Aortic valve repair leads to a low incidence of valve-related complications

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Abstract

Objective: Aortic valve replacement for aortic regurgitation (AR) has been established as a standard treatment but implies prosthesis-related complications. Aortic valve repair is an alternative approach, but its mid- to long-term results still need to be defined.

Methods: Over a 12-year period, 640 patients underwent aortic valve repair for regurgitation of a unicuspid (n = 21), bicuspid (n = 205), tricuspid (n = 411) or quadricuspid (n = 3) aortic valve. The mechanism of regurgitation involved prolapse (n = 469) or retraction (n = 20) of the cusps, and dilatation of the root (n = 323) or combined pathologies. Treatment consisted of cusp repair (n = 529), root repair (n = 323) or a combination of both (n = 208). The patients were followed clinically and echocardiographically; follow-up was complete in 98.5% (cumulative follow-up: 3035 patient years).

Results: Hospital mortality was 3.4% in the total patient cohort and 0.8% for isolated aortic valve repair. The incidences of thromboembolism (0.2% per patient per year) and endocarditis (0.16% per patient per year) were low. Freedom from re-operation at 5 and 10 years was 88% and 81% in bicuspid and 97% and 93% in tricuspid aortic valves (p = 0.0013). At re-operation, 13 out of 36 valves could be re-repaired. Freedom from valve replacement was 95% and 90% in bicuspid and 97% and 94% in tricuspid aortic valves (p = 0.36). Freedom from all valve-related complications at 10 years was 88%.

Conclusions: Reconstructive surgery of the aortic valve is feasible with low mortality in many individuals with aortic regurgitation. Freedom from valve-related complications after valve repair seems superior compared to available data on standard aortic valve replacement.

Keywords: Aortic valve; Aortic regurgitation; Aortic valve reconstruction; Valve-related complications; Aortic dilatation

1. Introduction

Aortic valve (AV) replacement is an established treatment for patients with severe AV regurgitation [1]. Valve replacement improves prognosis and quality of life [2], but exposes the patients to the typical prosthesis-related complications. Mechanical valves are associated with the risks of thromboembolism, valve thrombosis and anticoagulation-related haemorrhage [3]. Biologic valve substitutes undergo degeneration. The risk of prosthetic valve endocarditis remains both for biologic and mechanical substitutes [4]. The cumulative risk of valve-related complications reaches almost 50% at 10 years [3,5]. AV repair is an old approach [6] that has received increasing interest in the past 10 years. It is still uncertain whether reconstruction of the AV has proven advantages over replacement, as observed in mitral valve surgery [7].

Different techniques have been developed for the reconstruction of regurgitant AVs [8–13]. Aortic dilatation can be treated by subcommissural root plication [11], root remodelling [12] or re-implantation of the AV within a vascular graft [13]. Prolapse of aortic cusps can be corrected by different techniques [8,10], and cusp augmentation using pericardium has been proposed for cusp retraction [14,15]. These reconstructive procedures have been used in selected patients only.

Over a period of 12 years, we have systematically applied and attempted to advance reconstructive surgery to patients with regurgitant AVs. We have found that a combination of cusp and root pathology is present in the majority of patients [16]. To restore normal dimensions of the functional unit of AV and root, we have applied combinations of techniques adapted to individual pathology [17]. In this analysis of data accumulated prospectively, we analyse mid- and long-term results. The goal was to determine durability of repair and the incidence of valve-related complications.

2. Material and methods

Between October 1995 and February 2007, 2660 patients underwent a cardiovascular operation including correction of a malfunctioning AV. Aortic regurgitation (AR) was predomi-
nant in 795 instances (30%); in the remaining, pure or predominant aortic stenosis was present. The AV was repaired in 640 of these 795 patients (81%) with AR. The operations were performed by three surgeons (D.A., F.L. and H.J.S.), the majority (87%) by one surgeon (H.J.S.).

