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Reconstructed Bicuspid Aortic Valve after 10 Years: Clinical and Echocardiographic Follow-up

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ABSTRACT

Background: Sixteen patients (mean age, 30.9 ± 12.9 years; range, 9-79 years) with incompetent bicuspid aortic valves underwent valve-sparing correction between 1992 and 1995.

Methods: All patients underwent triangular resection of the enlarged leaflet. In addition, 13 patients underwent commissuroplasty. In 3 patients leaflet perforations were corrected with glutaraldehyde-fixed autologous pericardial patch. All patients underwent annual echocardiographic and clinical examinations at our institution.

Results: During follow-up 1 patient died of heart failure, and 3 patients underwent reoperations because of valve incompetence or dilatation of the sinus. Two patients underwent reoperation perioperatively. At long-term follow-up (mean, 10.06 ± 1.01 years) the remaining 10 patients were in New York Heart Association class I. No patient was receiving anticoagulation, and no thromboembolic, bleeding, or endocarditis events were observed in 107.2 cumulative patient-years of follow-up. Mean grade of regurgitation was 0.7 ± 0.5; mean aortic flow velocity was 2.29 ± 0.47 m/s. Optimal valvular function led to normal ventricular diameters (left ventricular end systolic diameter, 39.2 ± 4.3 mm; left ventricular end diastolic diameter, 56.2 ± 5.9 mm) and normal ventricular function (fractional shortening, 31.5% ± 0.1%). The dimensions of the aortic root were stable from 1-year to late follow-up (mean aortic annulus, 27.1 ± 6.8 mm; sinus of Valsalva, 33.0 ± 7.1 mm; sinotubular junction, 34.1 ± 7.7 mm; ascending aorta, 31.6 ± 7.4 mm).

Conclusion: In contrast to early follow-up results of 5 reoperations, clinical and echocardiographic results were excellent for 10 patients who had undergone reconstruction of bicuspid incompetent aortic valves, and the patients were in stable condition after 10 years. However, the mode of early failure is unknown. Reconstruction of bicuspid valves is possible in selected patients.

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INTRODUCTION

Bicuspid aortic valve (BAV) is one of the most common congenital valvular heart malformations, having a prevalence of 0.9% to 2% in the general population and more frequent occurrence in male than female patients [Roberts 1970, Hoffmann 2002]. Various complications, such as aortic stenosis, aortic regurgitation (AR), infective endocarditis, and aortic dissection, in patients with BAV are well known [Mills 1978, Ward 2000,]. With the decline of inflammatory valve disease BAV is frequently recognized as the cause of isolated aortic insufficiency. Although BAV is a predisposing factor for degeneration and infection, approximately 60% to 70% of persons born with BAV remain free of significant aortic valve disease [Mills 1978]. Nevertheless, because of congenital BAV, AR is the most frequent indication for surgical intervention in the young population.

Aortic valve repair avoids the complications of conventional valve replacement, such as thromboembolism, endocarditis, and problems related to lifelong anticoagulation [Cannegieter 1994], and therefore represents the optimal surgical procedure, especially for young patients. Several studies have shown excellent short-term and midterm results after valve-sparing operations in patients with BAV [Fraser 1994, Casselmann 1999, Rao 2000, Schafers 2000]. However, the durability of aortic valve repair is uncertain.

Between April 1992 and September 1995, 16 patients with significant AR due to BAV underwent aortic valve-sparing correction in our department. The early clinical and echocardiographic results have been described previously [Moidl 1995]. The purpose of this study was to evaluate the clinical and echocardiographic status of patients with BAV 10 years after aortic valve reconstruction.

