Aortic root stability in bicuspid aortic valve disease: patch augmentation plus reduction aortoplasty versus modified David type repair

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Received 12 October 2009; received in revised form 16 February 2010; accepted 3 March 2010; Available online 24 April 2010

Abstract

Objective: The unreinforced aortic root, in bicuspid aortic valve disease, has been shown to dilate and cause recurrent regurgitation. The objective of this study was to determine whether reduction aortoplasty can reliably prevent aortic root dilatation after aortic valve repair in bicuspid disease. Methods: A total of 66 patients, with a mean age of 41.2 ± 12 years and with incompetent bicuspid aortic valves and concomitant dilatation of the aortic root, were included in this study. As many as 49 patients had patch augmentation of the free edge of the bicuspid aortic leaflets and reduction aortoplasty, and a further 17 patients had patch augmentation and a modified David type repair. Patients were followed up by echocardiography and clinically in yearly intervals. Results: At midterm (mean follow-up was 5.1 ± 2.1 years), only one patient in the reduction aortoplasty group showed aortic root dilatation, leading to significant aortic valve regurgitation. Other than that, there was no progression of regurgitation in the whole group of patients. In the David type repair group, no re-operations, progression of aortic root dilatation or recurrent regurgitation occurred. In general, there was only one death in the reduction aortoplasty group. This patient developed endocarditis after 1 year and died of acute heart failure prior to readmission to our hospital. Conclusion: Both reduction aortoplasty and modified David type repair, paired with patch augmentation of the incompetent bicuspid valve, provide excellent midterm results. The reduction of the diameter of the ascending aorta by reduction aortoplasty seems to provide reliable stability that is comparable to the David type repair.

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Keywords: Aortic valve repair; Autologous pericardium; Aortic root

1. Introduction

In aortic valve reconstruction, primary competence and durability of repair are not achievable with a single technique alone. Instead, we rely on a combination of techniques that allow us to master the specific challenges put forward by the incompetent aortic root. Especially in bicuspid aortic valves, pathologies of the aortic leaflets and commissures, the aortic annulus and aortic root as well as the ascending aorta are often encountered and need to be addressed. Perhaps it is therefore not surprising that results of aortic valve reconstruction are less satisfying than those achieved for mitral repair [1].

Cosgrove et al. described the repair of bicuspid aortic valves in 1991 [2]. It involved triangular resection of prolapsing aortic leaflets and commissural plication. At midterm follow-up, this technique was associated with an unsatisfactory incidence of re-operations and residual aortic regurgitation [3].

As an alternative, we described the patch augmentation technique [4]. To obtain a greater area of leaflet coaptation, a strip of autologous glutaraldehyde-fixed pericardium was used to enhance the free edge of the fused leaflet. To treat concomitant dilatation of the ascending aorta, a reduction aortoplasty was carried out. Re-operations caused by redilatation of the aortic root have been described in literature and the question whether this type of repair is durable in the long term, remains unanswered. However, resuspending the aortic leaflets in a Dacron graft could be an option, as described in the David type repair [14].

Although developed primarily for tricuspid aortic valves, commissural resuspension can be used in bicuspid disease as well. However, the asymmetry of the bicuspid root indicates modifications to achieve a competent bicuspid valve. We adapted the patch augmentation technique [3] and the David technique [4] for cases of incompetent bicuspid aortic valves with concomitant ascending aortic aneurysms.

This article describes the technique and our clinical experience with the modification of the David procedure and pericardial patch augmentation combined with reduction aortoplasty in bicuspid disease.
leaflet was then carried out when necessary. Symmetry, a triangular resection of the prolapsing non-fused tissue on the one hand and on the other, to achieve resection of the fused leaflet was carried out, to excise its origin in the aortic wall and resected. Then, a triangular free edge of leaflets was shaved. The raphe was mobilised to changes of the leaflets could be observed. Thickening of the leaflet and a raphe were identified. Frequently, secondary bicuspid valve was examined. In all cases, the prolapsing aortotomy. After the placement of three stay sutures the aortic valve was approached through a transverse aortotomy. Access to the heart was gained via a median sternotomy.

