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Aortic Valve-Sparing Operations: Early and Midterm Results

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ABSTRACT

Background. Aortic valve-sparing operations have provided very good clinical outcomes. However, there is still a debate about valve durability because of the absence of the Valsalva sinuses, and various techniques have been proposed to reproduce the native anatomy of the aortic root. We reviewed our total experience with aortic valve-sparing operations to determine early and midterm outcomes.

Methods. Between July 2001 and August 2004, 85 patients underwent valve-sparing operations. There were 67 (78.8%) male and 18 (21.2%) female patients with a mean age of 58.8 ± 14.6 years. Sixty-five patients with an aortic root aneurysm underwent the David I reimplantation technique, and a Gelweave Valsalva graft was used in 57 patients. Twenty patients with an ascending aortic aneurysm underwent replacement of the ascending aorta with sinotubular junction reduction.

Results. There were 3 in-hospital deaths (3.5%) and 2 late deaths. Two of 4 patients with acute aortic dissection died. The 3-year survival for patients with an aortic root aneurysm was 95.4% ± 2.6%, and for patients with an ascending aortic aneurysm it was 89.2% ± 7.3 (P = .464). Seven patients developed 3 to 4+ aortic insufficiency, and 5 of them required aortic valve replacement. The 3-year freedom rate from grade 3 to 4 aortic insufficiency was 88.9% ± 5.2% for patients with an aortic root aneurysm and 88.2% ± 7.8% for those with an ascending aortic aneurysm. At 3 years, the freedom rates from late aortic valve replacement were 92.2% ± 4.9% in the aortic root aneurysm group and 88.2% ± 7.8% in the ascending aortic aneurysm group.

Conclusions. Aortic valve-sparing operations showed excellent results in patients electively operated on for aortic root ectasia, and the results in acute aortic dissection were very disappointing. The Gelweave Valsalva prosthesis demonstrated ease of implantability and good reproduction of the pseudosinuses. Long-term follow-up is necessary to determine if this graft will enhance the function and increase the durability of the aortic valve.

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INTRODUCTION

Aortic valve-sparing operations as described by Yacoub [1983] and David [1992] have provided very good clinical outcomes. The analysis of the results obtained with the reimplantation and the remodeling techniques indicates that the reimplantation method is more hemostatic, provides a more reliable stabilization of the aortic annulus, and may be associated with better long-term durability [Schäfers 1998; Yacoub 1998; Luciani 1999; David 2002; Leyh 2002; Miller 2003; Oliveira 2003]. There is still a debate about valve durability caused by the absence of the Valsalva sinuses and various techniques have been proposed to reproduce the native anatomy of the aortic root [Cochran 1995; Zehr 2000; De Paulis 2001; David 2002; Miller 2003]. In this study, we report our total experience with aortic valve-sparing operations in 85 patients.

MATERIALS AND METHODS

Between July 2001 and August 2004, 85 patients underwent valve-sparing operations. All patients with an aortic root aneurysm or an ascending aorta aneurysm associated with aortic insufficiency (AI) were included. Because our experience with the remodeling technique was limited to only 4 patients, we excluded them from this analysis. Patient ages ranged from 19 to 80 years (mean, 58.8 ± 14.6 years). There were 67 (78.8%) male and 18 (21.2%) female patients. All patients were preoperatively evaluated with transthoracic and/or transesophageal echocardiogram. Angiography was performed in patients who were older than 50 years of age or had a history of coronary artery disease (76% of cases). Clinical characteristics of Marfan syndrome were present in 6 patients (6.8%), and 15 patients (17%) had a congenital bicuspid aortic valve (BAV). Four patients (4.7%) suffered from acute type A aortic dissection. In Table 1, the clinical and demographic profile of patients is described according to the type of aortic pathology. Preoperative echocardiographic data are shown in Table 2.