MATERIALS AND METHODS

Patients

Between April 1992 and September 1995, 16 patients underwent repair of insufficient BAV (Figure 1). There were 14 male and 2 female patients with a mean age of 30.9 ± 12.9 years (range, 9-79 years). No patient had undergone a previous cardiac operation. One patient was in New York Heart Association (NYHA) class IV, and 3 were in NYHA class III. The remaining 12 patients were in NYHA class II and were

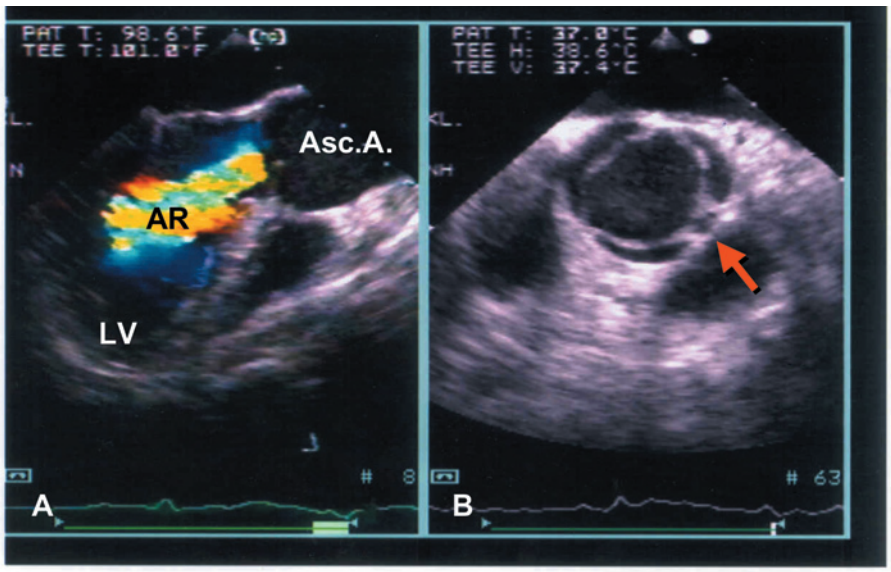

Figure 1. A, Transesophageal echocardiogram (longitudinal 2-chamber view) of insufficient bicuspid aortic valve. Asc.A indicates ascending aorta; AR, aortic regurgitation jet; LV, left ventricle. B, Transesophageal echocardiogram (cross section) of bicuspid aortic valve. Arrow indicates enlarged leaflet with the raphe.

operated on because of left ventricular dysfunction and increasing left ventricular dilation. Two patients were operated on in emergency status because of acute endocarditis. The patient demographic data are given in Table 1. Only patients with BAV and isolated AR were selected for aortic valve repair. Patients with calcification of the valve and significant ectasia of the sinus of Valsalva or the ascending aorta were excluded from valve repair procedures.

Surgical Procedure

The surgical techniques have been previously described in detail [Moidl 1995]. Triangular resection of the enlarged leaflet and mobilization of the raphe (Figures 2 and 3), closure of leaflet perforation with a glutaraldehyde-fixed autologous pericardial patch, and leaflet augmentation with a patch to adapt leaflet height were used as needed. In addition, commissuroplasty with 5/0 polypropylene (Prolene) pledgeted sutures was performed in 13 patients. After the repair, valve competence was assessed intraoperatively by transesophageal echocardiography (TEE) (HP Sonos 1000 and 1500 machines, 5-MHz; Hewlett-Packard, Palo Alto, CA, USA).

Echocardiography

Two-dimensional transthoracic echocardiography (TTE), spectral Doppler, and color Doppler echocardiographic measurements (HP Sonos 1000, 1500, and 2500 machines, 2.5-MHz; Hewlett-Packard) and clinical examinations were performed 1 to 3 days preoperatively, at discharge (8-15 days postoperatively), 1 year after surgery, and then every 2 years. Left ventricular end diastolic (LVEDD) and end systolic (LVESD) diameters were measured in the standard parasternal short-axis at the midpapillary level. Doppler echocardiographic measurements of aortic flow velocities were performed in the apical 4-chamber view. Severity of AR was graded semiquantitatively from 0 to 4 according to color flow Doppler criteria on the basis of the width of the regurgitation jet in the left ventricular outflow tract and its extension into the left ventricle [Weyman 1994]. The ascending aorta, aortic annulus, sinus of Valsalva, and sinotubular junction were measured in the parasternal long axis. All calculations were done from measurements of 3 different cardiac cycles.

