Ascending Aortic Replacement With Aortic Valve Reimplantation

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Background—Reimplantation of the native, structurally intact aortic valve within a Dacron tube graft in patients with aortic root aneurysms corrects annular ectasia and dilatation of the sinotubular junction. The durability of this valve repair with respect to the increased mechanical stress on valve cusps has been discussed, is quite controversial, and is yet unknown.

Methods and Results—From July 1993 to November 1998, a replacement of the ascending aorta with a repair of the aortic valve was performed in 75 patients (53 men and 22 women aged 50 ± 19 years). Twenty-one patients (28%) had Marfan syndrome, and 11 patients (15%) had an aortic dissection, type Stanford A (6 acute, 5 chronic). In 17 patients (23%), concomitant replacement of the aortic arch was necessary. Clinical and echocardiographic follow-up was performed in 6- to 12-month intervals for a cumulative study period of 137 patient-years. No operative deaths occurred. Two patients (3%) died 5 and 20 months postoperatively. One additional patient experienced a transient ischemic attack within the first postoperative week. Three patients (4%) with progressive aortic insufficiency required aortic valve replacement after 9, 11, and 14 months. All other patients had no or mild aortic insufficiency. The repairs have now remained stable for ≤ 65 months (mean, 22 ± 20 months). Other valve-related complications did not occur.

Conclusions—Our results demonstrate that this type of aortic valve repair achieves excellent results in selected patients. Perfect coaptation of valve cusps during the repair with no or only trace aortic insufficiency at initial echocardiography seems to be essential for durability. (Circulation. 1999;100[suppl II]:II-24–II-28.)

Key Words: aorta ■ aneurysm ■ valves ■ regurgitation ■ prosthesis

Aneurysms of the proximal ascending aorta represent a rare but potentially life-threatening disease. Major complications of the aneurysmatic aorta include acute dissection, rupture, and aortic valve incompetence. Despite structurally intact aortic valve cusps, severe secondary aortic regurgitation can occur in these patients. Dilatation of the sinotubular junction and/or annular ectasia result in distention of the aortic valve, with reduction of cusp coaptation, which leads to central aortic insufficiency (AI) (Figure 1). In the majority of patients, annuloaortic ectasia is the underlying disease. This is thought to be caused by a diffuse, degenerative process of connective tissue involving the media of the aortic wall, especially in Marfan syndrome or its forme fruste.

Standard surgical therapy for patients reaching a critical aortic diameter or who have hemodynamically relevant aortic incompetence is the replacement of the ascending aorta and aortic valve with a valved conduit. Reported results demonstrate that this technique achieves excellent results, with low patient morbidity and mortality. Thromboembolic- and anticoagulant-related complications of the mechanical valve prosthesis represent a potential disadvantage in long-term patient outcome. Contrary to results of mitral valve reconstruction, aortic valve repair has led to insufficient results in the past due to high mechanical stress on the aortic valve, a relatively small cusp coaptation area, and lack of aortic root stabilization. Valvular incompetence resulting from distention of the aortic root, with normal valve cusps, probably represents the ideal circumstance for aortic valve repair. Various techniques have been reported in these patients for the replacement of the aneurysmatic aorta, with preservation of the valve and correction of AI. Since 1993, we have used the technique reported by David et al almost exclusively; this involves reimplantation of the aortic valve within a Dacron prosthesis. The aim of this report is to summarize our experience with this technique over a 5-year period.

Methods

Between July 1993 and November 1998, 75 patients (53 men and 22 women; mean age, 50 ± 19 years; range, 9 to 78 years) underwent aortic root replacement with preservation of the aortic valve. All patients had an aneurysm of the ascending aorta that included the aortic root (mean diameter, 6.2 ± 1.4 cm; range, 4.5 to 10 cm). For systematic purposes, a descriptive classification of the causes of ascending aortic aneurysms was chosen; this is presented in Table 1.

In 17 patients (23%), an extension of the aneurysm into the aortic arch was present, which required surgery. Two patients had a
re-placement of the aortic arch, and in 4 patients, the elephant trunk technique was used. Eight patients required additional coronary artery revascularization, 3 patients underwent mitral valve repair due to leaflet prolapse, and 1 patient required correction of a chest-wall deformity (pectus carinatum) as a concomitant procedure. One patient suffered from acute dissection of the donor aorta 2 weeks after orthotopic heart transplantation. He underwent replacement of the ascending aorta with valve reimplantation using a nonvalved, cryopreserved, aortic homograft. Clinical characteristics of Marfan syndrome were present in 21 patients (28%). Our standard indications for this operation are shown in Table 2. In our more recent patients, we have liberalized the criteria for valve preservation to include patients who have aortic root diameters >4 cm with severe valve insufficiency (n=2) and/or structurally normal bicuspid valves (n=1).