Table 1. Clinical Data

	Aortic Root Aneurysm	Ascending Aortic Aneurysm	Overall	*P*
Number of patients	65	20	85	
Gender, male (%)	56 (86.2)	11 (55)	67 (78.8)	.009
Age, y (range)	55.9 ± 13.9 (19-76)	63.5 ± 15.7 (21-80)	57.8 ± 14.6 (19-80)	.043
Hypertension (%)	46 (71.9)	18 (90)	64 (76.2)	.135
Diabetes mellitus (%)	3 (4.7)	—	3 (3.5)	1
Coronary artery disease (%)	9 (14)	2 (10)	11 (12.9)	.989
Renal insufficiency (%)	2 (3.1)	—	2 (2.4)	1
Marfan Syndrome (%)	6 (9.4)	—	6 (7.1)	.328
Peripheral vascular disease (%)	3 (4.6)	2 (10)	5 (5.9)	.587
Bicuspid aortic valve (%)	9 (14.1)	3 (15)	12 (14.1)	.917
Type A dissection (%)				
Chronic	2 (3.1)	3 (15)	5 (5.9)	.048
Acute	2 (3.1)	2 (10)	4 (4.7)	.201
Reoperation (%)	2 (3.1)	—	2 (2.4)	1
New York Heart Association class (%)				
I	10 (15.4)	3 (15)	13 (15.3)	.715
II	37(56.8)	10 (50)	47 (55.3)	
III	16 (24.6)	7 (35)	23 (27.1)	
IV	2 (3.2)	—	2 (2.4)	

Operative Procedures

Patients with an aortic root aneurysm were treated with the David I reimplantation technique (65 patients). These operations were performed according to the David technique without any modification [David 2001]. A straight graft was used in 8 consecutive patients until the Gelweave Valsalva graft (Vascutek, Renfrewshire, Scotland, UK) became available, which we have since used exclusively in 57 patients. This prosthesis presents prefashioned neosinuses reproducing a physiological anatomy of the aortic root (Figure 1). As reported by De Paulis, the implantation technique using the Gelweave Valsalva graft does not differ from that of a conventional straight graft [De Paulis 2002]. The key point is the correct placement of the commissures at the level of the graft sinotubular ridge, ie, where the main body of the graft is joined to the bulged portion of the graft (skirt). This placement can be achieved by first measuring the height of the commissures, ie, from the level of the annular sutures to the top of the commissures. The graft collar is then trimmed so that the combined length of the collar remnants and skirt match that of the commissural height. This length ensures that the commissures, when the graft is sutured into position, reach the sinotubular ridge. Patients with ascending aortic aneurysms and AI had the ascending aorta replaced with a reduction of the sinotubular junction (STJ) diameter as advocated by David [2001]. This procedure was performed in 20 patients.

Eighteen patients—13 with an aortic root aneurysm and 5 with an ascending aortic aneurysm—had associated cusp repair consisting of: shortening the free margin either by central plication or by weaving a double layer with a 6/0 polyte-

Table 2. Echocardiographic Data

	Aortic Root Aneurysm	Ascending Aortic Aneurysm	Overall	*P*
Ejection fraction, % (range)	59.6 ± 7.5 (42-81)	59.6 ± 8.7 (40-75)	59.7 ± 7.7 (40-81)	.926
Diameter, mm (range)				
Annulus	25 ± 3 (20-30)	21 ± 2 (19-25)	24 ± 3 (19-30)	<.001
Valsalva sinuses	48 ± 7 (30-69)	37 ± 5 (27-43)	46 ± 8 (27-69)	<.001
Sinotubular junction	46 ± 7 (30-50)	34 ± 5 (27-42)	44 ± 7 (27-50)	<.001
Ascending aorta	50 ± 7 (30-65)	50 ± 10 (45-75)	50 ± 8 (30-75)	.880
Grade of aortic regurgitation (%)				<.001
0-1+	11 (16.9)	—	11 (12.9)	
2+	29 (44.6)	—	29 (34.1)	
3+	22 (33.9)	13 (65)	35 (41.2)	
4+	3 (4.6)	7 (35)	10 (11.8)	

