Evolving Strategies for Treatment of Acute Aortic Dissection Type A

Klaus Kallenbach, MD; Timm Oelze, MS; Rolf Salcher, MS; Christian Hagl, MD; Matthias Karck, MD, PhD; Rainer G. Leyh, MD, PhD; Axel Haverich, MD, PhD

Objective—To assess the outcome of 3 different surgical approaches for treatment of acute aortic dissection type A (AADA).

Methods and Results—Between October 1990 and October 2003, we operated on 295 patients (pts) for AADA. Follow-up was complete for 257 pts (87%). Supracommissural replacement (SCR) of the ascending aorta was applied to 145 pts, 64 pts received a composite replacement (comp), and 48 pts were treated with the aorta valve-sparing (AVS) reimplantation technique. Pts in SCR were older compared with AVS and comp (P=0.002), gender (overall 65% male, P=0.143) and presence of Marfan syndrome (overall 5%, P=0.109) were comparable. Cannulation of the aorta was performed more often in AVS (58%) than in comp (19%) or SCR (22%; P<0.001). Mean operation time, extracorporeal circulation time, and aortic cross-clamp time differ significantly between groups (P<0.001, respectively). Stay in the intensive care unit (P=0.12) and time of hospitalization (P=0.32) were comparable. Overall perioperative mortality was 24% and did not show significant differences between groups (AVS 10.4% versus comp 28% versus SCR 26%; P=0.053). Incidence of neurological complications was similar between groups (P=0.95). Mean time of follow-up was shorter for AVS (19±20 months) compared with comp (48±48 months) and SCR (46±45 months). Survival at 5 years was comparable with 89% for AVS, 85% for comp, and 80% for SCR (P=0.61). Two patients from AVS (4.1%) required reoperation for failure of the reconstructed valve. Pts in comp required less aortic reoperations than pts in SCR (comp 6.3% versus SCR 22%; P=0.005).

Conclusions—In acute aortic dissection type A, the reimplantation technique leads to results comparable to established techniques. Complete removal of diseased tissue, low incidence of reoperation, and lack of anticoagulation may favor this approach in selected patients.

Key Words: aortic dissection • valves • aorta • valve reconstruction • composite replacement

Acute aortic dissection type A (AADA) represents a rare but life-threatening emergency situation. Therefore, immediate surgical intervention is mandatory, because medical treatment leads to an unacceptable high early mortality of >50%, and delay between occurrence of dissection and surgical treatment correlates with increased mortality.1–3

Surgery requires resection of the entry side of the dissection, typically located 2 to 5 cm above the valvular commissures at the outside curvature of the ascending aorta,4 to exclude the fragile false lumen from high pressure blood flow. Supracommissural replacement (SCR) of the ascending aorta or composite replacement (comp) of the aortic valve and ascending aorta in cases with deteriorated aortic root or valvular insufficiency are established surgical techniques for treatment of AADA.5,6 However, early mortality rates of 20% to 35% remain almost unchanged over the past 30 years, despite improvement of surgical techniques.1,2,7,8 Furthermore, the risk of redissemination, secondary aneurysmatic dilatation of the aortic root, and aortic insufficiency after SCR with a high incidence of reoperation, as well as lifelong anticoagulation with risk for thromboembolic and bleeding complications after comp, are drawbacks of these techniques.6,9–11 Recently, valve-sparing techniques for replacement of the ascending aorta gained attention for use in AADA.4,12,13 The reimplantation technique, especially, first described by David,14 is theoretically well-suited for use in patients presenting with AADA. Complete removal of diseased tissue, excellent hemostasis, and avoidance of lifelong anticoagulation are clear advantages for treatment of the aortic root pathology in patients with morphologically unimpaired valve cusps. However, whether to use this technique in emergency patients presenting with AADA remains debatable. Prolonged operation times for valve reconstruction and the demanding technique applied under emergency conditions may bear an additional risk for the patient, who might benefit from a short and simple operation because of this unstable status.