Our technique for pericardial patch augmentation has been described elsewhere, in short. Access to the heart was gained via a median sternotomy. We routinely used aorto-atrial cannulation for extracorporeal circulation, antegrade and retrograde cold-blood cardioplegia, CO₂ insufflation of the thorax and moderate hypothermia. The aortic valve was approached through a transverse aortotomy. After the placement of three stay sutures the bicuspid valve was examined. In all cases, the prolapsing leaflet and a raphe were identified. Frequently, secondary changes of the leaflets could be observed. Thickening of the free edge of leaflets was shaved. The raphe was mobilised to its origin in the aortic wall and resected. Then, a triangular resection of the fused leaflet was carried out, to excise thickened tissue on the one hand and on the other, to achieve a slight bulging of the native leaflet. To optimise cusp symmetry, a triangular resection of the prolapsing non-fused leaflet was then carried out when necessary.

To obtain a greater area of leaflet co-apation, a strip of autologous glutaraldehyde-fixed pericardium was used to enhance the free edge of the fused leaflet. Our experience taught us that the ideal length of the strip corresponds to half the circumference of the sinotubular junction. The height of the strip was adjusted according to the desired area of co-apation, but was left slightly higher than the native non-fused leaflet edge. The pericardial strip was sutured to the free edge of the reconstructed aortic leaflet using 5/0 Cardionyl (Cardionyl™, Peters Laboratories, Bobigny-Cedex, France) suture. The suture line was extended slightly beyond the height of the native commissures and to the contralateral side. This was done to achieve overlap and optimal co-apation at the commissures.

The concomitant dilatation of the ascending aorta was corrected by taking larger bites at the transverse aortotomy with a 4/0 Prolene suture, thus achieving a reduction in diameter at the sinotubular junction. To treat the dilatation of the remaining ascending aorta, a longitudinal incision from the aortotomy to the aortic clamp was performed; in addition, an elliptical portion of the aortic wall just proximal of the cross-clamp was resected. For each millimetre in diameter, we resected 3 mm of circumference. A reduction aortoplasty was then carried out with a double-layered suture line using a 4/0 Prolene running suture and securing it with an additional 4/0 Prolene running suture.

3.2. **David type repair**

Access to the heart was gained through median sternotomy. The aortic valve was approached through a transverse aortotomy. After the placement of three stay sutures, the bicuspid valve was examined. The aortic sinus remnants are trimmed to a rim of 5—7 mm and the remaining root is dissected off adventitia down to the annular plane. In most cases, the annulus is not severely dilated and simple sizing of the annulus gives the measure for the size of the prosthesis.

Seven millimetres are added to the desired annular diameter to allow for the creation of neosinuses [3] A Dacon vascular prosthesis is then trimmed. Three stitches that crimp the prosthesis in circumference and height are placed, thus creating the base of the neosinuses (as described elsewhere). Then, the usual subannular stitches with 4/0 Ethibond (Ethicon, Somerville, NJ, USA) are placed. As we described it for the conventional repair of bicuspid valve [4], the raphe is mobilised and thickened closing edges of the leaflets are shaved, a patch of glutaraldehyde-fixed autologous pericardium is fashioned and sewn to the free edge of the fused leaflet with 5/0 Cardionyl (Peters Laboratories, Bobigny, France) running suture.

The pledget-armed stay sutures at the tip of the commissures are pulled through the prosthesis. The sub-annular sutures are passed through the base of the prosthesis and the prosthesis is tied in place. Then, the tips of the commissures are positioned within the prosthesis to match the geometry of the reconstructed valve. Tension is applied on the commissures, but not on the prosthesis. The commissural sutures are passed at corresponding height through the prosthesis and tied. Reduction of prosthesis diameter at the level of the sinotubular junction is achieved.
by three compression U-stitches at the commissures and additional three triangular stitches just distal to each commissure. The aortic sinus remnants are then sewn to the prosthesis with running 4/0 Prolene (Ethicon, Somerville, NJ, USA) mattress sutures. The procedure is completed in the usual way by reimplanting the coronary ostia and performing the distal graft-to-aorta anastomosis.