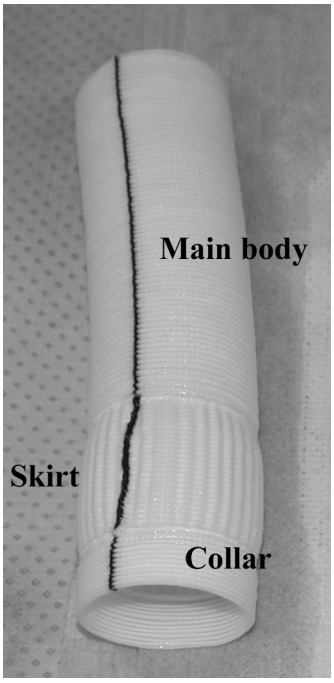

Figure 1. The Valsalva prosthesis (Vascutek, Zurich, Switzerland) is a standard Dacron conduit that incorporates a short segment with corrugations parallel to the conduit long axis. This segment (skirt) has a length equal to the graft diameter and is resilient in the horizontal plane so that, on implantation and pressurization, it will generate pseudosinuses of Valsalva. The suture joining the skirt with the main body acts as a new sinotubular junction, and a small collar at the bottom of the skirt completes the design.

trafluoroethylene suture (8 patients); raphe resection with annular plication (7 patients, in 2 of whom shortening of the free margin by a double layer suture was also performed, and in another of whom an autologous pericardium patch was utilized to reconstruct the leaflet where the raphe was present); or suturing of a cusp fenestration with a 6/0 polypropylene suture (3 patients).

Aortic arch replacement was performed in 11 patients (12.9%) and in 1 case an elephant trunk technique was utilized. Antegrade selective cerebral perfusion was used for cerebral protection in 15 cases. Six patients (7.1%) underwent coronary artery bypass. Table 3 summarizes the operative data.

Follow-Up

All hospital survivors were available for follow-up at intervals ranging from 3 months to 36.2 months (mean, 15.9 months). Follow-up information was obtained by our direct examination or by correspondence with the patient. Every patient had an echocardiogram at 3 and 9 months after the operation and then every year. In cases of grade 3 to 4 AI, the echocardiographic controls have been performed closely.

Statistical Analysis

Statistical analysis was performed with SPSS 11.0 statistical software (SPSS, Chicago, IL, USA). Continuous variables were expressed as the mean ± standard deviation and were compared with an unpaired 2-tailed *t* test. Categorical variables were analyzed with a χ^2 test or Fisher exact test where appropriate. Survival analyses were calculated using the Kaplan-Meier actuarial technique; in addition, freedom from grade 3 or 4 AI and freedom from aortic valve replacement (AVR) were calculated. Subgroup comparisons were made by means of the log-rank test.

RESULTS

Early Outcomes

There were 3 in-hospital deaths (3.5%): 2 due to multiple organ failure (MOF) and 1 due to low cardiac output. All patients who died had undergone the reimplantation procedure: 2 because of acute type A aortic dissection and 1 because of annuloaortic ectasia. A patient operated on for acute dissection developed an acute severe AI on the second postoperative day. During reoperation a commissural detachment causing prolapse of the left and the noncoronary cusps was found. The patient underwent AVR with a mechanical valve leaving the reimplanted aortic tissue inside the graft. Three days later, transesophageal echocardiography showed a malfunction of the valve due to a mechanical leaflet blockage. This blockage had been caused by some aortic wall tissue becoming detached from the graft. The patient underwent a third operation for total root replacement with a composite valve graft. Weaning from cardiopulmonary bypass was impossible and a biventricular assist device was implanted. The patient died 2 days later. One other patient died; he was operated on for acute dissection with peripheral malperfusion and tamponade. He underwent successful reimplantation but died after 10 days of MOF. The third nonsurviving patient was operated on for annuloaortic ectasia complicated by aortic dissection originating from the distal anastomosis. The

