Surgical experience with "waistcoat aortoplasty": an update

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Background. **Some patients with primary aortic valve disease can present with an associated asymmetrical dilation of the aortic root and/or ascending aorta without diffuse congenital aortic wall defects. In such cases "waistcoat aortoplasty" has been performed: the present study updates the report of the results of 73 procedures.**

Methods. **Seventy-three patients underwent aortic valve replacement and waistcoat aortoplasty. Sinus dilation was repaired by plicating the subcoronary redundant aortic wall using the anchoring sutures of the valve prosthesis. Through a triangular resection the most diseased segment of the aortic wall was removed and the aorta was reconstructed with a double layer technique. Thus autologous reinforcement of the convex right postero-lateral wall and stress reduction on the aortotomy suture line were both achieved. Echocardiography was performed preoperatively, postoperatively and then every 6 months. The paired Student's t-test was employed to evaluate the significance of the diameter variations.**

Results. **The procedure was performed with no hospital mortality and a low postoperative morbidity. The post-reduction diameters at the sinuses, sinotubular junction and ascending aorta were significantly smaller than the preoperative ones ($p < 0.001$). During an echocardiographic follow-up of 39.2 ± 12.5 months (range 14-58 months), no significant increase in the root ($p = 0.18$), sinotubular junction ($p = 0.22$), and ascending diameter ($p = 0.34$) was observed.**

Conclusions. **Although further studies are needed to confirm these results in the longer term, waistcoat aortoplasty should be taken into consideration in case of asymmetric ascending dilation secondary to aortic valve disease-related medial degeneration.**

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Introduction

The most commonly performed procedure for simultaneous aortic valve and aortic root disease is the Bentall operation[1,2]. The theoretical basis for radicalism is represented by the intrinsic systemic arterial wall weakness due to genetic disorders of the media components, as already demonstrated in the Marfan syndrome and postulated in other inherited conditions[3]. Other options such as separate valve and supracoronary graft replacement, for cases without aortic root dilation, and aortic valve sparing operations, when the aortic valve dysfunction is not structural but likely to be secondary to the enlargement of the sinotubular ridge and/or the aortic surgical annulus are available[4,5]. Besides the etiology and anatomy of the aortic root and valve disease, it is important to take the underlying pathology into account when deciding surgical management: in case of congenital elastic tissue disease, the aortic root should be treated even if it is almost normal in diameter at the time of aortic valve replacement[1,6]. On the other hand, in case of asymmetric aortic dilations not linked to congenital disorders but associated with aortic valve structural disease, in which medial changes have been demonstrated to affect the convex aspect of the aorta with relative sparing of the concave aspect, radical resection could expose the patient to an otherwise avoidable increase in operative risks[7,8].

In order to treat asymmetrical dilations of the ascending aorta associated with aortic valve structural disease without exposing the patient to the risks related to prosthetic replacement and coronary reimplantation, a novel surgical technique, "waistcoat aortoplasty", was developed. The early results have already been acknowledged elsewhere[9]: we report and update our surgical experience in 73 patients.

Methods

Between June 1998 and April 2003, 73 patients (55 males, 18 females, mean age

56 ± 7.5 years, range 35-75 years) with non-complicated dilation of the intrapericardial aorta associated with aortic valve structural disease underwent elective aortic valve replacement and waistcoat aortoplasty. The indications for aortic valve replacement included severe fibrocalcific insufficiency in 19 patients, symptomatic stenosis in 33, mixed disease in 20, and calcific degeneration of a porcine bioprosthesis in 1 patient. The indication for associated surgery of the ascending aorta was an aortic ratio > 1.5[1] at either the sinus or tubular level or both. All patients underwent preoperative, postoperative (pre-discharge) and follow-up (every 6 months) M-B-mode transthoracic echocardiography. Investigations were always performed by the same external operator, who was not involved in the study, using an Acuson Sequoia C256 machine (Mountain View, CA, USA) with a multifrequence 3V2C sector scan. The ascending aorta diameter at the level of the left pulmonary artery, the aortic root diameter at the level of the sinuses of Valsalva, and the diameter of the sinotubular junction were recorded in all cases. As an index of elongation of a dilated aortic root, which implies cephalad displacement of the coronary ostia, the distance between the aortic annulus and the sinotubular junction (aortic root height) was assessed in the left parasternal long-axis view. Macroscopic alterations such as calcifications, intimal flaps, atherosclerotic lesions and the presence of a hematoma, as well as clinical signs or a family history of Marfan-like elastic tissue disorders or the presence of a congenital bicuspid aortic valve have been considered contraindications to the conservative procedure. The indication to aortoplasty was confirmed in all cases by the finding, at surgical inspection, of an asymmetrically dilated intrapericardial aorta with predominant enlargement of the convex aspect.

