Surgery for Aneurysms of the Aortic Root
A 30-Year Experience

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Background—This study evaluated long-term results of aortic root replacement and valve-preserving aortic root reconstruction for patients with aneurysms involving the aortic root.

Methods and Results—Two-hundred three patients aged 53±16 years (mean±SD; 153 male, 50 female) underwent elective or urgent aortic root surgery from 1971 to 2000 for an aortic root aneurysm: 149 patients underwent a composite valve conduit reconstruction, and 54 patients underwent valve-preserving aortic root reconstruction. Fifty patients had Marfan syndrome. In-hospital and 30-day mortality was 4.0% (8/203) overall: for a composite valve conduit procedure, the corresponding value was 4.0% (6/149) and for valve-preserving procedure, 3.7% (2/54) (P=NS). Morbidity included 3 strokes (1%), 10 perioperative myocardial infarctions (5%), and 8 reoperations for bleeding (4%). Actuarial survival at 5, 10, 15, and 20 years was 93% (95% confidence interval [CI] = 88% to 97%), 79% (95% CI = 71% to 87%), 67% (95% CI = 57% to 79%), and 52% (95% CI = 36% to 69%), respectively. Freedom from reoperation was 72% (95% CI = 54% to 86%) at 20 years. Complications with anticoagulation occurred in 29 patients; with valve thrombosis, in 2; and with hemorrhage, in 27 (4 life threatening and 23 minor). Freedom from thromboembolism was 91% (95% CI = 77% to 98%) at 20 years. Freedom from endocarditis was 99% (95% CI = 92% to 100%) at 20 years. Multivariate analysis revealed preoperative mitral valve regurgitation (+3 to 4) and older age to be significant predictors of late death ($P \leq 0.005$), and Marfan syndrome, initial valve-preserving aortic root reconstruction, and need for a concomitant procedure at initial operation to be significant predictors of the need for reoperation ($P \leq 0.01$).

Conclusions—Aortic root replacement for aortic root aneurysms can be done with low morbidity and mortality. Composite valve conduit reconstruction resulted in a durable result. There were few serious complications related to the need for long-term anticoagulation or a prosthetic valve. Reoperation was most commonly required because of failure of the aortic valve when a valve-preserving aortic root reconstruction was performed or for other cardiac or aortic disease elsewhere. **(*Circulation*. 2004;110:1364-1371.)**

Key Words: surgery ■ aneurysm ■ aorta

Aneurysms of the aortic root involving the sinuses of Valsalva, the sinotubular junction, and the proximal ascending aorta are a distinct entity from atherosclerotic ascending aortic aneurysms or the asymmetric aneurysmal dilatation often associated with a bicuspid aortic valve, which occur distal to the sinotubular junction. Classically, aortic root aneurysms occur in patients with connective-tissue disorders.[1] However, the majority of patients lack phenotypic expression of a connective-tissue disorder. Cystic medial degeneration is the pathologic feature for either etiology.[2,3] Therefore, for this analysis, we chose to evaluate patients with the anatomic abnormality of an aortic root aneurysm.

Since Bentall and De Bono[4] introduced the surgical technique of composite mechanical valve conduit replacement of a large aortic root aneurysm in 1968, various adaptations of the original concept have been the standard therapy for patients with an aortic root aneurysm.[5–8] In an attempt to avoid anticoagulation in this relatively young patient population, Sarsam and Yacoub[9] and David and Feindel[10] have described valve-preserving aortic root reconstruction techniques. Despite the fact that the valve cusps often appear functionally normal, there is evidence that they have abnormalities similar to those in the aortic wall tissue,[11–13] potentially limiting their durability. One of the objectives of this study was to evaluate whether or not the benefit of avoiding anticoagulation is offset by the need for reoperation. This study evaluated the long-term results of methods of aortic root reconstruction for the specific anatomic diagnosis of an aortic root aneurysm in the absence of type A dissection and/or aortic rupture.