4. Assessment of reconstruction

The success of aortic valve repair was assessed intraoperatively by trans-oesophageal echocardiography. Special attention was focussed on leaflet motion, valve geometry, coaptation surface, trans-valvular gradients, residual aortic regurgitation and effective orifice area. In addition, the dimensions of the aortic annulus, sinus of Valsalva, sinotubular junction and ascending aorta were noted. Trivial-to-mild residual aortic valve regurgitation was considered a successful repair. As none of the patients had moderate regurgitation or higher, intra-operative re-exploration of the aortic valve to improve the repair was not necessary. After discharge from hospital, patients were followed up by transthoracic echocardiograms at annual intervals.

5. Statistical analysis

For the purpose of this investigation, we included all patients who underwent pericardial patch augmentation of incompetent bicuspid valves and who had concomitant treatment of dilated ascending aorta. There were two treatment options for the ascending aorta and this resulted in two groups being formed. Although patients were followed up in yearly intervals, data collection was retrospective in nature. With respect to the difference in group size, categoric variables were expressed as percentages and continuous variables were expressed as ± standard deviation. Comparison of categoric variables was performed with $\chi^2$ or Fisher exact tests, and continuous variables were analysed with unpaired $t$ tests or Wilcoxon tests. A $p$ value of less than 0.05 was defined as statistically significant.

All data were collected in a FileMaker-based database (FileMaker 7.0, Inc., Santa Clara, CA, USA). All statistical analyses were performed with StatView (version 5.0) for Windows software (SAS Institute, Inc., Cary, NC, USA).

6. Results

The mean follow-up was 5.1 ± 2.1 years. Except one, all patients were alive at latest follow-up. There were no perioperative deaths in any of the groups. Perioperative results are shown in Table 2. One patient in the aortoplasty group died within the first postoperative year. He developed endocarditis and subsequent acute cardiac failure. Two patients in the David type repair group were re-explored for perioperative bleeding complications. In all patients, attempted aortic valve reconstruction was successful, with none of the patients requiring intra-operative revision or postoperative re-exploration of the reconstructed aortic valve. One re-operation occurred in the aortoplasty group. This patient developed postoperative root dilatation. There were no cases of thrombo-embolism, or conduction disturbances in any of the patients.

The degree of aortic regurgitation was trivial at the most, as confirmed by intra-operative trans-oesophageal echocardiography and transthoracic echocardiography at discharge, in seven patients. At latest follow-up, only four patients showed trivial regurgitation in the aortoplasty group and eight in the David type repair group. All other valves were competent. During the postoperative follow-up period, we did not observe new aortic regurgitation or an increase in the degree of regurgitation, except for the patient who developed root dilatation. None of the valves were stenotic postoperatively. The spherical belly shape of the aortic leaflets was restored and a large co-aperture surface was achieved for all patients, as confirmed echocardiographically.

Postoperatively, all patients were put on beta blockers. A low or moderate dose of 25–50 mg Metoprolol twice daily was administered in normotensive patients. In hypertensive patients, the dose was increased to 100 mg twice daily. At 5-year follow-up, systolic blood pressures ranged from 95 to 150 mm Hg and heart rates from 65 to 105 beats min$^{-1}$.

Histological evaluation of the ascending aorta did not show cases of Marfan’s syndrome, cystic media necrosis or Erdheim–Gsell disease.

Results at 5 years are summarised in Tables 3 and 4.

7. Discussion

Bicuspid aortic valve disease is often accompanied by dilatation of the ascending aorta.

