

Early results with annular support in reconstruction of the bicuspid aortic valve

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Objective: Repair of the bicuspid aortic valve may be performed in aortic regurgitation and aneurysm. Dilatation of the atrioventricular junction has been identified as a risk factor for repair failure, and we have used suture annuloplasty to correct atrioventricular junction enlargement. The objective was to compare the early results of aortic repair with and without annuloplasty.

Methods: Between November 1995 and January 12, a total of 559 patients were treated with bicuspid aortic valve repair for predominant regurgitation (n = 389), aortic aneurysm (n = 158), or acute dissection (n = 12). Isolated valve repair (aortic valve repair) was performed for aortic valve regurgitation with preserved aortic dimensions (n = 208) and sinotubular junction remodeling plus valve repair for aortic aneurysm and preserved root size (n = 116). Root remodeling was used for dilatation involving the root (n = 235). In 193 patients, dilatation of the atrioventricular junction (>27 mm) was corrected with suture annuloplasty.

Results: Hospital mortality was 0.5% (n = 3); 2 patients required pacemaker implantation. Reoperation was necessary for recurrent regurgitation (n = 54) or stenosis (n = 2); 10-year freedom from reoperation was 82% but was inferior after isolated valve repair (70%, *P* = .007) compared with the 2 other techniques. Application of suture annuloplasty improved 3-year freedom from reoperation after isolated repair (84%) to 92% (*P* = .07). In all groups, the proportion of patients with no or trivial regurgitation was significantly higher with annuloplasty.

Conclusions: Preservation of the bicuspid aortic valve is feasible in many patients. Long-term stability of the repaired valves is good; the negative impact of a dilated atrioventricular junction can be reduced by suture annuloplasty. (*J Thorac Cardiovasc Surg* 2013;145:S30-4)

Bicuspid aortic valve (BAV) is the most frequent congenital cardiac anomaly.¹ A relevant proportion of those with BAV will require surgical treatment for aortic regurgitation (AR), even though hemodynamically normal function of BAVs has been observed in the seventh decade of life.² Aneurysmal aortic dilatation develops in more than 50% of individuals with BAV,^{3,4} either involving the root primarily or with predominant dilatation of the tubular ascending aorta.

Reconstruction of the regurgitant BAV was proposed as early as 1992 with excellent early results.⁵ It was shown that concomitant aortic dilatation could be treated simultaneously by root replacement or sinotubular junction remodeling.^{6,7} Subsequent studies showed a relevant proportion of repair failures in patients with BAV.^{8,9} Different predictors of repair failure were proposed, such as aortic dilatation⁸ or

triangular resection as part of the cusp repair.⁹ We found that symmetric postoperative prolapse was a relevant cause of failure that could be minimized reproducibly by systematically measuring and correcting effective cusp height.⁷ In a recent larger investigation, we found that anatomic denominators of the BAV, in particular marked dilatation of the atrioventricular junction (AVJ), remained a predictor of midterm repair failure.¹⁰ After valve-preserving root replacement including the tricuspid aortic valves, preoperative dilatation of the AVJ was a predictor of valve failure.¹¹

On the basis of these results, we modified the repair procedure in those with BAV by adding suture annuloplasty to correct dilatation of the AVJ. The current analysis compares the early results of our differential treatment of the valve and aortic pathology and analyzes the effect of the annuloplasty suture.

PATIENTS AND METHODS

Between November 1995 and January 2012, a total of 559 patients (485 male, aged 3-86 years; mean, 47.2 ± 14.1) were treated by valve preservation or repair of BAV at the Saarland University Medical Center.

The predominant pathology was AR (n = 389), aortic aneurysm (n = 158), or acute dissection (n = 12). The operations initially were performed without correcting dilatation of the AVJ. Since December 2008, dilatation of the AVJ (>27 mm) has been corrected with a circumferential annuloplasty suture. Thus, 366 patients were treated without an annuloplasty and 193 patients were treated with an annuloplasty. The early outcomes without and with annuloplasty were compared. The study was approved by the local ethics committee and approved for publication of the patient data in an anonymous fashion.

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Abbreviations and Acronyms

AR = aortic regurgitation
 AVJ = atrioventricular junction
 BAV = bicuspid aortic valve

The patients were treated with a consistent technique,⁷ although slight modifications were made over time. Isolated valve repair was performed for AR with preserved aortic dimensions (<42-45 mm; n = 208). Sinotubular junction remodeling plus valve repair was chosen for aortic aneurysm (>45-50 mm) and preserved root size (n = 116); root remodeling was used for dilatation involving the root (n = 235).

The degree of AR ranged from trivial (0) to severe (4), with a mean of 2.6 ± 1.1 . There was no significant difference between mean severity of regurgitation between the initial cohort (2.5 ± 1.1) and the 193 patients with annuloplasty (2.8 ± 0.9 ; $P = .07$). The mean diameter of the AVJ was 27.8 ± 2 mm in those without annuloplasty (n = 366) and 31.9 ± 3 mm in those with annuloplasty ($P < .0001$). Cardiac comorbidity requiring additional treatment included mitral regurgitation (n = 20), tricuspid regurgitation (n = 5), coronary artery disease (n = 42), and atrial fibrillation (n = 20).