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Methods

A retrospective review of our database identified patients who had undergone aortic root reconstruction for an aortic root aneurysm between January 1971 and December 2000. All patients with a type A dissection, acute or chronic, and with aortic rupture were excluded. Data were collected by chart review. Follow-up was obtained by chart review and a detailed questionnaire sent to surviving patients. Echocardiographic data were obtained for 158 (78%) patients at follow-up.

Two hundred three patients aged (mean±SD) 53±16 years (153 male, 50 female) underwent aortic root reconstruction: 149 patients underwent a composite valve conduit reconstruction (128 mechanical valve, 21 bioprosthetic valve), and 54 patients underwent valve-preserving aortic root reconstruction. Fifty patients had Marfan syndrome. Preoperative variables are detailed in Table 1.

Statistical Analysis

Postoperative survival and freedom-from-event curves were estimated by the Kaplan-Meier method. Overall survival was compared with the expected survival of persons of the same age and sex, as derived from vital statistics for the West North Central region of the United States (Figure 1). The statistical significance of observed versus expected survival was assessed with a 1-sample log-rank test. The associations of potential risk factors to survival were assessed with log-rank tests and a Cox proportional-hazards model. Patients undergoing composite valve conduit aortic root replacement and those undergoing valve-preserving aortic root reconstruction were compared with χ^2 tests for categorical variables and rank-sum tests for continuous variables. Data were expressed as mean±SD, and statistical significance was considered at $P<0.05$.

Results

Operative techniques have been well described in previous publications for the classic Bentall procedure,[4] the modified Bentall procedure,[8] the Yacoub remodeling valve-preserving aortic root reconstruction,[9] and the David reimplantation valve-preserving aortic root reconstruction.[10] Operative procedures performed are detailed in Table 2. Pathologic results were available for 149 patients and confirmed cystic medial necrosis in 131 patients, giant-cell aortitis in 9, and atherosclerotic changes in addition to aortic medial abnormalities in 9. Morbidity included 3 strokes (1%), 10 perioperative myocardial infarctions (5%), and 8 reoperations for bleeding (4%). Operative and perioperative data are delineated in Table 3. In-hospital and 30-day mortality was 4.0% (8/203). Early mortality was caused by a ventricular arrhythmia in 3 patients, septic shock in 1 patient, intraoperative bleeding in 1 patient, gastrointestinal bleeding in 1 patient, respiratory arrest in 1 patient, and acute heart failure in 1 patient. Of 35 late deaths, the cause was clearly cardiac in only 9 patients, 3 patients died secondary to coronary artery disease, 2 died of congestive heart failure, 2 died of a ruptured aneurysm elsewhere, 1 died of a ruptured false aneurysm at the distal anastomosis, and 1 died of cardiac arrhythmia. Follow-up data are detailed in Table 4. Actuarial survival at 5, 10, 15, and 20 years was 93% (95% confidence interval [CI] = 88% to 97%), 79% (95% CI = 71% to 87%), 68% (95% CI = 57% to 79%), and 52% (95% CI = 36% to 69%), respectively (Figure 1). There was no difference in late survival between those patients having a composite valve conduit reconstruction versus those having a valve-preserving operation (Figure 2).