From the Hannover Medical School, Department of Thoracic and Cardiovascular Surgery, Hannover, Germany.
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Correspondence to Dr. Klaus Kallenbach, Medizinische Hochschule Hannover, Klinik für Thorax-, Herz- und Gefäßchirurgie, Carl-Neuberg-Straße 1, D-30625 Hannover, Germany. E-mail kallenbach@thg.mh-hannover.de
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Thus, aim of the study was the comparison of the established techniques (SCR and comp) with the reimplantation technique (aortic valve-sparing [AVS]) with regard to perioperative outcome and mid-term follow-up. We analyzed the data of 257 consecutive patients admitted with AADA to our institution, aiming to answer the question for the best surgical strategy.

Methods

Patients

Between October 1990 and October 2003, 295 patients with AADA underwent operation at our institution. The dissection was considered acute if symptoms occurred within 14 days. Diagnosis of AADA, defined as involvement of the ascending aorta according to previously published criteria, was established by computed tomography scans, magnetic resonance imaging, and/or transesophageal echocardiogram. Most diagnoses were performed in external hospitals and patients were transferred to our institution for emergency surgery. If diagnostic information was complete at admission to our emergency room, patients were transferred to the operation room for immediate surgery without any delay. The final decision of the surgical strategy was made by the surgeon intraoperatively. For patients undergoing the reimplantation technique, intraoperative control of aortic valve function was determined with transesophageal echocardiography, if available.

All clinical data were obtained by retrospective review of hospital records. Follow-up was complete for 257 patients (87%). For analysis, these patients were divided into 3 subgroups by surgical treatment: 145 patients operated with SCR of the ascending aorta, 64 patients were treated with a composite graft (comp), and in 48 patients the native aortic valve was reimplanted into a Dacron tube replacing the ascending aorta (AVS). These groups were analyzed and statistically compared with each other. Preoperative characteristics and demographic data showed high homology between groups. Age was found to be the only significant difference between groups. Other factors that are known to influence the outcome, such as delay between onset of symptoms and operation, clinical symptoms of malperfusion, pericardial effusion, cardiogenic shock, and neurological symptoms did not show statistically significant differences between groups. Detailed clinical data and patient demographics are listed in Table 1.

Surgical Technique

The 3 different surgical techniques applied to patients presenting with AADA have been described in detail before by our group.5,15 Generally, the anesthesiologist placed arterial lines in both radial arteries and 1 femoral artery for detection of peripheral malperfusion. The patient’s head was placed in a tub for topical brain protection with ice. During the past years, cerebral blood oxygen saturation was monitored online during the procedure. Before median sternotomy and pericardectomy, the left femoral artery was dissected for arterial cannulation in unstable patients with pericardial effusion. In stable situations and more recently, cannulation of the ascending aorta and the right atrium for extracorporeal circulation was undertaken. Cooling to a rectal temperature of 28°C to 30°C was initiated and myocardial protection was conducted with repetitive doses of cold blood cardioplegia in an antegrade fashion after aortic cross clamping and transection of the ascending aorta above the commissures. After careful inspection, the decision for reimplantation of the aortic valve, composite replacement, or supracommissural replacement depended on the morphological appearance of the cusps and root geometry, as well as the involvement of the aortic root by the dissection. Generally, our goal was to reimplant any valve without gross structural defect. If a contraindication for reimplantation was observed by direct inspection, such as cusp degeneration or involvement of the aortic bulb by the intima tear, we implanted a composite graft. In case of dissection of the root involving the commissures but feasibility of valve reconstruction, the wall layers were readapted with galamine-resorcin-formaldehyde (GRF) glue. If necessary, dissected coronary artery ostia were reconstructed using GRF glue. SCR was only applied to older patients with completely unimpaired aortic bulb, which required no gluing or reconstruction.

For composite replacement, the aortic valve and the aortic root were resected to the annulus and the valved conduit was anchored in the aortic annulus using pledgetted 2-0polypropylene sutures. Reimplantation of coronary ostia was then performed either by Bentall or button technique.

For supracommissural replacement of the ascending aorta, the ascending aorta was resected ~5 mm above the commissures and a Dacron prosthesis was sawn with a running suture to the remaining aortic root. If necessary, the root was reconstructed with GRF glue.

