Decade of Aortic Valve Sparing Reimplantation
Are We Pushing the Limits Too Far?

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Background—This single center study assesses the outcome of aortic valve sparing reimplantation (AVS) in 284 consecutive patients who were operated on for various indications during the last 11 years.

Methods and Results—From July, 1993, to July, 2004, 284 patients underwent AVS. Mean age was 53±16 (range 8 to 84) years. Of the 284 patients, 184 were male (64.8%) and 54 (19%) experienced Marfan’s syndrome. Acute aortic dissection Stanford type A was present in 53 patients (19%) and a bicuspid aortic valve was present in 17 patients (6%). Concomitant arch replacement was necessary in 120 patients (42%). Additional procedures were performed in 66 patients (23.2%). Mean follow-up time was 41±32 (range 0 to 130) months. The 30-day mortality was 3.2% overall, 11.3% in emergency patients, and 1.3% in elective patients. Mean bypass time was 174±48 (range 90 to 440) minutes and aortic cross clamp time was 132±33 (range 64 to 283) minutes. In patients undergoing arch replacement, circulatory arrest was 25±17 (range 7 to 99) minutes. Rethoracotomy for bleeding was required in 4.6% of patients. During follow-up, there were 20 (7.3%) late deaths. Reoperation of the reconstructed valve was required in 15 patients (5.3%); underlying reasons were endocarditis (n=4) and aortic insufficiency (n=11) requiring aortic valve replacement. Average grade of aortic insufficiency increased significantly from 0.23±0.46 postoperatively to 0.34±0.59 at latest evaluation (P=0.026). Two patients experienced a transient ischemic attack early postoperatively; no further thromboembolic complications were noticed. The majority of patients (96%) presented with a favorable exercise tolerance at last contact.

Conclusions—The aortic valve reimplantation technique leads to excellent clinical outcome in patients with various pathologies. Lack of anticoagulation and favorable durability should encourage the extension of indications for this technique. (Circulation. 2005;112[suppl 1]:I-253–I-259.)

Key Words: aorta ■ surgery ■ valves

The aortic valve-sparing reimplantation technique, first described by David and Feindel more than a decade ago, was originally developed as an aortic valve-sparing operation for patients with aortic valve incompetence and aneurysm of the ascending aorta. Indication for this technique has been an aneurysm of the aortic root or the ascending aorta causing aortic insufficiency by outward displacement of the commissures, a tricuspid aortic valve without gross structural defects, and absence of severe cusp prolapse or asymmetry. For selected patients presenting with this entity, the reimplantation technique gained wide acceptance as an aortic valve-sparing technique that partially replaced the gold standard approach of implantation of a mechanical valved aortic composite graft, with the drawback of lifelong anticoagulation with coumadin. Excellent clinical outcome and favorable mid-term valvular stability have been achieved with the reimplantation technique. We and others, however, have expanded the indications for the reimplantation technique to bicuspid valves, aortic valves with significant cusp prolapse, Marfan’s syndrome with a root diameter above 4 cm with a family history of acute aortic dissection, complex aortic pathologies, reoperation, presentation in emergency situation with acute aortic dissection type A; we have also expanded it to be applicable to younger or older patients. Freedom from the need for lifelong anticoagulation is the proposed benefit of this technique, and this advantage led to expansion of indications away from the original concept of morphological intact cusps. A major drawback, however, might be the increased risk of aortic valve reoperation due to limited durability of the reconstructed valve. Little is known regarding whether the application of the reimplantation technique for wider indications will negatively influence clinical outcome and valvular durability. Today, large patient series and long-term results of the reimplantation method are still limited. Thus, the aim of this study was to assess the outcome of the aortic valve-sparing reimplantation technique in 284 consecutive patients operated on for various indications at a single center during the last 11 years.
Surgical Technique
In elective patients, standard median sternotomy and extracorporeal circulation with cannulation of the aorta and the right atrium, as well as standard myocardial protection techniques, were used. For unstable patients with acute aortic dissection type A and pericardial effusion, the left femoral artery was dissected for arterial cannulation before median sternotomy and pericardioectomy. In stable situations without low cardiac output or relevant pericardial effusion, the left femoral artery was dissected for arterial cannulation without low cardiac output or relevant pericardial perfusion and in more recent times (for the last 4 years), cannulation of the ascending aorta and the right atrium for extracorporeal circulation was undertaken.