Statistical Analysis

Mean and SD were calculated when appropriate. The Student *t* test was used for analysis of changes between preoperative and postoperative measurements. Analysis of variance for repeated measures was used for analysis of changes between measurements at discharge, after 1-year of follow-up, and after 10 years of follow-up. Statistical significance was assumed at $P < .05$.

RESULTS

Perioperative Results

In 1 patient intraoperative TEE showed significant AR. This patient underwent pulmonary autograft valve replacement

Table 1. Preoperative Demographic Data

Age, y	30.9 ± 12.9
Sex, M/F	14/2
New York Heart Association class	2.6 ± 0.7
Aortic regurgitation, grade 0-4	3.5 ± 1.0
Aortic annulus, mm	29.3 ± 4.9
Sinus of Valsalva, mm	37.9 ± 5.6
Sinotubular junction, mm	31.4 ± 3.9
Ascending aorta, mm	34.4 ± 6.4
Left ventricular end diastolic diameter, mm	75.39 ± 9.37
Left ventricular end systolic diameter, mm	53.57 ± 8.65

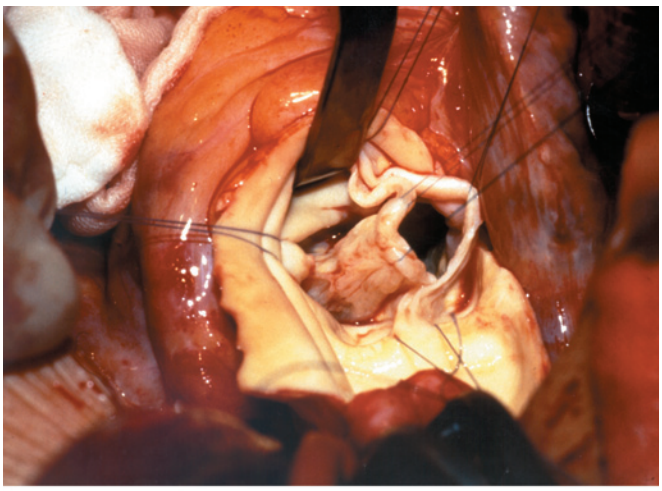

Figure 2. Intraoperative image showing a bicuspid aortic valve before repair.

in a second pump run. Within the first week 2 patients developed significant AR that necessitated reoperation. In 1 of those patients leaflet rupture at the base of the leaflet caused the eccentric regurgitation jet. Valve repair with a glutaraldehyde-fixed autologous pericardial patch was performed. The second patient underwent pulmonary autograft valve replacement; no clear cause of AR was identified. The 2 patients receiving pulmonary autografts were excluded from further analysis. The early results have been reported previously [Moidl 1995].

Echocardiographic examination at discharge revealed a significant decrease in AR from the preoperative to the postoperative findings (3.5 ± 0.1 to 0.5 ± 0.1; $P < .001$). LVEDD also decreased significantly (preoperative diameter, 73.5 ± 3.5 mm; postoperative diameter, 61.6 ± 2.8 mm; $P < .002$).

Follow-up

The mean follow-up period was 10.06 ± 1.01 years with a range of 8.2 to 11.6 years and 107.2 cumulative patient years. The follow-up study included 14 patients.

There was 1 death due to heart failure in a 79-year-old patient who had undergone combined aortic valve repair and mitral valve replacement 46 months after surgery. There were 3 reoperations in midterm follow-up. In 2 patients dilatation of the sinus of Valsalva was detected. Thirty-three months after aortic valve repair, 1 patient underwent pulmonary autograft valve replacement. After 48 months a second patient underwent the Bentall procedure. After 44 months a third patient underwent aortic valve replacement with a mechanical valve prosthesis to manage recurrent endocarditis.