All patients preoperatively underwent cardiac catheterization with coronary angiography and aortography. Critical coronary lesions were found in 4 patients (left anterior descending in 2, right coronary in 1 and both left anterior descending and right in 1). Coronary revascularization was associated with aortic valve replacement and aortoplasty in all 4 cases. In another 3 patients a concomitant mitral valve replacement was performed.

At surgery, performed through a median sternotomy, moderate hypothermic (26°C) cardiopulmonary bypass was accomplished by cannulating the proximal transverse aortic arch and the right atrium and by venting the left atrium through the right superior pulmonary vein. The aorta was clamped proximally to the innominate artery and a reversed L-shaped aortotomy was performed as shown in figure 1. Triangular resection of the aortic wall corresponding to the convexity was the next step (Fig. 1). The excised aortic wall corresponding to the convexity was sent for histological analysis in all cases, along with a few millimeter wide specimen taken from the left edge of the resection. Intermittent crystalloid cardioplegia was directly infused in the coronary ostia every 30 min. A bileaflet mechanical valve was implanted in all cases but 5 (bioprostheses), always with interrupted 2/0 Tevdek sutures: in 68 patients with associated dilation of the aortic sinuses, in order to remodel the aortic root geometry, every stitch bite included the redundant subcoronary portion of the aortic wall thus plicating the three sinuses (Fig. 2). The aorta

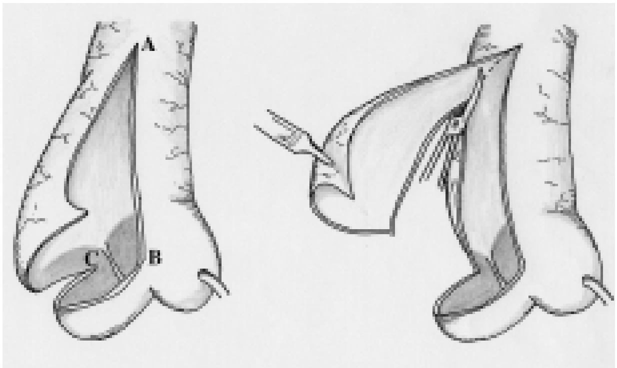

Figure 1. Left: *the aortotomy starts from just below the clamp (point A) and runs proximally to 2 cm above the commissure between the right coronary sinus and the non-coronary sinus (point B). It then deflects by 90° and continues towards the commissure between the left coronary and the non-coronary sinus (point C).* Right: *a triangular resection of the dilated aortic wall is obtained by prolonging the incision from point C to point A.*

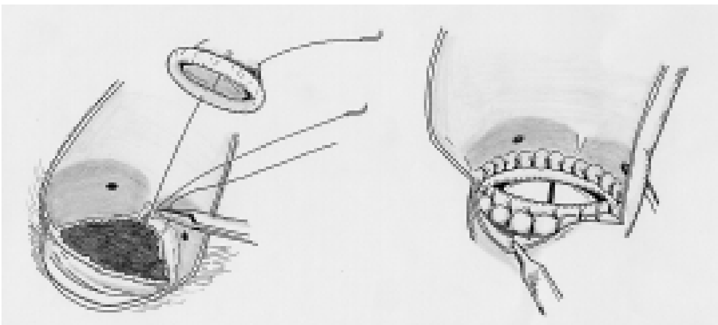

Figure 2. Left: *the stitches employed for aortic valve replacement included the subcoronary dilated wall.* Right: *when tying the sutures down the sinuses were folded up, thus obtaining a bidimensional (longitudinal and radial) plication.*

was reconstructed using a double layer technique termed "waistcoat aortoplasty". A first suture fixed the right postero-lateral free edge of the resection to the inner surface of the anterior wall leaving a 1 to 2 cm wide anterior flap (Fig. 3). The anterior flap was then used to cover and reinforce the neo-convexity and its free margin was sutured on the right-posterior wall (Fig. 3). In order to avoid the development of an intimal scar which could be a risky *locus minoris resistentiae,* this 5/0 polypropylene running suture was not crossed through the whole thickness of the aortic wall; it was meant to share the hemodynamic stress with the first suture line, hence reducing its stretching.