Overall freedom from reoperation was 88% (95% CI = 83% to 93%), 86% (95% CI = 79% to 92%), 79% (95% CI = 69% to 89%), and 72% (95% CI = 54% to 86%) at 5, 10, 15, and 20 years, respectively. There was a significantly higher freedom from reoperation in patients undergoing composite valve conduit reconstruction compared with those undergoing a valve-preserving operation, 96% (95% CI = 92% to 100%) versus 63% (95% CI = 48% to 82%) at 5-year follow-up ($P<0.001$) (Figure 3). Of 30 reoperations in 26 patients (Table 4), only 3 were required secondary to complications of the initial operation. These patients required repair of an anastomotic pseudoaneurysm at 0.9, 15.2, and 15.3 years postoperatively. Eleven patients required aortic valve replacement; of these, 10 occurred after a valve-sparing procedure for progressive aortic regurgitation or aortic stenosis at a mean time to reoperation of 1.7±1.3 years. Ten operations were performed for aortic disease elsewhere, and these patients underwent reoperation at a mean time of 4.7±4.6 years. Of these, 7 had recurrent aneurysms (1 ascending aorta, 2 descending thoracic aorta, and 4 abdominal aorta). There were 3 dissections (2 descending thoracic aorta, 1 aortic arch and descending thoracic aorta). Six reoperations were performed for other cardiac problems at a mean time to reoperation of 9.8±5.6 years (4 mitral valve repair or replacement, 2 coronary artery bypass graft). Seven of the late deaths occurred in patients who required reoperation. Two were in-hospital deaths, 1 after pseudoaneurysm repair and 1 after repair of an aneurysm elsewhere in the aorta. The other 5 occurred 1, 2, 5, 5, and 16 years after the reoperation: 3 from unknown causes, 1 from a ruptured thoracic aneurysm, and 1 from left ventricular failure. All had received an initial composite valve conduit reconstruction.

Recent echocardiograms were available for 36 of 42 patients being followed up after a successful valve-preserving procedure. Mild or less aortic regurgitation was present in 32 (89%) and moderate in 4 (11%). Overall, freedom from thromboembolism was 97% (95% CI = 94% to 100%), 96% (95% CI = 91% to 99%), 91% (95% CI = 83% to 98%), and 91% (95% CI = 77% to 98%) at 5, 10, 15, and 20 years, respectively. Five strokes resulted in permanent deficit, but in 3 patients the effects were transient. Two patients died because of the stroke. For patients receiving a mechanical composite valve conduit versus those undergoing a valve-preserving aortic root reconstruction, there was no significant difference in freedom from thromboembolism at 5-year follow-up: 97% (95% CI = 93% to 100%) versus 97% (95% CI = 88% to 100%), respectively. Complications with chronic anticoagulation occurred in 29 patients receiving anticoagulation therapy (Coumadin) after mechanical valve conduit replacement. This included valve thrombosis in 2, life-threatening hemorrhage in 4, and minor hemorrhage in 23. The valve thromboses were successfully treated medically. Four patients died of cerebral hemorrhage. Freedom from a minor or major hemorrhagic complication was 73% (95% CI = 62% to 85%) at 15 years. Overall, freedom from endocarditis was 99% (95% CI = 95% to 100%) at 15-year follow-up. There were only 2 events. Both patients were successfully treated medically. One event occurred in each group. Univariate predictors for late death and need for reoperation are detailed in Table 6. Multivariate analysis revealed preoperative mitral valve regurgitation (+3 to 4) and older age to be significant predictors of late death ($P\leq0.05$)

