A quarter of a century of experience with aortic valve-sparing operations

Tirone E. David, MD, Christopher M. Feindel, MD, Carolyn M. David, BN, and Cedric Manlhiot, BSc

Objective: To examine the late outcomes of aortic valve-sparing operations to treat patients with aortic root aneurysm with and without aortic insufficiency (AI) in a cohort of patients followed up prospectively since 1988.

Methods: A total of 371 consecutive patients had undergone aortic valve-sparing surgery (mean age, 47 ± 15 years; 78% men) from 1988 through 2010. In addition to the aortic root aneurysm, 47% had moderate or severe AI, 35.5% had Marfan syndrome, 12.1% had type A aortic dissection, 9.2% had bicuspid aortic valve, 8.4% had mitral insufficiency, 16.1% had aortic arch aneurysm, and 10.2% had coronary artery disease. Reimplantation of the aortic valve was used in 296 patients and remodeling of the aortic root in 75. Cusp repair by plication of the free margin along the nodule of Arantius was used in 36.6% of patients, and reinforcement of the free margin with a double layer of fine Gore-Tex suture in 24.2%. The patients were followed up prospectively with images of the aortic root for a median follow-up of 8.9 ± 5.2 years.

Results: A total of 4 operative and 39 late deaths occurred. Survival at 18 years was 76.8% ± 4.31%, lower than that for the general population matched for age and gender. Age, type A aortic dissection, impaired ventricular function, and preoperative AI were associated with increased mortality on multivariable analysis. Reoperations on the aortic valve were performed in 8 patients for recurrent AI and in 2 for infective endocarditis. Freedom from reoperation on the aortic valve at 18 years was 94.8% ± 2.0%. No predictors of the need for reoperation were found on multivariable analysis. Eighteen patients developed AI greater than mild. Freedom from AI greater than mild at 18 years was 78.0% ± 4.8%. No predictors of recurrent AI were identified on multivariable analysis.

Conclusions: Aortic valve-sparing operations continue to provide excellent clinical outcomes, although a slow but progressive deterioration of aortic valve function seems to occur during the first 2 decades of follow-up. Preoperative AI and cusp repair had no adverse effect on valve function. (J Thorac Cardiovasc Surg 2014;148:872-80)

A quarter of century has passed since aortic valve-sparing (AVS) operations were introduced in our cardiac unit.[1,2] At first, we were concerned that the aortic cusps would not function normally for a prolonged period because they were placed inside a rigid root made of Dacron fabric. Also, only patients with echocardiographically normal aortic cusps were offered these operations as an alternative to aortic root replacement with a valved conduit.[2] As our confidence in AVS operations increased, we expanded their use to include patients with cusp prolapse due to elongation of the free margin or stress fenestrations in the commissural areas. We believed these cusps abnormalities were caused by increased mechanical stresses resulting from dilatation of the sinotubular junction and/or aortic annulus. Thus, shortening their free margins by plication or triangular resection along the nodule of Arantius and/or reinforcement of the free margin of the cusp with a double layer of a fine Gore-Tex suture (W.L. Gore, Inc, Newark, Del), in addition to correction of the mechanism by which they became abnormal, would restore aortic valve function and expand the indications for AVS surgery. These types of cusp repair during AVS operations have had no late deleterious effects on valve function 5 to 10 years after surgery.[3-5]

We have proposed a classification of AVS surgery into 2 basic types: aortic valve reimplantation and remodeling of the aortic root.[6] In aortic valve reimplantation, the aortic annulus, the aortic cusps, and a rim of the aortic sinuses are placed inside a tubular Dacron graft and secured below and above the aortic annulus, fixing the diameter and shape of the aortic annulus and sinotubular junction. In remodeling of the aortic root only, the aortic sinuses are replaced with an appropriate Dacron graft to re-create the normal scalloped shape of the aortic annulus, as originally

From the Division of Cardiovascular Surgery, Peter Munk Cardiac Centre, Toronto General Hospital and University of Toronto, Toronto, Ontario, Canada.

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Address for reprints: Tirone E. David, MD, Division of Cardiovascular Surgery, Peter Munk Cardiac Centre, Toronto General Hospital and University of Toronto, 200 Elizabeth St, 4N453, Toronto, ON M5G 2C4, Canada (E-mail: tirone.david@uhn.ca).

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Abbreviations and Acronyms
- AI = aortic insufficiency
- AVS = aortic valve-sparing
- CI = confidence interval
- HR = hazard ratio

described by Sarsam and Yacoub.[7] If the aortic annulus were dilated, we combined AVS surgery with a reducing annuloplasty by suturing a band of Dacron fabric on the outside of the intervalvular fibrous body.[8] Numerous modifications to these 2 basic procedures have been introduced.[9-12]

The present report describes the clinical and echocardiographic outcomes of AVS operations at our institution during the past 2 decades.

