2007, Szeto and colleagues¹¹ reported a 30-day mortality of 11.5% in 156 patients who underwent a reoperative ARR after a previous aortic valve replacement. Raanani and colleagues,¹² from Toronto General Hospital, reported an operative mortality of 3% in a small consecutive series of 31 patients who had undergone a previous Bentall procedure.

The objective of this study was to examine the short- and long-term outcomes of ARR as a reoperative surgery after a previous ARR.

PATIENTS AND METHODS

From September 1985 to February 2011, 84 patients underwent ARR as a reoperative procedure after ARR. The interval between the first ARR and the redo ARR was 11.5 ± 7.3 years. The patients' clinical profile, the type of valve used in the previous ARR, and the indications for reoperations are summarized in Table 1. Most patients had undergone only 1 previous ARR, but 3 patients had undergone 2 previous ARRs, and 2 patients had undergone 3 previous ARRs in this series.

Operations were performed following standard techniques for ARR whenever possible. Certain modifications were needed for more complex aortic root pathology, particularly cases of aortic root abscess with extensive destruction of the aortoventricular junction and surrounding structures.¹²⁻¹⁶ Table 2 summarizes the operative data.

Twenty-two patients underwent ARR by suturing a tubular Dacron graft to the left ventricular outflow tract (LVOT), reimplanting the coronary arteries to this conduit, and implanting a bioprosthetic or mechanical aortic valve inside the Dacron graft.¹⁴ The rationale for this technique was to

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Abbreviations and Acronyms

ARR = aortic root replacement

LVOT = left ventricular outflow tract

be able to tailor the Dacron graft to any defect in the LVOT and to allow for reimplantation of the coronary arteries without having to interpose a graft between the main conduit and the coronary arteries. However, an interposition graft of Dacron or saphenous vein between a main coronary artery and the neo-aortic root was used in 19 patients (in the right coronary artery in 3, in the left main artery in 6, and in both main arteries in 10). Most of these grafts were less than 2 cm in length.

The research ethics board of Toronto General Hospital approved this study, and patient consent was waived considering the observational study design.

The primary end point of this study was survival after surgery. Operative mortality was defined as any death in hospital or during the first 30 postoperative days. Perioperative complications were analyzed, such as myocardial infarction, low cardiac output syndrome, stroke, renal failure, wound infection, sepsis, pulmonary complications, atrial fibrillation, use of intra-aortic balloon pump, need for inotropes, duration of assisted ventilation, and length of stay in intensive care unit and hospital. Secondary end points were freedom from reoperation on the aortic valve for any cause and freedom from valve-related death.

The following preoperative variables were examined for the potential effect on outcomes: age, sex, body surface area, New York Heart Association functional class, congestive heart failure, angina, urgent or emergency surgery, previous coronary artery bypass, preoperative shock, severe chronic obstructive pulmonary disease (forced expiratory volume < 1.0 L/s), left ventricular ejection fraction, diabetes mellitus, hypertension, hyperlipidemia, peripheral vascular disease, active endocarditis, remote or active endocarditis, previous stroke or transient ischemic attack, atrial fibrillation, preoperative renal failure, Marfan syndrome, cardiopulmonary bypass and aortic clamping times, and technical aspects of the surgery, such as type of valve explanted, technique of coronary artery reimplantation, and combined operative procedures.

All data were prospectively collected and validated by a full-time research team. Follow-up data were obtained from electronic patient records and updated by telephone interviews. The median follow-up was 5.5 years, and the mean follow-up was 5.0 years (0-20.9 years). The follow-up was 100% complete.

Statistical Analysis

Categorical variables are reported as number and percentages. Continuous variables are expressed as mean $\pm$ standard deviation or median and interquartile range when appropriate. All statistical analyses were performed with SAS 9.1 software (SAS Institute, Inc, Cary, NC). Statistical analysis was performed using the chi-square test or Fisher exact test for categorical variables and *t* tests or Wilcoxon rank-sum test for continuous variables depending on the distribution. No multiple imputation or adjustments for multiplicity were considered. Cox proportional hazard regression modeling was performed to identify predictors of survival.¹⁷ Kaplan–Meier curves were constructed using STATA SE 11.2 (StataCorp LP, College Station, Tex). Kaplan–Meier curves were plotted up to 150 months of follow-up to maintain a meaningful minimum of 10% of the population at risk.