Prior to the introduction of reconstructive techniques to preserve the aortic valve, surgical treatment consisted of composite graft replacement, thus addressing the incompetent aortic valve and the dilated ascending aorta [5,6]. This
bicuspid anatomy. Therefore, root remodelling has been proposed for incompetent bicuspid aortic valves and concomitant aortic dilatation. Schäfers et al. report excellent 5–10-year data, showing the stability of remodelling in the presence of bicuspid aortic valves [13].

In our series of 66 patients with ascending aortic aneurysm and bicuspid aortic valves repair of leaflet pathology was identical in all patients. However, treatment of concomitant aortic root dilatation was treated by aortoplasty in most and by the David type repair in 17 patients. There were no significant differences in operative risk, survival or complications between the groups. Although one patient developed aortic root redilatation and required re-operation, all other patients with unrefined aortic root had stable aortic root diameters, up to 5 years postoperatively. It is also noteworthy, that none of the patients had progression of aortic valve regurgitation, proving that patch augmentation with its added co-aptation height, provides a very reliable and simple form of reconstruction. Based on these findings, we recommend the David type repair for patients who have a dilated aortic annulus.

### References


### Table 4

Postoperative clinical and echocardiographic data of both groups.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>David (n = 17)</th>
<th>Patch (n = 49)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>None</td>
<td>n = 1 (endocarditis)</td>
<td>ns</td>
</tr>
<tr>
<td>Re-operation</td>
<td>None</td>
<td>n = 1 (root dilatation)</td>
<td>ns</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>None</td>
<td>n = 1 (death)</td>
<td>ns</td>
</tr>
<tr>
<td>Conduction disturbance</td>
<td>None</td>
<td>None</td>
<td>ns</td>
</tr>
<tr>
<td>Aortic regurgitation grade 0</td>
<td>n = 8</td>
<td>n = 35</td>
<td>ns</td>
</tr>
<tr>
<td>Aortic regurgitation grade 0–1</td>
<td>n = 6</td>
<td>n = 4</td>
<td>ns</td>
</tr>
<tr>
<td>Aortic regurgitation grade &gt;1</td>
<td>n = 0</td>
<td>n = 0</td>
<td>ns</td>
</tr>
<tr>
<td>Mean aortic gradient (mm Hg)</td>
<td>5.2 ± 2.6</td>
<td>3.8 ± 3</td>
<td>ns</td>
</tr>
<tr>
<td>Peak aortic gradient (mm Hg)</td>
<td>10.2 ± 4.1</td>
<td>7.6 ± 5</td>
<td>ns</td>
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<tr>
<td>Effective orifice area (cm²)</td>
<td>2.9 ± 1.2</td>
<td>2.8 ± 1</td>
<td>ns</td>
</tr>
<tr>
<td>Planimetric orifice area (cm²)</td>
<td>3.7 ± 0.61</td>
<td>3.6 ± 1</td>
<td>ns</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>58.2 ± 10.6</td>
<td>54.8 ± 6</td>
<td>ns</td>
</tr>
<tr>
<td>Height of co-aptation surface (mm)</td>
<td>12.3 ± 3.1</td>
<td>11.7 ± 4</td>
<td>ns</td>
</tr>
</tbody>
</table>
Appendix A. Conference discussion

**Dr J. Bachet (Abu Dhabi, United Arab Emirates):** Obviously through your associated techniques of valve repair and aortoplasty, you have achieved a good experience with satisfactory results.

There are indeed two very different topics addressed in your talk. The first one deals with the valve repair. I have very limited experience in this matter, so I shall not discuss it lengthily. However, I am somewhat surprised that all your bicuspids valves had a raphe that could be resected and repaired and that all the leaflets were solid enough to tolerate a triangular resection and the insertion of a pericardial patch on their free edges. Haven’t you ever encountered cases in which the leaflets were quite fragile and have started to tear off while the sutures were carried out, especially considering that, as is indicated in your manuscript, you use 5/0 cardionyl suture to do this repair, which for me is a very large thread?

