Aortic root remodeling in atheromatous aneurysms: The role of selected sinus repair

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Abstract

Objective: Atheromatous ascending aortic aneurysms (AAA) frequently present with aortic regurgitation (AR) from dilatation of the sinotubular junction (STJ) and extension of the pathological process into the root. Experience suggests that root dilatation begins in the non-coronary, then right coronary sinus. Rather than employ aortic root replacement or the David procedure, we have elected to replace the ascending aorta and remodel the STJ and involved sinuses. We studied the outcome after selective sinus replacement in 29 consecutive AAA patients between 1995 and 2001.

Methods: There were nine male and 20 females. Age ranged from 47 to 79 years (mean 67.5). Seven had arch aneurysms and four coronary artery disease. Nineteen were NYHA III or IV. Grade of AR was IV in 20, III in five and II in four. The STJ was dilated >50% of annulus diameter in each case (5.3–10.0 cm, mean 6.4 cm). All valves had three cusps. All patients underwent ascending aortic replacement. Seven had arch replacement and four coronary artery bypass. Seven had replacement of both right and non-coronary sinuses with re-implantation of the right coronary ostium. Twelve had replacement of the non-coronary sinus alone whilst nine had right coronary sinus replacement. One with dextrocardia had left coronary sinus replacement with ostial re-implantation. The graft size was within 2 mm of annulus size except for two patients (24 mm 12, 26 mm 11, and 28 mm six). Post operative echocardiographic studies were performed. None of the patients received anticoagulation.

Results: There were no hospital or late deaths and no thromboembolic or infective complications. Two patients had mild to moderate aortic regurgitation. These had a size 28 graft, which in retrospect was too large. Others had no significant regurgitation.

Conclusions: The native aortic valve can be preserved in the majority of patients with AAA. Remodelling of the STJ and selective sinus replacement restores valve competence. Anticoagulation and prosthesis related complications are thereby avoided.

Keywords: Atheromatous aneurysms; Sinus; Valve

1. Introduction

Aortic root remodeling procedures are well tried and tested in patients with annulo aortic ectasia [1]. Follow-up studies suggest that root and valve repair provides a durable alternative to aortic root replacement thereby avoiding prosthesis related complications [2,3]. To-date, root remodeling operations are less well established in hypertensive patients with atheromatous ascending aneurysms and aortic regurgitation. These aneurysms begin in the ascending aorta and extend into the root and arch. The pattern of root dilatation is determined by pressure and flow characteristics. The sinotubular junction (STJ) enlarges first followed by the non-coronary and right coronary sinuses. Though the annulus remains stable, the respective valve cusps are retracted and splayed producing central aortic regurgitation (Figs. 1A,B). The left coronary sinus usually retains normal dimensions until a very advanced stage, except in patients with situs inversus where the left sinus dilates first.

In patients with minimal involvement of the aortic sinuses, resection of the aneurysm and restoration of the STJ to a diameter 10–15% less than the valve annulus will restore competence. In contrast, preservation of dilated diseased sinuses allows persistent aortic regurgitation.

Since 1996, we have studied atheromatous ascending aortic aneurysm patients presenting with aortic regurgitation (greater than Grade 2) which required valve repair or replacement. Aortic root replacement was employed only in those with a bicuspid valve. All others were treated by selective aortic sinus replacement and restoration of the STJ to approximate with annulus diameter. This manuscript describes the root morphology and results of valve repair in
consecutive descending aneurysm patients with aortic regurgitation and a three cusp valve.

2. Patients and methods

Between January 1996 and May 2001, we performed selective sinus replacement in 29 consecutive atheromatous aneurysm patients with associated aortic regurgitation and three non-pathological valve cusps. Within this time frame, two others with a bicuspid valve and three with abnormal valve cusps (probably aortitis) underwent aortic root replacement. We did not employ ascending aortic replacement and separate aortic valve replacement (AVR) leaving pathological aortic sinuses in situ. Neither did we apply selective sinus replacement to patients with annulo aortic ectasia or the Marfan syndrome where the David or Yacoub operations are preferable.