RESULTS

Perioperative Mortality and Morbidity

The operative mortality was 6% (5 patients). The causes of death were ruptured thoracoabdominal aortic aneurysm in 1 patient, technical problems related with bleeding

during surgery for an extensive aortic root abscess in 1 patient, multiorgan failure in 1 patient, unexplained cardiac arrest in 1 patient, and sudden death in 1 patient. Perioperative morbidity is presented in Table 3.

Patients' Survival

There were 5 operative and 15 late deaths. The causes of late death were endocarditis in 4 patients, congestive heart failure in 2 patients, cancer in 2 patients, hemophilia in 1 patient, coagulopathy in 1 patient, anticoagulation-related hemorrhage in 1 patient, motor vehicle accident in 1 patient, myocardial infarction in 1 patient, sudden death in 1 patient, and death after back surgery in 1 patient. Patients' survivals at 5, 10, and 12 years were $82.5\% \pm 4.7\%$, $72.5\% \pm 6.4\%$, and $65.0\% \pm 7.6\%$, respectively (Figure 1).

Freedom From Reoperation on the Aortic Valve for Any Reason

During the follow-up, 4 patients underwent reoperation. The causes for reoperation were prosthetic valve endocarditis in 2 patients, tissue valve failure in 1 patient, and sub-aortic stenosis with mitral stenosis in 1 patient. All 4 patients survived reoperation. Freedom from reoperation on the aortic valve for any reason at 5, 10, and 12 years was 100%, $92.3\% \pm 5.2\%$, and $92.3\% \pm 5.2\%$, respectively (Figure 2). Reoperations were performed at 99, 102, 155, and 251 months.

Freedom From Structural Valve Deterioration

Structural valve deterioration developed in 1 patient at 155 months of follow-up. Freedom from reoperation on the aortic biological/bioprosthetic valve (*n* = 30) for any reason up to 12 years was 100%.

Freedom From Valve-Related Mortality

Seven patients died of valve-related causes: prosthetic valve endocarditis in 4 patients, sudden death in 1 patient, coagulopathy in 1 patient, and anticoagulant-related hemorrhage in 1 patient. The valve-related mortality event was at 4, 21, 33, 54, 71, 122, and 152 months of follow-up. Freedom from valve related mortality at 5, 10, and 12 years was $93.1\% \pm 3.4\%$, $90.8\% \pm 4.0\%$, and $86.2\% \pm 5.8\%$, respectively.

Cox Proportional Hazard Regression Analyses for Death From Any Cause

The only 2 variables predictive of death from any cause were age by increments of 5 years (hazard ratio, 1.20; 95% confidence interval, 1.03-1.40) and prosthetic valve endocarditis (hazard ratio, 2.66; 95% confidence interval, 1.05-6.72).

DISCUSSION

Given the technical challenges of performing an ARR in a patient who already underwent one, we decided to