At the latest follow-up examination, all 10 remaining patients were in NYHA class I. No patient was undergoing anticoagulation, and no thromboembolic or bleeding events were observed.

The patients had stable aortic valve function, aortic root dimensions, and LV dimensions and function. Echocardiographic examination revealed a mean grade of regurgitation of 0.7 ± 0.5. Mean aortic flow velocity was 2.29 ± 0.47 m/s with peak gradient of 21.6 ± 7.2 mm Hg and a mean gradient of 12.8 ± 5.3 mm Hg. Optimal valvular function led to normal ventricular diameters (LVESD, 39.2 ± 4.3 mm; LVEDD, 56.2 ± 5.9 mm) and normal ventricular function (fractional shortening, 31.5 ± 0.1%). The dimensions of the aortic root were stable without any statistically significant changes from 1 year to late follow-up (mean aortic annulus, 27.1 ± 6.8 mm; sinus of Valsalva, 33.0 ± 7.1 mm; sinotubular junction, 34.1 ± 7.7 mm; ascending aorta, 31.6 ± 7.4 mm). Postoperative and follow-up data are detailed in Table 2.

DISCUSSION

We describe the long-term results after aortic valve repair in patients with congenital BAV and isolated AR.

The mechanism and geometry of the aortic valve have been the subjects of several investigations [Mercer 1973, Brewer 1976, Westaby 1984, Thrubikar 1990]. Each aortic leaflet or cusp has a central load-bearing area, which receives its principal support from the coaptation surface of the leaflet. The size of the coaptation surface is determined by commissural height [Thrubrikar 1990]. Two factors are responsible for regurgitation in the BAV. First, the oversized length of one leaflet is translated into a larger load-bearing area, leading to prolapse of the leaflet, which requires support. Second, the inadequate commissural height is unable to support the load-bearing area [Fraser 1994].

Our surgical approach was to restore normal leaflet size with triangular resection and closure with a continuous suture. This procedure was performed in all patients in our series. In 3 patients with leaflet rupture or perforation, the defect was closed with a glutaraldehyde-fixed autologous pericardial patch. In addition, to reduce the triangle between the leaflets and increase the commissural height (which leads to an increased area of leaflet coaptation) commissuroplasty was performed in 13 patients. One patient needed pulmonary autograft valve replacement in the same operation because of significant AR, and 2 others needed reoperations within the first week. The complexity of the morphological leaflet abnormalities in the BAV plays a crucial role in success of

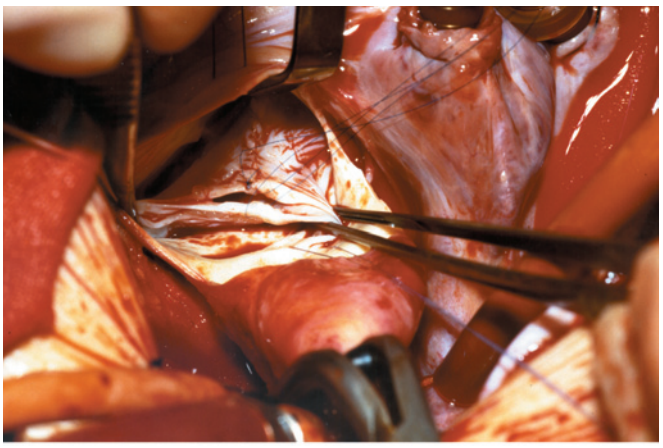

Figure 3. Intraoperative situs after triangular resection of the raphe.