In all 284 patients, we exclusively used the original aortic valve-sparing reimplantation technique described by David and Feindel,7 also called “David I.” The operative technique used for this procedure was recently described by our group.7 After assessing the suitability of valve reconstruction, excision of the coronary ostia and resection of aortic sinuses up to a rim of 2 to 3 mm of aortic wall, as well as extensive external dissection and mobilization of the aortic root, were performed. The diameter of the prosthesis was calculated from the diameter of the left ventricular outflow tract and the height of the aortic cusps. Practically and instead of direct measurement, the annulus was sized with a Hegar dilator. The free commissures were lifted by suture lines and brought together, thus creating a triangle that allowed cusps resuspension. When optimal geometry was archived, the diameter of the sinotubular junction was measured by insertion of a valve sizer (St. Jude Medical) in between the commissures. The diameter of the sinotubular junction determined the diameter of the graft, with an additional oversizing of 1 to 2 mm.

Figure 1. Intraoperative photography of a reimplanted aortic valve. Coronary button reinsertion is not completed.
Overall early (30-day) mortality was 3.1%. None of the deaths were related to the reconstructed valve. In elective patients, early mortality rate was 1.3% (3 patients). Of those, 1 patient with chronic aortic dissection type B required complex additional surgery with repeat coronary artery bypass grafting, mitral valve replacement, and aortic arch replacement with elephant trunk extension. She died because of myocardial failure 3 days after the operation. Another patient received additional arch replacement and elephant trunk extension without any intraoperative complication. He died from sudden cardiac death in the referring hospital 17 days after the operation. A third patient received additional coronary artery bypass grafting because of diffuse coronary artery disease. After an initially uneventful operation, he died of an acute myocardial infarction on the first postoperative day. The mortality rate for emergency patients presenting with acute aortic dissection type A was 11.3% (6 patients). Reasons for early mortality were myocardial failure, cerebral ischemia, multiorgan failure, sepsis, and abdominal ischemia due to malperfusion.

During the first 30 days, 2 patients required reoperation on the reconstructed aortic valve. A 39-year-old female patient with Marfan’s syndrome received a 24-mm prosthesis in an uneventful operation; intraoperative transesophageal echocardiography revealed complete aortic valve competence after reimplantation. During hospitalization, however, she developed progressive aortic insufficiency. On postoperative day 20, she was taken to the operating room for composite replacement. Further recovery was uneventful. Intraoperatively, cusps as well as geometry were intact. The reason for valve failure remained unclear. Another female Marfan patient, 36 years old, experienced postoperative biventricular dysfunction for unknown reason. Aortic valve incompetence and myocardial infarction were ruled out. She underwent orthotopic heart transplantation 4 weeks after the David I procedure. Unfortunately, intraoperative graft failure led to implantation of a biventricular assist device. She died 4 weeks later because of multiorgan failure.

The overall rate for rethoracotomy due to postoperative bleeding was low (4.6%). Within the first postoperative week, 2 patients experienced a transient ischemic attack without residuals. Early mortality rates, perioperative complications, length of stay in the ICU, and length of hospitalization are listed in Table 3.

### Results

**Perioperative Results**

In all 284 patients, the aortic valve was successfully preserved. Mean aortic cross clamp time was above 2 hours and the average time of extracorporeal circulation was almost 3 hours. Operative times were substantially influenced by the nature of the additional procedures; if only the reimplantation procedure was conducted, aortic cross clamp times of less than 90 minutes were normal. In the majority of patients (58%), a 28-mm Dacron prosthesis was used for replacement of the ascending aorta. In 60% of patients, additional procedures regarding the heart or aorta were necessary. Intraoperative variables and additional procedures are listed in Table 2.
Follow-Up
During follow-up, 20 patients died (7.3%). Thirteen deaths (4.7%) were considered cardiac-related, including deaths for unknown reason.\textsuperscript{13} Reasons for cardiac-related death were ventricular fibrillation in 2 patients, biventricular cardiac failure, sudden death, and septic endocarditis, as well as several unknown reasons. In those patients, the last echocardiography revealed no relevant aortic incompetence. Actuarial survival was 96.2% ± 1.3%, 90.7% ± 2.5%, and 80.4% ± 5.7% at 3, 5, and 10 years, respectively, when early mortality is excluded. Kaplan-Meier estimates and actuarial survival are given in Figure 2.