Coronary angiography, aortic root angiograms, transthoracic echocardiography, and computed tomography scans or magnetic resonance images were routinely performed diagnostic procedures. The final decision to preserve the aortic valve was made intraoperatively after inspection of the valve cusps and root geometry.

Surgical Technique
Standard median sternotomy and extracorporeal circulation techniques were used in all patients. Myocardial protection was performed with repetitive doses of cold blood cardioplegia in an antegrade and retrograde fashion. After aortotomy and aortic valve and root inspection, the decision regarding valve reconstruction was made. The excision of the coronary ostia and resection of aortic sinuses up to a remnant of 2 to 3 mm, as well as extensive external dissection and mobilization of the aortic root, were then performed. Prosthesis diameters were calculated from the diameter of the left ventricular outflow tract and the height of the aortic cusps. Ideal valve coaptation was considered to occur when 30% to 50% of the cusp area was involved. The mean diameter of prostheses was 27±1.2 mm (24 mm, n=5; 26 mm, n=31; and 28 mm, n=39).

Proximal anastomosis was performed with 14 to 18 threads of 3-0 coated polyester fiber (Ethibond, Ethicon Inc) used as horizontal mattress sutures placed through the annulus underneath the valve. The aortic cuff, including the commissures, was then reimplemented into the Dacron prosthesis with three 4-0 polypropylene sutures (Prolene, Ethicon Inc) using the running technique. Utmost care was taken to achieve correct cusp geometry, sufficient height of commissural resuspension within the prosthesis, and adequate coaptation area. Anastomoses of the coronary ostia with the button technique completed the aortic root reconstruction. In cases with more extensive ascending aortic or arch replacements, a second prosthesis was used.

Follow-Up
Routine intraoperative control of aortic valve function was determined with transesophageal echocardiography. All patients received either acetylsalicylic acid or warfarin for 2 months postoperatively. Antiplatelet therapy was continued in all 8 patients who had concomitant coronary artery bypass surgery. No patient required continuation of warfarin therapy for atrial fibrillation. Follow-up was performed clinically with transthoracic color Doppler echocardiography after 3, 6, and 12 months, and at yearly intervals thereafter. Valve morphology and systolic and diastolic function were assessed in accordance with published criteria. Aortic regurgitation was assessed semiquantitatively as follows: 0, none; I, minimal; II, mild; III, moderate; and IV, severe. Infectious, thromboembolic, and bleeding complications were recorded as required by the guidelines of the American Association for Thoracic Surgery/Society of Thoracic Surgeons. The cumulative follow-up period was 1645 months (137 patient-years), with a minimum of 1 month and a maximum of 65 months (mean, 22±20 months).

In a subgroup of 40 patients (28 men; mean age, 45±19 years; 15 had Marfan syndrome) who had a follow-up of ≥1 year or until reoperation, the risk for early valve regurgitation (AI>II) was determined using the morphology of the reimplanted valve. For this purpose, cusp coaptation area in relation to the lower edge of the Dacron prosthesis was graded prospectively by 2 different cardiologists using transthoracic echocardiography before hospital discharge (Figure 2). Aortic regurgitation was documented at hospital discharge and at 1 year postoperatively or immediately before reoperation.

Statistical Analysis
Continuous variables are expressed as mean±1SD, and actuarial data are reported as mean probability estimates. The statistical significance of differences in AI between preoperative and postoperative echocardiograms was tested using paired Student’s t tests. Differences in AI between groups were evaluated with ANOVA and the Bonferroni t test. P<0.05 was considered significant.

Results
In all 75 patients, the aortic valve was successfully preserved. No patient died within 30 days of the operation or in the

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**TABLE 1. Causes of Ascending Aortic Disease**

<table>
<thead>
<tr>
<th>Category</th>
<th>n (%)</th>
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<tbody>
<tr>
<td>Degenerative tissue disease (bulbus aneurysm)</td>
<td>45 (60)</td>
</tr>
<tr>
<td>Atherosclerotic disease (tubular aneurysm)</td>
<td>16 (21)</td>
</tr>
<tr>
<td>AADA (1× after oHTx)</td>
<td>6 (8)</td>
</tr>
<tr>
<td>CADA</td>
<td>5 (7)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Inflammatory</td>
<td>1</td>
</tr>
<tr>
<td>Bicuspid valve</td>
<td>1</td>
</tr>
<tr>
<td>Tetralogy of Fallot (25 years after surgical correction)</td>
<td>1</td>
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AADA indicates acute aortic dissection, Stanford type A; CADA, chronic aortic dissection, Stanford type A; and oHTx, orthotopic heart transplantation.