For aortic valve reimplantation, 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 conducted. Prosthetic diameters were calculated from the diameter of the left ventricular outflow tract and the height of the aortic cusps. Practically, the annulus was sized with a Hegar dilator and the sinotubular junction with a valve sizer. Valve coaptation was considered ideal if 30% to 50% of the cusp area was involved after extensive external dissection and mobilization of the aortic root, were conducted. Prosthetic diameters were calculated from the diameter of the left ventricular outflow tract and the height of the aortic cusps. Practically, the annulus was sized with a Hegar dilator and the sinotubular junction with a valve sizer. Valve coaptation was considered ideal if 30% to 50% of the cusp area was involved after modification of the sinotubular junction. Proximal anastomosis was performed with 12 threads of 3-0 coated polyester fiber used as a horizontal mattress suture placed circumferentially through the annulus underneath the valve. The valve cuff was then reimplanted into the Dacron prosthesis using 3-4-0polypropylene sutures. Utmost care was taken to achieve correct cusp geometry and sufficient height of commissural resuspension within the prosthesis. Reimplantation of coronary ostia button into the Dacron graft completed the root reconstruction.
For inspection of the aortic arch, deep hypothermic circulatory arrest, or, more recently, moderate hypothermic circulatory arrest with cold (15°C) antegrade cerebral perfusion was used. Depending on the expansion of the dissection, the diseased aortic wall was reconstructed with GRF glue for an open distal aortic anastomosis or the dissected aorta was removed and the arch replaced by a second Dacron prosthesis. In case of more extensive distal dissection, an elephant-trunk extension of the arch prosthesis into the proximal descending aorta was used.

Follow-Up
Postoperative follow-up was comparable for SCR (46±45 months, minimum 0 to maximum 145 months, timeframe October 1990 to October 2003) and comp (48±48, 0 to 147 months, November 1990 to June 2003), but was significantly shorter for AVS (19±20, 0 to 91 months, August 1995 to October 2003; P<0.001). Follow-up was obtained by written and/or telephone communication with the patients and/or home physicians. Before hospital discharge and at follow-up, valve function was re-evaluated using transthoracic color Doppler echocardiography for patients treated with the reimplantation technique. 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.16

Statistical Analysis
Continuous variables are expressed as mean±SD. Data analyses were performed with SPSS 11.5 for Windows (SPSS Inc). Demographic and baseline variables were analyzed by using the 1-way ANOVA test for multiple groups of continuous variables. The Tukey B test was applied for identification of homogeneity between subgroups. Comparison between groups was performed by using χ² test for the analysis of contingency tables. Kaplan–Meier analysis was used for the evaluation of time-related variables. Differences between survival curves were evaluated with the log–rank statistic. Statistical significance of differences in aortic insufficiency was analyzed by the Wilcoxon test, and NYHA class between groups was tested using the Kruskal–Wallis signed rank test for normally distributed data. A value of P<0.05 was considered significant.

Results
Perioperative Results
Mean operation times, extracorporeal circulation times, and aortic cross-clamp times were significantly different between groups (P<0.001, respectively). For all 3 parameters, AVS took the longest times, and SCR was the shortest procedure. Aortic cross-clamp time was twice as long for AVS (156±39 minutes) compared with SCR (74±29 minutes). Although need for proximal arch replacement was equally distributed between groups, more complex aortic surgery was required in AVS, such as total arch replacement and elephant-trunk extension into the descending aorta, explaining partly the longer operation times in AVS. No reimplanted valve had to be surgically corrected because of unsatisfactory result intraoperatively. Significantly more patients from AVS had direct cannulation of the ascending aorta instead of femoral artery cannulation. Detailed intraoperative findings are listed in Table 2.

Overall early (30-day) mortality was 24% and did not differ statistically significant between groups. A trend toward lower early mortality is observed for AVS (10.4%) compared with SCR (24%) and comp (26%; P=0.053). The operative mortality rates for patients operated with the 3 different techniques were assessed during 4 time windows and are shown graphically in Figure 1. No significant differences between time windows with regard to mean early mortality were observed. Reasons for early mortality have been myocardial failure (44%), cerebral ischemia (25%), uncontrolled