TABLE 1. Clinical profile and indications for reoperation

No. of patients	84 (100)
Mean age $\pm$ SD (range)	46 $\pm$ 15 (19-80) y
Body surface area $\pm$ SD,	1.96 $\pm$ 0.26 m ²
Male gender	72 (86)
Urgent/emergency surgery	11 (13)
NYHA class IV	36 (43)
Congestive heart failure	48 (57)
Angina pectoris	11 (13)
Preoperative shock	2
Electrocardiogram	
Sinus rhythm	76 (90)
Atrial fibrillation	4
Heart block (paced beats)	4
Associated diseases:	
Hypertension	30 (36)
COPD	1
Hyperlipidemia	19 (23)
Diabetes	4
Renal failure	2
Previous stroke	10 (12)
Marfan syndrome	8
Chronic type A aortic dissection	5
Prosthetic valve infective endocarditis	
Active (with or without abscess)	18 (21)
Remote	8
Previous operations	
ARR	84 (100)
Aortic root homograft	32 (38)
Medtronic Freestyle (Medtronic Inc, Minneapolis, Minn) root	14 (17)
Bioprosthesis in Dacron tube	17 (20)
Ross procedure	7 (8)
Mechanical valve	14(17)
CABG	2
Pulmonary valve replacement	7
Resection of subaortic membrane	2
Repair of ventricular septal defect	2
Mitral valve repair/replacement	5
Tricuspid valve repair	1
Indication for surgery	
Prosthetic valve/graft endocarditis	18
Failed biological or bioprosthetic valve	55
Stenotic mechanical valve (pannus)	9
Subaortic stenosis and false aneurysm	1
Subaortic false aneurysm	1

Percentages are shown in parentheses. *SD*, Standard deviation; *NYHA*, New York Heart Association; *COPD*, chronic obstructive pulmonary disease (forced expiratory volume <1 L/s); *ARR*, aortic root replacement; *CABG*, coronary artery bypass graft surgery.

examine the outcomes of this type of reoperation. To the best of our knowledge, observational studies addressing the clinical course and long-term outcomes of patients undergoing ARR after a previous ARR have not been reported. In 2001, we reported our experience with 31 patients who underwent redo ARR and indicated that interposition of a graft to extend 1 or both coronary arteries was necessary

TABLE 2. Operative data

Operations performed	No.
Aortic root re-replacement	84
Reconstruction of LVOT	4
Mitral valve replacement	9
Reconstruction of the mitral annulus	2
Mitral valve repair	8
Tricuspid valve repair	1
Coronary artery bypass graft	12
Left main/right coronary artery graft interposition	19
Hemi- or total arch replacement	11
Pulmonary valve re-replacement	3
Aortic valves implanted at reoperation:	
Mechanical valves	54
Bioprosthetic valve into a Dacron tube	10
Medtronic Freestyle	9
Aortic root homograft	9
Ross procedure	2
Aortic valve (mechanical and bioprosthetic) sizes:	
Range of sizes	21-29
Mean size $\pm$ SD	26 $\pm$ 2
Cardiopulmonary bypass time $\pm$ SD	149 $\pm$ 55 min
Aortic clamping time $\pm$ SD	117 $\pm$ 41 min

LVOT, Left ventricular outflow tract; *SD*, standard deviation.

in approximately one half of the patients, and we expressed concerns about this technique.¹² Although we have tried to avoid this technique, our experience suggests that it has no apparent adverse effect on survival or any other clinical outcome.

Reoperative ARR is complex, and every step of the procedure is important. We pay extreme attention to myocardial protection and patency of the coronary arteries. We always start a redo ARR by detaching the coronary arteries from the old graft and making sure that they are patent and that there is enough tissue around the orifice to reimplant

TABLE 3. Perioperative adverse events

Variable	No.
Operative mortality	5
ICU stay (mean $\pm$ SD)	33 $\pm$ 33 h
Assisted ventilation (mean $\pm$ SD)	8 $\pm$ 10 h
Reexploration for bleeding	5
Stroke	1
Perioperative myocardial infarction	2
Sepsis	3
Pulmonary complications	7
Superficial sternal wound infection	3
Renal failure	3
Low cardiac output syndrome	7
Intra-aortic balloon pump	5
Permanent transvenous pacemaker	8
Transient new atrial fibrillation	12
Hospital stay (mean $\pm$ SD)	7 $\pm$ 3 d

ICU, Intensive care unit; *SD*, standard deviation.