In 155 instances, the regurgitant AV was replaced. Reasons for replacement were acute endocarditis with marked destruction of cusps and/or root (n = 48) or extensive dissection of the aortic root (n = 8). In 63 instances, marked retraction or calcification of cusps led to replacement; 30 AVs were replaced early in the experience. In six instances, the AV was replaced after attempted repair with consecutive regurgitation of more than grade II.

The AV anatomy was bicuspid in 205 and tricuspid in 411 individuals. A unicuspid valve was seen in 21, a quadricuspid valve in three patients. The degree of AR varied from mild to severe. AR was severe and symptomatic or associated with left ventricular dysfunction in 303 individuals. The mechanism of regurgitation involved cusp pathology in 529 patients. Prolapse was present in 469, retraction in 20. Aortic root dilatation without alteration of cusp geometry was found in 115 patients, and 208 individuals had a combination of root dilatation and cusp pathology.

In the 640 patients, isolated regurgitation without need for concomitant surgery was present in 122 instances. In most individuals, AR was found in combination with coronary artery disease, aortic aneurysm, acute aortic dissection or other cardiac diseases (Table 1).

All patients required surgical treatment of the AV according to current guidelines, either for severity of AR and presence of symptoms or left ventricular dysfunction, or because of the need of aortic root replacement for aneurysm or dissection [18]. The primary indication for surgery was severe AR in 303 patients, aortic aneurysm in 252, acute aortic dissection in 64, coronary artery bypass grafting in 13, mitral regurgitation in seven and congenital ventricular septal defect in one patient.

For decision-making of the individual repair strategy, the diameters of the aortic root were measured intra-operatively at aorto-ventricular and sinu-tubular levels, and the operative approach to the root chosen according to the degree of dilatation [17]. Maximum sinus diameter was measured by trans-oesophageal echocardiography. No surgical procedure on the root was undertaken if dimensions appeared preserved (sinu-tubular diameter <27 mm and aorto-ventricular diameter <27 mm). In the presence of mild dilatation (sinu-tubular diameter <32 mm, aorto-ventricular diameter <29 mm and maximum sinus diameter <40 mm (trans-oesophageal echocardiography)) subcommissural plication was performed [11]. If dilatation was more pronounced at the level of the sinu-tubular junction and in the sinuses (sinu-tubular diameter >32 mm, sinus diameter ≥40 mm) root remodelling was chosen in order to restore root dimensions [12]. In the presence of more severe root dilatation at the level of aorto-ventricular junction (≥30 mm) or the presence of Marfan’s syndrome, the AV was re-implanted within a vascular graft [13].

The cusps were carefully inspected for structural integrity, symmetry and the presence of prolapse. Cusp prolapse was seen on the fused cusp in bicuspid AVs (n = 205) and due to stretching of cusp tissue (n = 97) or in the presence of congenital fenestrations (n = 48) in tricuspid AVs. Cusp prolapse was also seen in conjunction with root dilatation (n = 208) in bicuspid (n = 78) and tricuspid AVs (n = 130). Limited calcifications of a median raphe were found in 74, healed endocarditic perforations in six and cusp retraction in 20 cases. Pathology was identified in one (n = 214), two (n = 241) or three cusps (n = 53).

Prolapse was initially defined as a difference in the height of a free margin relative to the other margin(s) of 2 mm or more. In the more recent years, we have measured the height difference between the central free margin and the lowest point of the aortic insertion line of each cusp, which we have called effective height. Based on published data and own echocardiographic observations on normal AVs, we have aimed to achieve an effective height of 9–10 mm [19]. We have measured effective height intra-operatively with a calliper and found good correlation between these measurements and echocardiographic determination. Thus, definition of prolapse has changed to include either height of the cusp margin in relation to the other(s) as well as an effective height of less than 6–7 mm.

Correction of prolapse was achieved by plication of the free margin and/or limited triangular resection of cusp tissue. In the presence of fenestrations, endocarditic destruction or cusp defects after resection of limited calcifications, we used autologous pericardium (Fig. 1) for cusp reconstruction. We also used autologous pericardium to augment the cusps in case of retraction.