| Table 2. Intraoperative Data for Patients With AADA Treated With Different Surgical Methods |
|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                  | SCR              | Comp             | AVS              | Overall          | P                |
| Operation time, min | 242±68           | 301±121          | 305±75           | 267±90           | <0.001           |
| ECC time, min       | 141±54           | 189±100          | 209±57           | 186±74           | <0.001           |
| X-clamp time, min   | 74±29            | 108±35           | 156±39           | 98±45            | <0.001           |
| Circulatory arrest, min | 24±14           | 24±16            | 29±18            | 25±15            | 0.20             |
| Aortic cannulation (%) | 31 (22)           | 11 (19)          | 28 (58)          | 28               | <0.001           |
| Proximal arch replacement (%) | 74 (51)        | 32 (50)          | 22 (46)          | 128 (50)         | 0.18             |
| Sub/total arch replacement (%) | 28 (19)        | 12 (19)          | 18 (38)          | 58 (23)          | 0.023            |
| Elephant trunk (%)   | 5 (3)            | 2 (3)            | 7 (15)           | 14 (5)           | 0.008            |
| CABG (%)             | 13 (9)           | 8 (13)           | 3 (6)            | 24 (9)           | 0.52             |
| Fenestration (%)     | 4 (3)            | 1 (2)            | 2 (4)            | 7 (3)            | 0.70             |

ECC indicates extracorporeal circulation; CABG, coronary artery bypass grafting.
bleeding (10%), multiorgan failure (10%), sepsis (6%), and abdominal ischemia because of malperfusion (6%) and did not differ between groups. In AVS, none of the deaths has been valve-related. No significant differences were observed between groups for need for rethoracotomy, postoperative neurological complications, need for postoperative support by intra-aortic balloon pump, intensive care unit stay, and length of hospitalization. Perioperative results are listed in Table 3.

The frequency for the use of the 3 techniques has been changed by years, as graphically shown in Figure 2. Although SCR was the most often used technique in the first half of the 1990s, the AVS technique was first applied in 1995, then taking an increasingly higher percentage, up to half of all operations performed in patients with AADA.

**Postoperative Follow-Up**

Survival during follow-up was comparable between groups. Actuarial survival at 5 years was 80 ± 4% for SCR, 85 ± 6% for comp, and 89 ± 5% for AVS (log rank: P = 0.61). Actuarial survival is graphically shown in Figure 3. Reasons for death have been myocardial failure, cerebral ischemia, paraplegia, aortic rupture, and reasons not related to AADA. Because of refusal of autopsy, reason for death was unclear in a high percentage of patients during follow-up. None of the deaths in AVS was valve-related.

During follow-up, 18 patients from SCR, 2 patients from comp, and 2 patients from AVS have been reoperated on the aortic valve because of valvular morbidity. Freedom from reoperation because of aortic valve morbidity after 5 years was 88 ± 3% for SCR, 96 ± 3% for comp, and 65 ± 26% for AVS (log rank: P = 0.092). Actuarial freedom from reoperation because of valvular morbidity is shown in Figure 4. Reasons for reoperation in AVS have been endocarditis in both cases. A 63-year-old man was initially operated for AADA with the reimplantation technique. His postoperative course was complicated by rethoracotomy because of massive bleeding a few hours postoperatively. He had to be reoperated for acute fungal endocarditis involving the aortic leaflets 4 months later. A free root replacement with an aortic homograft was performed, and the patient recovered finally. Another patient experienced AADA of the donor aorta 2 weeks after orthotopic heart transplantation. He received a nonvalved cryopreserved aortic homograft in which his native valve was reimplemented. Five years later, our patient had aortic insufficiency grade III. He received biological aortic valve prosthesis. Postoperative investigation showed fibrotic endocarditis with detection of staphylococcus epidermidis, which has been treated successfully with intravenous antibiotics. Eighty-five patients (33%) required reoperations on the aortic valve and aorta during follow-up. In AVS, 5 aortic reoperations were performed: in 2 patients (4.2%), replacement of the reimplanted aortic valve, in 1 patient (2.1%), replacement of the prosthesis of the ascending aorta, and in 2 patients (4.2%), replacement of the aortic arch/downstream...