Reoperation of the reconstructed aortic valve because of progressive insufficiency was required in 15 patients (5.3%). Freedom from reoperation was 95.7% ± 1.4%, 91.1% ± 2.5%, and 87.1% ± 4.5% at 3, 5, and 10 years, respectively. Figure 3 shows the actuarial freedom from reoperation due to incompetence of the reconstructed aortic valve. Reasons for reoperation were endocarditis, degeneration of reimplanted aortic cusps, early postoperative aortic insufficiency due to cusp coaptation beneath the prosthesis, resulting in consecutive cusp prolapse as identified by echocardiography, as well as progressive aortic insufficiency for unknown reasons. A patient experienced acute aortic dissection type A of the donor aorta 2 weeks after orthotopic heart transplantation. He received a nonvalved, cryopreserved aortic homograft in which his native valve was reimplanted. Five years later, this patient developed aortic insufficiency grade III. He received a biological aortic valve prosthesis. Postoperative investigation showed fibrotic endocarditis with detection of \textit{Staphylococcus epidermidis}, which was treated successfully with intravenous antibiotics. One patient experienced Wegener’s disease while undergoing long-term hemodialysis. Although the aortic cusps appeared undamaged at the time of the first operation, the patient developed inflammatory cusp changes, leading to significant aortic insufficiency grade III. He finally received a mechanical aortic valve replacement 11 months postoperatively. A similar course showed a female patient with colitis ulcerosa...
who required reoperation for aortic insufficiency grade III. Intraoperatively, aortic cusps appeared shrunken and thickened, probably because of an inflammatory process. Table 4 displays the frequency and underlying reasons for replacement of the reconstructed valve.

Expanded indications for operation have been investigated for their influence on both survival and need for reoperation of the reconstructed valve (Table 5). No patient with reconstructed aortic cusps because of prolapse had an additional operation thus far. Age above 70 years influenced survival negatively. Of 54 patients with Marfan’s syndrome, seven (13%) had to have an additional operation on the reconstructed valve. Presence of Marfan’s syndrome led to a statistically significant increased need for reoperation on the reimplanted valve. Analysis of underlying reasons for reoperation revealed no increased degeneration of cusps in this subgroup; 2 female patients required reoperation early postoperatively, as described above. Another 3 patients with Marfan’s syndrome had another operation for aortic insufficiency because of cusps coaptation beneath the prosthesis and consecutive cusps prolapse during the first postoperative year. The other 2 patients had another operation for progressive aortic valve insufficiency 4 and 7 years postoperatively.

At follow-up, 3 patients presented with aortic valve insufficiency grade III. Grade of aortic insufficiency preoperatively, early postoperatively, and at last visit for the whole cohort is shown in Figure 4. Aortic incompetence was reduced significantly from grade 2.3 ± 1.1 (range 0 to 4) preoperatively to 0.23 ± 0.46 (range 0 to 2) postoperatively (P < 0.001), and to 0.34 ± 0.59 (range 0 to 3; P < 0.001) at last evaluation. The increase in aortic insufficiency from early postoperative to last visit reached the level of significance (P = 0.026), but was irrelevant in terms of clinical symptoms.

The majority of patients presented with a favorable exercise tolerance at last visit. Ninety-six percent of patients were in NYHA class I or II (68% in NYHA class I, 28% in NYHA class II). Nine patients (4%) were found in NYHA class III. None of these patients experienced relevant aortic valve incompetence. Neither thromboembolic events nor bleeding complications were seen in any patient during follow-up.

**Discussion**

The reimplantation technique for valve-sparing aortic root reconstruction, originally developed for patients presenting with aortic valve incompetence due to an aneurysm of the ascending aorta, is applicable to a wide range of patients with various indications. As a result of this study, expansion of indications for this procedure is feasible with excellent clinical outcome, comparable to patients who underwent the reimplantation operation for the original indication. Furthermore, durability of the reconstructed valve is not influenced by the underlying reason for operation after a follow-up period of 11 years.

When isolated indications were compared with the overall cohort in regard to survival, only age above 70 years at time of operation influenced survival adversely. This finding is not surprising, as life expectancy is naturally limited for this subgroup compared with patients with an average age of 53 years at operation. It may be debatable whether patients of higher age will benefit from a reconstructive operation with prolonged operation times. Early mortality was not influenced by the age of the patient at operation, however, and freedom from anticoagulation postoperatively is appealing for older patients, too.