TABLE 1. Preoperative Data

	Composite Reconstruction	Valve-Preserving Operation	*P*
Sex			
Male, n (%)	114 (77)	39 (72)	0.53
Female, n (%)	35 (23)	15 (28)	0.18
Age, y	54±16	51±15	
Marfan syndrome, n (%)	34 (23)	16 (30)	0.32
Previous surgery, n (%)	6 (4)	1 (2)	0.68
Preoperative symptoms			
Any symptoms, n (%)	105 (70)	29 (54)	0.03
Dyspnea	78 (52)	18 (33)	0.02
Chest pain	48 (32)	14 (26)	0.39
Palpitations	16 (11)	4 (7)	0.48
Presyncopy/syncopy	4 (3)	4 (7)	0.21
Back pain	4 (3)	2 (4)	0.66
Transient ischemic event	5 (3)	3 (6)	0.44
History of cardiac murmur, n (%)	74 (50)	29 (54)	0.51
History of cardiac dysrhythmia, n (%)	17 (11)	3 (6)	0.22
NYHA class, n (%)			
I	66 (44)	36 (67)	0.004
II	64 (43)	15 (28)	
III	15 (10)	2 (4)	
IV	1 (1)	0 (0)	
Systolic blood pressure, mm Hg	136±23	131±19	0.19
Diastolic blood pressure, mm Hg	65±13	75±16	0.0001
Heart rate, bpm	74±13	67±11	0.0004
Preoperative medications, n (%)			
β-Blocker	41 (28)	31 (57)	<0.0001
Calcium channel blocker	12 (8)	4 (7)	1.00
ACE inhibitor	34 (23)	14 (26)	0.65
Maximal aortic diameter, mm	60±17	52±13	<0.0001
Sinus of Valsalva dimension, mm	59±13	50±7	<0.0001
Sinotubular junction diameter, mm	58±15	44±10	<0.0001
Proximal ascending aorta diameter, mm	58±14	50±9	0.002
Aortic arch diameter, mm	39±16	34±6	0.39
Aortic regurgitation, n (%)			
None to trivial	6 (4)	11 (20)	<0.0001
Mild	10 (7)	14 (26)	
Moderate	41 (28)	13 (24)	
Severe	69 (46)	7 (13)	
Mitral regurgitation, n (%)			
None to trivial	79 (53)	28 (51)	0.97
Mild	37 (25)	16 (30)	
Moderate	7 (5)	1 (2)	
Severe	4 (3)	1 (2)	
Left ventricular hypertrophy (by ECG), n (%)	82 (55)	6 (11)	<0.0001
Left ventricular size			
End-diastolic diameter, mm	65±12	61±27	<0.0001
End-systolic diameter, mm	43±12	38±13	0.0009
Left ventricular ejection fraction	0.53±0.13	0.60±0.09	0.0002
Bicuspid aortic valve, n (%)	18 (12)	8 (15)	0.70
Mitral valve prolapse, n (%)	14 (9)	8 (15)	0.27

NYHA indicates New York Heart Association; bpm, beats per minute; and ACE, angiotensin-converting enzyme. Values are mean±SD, unless indicated otherwise.

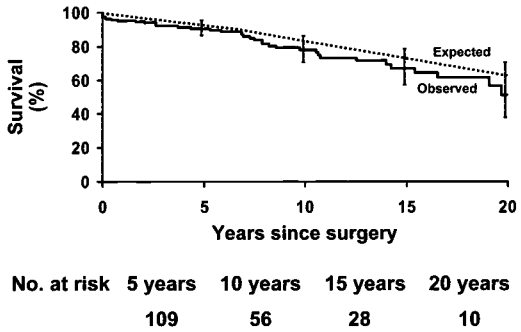


Figure 1. Observed late survival for all surviving patients compared with expected survival curve for general population. $P=0.18$.

(Table 5), and the presence of Marfan syndrome, initial valve-preserving aortic root reconstruction, and need for a concomitant procedure at initial operation to be significant predictors of the need for reoperation ($P \leq 0.05$) (Table 6).

Discussion

The objective of therapy for an aortic root aneurysm is to avoid the inevitable vascular catastrophe of aortic dissection and/or aortic rupture. Our study confirms a low early mortality rate in patients undergoing nonemergent operations. Similarly, Gott et al[14] have shown that elective aortic root reconstruction carries a significantly reduced morbidity and mortality compared with urgent or emergent interventions. In a multi-institutional study of 10 centers, 675 patients with Marfan syndrome underwent primarily composite graft aortic root reconstruction. Elective early mortality was 1.5%, urgent cases had a 2.6% mortality, and the mortality was 11.7% among those undergoing emergent procedures.

TABLE 2. Procedures Performed

Procedures	No. (%)
Elective operation	189 (94)
Urgent operation	12 (6)
Primary procedure performed	
Composite valve conduit reconstruction	142 (71)
Bentall	24
Modified Bentall	118
Mechanical composites	127
Bioprosthetic composites	14
Valve-preserving aortic root reconstruction	54 (27)
Aortic root reimplantation technique	46
Aortic root remodeling technique	8
Homograft aortic root reconstruction	7 (3.5)
Cabrol coronary modification	7 (3.5)
Associated procedures	32 (16)
Coronary artery bypass grafting	26 (13)
Mitral valve replacement	4 (2)
Mitral valve repair	4 (2)
Hypothermic circulatory arrest used	13 (7.5)

Values are mean±SD, unless indicated otherwise.