2.1. Patient characteristics

There were nine male and 20 female patients with ages ranging from 47 to 79 years (median 67.5). Clinical data are summarized in Table 1. Presentation was by detection of a murmur, progressive breathlessness, angina or atypical chest pain, or chance chest X-ray finding. All were, or had been, smokers. All were hypertensive or undergoing treatment for hypertension. In seven patients, the aneurysm extended into or around the aortic arch. Four patients had coronary artery disease. One 78 year-old female patient had complete situs invertus with dextrocardia (Fig. 2). All patients were assessed by CT or MRI scan, transthoracic echocardiography, and coronary angiography. These imaging techniques were used to define annulus diameter, STJ diameter, size of the individual sinuses and the dimensions of the ascending aorta and arch. Aortic regurgitation was Graded (II–IV) by colour Doppler echocardiography (Table 1). The need for concomitant coronary bypass or aortic arch replacement was defined.

Aortic annulus diameter ranged from 22 to 28 mm (median 24). Pre-operative STJ diameter ranged from 53 to 100 mm (mean 64 mm). Aortic regurgitation was Grades 3 or 4 in 25 patients and Grade 2 in four patients. Twenty-two patients had significant enlargement of one sinus only in comparison to the stable left coronary sinus. This was the non-coronary sinus in 12 and the right coronary sinus in

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Table 1

<table>
<thead>
<tr>
<th>Number of patients</th>
<th>29</th>
</tr>
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<tbody>
<tr>
<td>Age</td>
<td>67.5 (47–79)</td>
</tr>
<tr>
<td>Sex</td>
<td>9:20</td>
</tr>
<tr>
<td>NYHA</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Grade of aortic regurgitation</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>6</td>
</tr>
<tr>
<td>Transverse arch aneurysm</td>
<td>7</td>
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</table>

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murmur, progressive breathlessness, angina or atypical chest pain, or chance chest X-ray finding. All were, or had been, smokers. All were hypertensive or undergoing treatment for hypertension. In seven patients, the aneurysm extended into or around the aortic arch. Four patients had coronary artery disease. One 78 year-old female patient had complete situs invertus with dextrocardia (Fig. 2). All patients were assessed by CT or MRI scan, transthoracic echocardiography, and coronary angiography. These imaging techniques were used to define annulus diameter, STJ diameter, size of the individual sinuses and the dimensions of the ascending aorta and arch. Aortic regurgitation was Graded (II–IV) by colour Doppler echocardiography (Table 1). The need for concomitant coronary bypass or aortic arch replacement was defined.

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Fig. 1. (A) Echocardiography showing a longitudinal section through the valve annulus (normal), and enlarged sinotubular junction (STJ) and ascending aortic aneurysm. (B) Doppler echocardiography showing failure of cusp coaptation through a dilated STJ and coronary sinus before surgery (left) then a competent valve after repair (right).

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Fig. 2. Plain chest X-ray in the female patient with dextrocardia.
nine. The remaining patient had dextrocardia with reciprocal enlargement of the anteriorly situated left coronary sinus. Seven patients had important dilatation of both the right and non-coronary sinuses.

Accordingly, all patients underwent radical remodeling of the STJ with a 28 mm graft in six patients, 26 mm graft in 11, and 24 mm graft in 12 cases. Twelve patients underwent non-coronary sinus replacement, nine underwent right coronary sinus replacement and one had left coronary sinus replacement. Seven patients had both right and non-coronary sinus replacement. The corresponding coronary ostia were mobilized and reimplanted just above their respective neo-aortic sinuses (Table 2).

2.2. Surgical methods

Detailed aortic root echocardiography determined the sinuses to be replaced and predicted the size of the ascending aortic graft necessary to reconstitute and stabilize the STJ, to match graft size with annulus size. Transoesophageal echocardiography was used in the operating room. All operations were performed via median sternotomy. Cardiopulmonary bypass was established using an arterial cannula in the arch or femoral artery and venous drainage from the right atrium. Deep hypothermic circulatory arrest at 16°C was used for concomitant arch replacement, in which case the aortic root was remodeled during the cooling period. Cold cardioplegic arrest was obtained with 1000 ml St. Thomas’s solution delivered directly into the coronary ostia. An apical left ventricular vent was used routinely. Where necessary, the distal anastomosis for coronary bypass were performed before root and arch reconstruction.