**TABLE 2. Indications for Aortic Valve Reimplantation**

<table>
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<th>Indication</th>
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<tr>
<td>Aneurysm of ascending aorta or aortic root (&gt;5–6 cm)</td>
</tr>
<tr>
<td>Tricuspid valve without gross structural defect</td>
</tr>
<tr>
<td>Absence of severe cusp prolapse or asymmetry</td>
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hospital. Intraoperative variables are presented in Table 3. In 17 patients (23%), concomitant partial or total aortic arch replacement was necessary; the elephant trunk technique was used in 4 patients. Hypothermic circulatory arrest times ranged from 7 to 43 minutes (mean, 22 \pm 10 minutes).

Perioperatively, 1 patient suffered from a transient ischemic attack (which resolved completely), and 3 patients required rethoracotomies due to bleeding. Neither arrhythmia nor thromboembolism was seen during follow-up. Aortic valve incompetence was reduced significantly, from grade 2.5 \pm 0.9 preoperatively to 0.3 \pm 0.5 postoperatively (P < 0.01). The mean postoperative pressure gradient was 6 \pm 3 mm Hg, and it remained unchanged throughout the study period. Aortic valve function remained stable during follow-up in the majority of patients (n = 68) with either no (n = 49) or minimal (n = 19) aortic valve incompetence (Figure 3). Four patients developed progressive AI during the first postoperative year; they are now stable at grade II, with no further deterioration or increase in left ventricular dimensions. Two of these patients had Marfan syndrome. Three additional patients had reoperations 9, 11, and 14 months postoperatively due to worsening AI (grade III). At reoperation, cusp prolapse due to inadequate technique could be identified in 2 patients; inflammatory cusp lesions were found in 1 patient with Wegener granulomatosis, renal insufficiency, and hemodialysis. All 3 patients demonstrated less than optimal cusp coaptation with aortic regurgitation >grade I in the early postoperative period. At reoperation, valve replacement was performed within the Dacron prosthesis, without difficulty, by using 23-mm mechanical prostheses. All patients recovered promptly from the second operation.

Two patients, both 76 years old, died during follow-up. One woman with ischemic heart disease died at home from sudden cardiac death 20 months postoperatively. The other patient suffered from bacterial mitral valve endocarditis 5 months after the operation. Intraoperatively, an abscess was

found at the base of the anterior mitral leaflet, with a perforation between the left atrium and left ventricle; the abscess reached the aortic prosthesis in the coronary sinus. The aortic valve repair was intact, but a small perforation in the middle of the anterior cusp was found. He died of septic shock 3 days after mitral valve replacement using pericardial patch reconstruction of the left atrium and implantation of a valved conduit.

Actuarial survival and freedom from reoperation were 98.5% and 95%, respectively, at 1 year. Both were 95% and 93% at 2 and 5 years, respectively (Figure 4).

Analysis of early repair failure (AI II) at 1 year postoperatively demonstrated a significant increase in aortic valve insufficiency on echocardiography for patients with an initial type C repair (Figure 5). All patients who either required reoperation or had a current AI II were classified as having a type C repair immediately postoperatively.

**Discussion**

Surgery for aortic root aneurysms is routinely performed using a valved conduit. Complications of mechanical prostheses represent the greatest disadvantage of this technique, especially in young patients. Despite initial high expectations for biological valve replacements (ie, xenografts and homografts), structural degeneration significantly limits their long-term performance.\(^1\)\(^,\)\(^1\)\(^,\)\(^4\) Thus, preservation of the patient’s own aortic valve has clear advantages; this has been done with encouraging results in patients with aortic root

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**Table 3. Intraoperative Data**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
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<tr>
<td>Bypass time, min</td>
<td>155 ± 32 (102–252)</td>
</tr>
<tr>
<td>X-clamp time, min</td>
<td>121 ± 24 (80–203)</td>
</tr>
<tr>
<td>Circulatory arrest, min</td>
<td>22 ± 10 (7–43)</td>
</tr>
<tr>
<td>Annular diameter, mm</td>
<td>27 ± 2</td>
</tr>
<tr>
<td>Diameter of ascending aorta, mm</td>
<td>65 ± 9</td>
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Values are mean ± SD (range).
aneurysms. Of 75 patients who were operated on at our institution between 1993 and 1998, 72 had excellent function of their native, reimplanted valve for ≤5 years. In 4 patients, moderate regurgitation occurred, without hemodynamic relevance. Three other patients required reoperation for progressive valvular insufficiency.