TABLE 3. Operative and Perioperative Data

	Composite Reconstruction	Valve Preserving	*P*
Aortic cross-clamp time, min	96±28	107±30	0.01
Cardiopulmonary bypass time, min	131±40	142±43	0.17
Intra-aortic balloon pump, n (%)	3 (2)	1 (2)	1.0
Inotropes, n (%)	36 (24)	7 (13)	0.08
Dopamine	34 (23)	7 (13)	0.12
Epinephrine	8 (5)	1 (2)	0.45
Postoperative arrhythmias, n (%)	46 (31)	14 (26)	0.49
Atrial fibrillation	42 (28)	14 (26)	0.75
Ventricular tachycardia	4 (3)	1 (2)	1.0
Transfusion requirement, n (%)	110 (74)	37 (67)	0.45
Complications, n (%)			
Reoperation for bleeding	6 (4)	2 (4)	1.0
Perioperative myocardial infarction	8 (5)	2 (4)	1.0
Low cardiac output syndrome	3 (2)	2 (4)	0.61
Permanent pacemaker insertion	4 (3)	0 (0)	0.58
Perioperative stroke	3 (2)	0 (0)	0.57
Permanent	1 (1%)	0 (0)	1.0
Transient	2 (1%)	0 (0)	1.0

Values are mean±SD, unless indicated otherwise.

Clearly, intervention before the onset of heart failure symptoms is advantageous. However, in a multivariate analysis, only the presence of moderately severe to severe mitral regurgitation was significant for decreased late survival. Other variables such as reduced ejection fraction, severity of aortic regurgitation, and increased left ventricular dimension were not found to predict late mortality. This is likely due to fact that the size of the aneurysm indicated the need for surgery before the onset of severe heart failure in the majority of patients. This is evidenced by the significant late left ventricular remodeling that occurred. Echocardiography at follow-up revealed left ventricular diastolic diameter to have decreased from 64±17 to 54±9 mm and systolic diameter from 43±13 to 37±9 mm ($P<0.05$), whereas ejection fraction stayed the same (55% to 56%).

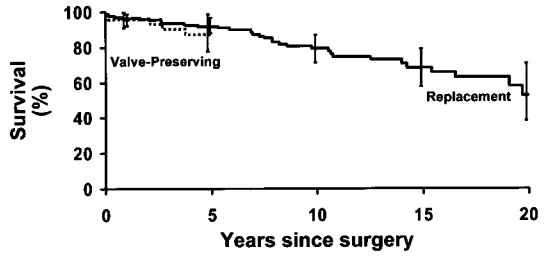
Composite valve conduit reconstruction resulted in a more durable result compared with the valve-preserving procedure. There were only 30 reoperations in 26 patients during the follow-up period. There were only 3 patients requiring a reoperation related to problems from a composite reconstruction. Two were related to aneurysms at the distal anastomosis, and 1 was related to an aneurysm that occurred at the proximal suture line. The majority of the composite valve conduit procedures in our series incorporated the modifications of the Bentall procedure. These were (1) using an open technique instead of the inclusion wrap technique and (2) using the Carrel button technique to reattach the coronary ostia, as introduced by Kouchoukos et al.[8] Savunen et al[15] reported a 3% early mortality in 100 patients undergoing a modified Bentall procedure with no anastomotic problems in the follow-up period. Ergin et al[16] reported a significantly reduced reoperative rate and better survival in patients un-