| TABLE 3. Perioperative Results for Patients With AADA Treated With Different Surgical Methods |
|-----------------------------------------------|---------|---------|---------|---------|---------|
| SCR  | Comp  | AVS  | Overall |
| 30-day mortality (%) | 38 (26) | 18 (28) | 5 (10.4) | 61 (24) | 0.053 |
| Rethoracotomy (%) | 24 (17) | 9 (14) | 4 (8) | 37 (14) | 0.37 |
| Neurologic complications (%) | 32 (23) | 13 (21) | 8 (21) | 53 (22) | 0.95 |
| IABP (%) | 1 (0.7) | 2 (3) | 0 | 3 (1) | 0.23 |
| ICU stay, d | 6±7 | 4±3 | 4±5 | 5±6 | 0.12 |
| Hospitalization, d | 13±9 | 15±9 | 15±9 | 14±9 | 0.32 |

ICU indicates intensive care unit; IABP, intraaortic balloon pump.
aorta. Because of shorter follow-up for AVS, statistical comparison has been performed between comp and SCR only. Reoperations of the aortic valve and ascending aorta were more often performed on patients from SCR (22%) than from comp (6.3%) ($P < 0.005$). Frequency and location of aortic reoperations are listed in Table 4.

During follow-up, reconstructed valves from AVS remained stable. Only 2 patients from AVS presented with aortic insufficiency greater than grade I at last contact (all grade II). Mean grade of aortic insufficiency differed significantly between preoperatively and early postoperatively (1.5 ± 1.3 versus 0.18 ± 0.39; $P < 0.001$) but showed no significant difference between early postoperative and at last contact (0.18 ± 0.39 versus 0.25 ± 0.57; $P = 0.32$).

Postoperative performance, quantified by the NYHA classification, was favorable at last contact and did not differ between groups (mean AVS 1.4 ± 0.6 versus comp 1.2 ± 0.4 versus SCR 1.3 ± 0.5; $P = 0.094$). All except 4 patients (2 each from AVS and SCR), who were judged for NYHA class III, presented in NYHA classes I (75%) and II (23%) at last contact.

**Discussion**

The indication for use of the reimplantation technique in emergency patients presenting with acute aortic dissection remains a subject of debate. The reimplantation technique leads to excellent results in patients electively operated for aortic root ectasia. Should such a demanding, time-consuming technique be used in the different entity of AADA as well, in an emergency situation, most often in the middle of the night? Or should the most simple and quickest technique be applied, such as the supraommissural aortic replacement or the composite replacement? Unquestionably, reconstruction of the aortic root with GFR glue and supraommissural replacement of the ascending aorta represent the probably easiest and quickest approach but leaves diseased
aortic tissue in place, ignoring the underlying aortic wall pathology. Possible resection or aneurysm formation may bear a vital risk for the patient and may require further operation of the proximal ascending aorta. These aneurysms are the main reason for reoperations because of development of relevant aortic regurgitation with an incidence of 25% to 45%. In patients with structurally impaired aortic wall tissue such as Marfan syndrome and in those who had acute dissection with pre-existing anulooaortic ectasia on the basis of cystic medial necrosis, the incidence may be even higher and composite replacement has been recommended. The replacement of the aortic wall and the dissected ascending aorta with a composite graft carrying mechanical valve prosthesis represents an established surgical treatment with excellent results. However, the lifelong need for anticoagulation with the risk for bleeding and possible thromboembolic events after mechanical valve replacement cause complications with an annual incidence of 2% to 4% in the literature. These complications can be avoided by the use of the valve preserving reimplantation technique. In addition, absence of anticoagulation is particularly appealing in patients requiring additional surgery because of aneurysmatic transformation of dissected distal aortic segments.

Besides the reimplantation technique, aortic root remodeling, first described by Yacoub et al., is an alternative with excellent results for aneurysmatic dilation of the aortic root. However, results for patients with AADA operated with the remodeling technique are unfavorable. Our group reported a high failure rate of remodeled aortic valves in AADA. De Oliveira et al. reported of a rethoracotomy rate of 3% for Marfan patients undergoing the reimplantation operation versus 18% in the remodeling group. This difference was found to be statistically significant (P = 0.01). Miller stated in a recent review of valve-sparing aortic root replacement in patients with the Marfan syndrome that the reimplantation concept is better for acute aortic dissection because it is more hemostatic—the only suture lines that can bleed are the coronary buttons and the distal aortic anastomosis. In our cohort, the rethoracotomy rate was 8% for patients in AVS, which is acceptable in comparison to 14% for comp and 17% for SCR (P = 0.37).