All patients were studied intra-operatively, using trans-oesophageal echocardiography (Acuson Sequoia C512 Siemens, Erlangen, Germany). After weaning from extracorporeal circulation, a diastolic blood pressure of 70 mm was maintained. The degree of AR was determined according to current guidelines [18]. Further echocardiographic studies were performed using trans-thoracic echocardiography. All patients were studied between postoperative day 5 and 8. Follow-up studies were performed after 3, 6 and 12 months.
and yearly thereafter. All patients were followed and a careful history taken for clinical evidence of embolic events, bleeding complications and other possible valve-related problems. Follow-up was complete for 98.5% of patients (627/640). Thirteen patients were lost to follow-up. The follow-up ranged between 1 and 154 months with a mean of 4.8 ± 2.8 years. A total of 565 patients completed follow-up after 1 year, 219 after 5 years and 45 after 10 years. Cumulative follow-up was 3035 patient-years.

All continuous data are presented as mean ± standard deviation. Statistical analysis included comparison of parametric and continuous variables between the groups using one-way analysis of variance (ANOVA). Kaplan—Meier curves were calculated for freedom from relevant regurgitation, freedom from re-operation and freedom from valve replacement using a commercially available software package (Prism, GraphPad Inc., San Diego, CA, USA). The curves were compared between the groups using the Mantel—Haenszel log rank test. A \( p < 0.05 \) was considered as statistically significant.

3. Results

Hospital mortality (30 days) was 3.4% (22/640). Patients older than 70 years had a hospital mortality of 6.7% (10/149) compared to 2.4% (12/491) in patients 70 years or younger. Patients receiving additional coronary artery bypass grafting (CABG) showed a hospital mortality of 8.1% (11/136) compared to 2.2% (11/504) in patients without CABG. One of the 123 patients who underwent isolated AV repair died (0.8%). Mortality of emergency operations for acute dissection was 7.8% (5/64). The causes of death were cerebral (\( n = 2 \)), non-occlusive mesenteric ischaemia (\( n = 7 \)), sepsis (\( n = 6 \)), cardiac failure (\( n = 6 \)) and pulmonary embolism (\( n = 1 \)). No fatal outcome was directly or indirectly related to inadequate function of the reconstructed AV.

Postoperative morbidity was low. Eighteen patients had to be re-explored for bleeding. There was no postoperative AV block. Pacemaker insertion was required for sinus node dysfunction in two of 27 patients who had undergone concomitant left atrial ablation for permanent atrial fibrillation. Systolic gradients remained low over time both in tricuspid and bicuspid AVs. Mean systolic gradients at the last follow-up were 8 ± 7 mmHg in tricuspid and 10 ± 8 mmHg in bicuspid AVs.

Survival for the whole patient cohort was 92% at 5 years and 80% at 10 years with significantly better survival in patients with a bicuspid rather than a tricuspid AV (\( p = 0.0004 \)). Survival at 10 years was worse in patients with concomitant coronary artery bypass grafting (75% vs 85%; \( p = 0.42 \)).

4. Valve-related complications

At 5 and 10 years freedom from AR ≥ II was 87% and 80% for tricuspid and 86% and 83% for bicuspid AVs (Fig. 1a). Freedom from AR ≥ II was significantly better in patients with mild-to-moderate AR preoperatively compared to patients with severe AR (\( p = 0.03 \)). Freedom from AR ≥ II was significantly
better in patients having undergone root replacement (5 years: 89%; 10 years: 84%) compared to AV repair without root replacement (5/10 years: 83%) (p = 0.025).

To analyse the effect of learning curves, the 10-year period was divided into three operative periods: 1995–1998, 1999–2002 and 2002–2007. Comparing these periods, a striking difference was seen in the frequency of detection (and correction) of cusp pathology. Initially, cusp pathology was seen in only 21% of aortic valves; this increased to 68% in the second period and 87% in the last period. Despite extension of reconstructive surgery to valves with more complex pathology, aortic competence and durability were not affected negatively. Instead, function and stability of bicuspid aortic valves have remained constant throughout the 10 years, while marked improvements could be made in the reconstruction of tricuspid aortic valves (Fig. 1b; p = 0.025).