After opening the aneurysm longitudinally to deliver cardioplegia, the aorta was transected completely 5 mm distal to the STJ. The morphology of the aortic sinuses and valve cusps was assessed and the annulus size measured. During the learning curve, we were not sufficiently radical in reducing STJ diameter. As a result, two patients received a graft that was 10% larger than the annulus (25 mm annulus and 28 mm graft). The patients had Grade 2 aortic regurgitation post-operatively after which we rigidly kept graft size equivalent to or slightly less than annulus diameter. When the graft size was determined and the decision about sinus replacement made, a Hemashield graft (Meadox, NY) was tailored for the repair (Fig. 3). The pathological sinuses were then excised to within 3 mm of the commissure and annulus. The graft was sewn into place with three continuous 4/0 polypropylene sutures distributed symmetrically around the graft and beginning above each commissural pillar. This process reconstituted the STJ and restored central coaptation of the aortic cusps. The graft was then trimmed to length and the distal anastomosis performed. For arch replacement patients, deep hypothermic circulatory arrest was undertaken at 16°C and the remaining aneurysm excised. A separate graft was employed for total arch replacement in three patients and the brachiocephalic arteries implanted together on a button.

Table 2

<table>
<thead>
<tr>
<th>Operative data</th>
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<tr>
<td>Aortic valve morphology</td>
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<tr>
<td>Tricuspid</td>
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<tr>
<td>Bicuspid</td>
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<tr>
<td>Remodelling of STJ</td>
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<tr>
<td>One sinus replacement</td>
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<tr>
<td>Non-coronary sinus</td>
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<tr>
<td>Right coronary sinus</td>
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<tr>
<td>Left coronary sinus</td>
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<tr>
<td>Two sinus replacement</td>
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<tr>
<td>Non and right coronary sinuses</td>
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<tr>
<td>Replacement of transverse arch</td>
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<td>Coronary artery bypass</td>
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*a Situs inversus, dextrocardia.*

Fig. 3. Dacron graft shaped for single or double sinus replacement.
Discussion

There has been no thromboembolism, endocarditis, or deterioration in ventricular function. All patients are NYHA I. None has not required re-operation for either symptoms or deteriorating function 28 mm grafts which were between 10 and 15% larger than their valve annulus. This did not worsen with time and restoring valve competence was achieved in all patients with a three-cusp valve up to STJ diameter of 100 mm. (when the sino-tubular junction is greatly enlarged it is difficult to discern its existence) Valve repair appears to be durable and retained native sinuses are stable. The vascular graft together with scarring at the suture line prevent further aortic dilatation. Complications of valve prostheses are thereby avoided.

Sizing of the ascending aortic graft is critical and must focus on functional rather than anatomical constraints. In ascending aneurysm patients the annulus and valve cusps are usually unaffected by the pathological process and valve function can be restored by correcting root morphology. In relation to root repair, Kunzelman and colleagues showed the diameter of the normal STJ to be 15% less than annulus diameter [6]. Size increases with age and we do not aggressively reduce the STJ during the repair. In young infants As ascending aortic aneurysm size increases and extends to involve the root, the STJ dilates asymmetrically above the non-coronary and right coronary sinuses thereby retracting the valve commissures to produce central aortic regurgitation. Some of our patients had massive discrepancy between annulus and STJ with Grade IV aortic regurgitation. Even so, radical excision and down sizing of two aortic sinuses allowed the STJ to be remodelled to annulus size thereby restoring valve competence. The shape and functional characteristics of the aortic sinuses also seem to be retained with this operation. We had no difficulty in adapting the ascending aortic graft to fit the distal anastomosis.

Methods to preserve the aortic valve in aneurysm operation began in 1979 when Yacoub and associates preserved the native valve in young patients with annuloaortic ectasia (with or without Marfan syndrome) [1]. In this condition, all three sinuses dilate progressively. The operation consisted of removing all of the sinus aorta except for a small rim of aortic tissue around the coronary ostia. All three sinuses were then replaced with a scalloped graft approximately 10% less than annulus size to achieve co-aptation of the aortic valve cusps.