The most important determinant to judge a surgical technique is early mortality and survival. Overall early mortality in our series was 24% and is comparable to that in recent reports of others. Early mortality in patients with AADA is mainly determined by the general status of the patient at presentation; at our institution, we do not exclude patients with cerebral impairment or ongoing resuscitation from surgery. Early mortality for patients undergoing AVS was low, with 10.4% compared with SCR (26%) and comp (28%), although this difference failed to show statistical significance (P = 0.053). This is remarkable in light of high homology between patient collectives; only age was found to be significantly higher in SCR, whereas other important factors predicting the outcome were comparable. Three factors may explain the improved outcome of patients in AVS. First, the procedures took place in more recent years compared with SCR and comp, and improvement of general surgical and anesthesiological techniques have been implemented during the past years. Second, surgeons able to apply the AVS technique in AADA are considered to be more experienced. Third, there might be a selection of patients by the severity of the disease. Despite high homology between groups, the critically ill patient might have preferred treatment with the composite technique instead of AVS. This assumption is supported by the high mortality rate of 50% for comp compared with 8% for AVS in the time window 2001 to 2003. Furthermore, the reimplantation technique can only be applied to patients with unimpaired valvular cusps, thus excluding patients with aortic valve deterioration and consecutive myocardial impairment from AVS. However, mean early mortality did not change between time windows, and early mortality is rather influenced by nonvalve-related complications such as myocardial failure and cerebral and peripheral malperfusion, etc.

During follow-up, survival was favorable after 5 years and did not differ between treatment groups. None of the deaths in AVS was valve-related. The reported high incidence of reoperations for root dilation in SCR is confirmed by our findings; patients in SCR required more reoperations for the aortic valve and ascending aorta (22%) than those in comp (6%) and AVS (6%). The longevity of a reconstructed valve represents an important issue for judgment of the surgical technique. In patients with aortic root aneurysms, the reimplantation technique leads to excellent midterm results of 96% valvular stability after 5 years. In this study, we had to reoperate on 2 patients (4.1%) from AVS for endocarditis. One patient had a complicated initial course with emergency rethoracotomy and open resuscitation, the other was under immunosuppression after heart transplantation. In both cases, the initial reconstructive result of the valve was excellent. We did not observe insidious deterioration of reconstructed valves by time, because echocardiography revealed almost identical findings early postoperatively and at last visit.

There were significantly more reoperations required on the aortic valve and ascending aorta in patients from SCR compared with comp during a comparable follow-up period. It is important to stress that a major drawback of SCR is the higher incidence of reoperations on the aortic root compared with surgical methods with replacement of the complete aortic root and ascending aorta, such as comp and AVS. Although AVS cannot be compared with the other groups because of shorter follow-up in this study, it can be assumed that the incidence of reoperations on the aortic root/ascending aorta is markedly reduced compared with SCR because aneurysm formation is impossible. However, longevity of the reimplanted valve remains unclear and may limit this advantage.
Certain limitations of this study have to be acknowledged. Instead of randomization, the surgical strategy was decided by individual judgment of the surgeon, and individual experience and appearance of the patient might have influenced the decision. Furthermore, patients undergoing AVS have been selective because of requirement of nondeteriorated aortic valve cusps. Follow-up for patients from AVS is limited and allows only interpretation of midterm results. However, to our knowledge, this is the largest cohort of patients with AADA treated with a valve-sparing technique so far. In further long-term studies, it has to be proven if long-term survival, longevity of the reconstructed valve, and need for reoperation are superior compared with SCR.

In conclusion, we report the outcome of 257 consecutive patients who have undergone operation for AADA with 3 different surgical strategies at a single center. Despite longer operation times, AVS showed comparable clinical and functional results to the established techniques with a trend toward lower early mortality compared with SCR and comp. Durability of the reconstructed valve was favorable. Need for reoperations of the aortic root including aortic valve and ascending aortic were less often required in comp compared with SCR. Today, the valve-sparing reimplantation technique represents the surgical technique of choice for treatment of AADA at our institution in suited patients.

References
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