Detailed intraoperative analysis demonstrated that resuspension of the commissures was too low in 2 patients, which led to cuspal prolapse. One patient who had inflammatory disease (morbus Wegener) had thickened and shrunken leaflets, with histological evidence of inflammatory changes in valve cusps. None of the reoperated patients had any evidence of cuspal degeneration, which could result from contact with the graft or unphysiological biomechanical stress. Additionally, echocardiographic follow-up demonstrated no degenerative changes in cusps (ie, calcification, cusp perforation, or cusp thickening), which could be attributed to the above mechanisms. Modification of the surgical technique and exclusion of patients with inflammatory disease have eliminated the need for reoperation in the past 3 years. All patients demonstrated a type A or B repair in the early postoperative period. Analysis of echocardiographic morphology after valve reimplantation in our patients demonstrated the importance of proper placement of the valve inside the prosthesis.

Aggressive dissection of the aortic root and adequate height of resuspension seem to be critical technical factors. We currently dissect the aortic root as completely as possible down to the fibrous skeleton of the valve. This is sometimes difficult at the base of the right coronary sinus, where the muscle of the right ventricle has to be mobilized to seat the valve deep inside the prosthesis. Furthermore, we do not stretch the prosthesis to resuspend the commissures, which are pulled up as high as possible; we carefully assess the coaptation area of the cusps to determine if they are adequate (30% to 50% of cusp area). Thromboembolic and bleeding complications after the perioperative period were not observed. These results confirm our own early experience and the results of other published reports.15–17 Low perioperative morbidity and mortality as well as stable function of the reconstruction during the observation period should be noted in our series.

In addition to the aortic valve preservation technique used in our patients, an alternative surgical strategy to correct the sinotubular junction in such patients has been reported by Sarsam and Yacoub.18 Instead of resuspending the aortic valve within a prosthesis, their technique resects the aortic sinus and remodels the sinotubular junction. This minimizes the risk of cusp contact with the prosthetic wall and potentially preserves the dynamic function of the aortic root better than our technique. The reasons we continue to use David et al’s4 original technique are as follows: the more radical support of the diseased aortic wall, routine annular stabilization, and lesser risk for suture line leakage. Long-term results will be required for a final judgment between the 2 procedures. Thus far, we have not observed any morphological or functional degeneration of aortic valve cusps, and we have seen excellent hemodynamics. Despite these favorable initial results with valve-preserving aortic-root replacement, specific questions remain in the management of patients with Marfan syndrome.

Increasing diameters of the ascending aorta carry an elevated risk for acute aortic dissection. Elective replacement of the aortic root and ascending aorta with a valved conduit significantly improved survival in patients with Marfan syndrome.19 It is unknown to what extent the structural fibrillin-1 defect (resulting from a mutation of the fibrillin gene locus on chromosome 15) can affect the stability and durability of valve reconstruction. Recently published data confirm fibrillin fragmentation and deficiency in the aortic cusps of patients with Marfan syndrome and significant valve deterioration in patients with advanced disease.20 This contrasts with the intraoperative aspect in early disease stages and with the excellent results of valve preservation in this patient group.21 Furthermore, the risk of dissection in other aortic areas, with the need for a second or third operation, makes patient management more difficult when continuous anticoagulation is necessary. Considering these aspects, we favor this valve-preserving operation in patients with Marfan syndrome who have normal valve cusps.

A significant limitation of our technique is the short observation period of our study. The longest follow-up in our patients is 5 years; results from >9 years exist in the Toronto group.9 Yet, significant degeneration in biological valves usually occurs after 10 years. Particularly with our technique, it is still unknown whether the more rigid aortic root can lead to abnormal cuspal stress and, ultimately, to early valve degeneration. Preservation of a viable valve with an ongoing cellular repair process might delay this process considerably. Therefore, continuing critical evaluation of this technique, with carefully documented patient follow-up, is necessary to allow further judgment of the risks and benefits for patients undergoing aortic root surgery. Whether it is safe to use this technique in patients with bicuspid valves and thin and pliable leaflets is yet unknown. In our opinion, selected patients most likely could benefit from this procedure if excellent initial coaptation of cusps can be achieved.

Conclusions
Our results demonstrate that valve-preserving aortic root surgery using this innovative technique represents a true...
alternative to composite graft implantation. Low perioperative morbidity and mortality, lack of anticoagulation, and excellent hemodynamics encourage further use of this repair. However, a final judgment on the long-term durability of this surgical technique will require further studies.

References