TABLE 4. Follow-Up Data

Mean follow-up, y	7.3±6.0
NYHA class (in-hospital and 30-day survivors), n (%)	
I	139 (71)
II	51 (26)
III	2 (1)
Left ventricular size, mm	
End-diastolic diameter	54±9
End-systolic diameter	37±9
Left ventricular ejection fraction	0.56±0.13
Mean aortic valve gradient, mm Hg	14±9
Proximal ascending aorta diameter, mm	33±6
Aortic arch diameter, mm	32±5
Late deaths, n (%)	35 (17.2)
Cardiac	9 (4.4)
Noncardiac	16 (7.9)
Unknown	10 (4.9)
Coumadin complication, n (%)	29 (14.0)
Valve thrombosis	2 (1)
Life-threatening hemorrhage	4 (2)
Minor hemorrhage	23 (11.0)
Thromboembolism, n (%)	8 (4)
Permanent	5 (2.5)
Transient	3 (1.5)
Mean time to thromboembolism, y	5.4±4.9
Late endocarditis, n (%)	2 (1)
Mean time to endocarditis event, y	0.9 and 1.9
Reoperation, n (%)	26 (13)*
Mean time to reoperation, y	4.5±5.0
Aortic valve replacement, n (%)	11 (5.5)
Recurrent aortic aneurysm, n (%)	7 (3.5)
Mitral valve repair or replacement, n (%)	4 (2)
Coronary artery bypass grafting, n (%)	2 (1)
Descending thoracic aorta dissection repair, n (%)	3 (1.5)
Pseudoaneurysm repair, n (%)	3 (1.5)

Values are mean±SD, unless indicated otherwise. NYHA indicates New York Heart Association.

*Thirty total procedures.

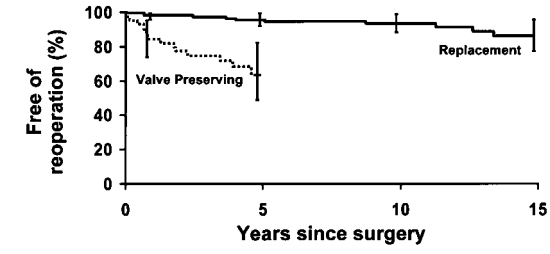


No. at risk	5 years	10 years	15 years	20 years
Replacement	93	56	28	10
Valve Preserving	16	0	0	0

Figure 2. Late survival for surviving patients, comparing patients undergoing composite graft reconstruction with those undergoing valve-preservation procedure. $P=0.56$.

dergoing the "button Bentall" procedure. Lewis et al[6] reported that only 9 of 241 patients required reoperation for problems related to the initial composite graft reconstruction procedure. Svensson et al[17] had no reoperations in 67 patients at intermediate-term follow-up. Savunen and Aho[2] performed angiography on 53 of 60 patients 3 years postoperatively after composite graft reconstruction. They found no pseudoaneurysms or coronary problems. Neiderhauser et al[18] observed only 7 reoperations in 181 patients related to the original composite graft. Other predictors of the need for reoperation in this series were Marfan syndrome and the need for concomitant procedures at the initial operation. The significance of these variables was related the predisposition of these patients to need mitral valve, coronary, and other aortic surgical procedures in the follow-up period. This study underscores that ongoing surveillance is necessary to avoid other cardiac problems unrelated to the initial aortic root surgery.

The 10 reoperations for aortic valve replacement occurring at a mean time of 1.7±1.3 years postoperatively after the performance of a valve-preserving procedure is a cause for concern. The higher reoperative rate in the valve-preserved group contrasts with data from other large series. However, we tend to reoperate early when a patient returns with recurrent regurgitation. No patients in our series being followed up after a valve-preserving procedure continued with >2+ regurgitation. Yacoub et al[20] reported that the probability of reoperation was 11% at 10 years in a series of 158 patients undergoing an aortic root remodeling technique; one third of patients had mild to moderate regurgitation and 3% had severe regurgitation at follow-up. David et al[21] have reported on 151 patients undergoing valve-preserving reconstruction. They reported that freedom from aortic valve replacement was 99±1% at 8 years for the reimplantation technique and 97±2% at 8 years for the remodeling technique. However, the freedom from significant aortic insufficiency (> 2+) at 8 years for the reimplantation technique was 90±3%, and for the remodeling technique it was 55±6%. Progressive annular dilation can result in recurrent aortic insufficiency. The fixed annulus has been suggested to be the



No. at risk	5 years	10 years	15 years
Replacement	88	52	25
Valve Preserving	11	0	0

Figure 3. Freedom from reoperation among late survivors, comparing patients undergoing composite graft reconstruction with those undergoing valve-preservation procedure. $P<0.001$.