Table 3. Operative Data

	Aortic Root Aneurysm	Ascending Aortic Aneurysm	Overall	*P*
Cusp repair (%)	13 (20%)	5 (25%)	18 (21.2)	.755
Aortic arch replacement (%)	2 (3.1%)	9 (45%)	11 (12.9)	<.001
Coronary artery bypass graft (%)	4 (6.2%)	2 (10%)	6 (7.1)	.622
Cardiopulmonary bypass time, min (range)	150.3 ± 44.3 (61-373)	117.5 ± 4.2 (66-204)	142.6 ± 45.7 (61-373)	.005
Cross clamp time, min (range)	122.7 ± 30.1 (50-229)	84.7 ± 32.5 (46-150)	113.8 ± 34.6 (46-229)	<.001

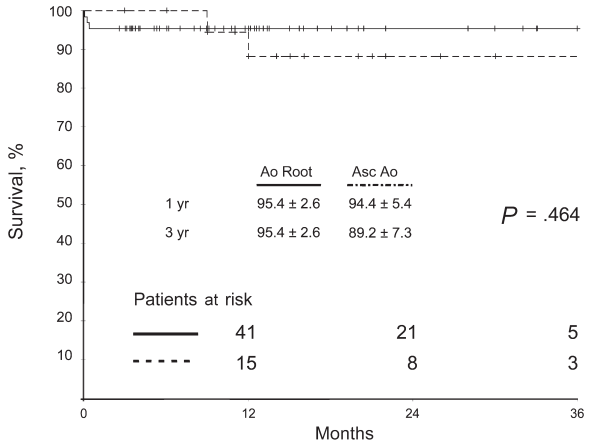

Figure 2. Actuarial survival of all patients with aortic root (solid line) and ascending aortic (dotted line) aneurysms.

patient developed renal insufficiency and died from MOF on the twelfth postoperative day. Four patients required rethoracotomy for bleeding: 3 from the reimplantation group and 1 from the STJ remodeling group. At the discharge echocardiography, 3 patients had grade 3 AI and1 had grade 4.

Late Outcomes

There were 2 late deaths: both patients had undergone STJ remodeling. The causes of death were pulmonary cancer and cardiac failure. The 3-year survival rate for patients with an aortic root aneurysm was 95.4% ± 2.6%, and for patients with an ascending aortic aneurysm it was 89.2% ± 7.3 ($P = .464$) (Figure 2). The echocardiography showed a good reproduction of the sinuses of Valsalva in all patients in whom the Valsalva graft had been used (Figure 3). Some patients also underwent a computed tomography scan that confirmed the echocardiographic findings (Figure 4).

Seven patients developed 3 to 4+ AI and 5 of these required late AVR. Two patients with 3+ AI were asymptomatic and are being followed closely with serial echocardiograms showing normal left ventricular size and function. Three of the 5 reoperated patients had a reimplantation procedure (2 with the Gelweave Valsalva graft), and the other 2 had STJ remodeling. The incidence of reoperation was significantly higher in patients who had undergone cusp valve repair (22.2% versus 1.5%; $P = .001$). Four of the 7 patients with grade 3 to 4 AI had a cusp repair procedure and all of them underwent reoperation.

The 3-year freedom rate from grade 3 to 4 AI was 88.9% ± 5.2% in patients with an aortic root aneurysm and 88.2% ± 7.8% in those with an ascending aortic aneurysm (Figure 5A). At 3 years, 92.2% ± 4.9% of patients with an aortic root aneurysm and 88.2% ± 7.8% of patients with an ascending aortic aneurysm were free from AVR (Figure 5B).