METHODS

From May 1988 through December 2010, 371 consecutive patients with an aortic root aneurysm or ascending aortic aneurysms and aneurysmal aortic sinuses with or without aortic insufficiency (AI) underwent AVS surgery. The clinical profile of all patients and the 2 main subgroups of AVS operations are listed in Table 1. The pertinent operative data are listed in Table 2. Reimplantation of the aortic valve was performed in 296 patients and remodeling of the aortic root in 75. During the first decade of experience, no particular criteria were in use for choosing one or the other type of AVS procedure. However, later in our experience, younger patients with inherited aortic root aneurysm underwent the reimplantation procedure exclusively, and older patients with ascending aortic aneurysm and secondarily dilated aortic sinuses underwent the remodeling procedure. We have described the technical aspects of our AVS operations in recent studies.[10,11]

The patients were followed up prospectively with annual echocardiographic studies during the first decade and every 2 to 3 years thereafter if the aortic valve function had remained stable. Images of the entire thoracic aorta were obtained every 5 years or more often if the patient had had dissection or residual aneurysm at surgery. For the present report, the follow-up period was closed December 31, 2013. The mean follow-up duration was 8.9 ± 5.2 years; 43 patients were followed up for >15 years but only 11 for >20 years. The clinical follow-up data were complete, and the echocardiographic studies were 98% complete during the most recent 3 years. The review ethic board of the University Health Network approved the study.

Statistical Analysis

Data are presented as the mean $\pm$ standard deviation or frequencies, as appropriate. The variables and categories with low frequency are reported as descriptive statistics but were collapsed (when possible) or excluded for additional analyses. Basic comparisons between groups were performed using Fisher's exact test for all categorical variables and Student's *t* test, assuming an unequal variance between samples (Satterthwaite methods). The freedom from time-dependent outcomes was modeled in a parametric survival model (using maximum likelihood estimates to resolve risk) that divides the risk over time in $\leq$3 distinct phases of risk (early, constant, and late) using standard mathematical algorithms from the HAZARD procedure (available at: http://www.clevelandclinic.org/heartcenter/hazard). All associations between the freedom from outcomes and the potential predictors were first screened in univariable regression models. The associations between patient and surgical characteristics and outcomes were included in a bootstrap bagging algorithm (500 resamples). The variables with high reliability (>50%; defined as the percentage of the resample in which a given variable was selected) were then included in a multivariable parametric survival regression model, with backward selection of variables to obtain a final regression model. All risk factor analyses were performed using a unified phase of risk, given the limited number of events in some phases of risk. Life tables from the Province of Ontario from 2000 to 2002 (available at: Statistics Canada, www.statcan.gc.ca/pub/84-537-x/4064441-eng.htm) were used to estimate the 20-year survival of the patient cohort according to the age and gender distribution. Mean imputation was used to account for missing variables. All statistical analyses were performed using SAS, version 9.3 (SAS Institute, Cary NC).

RESULTS

Perioperative Complications

Four patients died in hospital or within 30 days of surgery. The cause of death was low cardiac output syndrome in 1 patient, acute type B aortic dissection in 1, *Clostridium difficile* colitis in 1, and perioperative myocardial infarction in 1. Thirty-four patients (9.1%) required reopening of the chest for bleeding and/or pericardial tamponade. One patient required aortic root replacement 2 days after surgery because of persistent AI. One patient required re-exploration of the aortic root because of acute thrombosis of both coronary artery orifices with large white filamentous strands from a transient undiagnosed hematologic disorder associated with profound thrombocytopenia. One patient required laparotomy to repair a liver rupture caused by cardiac resuscitation. In addition, 4 patients experienced a perioperative myocardial infarction, 2 developed renal failure, 2 experienced a stroke, and 2 experienced a transient ischemic attack. Seventy-six patients developed new transient atrial fibrillation postoperatively. Four patients (3 reimplantation and 1 remodeling) required permanent transvenous pacemaker implantation because of complete heart block in 2 patients and sick sinus syndrome in 2. One patient developed sternal infection. One half of all the patients required blood product transfusion.

Late Mortality

A total of 39 late deaths occurred: 14 cardiovascular related (1 stroke, 5 sudden death, 2 myocardial infarction, and 6 related to complications of aortic dissection) and 25 non–cardiovascular-related deaths. Figure 1 shows the patient survival compared with that of the general population and matched for age and gender. The patients who had undergone AVS surgery had lower survival rates than the general population during the first 2 decades of follow-up ($P = .001$). The survival at various intervals is listed in Table 3. The possible predictors of mortality on univariable analysis are listed in Table 4. Multivariable analysis disclosed that age by 5-year increment (hazard ratio [HR], 1.41; 95% confidence interval [CI], 1.24-1.61;

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