TABLE 5. Predictors of Late Death

	Univariate *P*	Multivariate *P*	Hazard Ratio
Female sex	0.03	...	
Increasing age	0.0002	0.006	1.06 (1.02, 1.09)
Untreated with β-blocker at presentation	0.01	...	
Mitral regurgitation, +3–4 at presentation	0.005	0.02	3.61 (1.2, 10.9)
Mitral valve annular calcification	0.005	...	
Need for concomitant procedures	0.006	...	
Postoperative dysrhythmia	0.05	...	
Inotropes required postoperatively	0.02	...	

Values in parentheses are 95% confidence limits.

reason for the lower reoperation rate when reimplantation was performed compared with the remodeling technique.[20–24] However, of the 10 patients requiring reoperation in our valve-preserving group, 9 had a previous reimplantation procedure, and only 1 had a remodeling procedure. This points to a different mechanism of failure in this series.

Technique and judgment certainly play a significant role in proper aortic root reconstruction. In retrospect, we identified several failure modes. Two of our reoperations were for stenotic preserved bicuspid valves, likely due to crowding of the cusps with progressive stenosis of the reduced valve orifice. The closeness of the Dacron tube to the cusps can result in trauma to the cusps when they open, thus hitting the tube graft. We have previously reported 1 case from this series who presented with a macerated, torn cusp 1.5 years after a reimplantation procedure.[25] Three patients in this series required a reoperation for a torn cusp, presumably from this mechanism. These cases emphasize the importance of proper sizing of the Dacron tube graft. We most often use a 26-mm (13/54), 28-mm (19/54), or 30-mm (15/54) Dacron tube. This is chosen to best recreate the sinotubular junction's approximate 1:1 relation to the valve cusp's free margin and annulus diameter. There have been several modifications of both the remodeling and reimplantation techniques to create neosinuses and reduce cusp trauma. This evolution has been detailed in a review by Miller.[26] The importance of these efforts has yet to be proved. We have also previously shown that when surgical manipulation on an individual cusp or cusps was required to achieve good coaptation, the operation was more prone to fail.[27] An additional 2 patients underwent reoperation because of a previously manipulated prolapsing cusp at the original valve-preserving operation.

Progressive valvular prolapse of all 3 cusps resulting in severe central aortic regurgitation occurred in 3 patients with Marfan syndrome. The wisdom of preserving the valve in some of these patients is debatable. Although the aortic valve cusps often appear relatively normal, structurally this may not be true. Missirlis et al[11] showed that the compliance of the aortic cusp in a Marfan syndrome patient was an order of magnitude greater than that of the normal aortic valve cusp. It has been shown that abnormal fibrillin metabolism affects valve tissue in patients with bona fide connective-tissue disorders. Fleischer et al[13] showed that the aortic valve cusps and mitral valve leaflets in Marfan syndrome patients were equally effected by fibrillin-1 fragmentation compared with the aortic wall. These changes were most severe in patients >20 years of age. There are also histologic and biochemical data that suggest that the medial abnormalities of the aortic wall and elastin abnormalities of the aortic wall are no different between those with an aortic root aneurysm without phenotypic characteristics of a connective-tissue disorder compared with those with a connective tissue disorder.[2,3] De Oliveira et al[24] reported on 61 Marfan syndrome patients undergoing a valve-preserving reconstruction compared with 44 patient having a composite reconstruction. Freedom from reoperation at 10 years was 100% in the valve-preserved group. However, 25% of patients had >2+ aortic insufficiency in the valve-preserved group. A recently presented series[28] reported on 121 Marfan syndrome patients undergoing either composite graft aortic root replacement (n=76) or a valve-preserving procedure (n=45). There was no difference in survival. However, there was a definite trend toward the need for reoperation in patients undergoing a valve-preserving aortic root reconstruction (84%) versus composite graft replacement (95%), though not significant.