DISCUSSION

Since the introduction of the Bentall operation in 1968 [Bentall 1968], a significant prolongation of life expectancy for patients affected by a variety of conditions involving the ascending aorta and the aortic root has been obtained [Svensson 1992; Gott 2002]. However, despite refinements in the design of cardiac prostheses and anticoagulation management, mechanical valve replacement is still associated with a variety of valve-related complications, often leading to serious disability or death [Pacini 2003]. Moreover, patients with aortic root aneurysm often have normal or minimally diseased aortic cusps that can be preserved. To avoid the disadvantages of prosthetic heart valves, the valve-sparing procedure has been introduced. First Yacoub [1983] and then David [1992] proposed methods of aortic valve preservation in patients with aortic root aneurysms: the remodeling operation and the reimplantation technique (usually called the David procedure). Both techniques showed good late results.

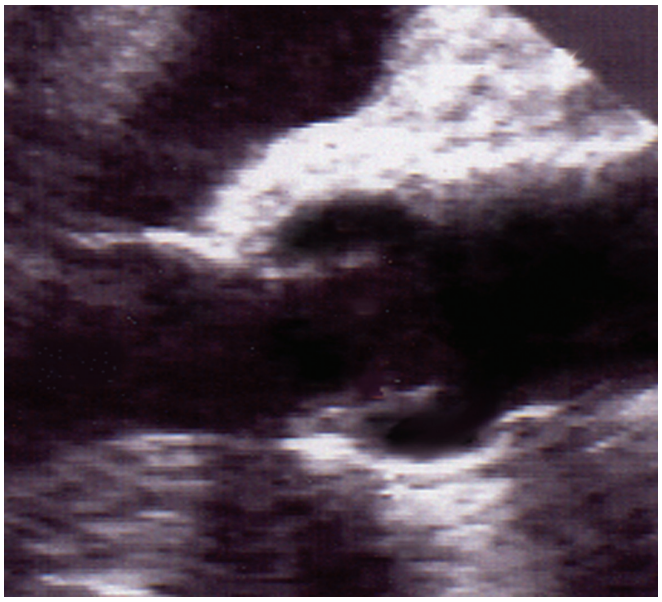

Figure 3. Transesophageal echocardiographic long-axis view of a patient after a reimplantation type of valve-sparing procedure with the Valsalva graft (Vascutek, Renfrewshire, Scotland, UK). The sinuses of Valsalva are well reproduced and they prevent the contact of the valve leaflets against the prosthesis.

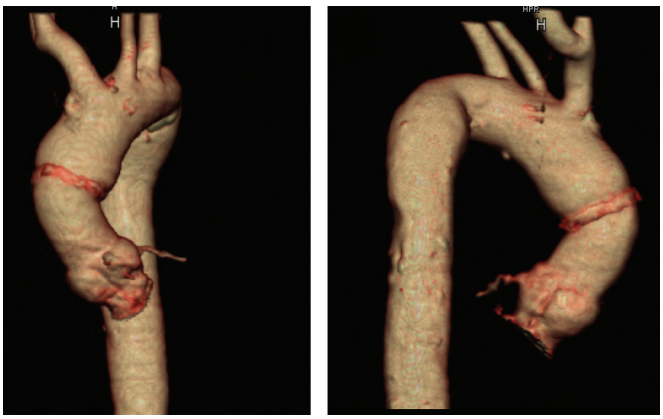

Figure 4. Multidetector-row computed tomography. Volume rendering images demonstrating a normal anatomy restoration of the aortic root after reimplantation technique using the Valsalva graft (Vascutek, Renfrewshire, Scotland, UK).