Valvular longevity during follow-up was significantly reduced for patients with Marfan’s syndrome. Of 54 patients with Marfan’s syndrome, 7 (13%) required a second operation on the reconstructed valve. It has been proposed that patients with Marfan’s syndrome may have a higher risk of early valve deterioration. The structural fibrillin-1 defect may affect the stability and durability of valve reconstruction. Published data confirm fibrillin fragmentation and deficiency in aortic cusps of patients with Marfan’s syndrome and significant valve deterioration in patients with advanced disease. Recent studies, however, report excellent outcomes both in survival and valve stability for patients with Marfan’s syndrome, regardless of the technique of valve preservation used.15,16 Our analysis of underlying reasons for reoperation revealed no increased degeneration of cusps in this subgroup; 2 female patients required reoperation early postoperatively, for progressive aortic valve insufficiency for unknown reasons with intact cusps, the other for myocardial failure with intact aortic valve. Another 3 patients with Marfan’s syndrome had an additional operation for aortic insufficiency due to cusp coaptation beneath the prosthesis and consecutive cusps prolapse during the first postoperative year. This happened during the beginning of our experience with the reimplantation technique and must be considered a technical challenge.
The reimplantation technique is well suited also for patients with Marfan’s syndrome. The lack of necessity of anticoagulation is highly appealing for these young patients, as possible pregnancy in female patients and further operations of the downstream aorta represent relevant drawbacks for anticoagulation with Coumadin. To avoid permanent damage to the aortic cusps, we tend to operate on patients with Marfan’s syndrome when the diameter of the aortic sinuses reaches 50 mm and echocardiography suggest normal cusps, and even earlier if a positive family history of acute aortic dissection is present.

Acute aortic dissection type A must be considered an emergency; immediate operation is mandatory to increase survival. A patient’s survival of the operation is the primary goal for surgeons dealing with the challenge of an acute aortic dissection type A. Therefore, it remains debatable whether the time-consuming valve reconstruction should be applied under these circumstances. In this study, 53 patients with acute aortic dissection type A were treated with the reimplantation technique. Results were excellent, as early mortality was 11.3%, and only 2 patients in this subgroup required reoperation of the reconstructed aortic valve, both because of endocarditis. Surprisingly, long-term survival of this subgroup was comparable to the overall cohort. We have recently shown that the reimplantation technique can be safely applied to patients presenting with acute aortic dissection type A, and the outcome is comparable to patients treated with a valved composite or supracommissural replacement of the ascending aorta. Despite these results, caution should be applied when using the reimplantation technique in acute aortic dissection type A. Profound experience with the technique in elective patients is pivotal, and selection of suited patients with morphologically intact cusps will probably exclude the sickest patients from valve reconstruction. At our institution, we used reimplantation of aortic valves of all capable patients as the procedure of choice. Excellent hemostasis favors this technique over remodeling of the root; the only suture lines that can bleed are the coronary buttons and the distal aortic anastomosis.

Recently, modifications of the initial reimplantation technique (the so-called David I technique) have been undertaken by David and others. The aim of all modifications is the creation of pseudosinuses to allow more physiological valvular movement. Additionally, new grafts, including an artificial pseudo-root, have been generated, and valvular movement has been superior compared with the David I technique. The theoretical advantage of creation of pseudosinuses is convincing, and more physiological valvular movement may indicate an improvement toward higher valvular longevity. However, mid- and long-term results are not available so far. Furthermore, a theoretical advantage of more physiological valvular movement has been proposed for the remodeling technique as well, but did not show clinical superiority over the reimplantation technique. Early cusp degeneration as well as cusp contact with the prosthesis, as described by Leyh et al and proposed as a potential drawback of the David I technique, were observed neither immediately postoperatively nor at follow-up. Thus far, the David I procedure, technically highly standardized and applied to 284 patients at our institution, led to favorable valvular durability after 11 years of follow-up; careful comparison of long-term data are needed to prove the advantage of grafts with neo-sinuses.

Certain limitations have to be acknowledged: First, follow-up was incomplete (93%). The incompleteness was caused by the fact that patient from the whole country and abroad were operated on in our institution, especially in the mid-1990s. Furthermore, a follow-up period of 11 years does not allow discussion of long-term results. Actuarial analysis at 10 years revealed only 8 patients at risk; thus, the value of actuarial analysis at 10 years is limited. To our knowledge, however, this is the largest cohort of patients treated with the valve-sparing reimplantation technique at a single center so far. Further observation in long-term studies is mandatory to draw final conclusions regarding the value and risks of the reimplantation technique.

In conclusion, we have shown in a large single-center cohort that mid-term results of clinical outcome and valvular longevity in patients operated on exclusively with the reimplantation procedure is favorable. The aortic valve reimplantation technique leads to excellent clinical outcome in patients with various pathologies. The fact that there is no need for anticoagulation and the favorable durability should encourage the extension of the indications for this technique.
References


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