Aortic Valve Function After Bicuspidization of the Unicuspid Aortic Valve

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Background. **Unicuspid aortic valve (UAV) anatomy leads to dysfunction of the valve in young individuals. We introduced a reconstructive technique of bicuspidizing the UAV. Initially we copied the typical asymmetry of a normal bicuspid aortic valve (BAV) (I), later we created a symmetric BAV (II). This study compared the hemodynamic function of the two designs of a bicuspidized UAV.**

Methods. **Aortic valve function was studied at rest and during exercise in 28 patients after repair of UAV (group I, n = 8; group II, n = 20). There were no differences among the groups I and II with respect to gender, age, body size, or weight. All patients were in New York Heart Association class I. Six healthy adults served as control individuals. All patients were studied with transthoracic echocardiography between 4 and 65 months postoperatively. Systolic gradients were assessed by continuous wave Doppler while patients were at rest and exercising on a bicycle ergometer.**

Results. **Aortic regurgitation was grade I or less in all patients. Resting gradients were significantly elevated in group I compared with group II and control individuals (group I, peak 33.8 ± 7.8 mm Hg; mean 19.1 ± 5.4 mm Hg; group II, peak 15.8 ± 5.4, mean 8.2 ± 2.8 mm Hg; control individuals, peak 6.0 ± 1.6, mean 3.2 ± 0.8 mm Hg; $p < 0.001$). At 100 W peak gradients were highest in group I (group I, 62.7 ± 16.7 mm Hg; group II, 28.1 ± 7.6 mm Hg; control individuals, 15.4 ± 4.6 mm Hg; $p < 0.001$).**

Conclusions. **Converting a UAV into a symmetric bicuspid design results in adequate valve competence. A symmetric repair design leads to improved systolic aortic valve function at rest and during exercise.**

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Unicuspid aortic valve (UAV) morphology is a rare cardiac anomaly. Its incidence has been estimated to be 0.02% in the general population [1]; by contrast, it is a frequent reason for aortic valve operations in young adults [2]. Approximately 4% to 6% of patients undergoing operations for pure aortic stenosis have unicuspid aortic anatomy [2].

There are two recognized types of UAVs, unicommissural and acommissural, based on whether or not there is a lateral attachment to the aorta above the level of the corresponding coronary orifice [3]. The unicommissural UAV has generally been described as one of the main causes for congenital aortic valve stenosis in infancy, childhood, and young adults [4, 5]. Unicommissural anatomy may also lead to predominant aortic regurgitation [1, 6]. Both dysfunctions ultimately require surgical treatment. Operation may also be required for treatment of aortic dilatation, which occurs in a relevant proportion of the affected individuals [1].

The most commonly surgical approaches for young patients with aortic valve disease include valve replacement, either with a mechanical valve or with a pulmonary autograft (Ross operation). The Ross operation has an excellent hemodynamic profile and improvement of quality of life, but it is a rather extensive surgical operation. Implantation of a mechanical prosthesis implies long-term anticoagulation and a relevant risk of valve-related complications [7–9].

We have previously proposed a reconstructive approach to the UAV. By resection of dysplastic tissue and creation of a second normal commissure with subsequent pericardial cusp extension, the valve was bicuspidized [10]. Initially we created the new commissure at the site of the rudimentary anterior commissure between the right and noncoronary cusps, thus copying the asymmetry of the bicuspid aortic valve typically present. From our experience with valve repair in bicuspid aortic valve disease, we learned that symmetry of a bicuspid valve is apparently a predictor of long-term valve stability [11]. Consequently, we changed our technique of unicuspid repair, creating a symmetric bicuspid valve with a 180° orientation of the commissures.

The purpose of this study was to compare the hemodynamic function of the aortic valve at rest and exercise in patients after the two different techniques of unicuspid valve repair. Healthy volunteers were used as control individuals.

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Table 1. Patient Characteristics

	Group I	Group II	Controls	p Value: Group I vs Group II	p Value: Group I vs Controls	p Value: Group II vs Controls
Gender (M/F)	3/5	14/6	5/1	0.15	0.09	0.51
Age (y)	38.6 ± 9.4[a]	35.4 ± 8.6[a]	24.7 ± 2.9[a]	>0.4	0.02	<0.001
Body size (cm)	172 ± 11.3[a]	174.2 ± 8.8[a]	180 ± 8.0[a]	>0.5	0.1	0.15
weight (kg)	70.9 ± 9.6[a]	80.4 ± 13.4[a]	72.2 ± 12.4[a]	0.09	0.77	0.2
Study data						
dPmax (mm Hg)	33.8 ± 7.8[a]	15.8 ± 5.4[a]	6.0 ± 1.6[a]	$p < 0.001$	$p < 0.001$	$p < 0.001$
dPmean (mm Hg)	19.1 ± 5.4[a]	8.2 ± 2.8[a]	3.2 ± 0.8[a]	$p < 0.001$	$p < 0.001$	$p < 0.001$
AR	mild (n 8)	no (n 6) mild (14)	no AR	p 0.05		
LVEDD (mm)	50.6 ± 4.6[a]	52.2 ± 4.6[a]	48.2 ± 2.5[a]	p 0.43	p 0.23	p 0.02
LVESD (mm)	31 ± 7.3[a]	36.5 ± 4[a]	32.8 ± 4.1[a]	p 0.08	p 0.56	p 0.09
FS (%)	34.6 ± 10.9[a]	30.5 ± 4.6[a]*	31.7 ± 7.8[a]	p 0.33	p 0.58	p 0.74