TABLE 6. Predictors of Need for Reoperation

	Univariate *P*	Multivariate *P*	Hazard Ratio
Marfan syndrome	0.02	0.02	2.65 (1.18, 5.93)
Mitral valve prolapse	0.0002	...	...
Preoperative atrial fibrillation	0.03	...	...
Aortic valve-preserving operation performed	<0.0001	<0.0001	13.3 (4.67, 37.9)
Concomitant procedure performed	0.03	<0.0001	8.03 (2.88, 22.4)

Values in parentheses are 95% confidence limits.

In our series, valve-preserving procedures were performed in patients with smaller aneurysms and less aortic regurgitation. The Toronto group[24] also observed that most aortic valve cusps appeared normal when the aneurysm was <5 cm. Only 50% appeared normal when the aneurysm was between 5 and 6 cm. In patients with aneurysms >6 cm, most aortic cusps were abnormal, and a composite graft reconstruction was more likely performed.

Annulus size is also important. A previous study from our institution has shown that an annulus size >25 mm before reconstruction is a significant predictor of the need for reoperation.[27] Casselman et al[29] reported an annulus size of 27 mm to be predictive of repair failure in routine repair of the bicuspid aortic valve. Again, failure in this subset of patients may occur because of higher stress on the cusp edges associated with a longer free edge. We observed relatively few long-term problems related to placement of mechanical valve conduits and from long-term anticoagulation therapy in these patients. Eight patients (4%) suffered thromboembolic events during the follow-up period. Only 5 were permanent, and only 2 resulted in death. One permanent event occurred in a patient after a valve-preserving procedure. Our low event rate is similar to that observed by Gott et al.[30] Only 4 patients of 256 hospital survivors suffered from a clinically significant thromboembolism. This corresponds to a rate of 0.42/100 patient-years of follow-up. In contrast, Kouchoukos et al[8] reported that freedom from thromboembolism was 82% at 12 years in his 168 patients who underwent composite valve conduit replacement. The differences in stroke rates are likely due to the lack of patients with atherosclerotic aneurysms in our series and that of Gott et al.[30] In our series, 2 patients (1%) suffered valve thrombosis; both did not require reoperation. Twenty-seven patients (13%) suffered hemorrhage related to Coumadin, but only 4 resulted in death from cerebral hemorrhage. The incidence of endocarditis was very low in this patient population. There was only 1 incident in each group. The main reason to perform a valve-preserving procedure is to avoid the deleterious effects of Coumadin therapy and the risk of stroke and endocarditis associated with a mechanical valve. This study presents data that these risks may be overplayed in this population.

A limitation of this study is the shorter length of follow-up for the patients undergoing a valve-preserving procedure. However, it is precisely these patients who are at risk of reoperation because of progressive aortic insufficiency. Longer follow-up will presumably add more reoperations to this group. In addition, the longer follow-up of those patients on anticoagulants emphasizes complications related to anticoagulation.

Our study underscores the success of the Bentall and modified Bentall procedures for aortic root reconstruction in patients with an aortic root aneurysm. Elective intervention affords acceptable life expectancy. The late cardiac deaths were infrequently related to the initial operation. Complications related to chronic anticoagulation were acceptably low. Reoperation was heavily influenced by other cardiac disease, the predisposition to form aneurysms elsewhere, and the performance of an initial valve-preserving operation. The valve-preserving procedure should be reserved for patients with near-normal valve cusps who wish to avoid anticoagulation for quality of life issues or other contraindications. That procedure is difficult to justify in patient subsets that have been shown to have high rates of failure.

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