David adopted a different approach by excising the pathological sinuses and re-implanting the valve within a Dacron tube. When the valve annulus is dilated in these patients, a reduction annuloplasty is performed to a diameter appropriate for the patients body size. This would generally be 25 mm for an average adult male, 27 mm for a larger male and 23 mm for a female. Though the native aortic sinuses are lost in these procedures, but are said to provide durable and

2.3. Follow-up

Transthoracic echocardiography was performed before hospital discharge and at outpatient review for periods 3–72 months (mean 34.7 months). Aortic valve competence and native sinus dimensions were determined.

3. Results

There were no hospital or late deaths. One arch replacement patient suffered a transient hemiplegia but recovered completely without residual signs or disability. Two patients required post-operative haemo-filtration for acute or chronic renal dysfunction but recovered. Echocardiography showed no leak in 20 patients (69%) and Grade 1 regurgitation in seven patients (24%) (Fig. 1B). Two patients had Grade 2 aortic regurgitation after receiving 28 mm grafts which were between 10 and 15% larger than their valve annulus. This did not worsen with time and has not required re-operation for either symptoms or deterioration in ventricular function. All patients are NYHA I. There has been no thrombo embolism, endocarditis, or anticoagulant related bleeding.

4. Discussion

Conservation of the native aortic valve has been an important step in reducing post-operative morbidity for patients undergoing repair of root and ascending aortic aneurysms [4]. Whereas the stability of root repair is now documented in annuloaortic ectasia and Type A dissection patients, there is little information after atherosclerotic aneurysm resection in patients with aortic regurgitation [5]. For these patients, separate supra coronary aneurysm repair with AVR or full aortic root replacement has usually been employed instead. For the last 5 years, remodeling of the STJ with selective sinus replacement has been our routine approach. This has proven feasible in all patients with a three-cusp valve up to STJ diameter of 100 mm. This did not worsen with time and restoring valve competence was achieved in all patients with a three-cusp valve up to STJ diameter of 100 mm. (when the sino-tubular junction is greatly enlarged it is difficult to discern its existence) Valve repair appears to be durable and retained native sinuses are stable. The vascular graft together with scarring at the suture line prevent further aortic dilatation. Complications of valve prostheses are thereby avoided.

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competent valves, Cochran and colleagues modified the David procedure by creating pseudo-aortic sinuses in the graft to improve valve opening and closing characteristics [7].

Definition of the pathological and structural alteration in the aortic root is the basis on which accurate and reproducible valve repair is undertaken [8]. This can be achieved by echocardiography, Spiral CT Scan and NMR to assess root dimensions. When the annulus and valve cusps are normal, the size of the ascending aortic graft employed determines valve function. With large aneurysms, it is tempting to oversize the graft to avoid substantial discrepancy at the anastomosis with the distal aorta. We found that even slight oversizing (28 mm graft, 25 mm annulus) resulted in Grade II aortic regurgitation and we subsequently ensured that graft size was equal to or less than annulus diameter. Measurement of the diameter at the aortic annulus is easier than measuring the average length of the free edge of aortic valve cusps as used by David or the distance between commissures as suggested by Morishita [9]. In reality, the aortic root is a dynamic structure and a normal STJ expands up to 35% during systole [10]. In contrast, annulus expansion does not exceed 5% so that measurement of root diameter at the base of the valve cusps, is a suitable guide for graft selection in ascending aneurysm patients. The circumference of the graft should then approximate with three times the length of the normal left coronary sinus. One or two sinuses are remodeled to achieve this.

In conclusion, aortic root remodeling by selective sinus replacement is an effective solution for aortic regurgitation in atheromatous aneurysm patients.

References


Appendix A. Conference discussion

Dr A. Haverich (Hanover, Germany): Can you always predict from preoperative assessment whether you will be able to perform this type of reconstruction or is it due to intraoperative assessment that you define your technique?