[a] Mean ± standard deviation.

AR = aortic regurgitation; dPmax = maximum pressure gradient; dPmean = mean pressure gradient; FS = fractional shortening; LVEDD = left ventricular enddiastolic diameter; LVESD = left ventricular endsystolic diameter.

Patients and Methods

From August 2001 to May 2011, 118 patients (86 male, mean age 27 ± 13 years) underwent an aortic valve repair procedure for a UAV. Predominant aortic regurgitation was present in 56 patients (age 30 ± 12 years) and aortic stenosis or combined aortic valve disease in 67 patients (age 25 ± 13 years). All patients had unicommissural unicuspid aortic valve anatomy with one normally developed commissure [12], in 117 patients this was the commissure between left and noncoronary cusp. Ten patients had previously undergone balloon valvuloplasty and 3 open commissurotomy for congenital aortic stenosis. Coexisting ascending aortic dilatation was found in 42 patients and was treated by sinotubular junction remodeling (n = 30) or valve-preserving aortic root remodeling (n = 12).

Of the 118 patients, 17 underwent were reoperation; in 8 patients the valve could be repaired again. At reoperation, 9 patients underwent valve replacement (Ross operation, n = 6; mechanical prosthesis, n = 2; biologic prosthesis, n = 1). Freedom from reoperation was 80% design I versus 86% design II at 3 years ($p = 0.61$).

For the purpose of this study, 28 patients were selected who had undergone bicuspidizing repair of a UAV. Inclusion criteria were a minimum age of 18 years and a minimum follow-up time of 3 months. Only patients were selected who lived geographically close to our center and who were willing to participate in the study.

Exclusion criteria were status after re-repair and more than trivial aortic regurgitation. Twelve patients had undergone isolated aortic valve repair; in 14 patients aortic repair had been combined with sinotubular junction remodeling and in 2 patients with aortic root remodeling. All patients were in New York Heart Association class I postoperatively. Six healthy adults served as control individuals.

All participants gave informed consent, and the institutional ethics committee agreed to the investigation and analysis and publication of the data with participants remaining anonymous.

All patients had undergone bicuspidizing repair of a UAV. In 8 patients, this had been performed with an asymmetric design (group I), copying the anatomy of the most frequent bicuspid valve anatomy. In 20 individuals, a symmetric bicuspid design had been created (group II).

In group I the aortic valve showed combined disease in 5 patients and predominant stenosis in 3. The primary indication for operation was symptomatic valve dysfunction (n = 5) or ascending aortic aneurysm (n = 3). Ascending aortic replacement was necessary in 4 patients. In group II, regurgitation was present in 11 patients and combined disease in 9. The primary indication was symptomatic valve dysfunction (n = 6) or ascending aortic aneurysm (n = 14), all of which required ascending aortic replacement.

There were no differences between groups I and II with respect to gender, age, body height, or weight (Table 1). Preoperative peak gradients were higher in group I (73.9 ± 14.2 mm Hg) than in group II (33 ± 25.5 mm Hg; $p < 0.001$). The preoperative degree of aortic regurgitation was significantly higher in group II ($p = 0.002$). In concordance, preoperative left ventricular diameters were lower in group I ($p = 0.02$). The mean follow-up times were 48 months in group I (range, 39–65 months) and 24 months in group II (range, 4–39 months) ($p < 0.001$).

At the time of the study, all 8 patients in group I had minimal aortic regurgitation. In group II, 6 patients had no and 14 had minimal aortic regurgitation ($p = 0.045$) (Table 1). Left ventricular end-diastolic diameter (group I, 50.6 ± 4.6 mm; group II, 52.2 ± 4.6 mm; $p = 0.43$) and fractional shortening (group I, 34.6 ± 10.9%; group II, 30.5 ± 4.6%; $p = 0.33$) were equal in groups I and II (Table 1). Aortic regurgitation was grade I or less in all patients. During follow-up, the degree of aortic regurgitation and the resting gradients remained constant in all patients.

Operative Procedures

The chest was opened by a median sternotomy, and cardiopulmonary bypass was accomplished by the use of