Cusp Repair Technique

The principles of cusp repair have been reported.^{7,10} Repair was pursued if the nonfused cusp did not exhibit calcifications. First, any prolapse of the nonfused cusp (commonly noncoronary) was eliminated using plicating sutures. The redundancy of the fused cusps was reduced primarily using plicating sutures on the free margin. Triangular resection with suture adaptation was performed if fibrosis or limited calcifications in the raphe made plication difficult. In the presence of more extensive calcifications, a pericardial patch was inserted to bridge the defect in the fused cusps. The diagnosis of prolapse initially was made by visual inspection. Since December 2004, an effective height of the nonfused cusp of less than 9 mm was considered as prolapse and corrected¹²; the fused cusp was always adjusted to a height identical to the free margin. Plication of redundant cusp tissue was performed in 454 instances, and triangular resection of cusp tissue was performed in 181 cases. A pericardial patch was inserted for partial cusp replacement in 181 valves.

Choice of Procedure

Isolated aortic cusp repair was performed if the ascending aorta was normal (<40 mm). Sinotubular junction remodeling was used if the sinotubular diameter determined by transeophageal echocardiography exceeded 35 mm and the maximum sinus diameter was less than 42 (body surface area <2 m²) to 45 mm.¹³ Since November 2004, the graft was first sutured to the sinotubular junction, and then cusp repair was performed only to detect and eliminate any prolapse induced by reduction of sinotubular junction.⁷ Root remodeling was performed as described previously.⁶ Graft size was generally chosen according to the body surface area of the patient (<1.8 m²: 24 mm; 1.8-2.2 m²: 26 mm; >2.2 m²: 28 mm).

Annuloplasty

A suture annuloplasty similar to procedures described by others^{14,15} was performed whenever the atrioventricular diameter exceeded 27 mm. In the initial 89 instances, a number 2 braided polyester suture (Ethibond, Ethicon, Hamburg, Germany) was used; in the subsequent 104 cases, a polytetrafluoroethylene suture was used (Gore-Tex CV-0; WL Gore and Associates, München, Germany).

For isolated aortic valve repair, a suture was started from the inside of the outflow tract 4 to 7 mm deep through septal muscle in a horizontal plane 2

mm below the nadir of cusp insertion, from the center of the right cusp to the center of the left cusp. The posterior arm was then passed from the inside to the outside close to the left fibrous trigone and fixed tangentially outside the nadir of the noncoronary sinus. The anterior arm was passed from the inside to the outside to the left of the membranous septum, leaving sufficient tissue between suture and septum (Figure 1). It was similarly fixed tangentially outside the nadir of the noncoronary sinus. In conjunction with root remodeling, the suture was passed only from the outside, passing through myocardial tissue outside the right coronary cusp and just outside the nadir of the sinuses. The suture was tied around a Hegar dilator, thus effectively reducing the atrioventricular diameter; the size of the dilator was chosen according to the body surface area of the patient (≥ 1.8 m²: 25 mm, <1.8 m²: 23 mm). All patients were followed clinically and echocardiographically; follow-up was complete in 98% of patients (cumulative, 2559 years; mean, 4.6 ± 3.6 years).

Statistical Methods

All continuous data are presented as mean \pm standard deviation. Group differences were tested by chi-square test for categorical variables and Student *t* test for continuous variables. Kaplan–Meier curves were calculated for survival, freedom from reoperation, and freedom from valve replacement (Prism, GraphPad Inc, San Diego, Calif). Group differences in the Kaplan–Meier analysis were tested by log-rank test.

RESULTS

Three patients died in hospital, for a hospital mortality of 0.5%. These 3 deaths occurred in the 366 operations without annuloplasty (0.8%); none were in patients with annuloplasty. Twelve patients died late; survival at 10 years was 96% after valve repair, 97% after sinotubular junction remodeling and 89% after root remodeling ($P = .99$). The incidence of atrioventricular block requiring pacemaker implantation was 0 of 356 in the initial group and 2 of 193 (1%) in the annuloplasty group.

The addition of annuloplasty to the procedure significantly increased the proportion of aortic valves completely competent or with only trivial regurgitation. This was seen early after isolated repair ($P = .01$) and 12 months postoperatively ($P = .038$; Figure 2) and after root remodeling, both early ($P = .00018$) and at 1 year ($P = .001$; Figure 3). After sinotubular junction remodeling, there was a trend at discharge ($P = .07$) and significant improvement at 12 months ($P < .001$; Figure 4).

Reoperation was necessary for recurrent regurgitation (n = 54) or stenosis (n = 2). Ten-year freedom from reoperation was significantly inferior after isolated valve repair (70%) compared with sinotubular junction remodeling (93%) or root remodeling (89%; $P = .0007$). Stabilization of the AVJ with suture annuloplasty led to a trend in improved 3-year freedom from reoperation after isolated valve repair from 84% to 92% ($P = .07$; Figure 5). The aortic valve suture had no effect on 3-year freedom from reoperation for the complete cohort or sinotubular junction remodeling and root remodeling.

Complications of the annuloplasty occurred in 5 individuals (2.6%). Four complications occurred in the first 89 individuals; 1 complication was observed in the more recent 104 individuals. Obstruction or distortion of the proximal circumflex artery was observed in 2 patients after isolated

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