Mr Westaby: It is really both, but I decided 5 years ago, this series is over 5 years, that I would attempt to repair the valve in every single atheromatous ascending aortic aneurysm patient, and unless they had a bicuspid valve or other reason to select it, this was a consecutive series of patients with three cusps that I thought could be repaired. So, on the whole, we decided preoperatively that we would repair it, and these are the results.

Dr U. Von Oppell (Cape Town, South Africa): In your experience, is there a guideline in terms of annulus diameter above which you would not have attempted this repair and gone for either a Freestyle or a composite valved graft instead? Were there any patients that you did not repair and elected to go for a root replacement, and if so, why?

Mr Westaby: Well, for the second part of that question, the only ones that I didn’t repair were patients with bicuspid valves or a small number of patients that had aortitis where the cusps were thickened, retracted and not normal. So, in other words, I decided, and you saw that very large aneurysm, that I would repair the valve in every ascending aortic aneurysm patient that had aortic regurgitation. Some of these sinotubular junctions were really up to 12 mm. So, in other words, I repaired all of them.

Dr D. Dougenis (Patras, Greece): If I may, I would like to make a comment on the terminology used regarding the atheromatous aneurysms. I believe we shouldn’t use anymore the term atheromatous, because actually most of the time it is not atheromatous in origin, and we should use the term degenerative instead of that. And my questions to you are: did you notice in your follow-up any cases of aortic regurgitation or pseudoaneurysms?

Mr Westaby: No pseudoaneurysms, and, as I say, when we chose a graft that was significantly larger, 3 or 4 mm larger than the sinotubular junction, that is when we got late aortic regurgitation, which was Grade II in two patients. They have not required reoperation. Their left ventricular function is stable. But, as I say, it is a technical error to oversize the graft.

Dr M. Turina (Zurich, Switzerland): When looking at your slides I see a great discrepancy between your echo findings and the actual appearance of the valve. Those valves which you have shown us look to me like having only Grade I aortic incompetence. When faced with a coronary ostium which is not elevated more than 8–10 mm above the annulus, most of us would be inclined to downsize a graft and replace only the ascending aorta. This will almost always take care of the Grades I and II aortic incompetence, without going into a much greater procedure. You made a very categoric statement at the beginning of your speech, that such an aorta should not be replaced at the level of the sinotubular junction. Do you have any proof for this statement?

Mr Westaby: Well, I used to do precisely that, whenever possible I used to try and leave the coronaries in place and the aortic sinuses in place with these aneurysms and narrow the sinotubular junction, which, again, was described by Tirone a long time ago. But just doing that, I had cases with persistent aortic regurgitation. Now, when you say you have got persistent aortic regurgitation, as we know, the echo doctors, and my Chinese colleague is an absolute genius with echo, they will tell you whether the valve looks completely normal, but they are very aggressive to tell you if they think the valve is not completely normal. So basically I moved from just narrowing the sinotubular junction to being more aggressive with the
sinuses. But, as I say, most of these patients had very significant aortic regurgitation. A few of them had Grade II.

**Dr A. Haverich (Hannover, Germany):** It looked from the first operative slide that it was not only atheromatous disease included but that it looked like a healed aortic dissection.

**Mr Westaby:** Well, as you know, sometimes with these very large aneurysms you see the tears inside. But, again, the comment from the floor was absolutely correct. We call atheromatous ascending aortic aneurysms most aneurysms that involve the ascending aorta. Some of them end up having aortitis where the cusps are not normal and you can’t preserve them.

**Dr Haverich:** Could you speculate to what degree your operation would have been successful if you would have done a full David repair, a complete repair of the aortic root by a David reconstruction, because that would be the more formal or uniform operation to be performed?

**Mr Westaby:** To replace all three?

**Dr Haverich:** Yes.

**Mr Westaby:** What I am advocating, as in most aortic surgery, is to try and simplify what we do. If you can just mobilize the right coronary and reimplant it and replace two sinuses instead of three, it shortens the operation, it is simpler, and I think that is what we need to head towards, doing things as simply as we can so that everybody can do them and not just Tirone David and Magdi Yacoub.