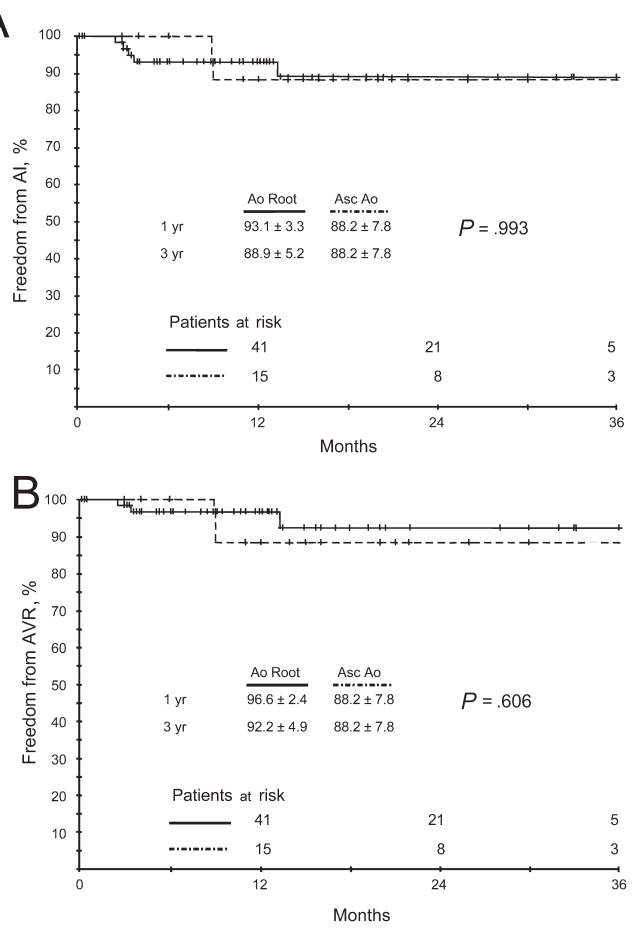

Figure 5. A, Actuarial freedom from 3 to 4+ aortic insufficiency. B, Actuarial freedom from reoperation on the aortic root.

This study reports our experience in aortic valve-sparing operations examining the outcomes in 2 distinct pathologies as classically reported by David [2001]: the ascending aortic aneurysm with AI and the aortic root aneurysm. The ascending aortic aneurysms were treated by STJ remodeling and ascending aorta replacement, and the aortic root aneurysms were treated by the David I reimplantation technique. We have very limited experience with the David II remodeling procedure, only 4 patients, and have therefore excluded them from the study.

The reimplantation technique with a conventional straight graft offers better annular stabilization, superior support of the aortic wall, and reduced bleeding when compared with the remodeling technique, but the main drawback of this procedure is the lack of sinuses [Kamohara 1999]. The importance of the sinuses of Valsalva in the function of the aortic valve has been debated since the time of Leonardo da Vinci [Robicsek 1991]. Recent investigators have demonstrated that the sinus ridge promotes the formation of vortices within the sinuses and facilitates smooth closure of the aortic valve [Kvitting 2004]. This smooth and rapid aortic valve closure minimizes the stress on the valve leaflets [Grande 1998; Dagum 1999]. The disturbance of the physiological valve closure mechanisms might contribute to long-term leaflet degeneration even if it has not been definitively proven. However, some cases of laceration or deterioration of the leaflets in patients that have undergone reimplantation procedure with straight grafts are reported in the literature. The reasons for these structural valve deteriorations can be attributed to the impact of the leaflets against the graft and/or to their abnormal coaptation [Zehr 2001; Ikonomidis 2002]. Various techniques have been proposed to reproduce the native anatomy of the aortic root [De Paulis 2001; David 2002; Miller 2003].

De Paulis developed a graft, the Gelweave Valsalva prosthesis with prefashioned neosinuses, that does not require any additional procedure or modification of the implantation technique [De Paulis 2000; 2002]. The most important point is the correct placement of the commissures at the level of the distal ridge of the prosthesis to avoid their lateral displacement and consequent AI. We started using this prosthesis when it first became commercially available and now implant it exclusively with good results. No early or late complications have been associated with the prosthesis and in all cases the sinuses were reproduced. Moreover, the presence of neosinuses makes for easier and tension-free coronary ostial reimplantation. Bethea and colleagues, from Johns Hopkins University, Baltimore, Maryland, reported similar results using this prosthesis in 19 patients starting in August 2002 [Bethea 2004].