FIGURE 1. Kaplan–Meier estimates of patients' survival.

them safely. If there is inadequate aortic wall around the orifice of the coronary artery, we suture a 6-mm Dacron graft or a large saphenous vein in an end-to-end fashion to give cardioplegia during the procedure and to facilitate reimplantation of the artery later. Next, the valved conduit is removed from the aortoventricular junction. Depending on the pathology, parts of the LVOT have to be excised along with the valved conduit. When this happens, we prefer to use a custom-made conduit instead of commercially available conduits. A tubular Dacron graft is tailored to fit the defective LVOT and sutured to it with a continuous polypropylene suture.¹⁴ The coronary arteries are reimplanted next, and a valve is implanted into the conduit. Patients with aortic root abscess require more extensive resection and reconstruction of the LVOT before a valved conduit can be implanted. Although we do favor an aortic valve homograft in these patients, we continue to believe that radical resection of all infected tissues and reconstruction with patches is probably more important than the type of valve implanted.¹⁸ In addition, the intervalvular fibrous body

and anterior leaflet of the mitral valve may be involved and destroyed by the abscess, and mitral valve replacement may be necessary.¹⁸

Our cohort of 84 patients had at least 1 previous ARR and required a reoperation. The principal reason for reoperation on patients who had a previous ARR was biological or bioprosthetic valve failure. The operative mortality was 6%, and perioperative morbidity was probably similar to that for most heart valve reoperations, but we had a relatively high incidence of complete heart block requiring permanent pacemaker. In addition, a 10-year survival just less than 73% is worrisome because our patients' mean age was only 46 years when they had the redo ARR. Although prosthetic valve endocarditis understandably may have a negative effect on survival, it is unclear to us why age by increments of 5 years played a role in late survival given the relative young age of our patients.

Kouchoukos and colleagues⁴ reported an operative mortality of 5.2% in a series of 172 patients who underwent the modified Bentall procedure between 1974 and 1990. This was one of the first series of Bentall procedures published, but the current operative mortality is probably less than 5.2% in first-time operations.^{3,7,8,10} Despite the fact that our series included patients who underwent operation as far back as 1985, the operative mortality of 6% is likely more a reflection of the technical challenges of this reoperative procedure than a temporal bias.

Recent series of the modified Bentall procedure described operative mortality ranging from 2.9% to 5.2%.^{3,7,19} In a study of 597 patients undergoing the modified Bentall procedure from 1995 to 2008, Etz and colleagues⁷ reported a 30-day mortality of 3.9%. Their study also provided strong evidence that the type of valve used in this setting had no impact on short- and long-term outcomes. In relation to these recent studies, our results compare favorably in terms of operative mortality.

In 2010, Bekkers and colleagues²⁰ reported 41 patients who underwent ARR after a Ross procedure using the ARR technique between 1988 and 2009. There was no mortality at 30 days, and the 5-year survival was 94%. The mean age was 36 years, and 33 patients required isolated pulmonary autograft replacement and 8 patients required replacement of the pulmonary autograft and homograft. Although that study deals with only 1 type of redo ARR, it reinforces the view that redo ARR is a safe operation.

Finally, the operative mortality for redo aortic valve replacement ranges from 2.3% to 17.6%.²¹ In a recent study by Leontyev and colleagues²¹ on 155 patients with redo aortic valve replacement, the 30-day mortality was 4.5% and the in-hospital mortality was 5.8%. There is no doubt that reoperations on heart valves are associated with increased operative mortality and morbidity, but the risk for redo ARR seems similar to that for redo aortic valve replacement.

FIGURE 2. Kaplan–Meier estimates for freedom from reoperation.

Study Limitations

This is a retrospective study and is associated with all the limitations of this type of study. An experienced heart valve surgeon performed operations on most patients, and the results may not be generalizable. In addition, the sample size was relatively small and the pathology was heterogeneous for a meaningful statistical analysis.

CONCLUSIONS

The results of this study on ARR after a previous ARR showed that the operative mortality and morbidity are relatively low and probably similar to those for other reoperative heart valve surgeries. The long-term survival is suboptimal, and advancing age and prosthetic valve endocarditis were found to be independent predictors of mortality.

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