Data obtained from early postoperative echocardiographic examinations (reported as mean ± SD) were compared with those recorded preoperatively using the paired Student's t-test. In those patients with at least two follow-up echocardiographic controls, the diameters recorded at the last follow-up examination were compared with the early post-reduction diameters using the paired Student's t-test.

Results

No case of hospital mortality was observed. Among the early postoperative complications one case of respiratory failure requiring prolonged ventilation and one case of acute renal failure were observed. The mean cross-clamping time was 47 ± 9.4 min. The mean postoperative bleeding was 593 ± 255 ml. The mean postoperative hospital stay was 6 ± 2.5 days. In all cases histology confirmed the surgical macroscopic finding of more severe involvement of the convexity, with worse medial degeneration in the excised wall portion than in the specimen retrieved from the resection margin. Specimens from the convexity always expressed severe (grade 2 or 3) medial degeneration, while among specimens from the resection margin, 4 were diagnosed as normal, 59 showed grade 1 degeneration, 10 grade 2, and none grade 3. The mean clinical follow-up was 34 ± 19.2 months (range 0.5-58 months). The follow-up was 98.6% complete. All patients were alive and functional postoperative evaluation revealed that 55 patients were in NYHA class I, 16 in class II and 2 in class III. One patient was readmitted during the second postoperative month for recurrent pleural effusion and then discharged 8 days later after complete recovery. Echocardiographic follow-up reached at least 12 months in 58 patients (mean follow-up 39.2 ± 12.5 months, range 14-58 months). A significant postoperative reduction in the sinus, sinotubular and ascending aorta diameters compared to the preoperative values was found: the mean postoperative diameter at the sinuses of Valsalva was 3.37 ± 0.35 vs 5.05 ± 0.57 cm, $p < 0.001$; the mean sinotubular diameter was 3.34 ± 0.44 vs 5.00 ± 0.63 cm, $p < 0.001$; the mean ascending aorta diameter was 3.41 ± 0.43 vs 5.43 ± 0.72 cm, $p < 0.001$; the mean postoperative aortic root height was 1.66 ± 0.34 vs 2.36 ± 0.5 cm, $p < 0.001$. No case of recurrent aneurysm or late postoperative aortic- (such as aortic acute or chronic dissection) or valve-related complication (including structural malfunction, endocarditis, thromboembolism and bleeding) was recorded. In no case did the sinus plication technique interfere with the free motion of the prosthetic leaflets.

With regard to the first 58 patients who reached at least 12 months of follow-up, echocardiography did not reveal any significant increase in the aortic diameters compared to the early postoperative evaluations (root 3.55 ± 0.37 vs 3.47 ± 0.42 cm, $p = 0.18$; sinotubular junction 3.51 ± 0.46 vs 3.49 ± 0.35 cm, $p = 0.22$; ascending aorta 3.55 ± 0.54 vs 3.53 ± 0.55 cm, $p = 0.34$; root height 1.7 ± 0.28 vs 1.78 ± 0.42 cm, $p = 0.25$). Only 2 patients among those undergoing waistcoat aortoplasty without sinus plication reached 12 months of follow-up: no case of aortic root enlargement was observed (preoperative diameters: 3.6 and 3.3 cm at the root level, 3.5 and 3.2 cm at the sinotubular level; follow-up diameters: 3.6 and 3.4 cm at the root level, 3.4 and 3.0 cm at the sinotubular level).

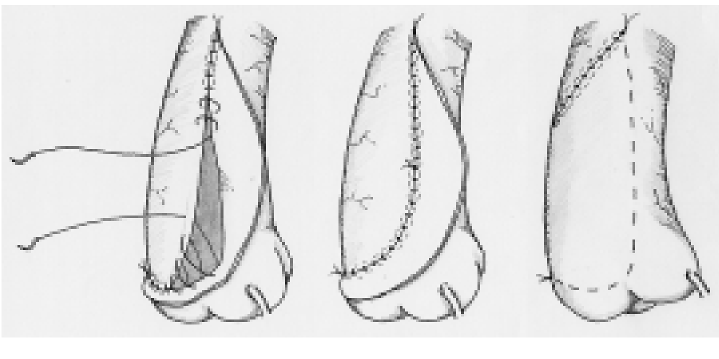

Figure 3. Left: *two running sutures starting at each end of the reversed L-shaped aortotomy fix the right postero-lateral edge of the resection transposed to the inner aspect of the anterior wall (reverted in the figure). A neo-convexity is thereby created using the residual right postero-lateral wall which is transposed anteriorly.* Middle: *at the end of this maneuver the aortic diameter is reduced and a flap of anterior aortic wall remains. This flap will be used to cover and reinforce the neo-convexity.* Right: *completed procedure. The hyphens delimitate the portion of aortic wall that is reinforced in double layer.*