Re-operation was necessary for recurrent regurgitation in 36 patients between 1 day and 5 years postoperatively. Reasons for re-operation were active endocarditis (n = 5), cusp retraction (n = 4), secondary aortic root dilatation (n = 4), suture line dehiscence after complex cusp repair (n = 9), progressive cusp prolapse (n = 13) and recurrent root dissection (n = 1). At re-operation, the valve was replaced in 11 patients and valve and root were replaced with a composite graft in two. All patients recovered from their re-operations.

There was a significant difference in freedom from re-operation between bicuspid and tricuspid AVs (Fig. 1c). The preoperative degree of AR had no significant effect on freedom from re-operation (Fig. 2a). Similarly, the need for root replacement showed a trend but not a significant effect on freedom from re-operation (Fig. 2b).

Since 13 out of 36 valves were re-repaired, freedom from valve replacement was similar in bicuspid and tricuspid AVs (Fig. 1d).

Seven patients suffered a transitory ischaemic attack and two patients a permanent stroke during follow-up; all episodes occurred in the presence of intermittent or persistent atrial fibrillation. The resulting linearised incidence of thrombo-embolic events was 0.2% per patient per year, freedom from thrombo-embolic events was 98% at 5 and 95% at 10 years. Eighteen patients are currently on coumadine-based anticoagulation for atrial fibrillation. There were no haemorrhagic complications in any of our patients.

Postoperative endocarditis of the reconstructed AV was seen in five patients. Two patients could initially be stabilised by antibiotic treatment and underwent re-operation for recurrent regurgitation within the first postoperative year. One patient developed endocarditis 5 years after AV reimplantation with cusp destruction and paravalvular abscess formation; the patient was treated by re-replacement of root and valve. Another patient was operated for active endocarditis limited to cusp destruction 10 years after AV re-implantation; a biologic valve was inserted into the prosthesis. In one individual healed endocarditis was found at re-operation for recurrent AR. The resulting linearised incidence of endocarditis was 0.16% per patient per year. Freedom from endocarditis was 99% after 5 and 97% after 10 years.

Freedom from all valve-related complications (re-operation, thrombo-embolism, endocarditis and haemorrhage) was 88% at 10 years with significantly better results after tricuspid than bicuspid AV repair (10 years: 93% vs 80%; p = 0.0017; Fig. 3).

5. Discussion

In AV replacement, both biologic and mechanical substitutes are associated with the inherent risks of valve-related complications [2–4]. Mechanical substitutes have a lower risk of re-operation, particularly in the younger age groups [3,5] but a higher risk of valve-associated morbidity, primarily due to haemorrhagic complications [3]. Interestingly, both prosthetic types have a similar linearised
incidence of valve-related complications of approximately 5% per patient per year, which was confirmed by other observations [20].

The pulmonary autograft implies a complex operative procedure and exposes the patient to the possibility of re-operation both on the autograft and pulmonary homograft; [21] freedom from re-operation is at best 90% at 10 years [21]. While it is an accepted option in the paediatric patients, recent observations [22] have raised considerable controversy regarding its use in adults.

The analysis of long-term results in mitral regurgitation has demonstrated that repair of the regurgitant mitral valve is advantageous over replacement regarding survival, incidence of thrombo-embolic complication, and the risk of haemorrhage [7]. For the mitral valve repair has thus become the treatment of choice, and its feasibility has led to recommendation of earlier surgery, that is, before irreversible cardiovascular changes occur [18]. So far, comparable data on AV repair are lacking. In the past 40 years, different reconstructive approaches for the regurgitant AV have been proposed, but no single technique has reproducibly led to consistent results in a relevant proportion of patients. This is most likely due to the fact that reconstructive techniques have addressed only a single component of the mechanism leading to AR. Valve-preserving aortic replacement only corrects regurgitation due to dilatation of the aortic root [12,13], while other techniques have addressed only isolated cusp pathology, that is, prolapse or retraction [8,15].