Table 2. Echocardiographic Measurements*

	Discharge	1-Year Follow-up	10-Year Follow-up	*P*
Aortic regurgitation, grade 0-4	0.7 ± 0.5	1.3 ± 0.9	0.7 ± 0.5	.08
V_{max}, m/s	241 ± 48.5	224.1 ± 47.6	228.8 ± 47.5	.73
Aortic annulus, mm	26.2 ± 4.8	26.6 ± 4.1	27.1 ± 6.8	.95
Sinus of Valsalva, mm	33.6 ± 5.7	36.6 ± 4.8	33.0 ± 7.1	.65
Sinotubular junction, mm	28.8 ± 5.0	30.7 ± 6.5	34.1 ± 7.7	.23
Ascending aorta, mm	32.2 ± 5.5	31.7 ± 5.6	31.6 ± 7.4	.79
LVEDD, mm	63.1 ± 7.7	53.6 ± 9.6	56.2 ±5.9	.08
LVESD, mm	47.2 ± 10.5	38.7 ± 9.9	39.2 ± 4.3	.07

*V_{max} indicates maximal flow velocity; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter.

repair. In addition, the aortic root, which includes the annulus, sinus of Valsalva, sinotubular junction, and the subvalvular ventricular outflow tract, functions as a unit, a characteristic important to valve competence [Mercer 1973, Brewer 1976, Westaby 1984, Kunzelman 1994].

Previous investigations have described histological abnormalities of the ascending aorta in patients with congenital BAV. One such abnormality is cystic medial necrosis, which frequently leads to degenerative changes in the aorta and in the pulmonary trunk [McKusick 1972, de Sa 1999]. Other studies have shown a high prevalence of associated dilatation of the aortic root in patients with functionally normal BAVs [Pachulski 1991, Hahn 1992, Ferencik 2003]. Those findings suggest a common developmental error as a cause of the association between BAV and aortic wall abnormalities [McKusick 1972]. Therefore patients with BAV are more inclined to establish aortic root dilatation or aortic dissection, even after valve-sparing correction of an insufficient aortic valve. In 2 patients in our series dilatation of the sinus of Valsalva occurred within the follow-up period. One of these patients underwent pulmonary autograft valve replacement, and the second underwent a Bentall procedure. A third patient needed reoperation with mechanical aortic valve replacement because of recurrence of endocarditis.

Up to 11.6 years after valve-sparing correction of the BAV, the 10 remaining patients were in functional class I, and TTE showed no or mild AR, normal cardiac function, and normal diameters of the aortic root and left ventricle.

Recent studies documented a 5-year rate of freedom from reoperation of approximately 70% to 100% [Casselman 1999, Rao 2000, Carr 2004]. Although in our series 5 patients needed reoperation within the midterm follow-up period, the remaining patients did not develop AR or aortic root dilatation in follow-up periods up to 11.6 years. This finding suggested that repair of BAV is indicated in certain patients and showed durability of valve repair.

Valve repair in the particular population described can have serious complications. Comparison of aortic valve repair and valve replacement revealed no difference in early outcome regarding reoccurrence of AR, echocardiographic measurements of the aortic root and left ventricular diameter, or clinical status [Davierwala 2003]. However, valve replacement with mechanical valve prostheses requires life-long anticoagulation and may be complicated by bleeding and thromboembolism [Cannegieter 1994]. Glutaraldehyde-fixed bioprostheses show early degeneration and calcification, especially in young patients [Jamieson 1988, Clarke 1993, Grabenwoeger 1996, McGiffin 1997]. The Ross operation, which is frequently used in these patients, requires right ventricular outflow tract reconstruction with a homograft. The durability of these homografts is limited, and the pulmonary autograft may also demonstrate histological abnormalities, which may predispose to dilation. Taking these aspects and our rate of early failure into account, we prefer valve repair for patients with congenital BAV and isolated AR. We use new surgical techniques and have introduced leaflet augmentation with autologous pericardial patch in these patients.

We conclude that reconstruction of incompetent BAV can be achieved with stable and excellent clinical and echocardiographic results up to 10 years. Because the alternatives we can offer to these mostly young patients have serious disadvantages, reconstruction of BAV and isolated AR should be attempted only in selected patients.

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