Discussion

Current surgical methods for treating concomitant aortic valve and root disease vary widely, and the basis for selecting one repair or replacement alternative over another continues to evolve. The aortic root has recently undergone sophisticated investigations aiming to clarify its normal morphology as well as the physiologic interactions between its structures, i.e. the role of the aortic root dynamics on valve function and stress distribution[10,11]. To date, the clinical relevance of these experimental studies has been referred to the possible implications in aortic valve sparing approaches for annuloaortic ectasia or in repair techniques for aortic valve incompetence[12,13]. Indeed, the recognition of the complexity of the aortic root structures and function may also suggest reconsideration of several surgical guidelines or current trends in the treatment of aortic root dilations associated with aortic valve disease. In particular, the normal aortic root and valve have been found to constitute an asymmetric, highly complex structure[10,12,13] in which hemodynamic stresses are not equally distributed along the circumference of the vessel. It is well known that medial degeneration alterations underlie the aging process of the normal aorta[14], and this has been attributed to hemodynamically induced bioengineering fatigue caused by longitudinal stretching and the circumferential distension effects of the pulse waves[15]. This has strongly contributed to the development of the hemodynamic theory to explain the genesis of medial degeneration as related to the interactions between wall structures and biomechanical stress.

Ascending aorta dilations associated with primary aortic valve structural disease tend to expand asymmetrically, with macroscopic prevalent involvement of the convex aspect of the vessel and relative sparing of the concave aspect[16,17]. Studies from our Institution reported the finding of a consistent asymmetrical distribution of the severity of medial degeneration lesions in non-Marfan patients with aortic valve dysfunction and aortic dilation: more severe lesions prevail at the convexity[7,8]. The concept that those findings may be in relation with the eccentricity of the abnormal flow in the ascending aorta of patients with aortic valve stenosis or regurgitation represents an appealing hypothesis. Indeed, even studies on prosthetic aortic valves have shown that the orientation of the leaflets has a major impact on the blood flow characteristics and affects the development of turbulence in the ascending aorta[18]. Severe aortic valve dysfunction, requiring valve replacement, causes significant turbulence and wall stress increase in the proximal aorta; nevertheless, according to the law of Laplace patients with even a moderately dilated aorta undergoing isolated aortic valve replacement have a risk of postoperative dissection or rupture which is proportionally correlated with the preoperative aortic diameters[19-21]. The technique of ascending aortoplasty named "waistcoat" was therefore developed with the aim of restoring an almost normal postvalvular rheology through aortic valve replacement and address both Laplace's criteria of diameter (plastic reduction) and wall thickness (autologous double layer reinforcement) whilst avoiding the implantation of foreign bodies in the pericardium.

Although a longer follow-up is needed to completely ascertain the validity of the technique in terms of the prevention of aorta redilation, dissection or rupture, the reported results, obtained during a mean postoperative period of 39.2 ± 12.5 months, may be considered encouraging. Previous single-suture unsupported aortoplasties have been shown to be associated with a relatively high risk of recurrence[16,22,23] and some authors have attributed this drawback to the lack of external reinforcement[24]. Nevertheless, while the effectiveness and safety of an external prosthetic reinforcement have never been demonstrated, it must be remarked that the lack of definite patient selection criteria was probably the main flaw of previously reported series on reduction aortoplasty: those techniques neglected the underlying aortic wall pathology characteristics, and were thereby employed both in post-stenotic dilations in which the hemodynamic stress is the most important etiologic factor, as well as in Marfan aneurysms or aortic dilations associated with bicuspid aortic valve, in which the main pathogenetic factor is represented by idiopathic wall weakness[25,26]. The present "waistcoat" technique was indicated exclusively for asymmetrical dilations of the ascending aorta associated with primary structural aortic valve disease. Patients with symmetrical aneurysms, in whom the underlying pathology (e.g. atherosclerotic aneurysms, connective tissue inherited disorders) is supposed to involve the entire vessel circumference, should undergo radical treatment with the modified Bentall operation or separate replacement of the aortic valve and ascending aorta.

Future efforts in basic research will continue to add insights to the acquired knowledge, probably further characterizing the different forms of ascending aorta dilations associated with aortic valve disease. It is hoped that they would thereby provide the theoretical bases for the selection of that surgical management which is best fitted for the individual case.

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