By limiting repair to one of the two key components of AR — either cusp or root pathology — AV reconstruction is bound to have only limited applicability. Any more generalised surgical approach to reconstructive treatment of AR has to take both aortic root and valve into consideration as a functional unit. In AR, only limited experience is available with the combined application of root and cusp reconstruction [16,23]. This, however, appears as an important prerequisite of standardised AV repair.

In the presence of normal or near-normal cusps, valve-preserving aortic replacement has consistently turned out reproducible results. Contrary to recent reports [24] both root remodelling and valve re-implantation have resulted in stable long-term AV function in our hands. Correction of cusp prolapse is possible by different means, such as plication of the free margin, triangular resection of redundant cusp tissue or support of the free margin using a polytetrafluoroethylene (PTFE) suture. All options have worked similarly well in our hands with comparable mid- and long-term results [25].

Our current results differ from previous publications primarily in that both cusp and root pathology were assessed and aggressively corrected by a combined approach. The proportion of such a combination of procedures has been more than 70% in the last years, and this probably is the main reason for the high repair rate of 80% in unselected patients with AR. Both short- and long-term results are encouraging and comparable to the results obtained with mitral repair [7,9]. Secondary repair failure could be re-repaired with good functional results, leading to freedom from valve replacement of 92% at 10 years. Freedom from re-operation or valve replacement is thus comparable to the long-term results with the pulmonary autograft [21].

Most importantly, our current data show a low incidence of valve-related complications after AV repair. We have not yet seen postoperative AV-block, a typical complication of valve replacement. In the absence of published data, we chose a low level of anticoagulation, with coumadine used only for patients in persistent atrial fibrillation. Aspirin was given to all other patients for 2 months postoperatively. The only thrombo-embolic complications we observed (seven transient ischaemic attacks (TIAs); two strokes) occurred in conjunction with intermittent atrial fibrillation. As a result of the limited use of anticoagulants, we have not yet observed haemorrhagic complications.

The linearised incidence of endocarditis (0.16% per patient per year) was low, and certainly lower than would have to be expected after valve replacement [3,5,20]. Three patients ultimately had to be re-operated upon after the active phase of the disease was treated conservatively. Primary re-operation was only necessary for paravalvular abscess formation or severe AR. Thus, repair seems to have advantages over replacement not only in the lower incidence of endocarditis, but also in the possibility of successful conservative treatment, which is rare after replacement [4].

The most frequent valve-related complication has been recurrence of AR leading to re-operation, with persistent or recurrent cusp prolapse as the most frequent cause. While recurrence of regurgitation and subsequent need for re-operation are inherent in any form of valve reconstruction, the current results include a learning curve effect, especially regarding recognition of cusp prolapse and generation of normal or near-normal cusp geometry.

Freedom from all valve-related complications was 88% at 10 years in our study. These data compare favourably with the incidence of valve-related complications of 4.4–5% per patient-year after AV replacement in several large studies. We did not observe valve-related mortality, and all re-operated patients did well after re-do surgery. This differs from the results after valve replacement, in which valve-related mortality averages approximately 8% at 10 years [3,5,20].

The limitations of our current investigation primarily relate to its retrospective nature and the limited follow-up. In order to generate better comparison between AV repair and replacement, a prospective study would be ideal. On the other hand, the current evidence on mitral reconstruction is based on well-analysed retrospective investigations that have been accepted as adequate. While the follow-up of the majority of our patients is still limited, we have observed stable valve function in all patients leaving the hospital with regurgitation grade 1 or less. For further judgement, however, very long-term results will have to be studied with a follow-up reaching 20 years.

Both short- and long-term results of AV reconstruction are thus encouraging and comparable to the results obtained with mitral repair [7]. In fact, freedom from re-operation/replacement is thus similar to the long-term results with the pulmonary autograft [21], without the need to resort to a complex operation on two valves and its inherent implications on pulmonary valve and right ventricular outflow tract. Reconstructive surgery appears as an attractive alternative to standard replacement of the AV.
References