We had adverse experiences (2 deaths out of 4 patients) in patients with acute aortic dissection. Some authors suggest that the reimplantation technique, even though demanding and time-consuming, is a useful procedure in this pathology with appealing advantages, such as rare bleeding complications and freedom from anticoagulation, compared to the classic, established methods [Kallenbach 2004]. However, we think that reimplanting the aortic valve with 3 to 4 mm of dissected aortic wall inside the prosthesis can predispose to a secondary rupture of the aortic wall and result in acute AI, as happened to our patient. After these disappointing results we abandoned this technique in acute aortic dissection, and now if a root replacement is necessary we perform a Bentall procedure, using a mechanical valve conduit for patients younger than 65 years or a home-made stented biological valve conduit and the Gelweave Valsalva graft for patients older than 65 years.

BAV is the second most common cause of clinically significant AI, and it is also a leading cause of aortic regurgitation in young adults. Moreover, we know now that BAV can function adequately into the seventh decade of life if it has not developed stenosis by the third or fourth decade [Fenoglio 1977; Mills 1978]. Consequently, the repair of BAV has become an attractive alternative to valve replacement that, despite improved results, is still associated with important complications such as structural valve deterioration in bioprosthetic valves and anticoagulation-related bleeding and thromboembolism in mechanical valves [Edwards 2001]. Some surgeons suggest that the anatomy of the BAV may facilitate the reconstruction of the leaflets due to the presence of redundant pliable cusp tissue in addition to the fact that only a single coaptation line has to be restored [Casselman

1999; Langer 2004; Alsoufi 2005]. However, other groups have reported suboptimal results after BAV repair [Moidl 1995; Kin 2003]. Nash et al [2005] have recently demonstrated that the features associated with a greater feasibility of successful repair are the presence of eccentrically directed AI and the absence of cusp thickness, commissural thickness, or cusp calcification. We operated on 15 patients with BAV and only 1 underwent reoperation. This was a case of a 25-year-old man with a calcified bicuspid valve who refused anticoagulation therapy. We performed a resection of the calcified raphe, a debridement of the leaflets, and a reconstruction of the leaflet with an autologous pericardial patch. The patient was reoperated on after 6 months for severe AI due to dehiscence of the pericardial suture.

Seven patients developed grade 3 to 4 AI and 4 of them had repair procedures on the cusps (4/18, 22.2% versus 3/64, 4.7%; $P = .038$). The only patient reoperated on for AI, who had no cusp repair, was a 75-year-old woman undergoing STJ remodeling. Eight months later she developed a central insufficiency probably related to a suboptimal restoration of the STJ. At the beginning of our experience, we adopted very strict indications and only valves with very good leaflets were preserved. Once we had gained more confidence with the procedure, we extended our indications to more complicated patients. We included young patients unwilling to take anticoagulation therapy and those with contraindications to anticoagulation. In addition, we have widened the indications to include patients presenting with a calcified bicuspid valve, prolapse of more then 1 cusp, large fenestration on the leaflets, etc. We had no late cases of thromboembolism or endocarditis.

The optimal timing of aortic root replacement is still controversial. We totally agree with Dr. David about the secondary damage of the cusps due to the increasing stresses on the leaflets when the root dilates. For this reason, we recommend the operation be performed before these changes in the leaflets occur because, in our experience, this is the principal cause of an unsuccessful valve-sparing procedure.

In conclusion, we have reported on the outcomes of 85 patients who underwent valve-sparing operations with 2 different surgical procedures: reimplantation technique and STJ remodeling. These procedures showed excellent results in patients electively operated on for aortic root ectasia, and the results in acute aortic dissection were very disappointing. If aortic leaflets are damaged or degenerated, a higher rate of reoperation should be expected. The Gelweave Valsalva prosthesis demonstrated ease of implantability and good reproduction of the pseudosinuses. Long-term follow-up is necessary to determine if this graft will enhance the function and increase the durability of the aortic valve.

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