And a subsidiary question comes to my mind. Does this experience include all the regurgitating bicuspids valves operated on in your department? If not, what is the proportion of valves that could be repaired as compared to the ones that had to be replaced or did not require anything?

The second issue deals with the dilatation of the aorta. As far as I know, there are grossly two pathological patterns in those patients. Some of them have a normal or almost normal aortic root and sinotubular junction but a dilatation of the ascending aorta. The root can be kept in place. Others have a complete dilatation of the root and the ascending aorta. I suppose that in this latter group you have preferred the David procedure.

But some important information is lacking in your manuscript. Neither do you indicate the mean diameter of those various structures in your patients, nor do you indicate the criterion on which you decided to perform an aortoplasty or a David procedure.

Some reports, like one from Toronto, for instance, or another one from Hannover, have demonstrated a few years ago that if the aorta has a diameter superior to 45 mm and a wall thickness less than 1.5 mm, the risk of further acute dissection or rupture is quite high. So at what diameter do you decide that something has to be done on the aorta? And in addition to the diameter itself, do you take into account the thickness and the possible fragility of the aortic root?

Personally, I have never been convinced by the various techniques of aortoplasty that are described from time to time in the literature. They often leave in place diseased tissues, their completion sometimes results in an imperfect geometry, and their long-term outcome is somewhat uncertain.

And this is my bottom line and most important question. What is your rationale for considering that such a technique is better than a simple replacement of the ascending aorta, that any average surgeon can do in 20 minutes, that is safe, has almost no drawbacks, and the very long-term results of which are excellent and well-documented?

Nevertheless, despite my skepticism, I must acknowledge that the results that you have presented are excellent and apparently durable.

**Dr Doss:** Your first question, whether we had encountered patients where the tissue of the valves was too fragile to place a pericardial strip. In fact, perhaps, this depends on what kind of patients we see. Usually if you see very young patients, perhaps patients who have very fragile tissues, then perhaps that could be an issue. The patients that we saw, apart from having a raphe which was partly calcified, and apart from having relatively thick leaflets, also usually required some shaving of the leaflets themselves. So there we had good tissue that we could attach the pericardium to. So those patients that you described, perhaps from pediatric experience, we did not see and did not include in this study.

Secondly, I’d like to comment on your question regarding stability of the aorta itself. Why did we prefer to do an aortoplasty rather than placing a simple graft? As Professor Moritz has already described, if you interposition a simple tube in the ascending aorta, that might or will increase preload before and increase pressures after the tube. So although it seems to be a very reliable technique, it doesn’t mean that you will not have dilatation of the root proximal to that graft. So that in itself is not necessarily a reason, or at least in our hands, a reason just to replace the ascending aorta at once.

**Dr Bachet:** Excuse me, but have you ever tried to do a flow study after this aortoplasty? And how do you know that this aortoplasty maintains the laminar flow into the ascending aorta? Because as far as I see in those aortoplasty techniques, the aorta geometry is rather poor, let alone the aesthetics. So how can you say that this preserves the laminar flow better than the Dacron prosthesis?

**Dr Doss:** No, actually we’re not saying it’s better. And it’s also not the aim of the study to say that this is better than the David technique or to say this is better than any flow that you will observe with a Dacron graft, which is obviously industrially fashioned. But what we are saying, or what we are trying to show, is that even an aortoplasty — and we’re not the only group who are saying that, also in Berlin, if you look at the work from Bauer and Hetzer, they also show that aortoplasty is a reliable form of repairing the ascending aorta — and when we look at our 5-year results and we see that we do not have any significant dilatation of the aorta, then this is, of course, a very simple way of treating this type of pathology.

But I just wanted to answer your last question, which was the question regarding in what patients we use the David technique. And you are right there, actually, the patients who received the David technique were patients who also had dilatation at the annular level, which was not the case in the patients that had aortoplasty alone.