Impact of ascending aorta replacement combined with a Ross procedure on autograft root distensibility and function in patients with combined pathology of the aortic valve and ascending aorta

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Abstract

In this study we aimed to assess the autograft root dimensions, distensibility, and autograft valve function in patients after Ross operation combined with replacement of the ascending aorta compared to patients that underwent Ross operation only. Forty patients received a Ross operation, and in 12 of them an additional replacement of the ascending aorta was performed. Autograft root dimensions, distensibility, and valve function were assessed by echocardiography. There were no differences in root size, distensibility, and valve function between groups. Our preliminary results indicate that replacement of the ascending aorta with a noncompliant prosthesis has no effect on the autograft root.

Keywords: Aneurysm; Autograft; Aortic valve; Aortic root

1. Introduction

Pathologies of the aortic valve requiring valve replacement or reconstruction are associated with significant dilation of the ascending aorta in up to 15% [1]. A surgical approach to the simultaneous repair or replacement of the aortic valve and ascending aorta reduces the risk of late aortic rupture and/or development of acute type A aortic dissection. The standard approach in those cases is the replacement of the aortic root and ascending aorta with a composite graft including a biological or mechanical valve prosthesis. However, composite graft replacement commits the patient to the disadvantages of mechanical and biological valve substitutes, thromboembolic events, hemorrhage due to anticoagulation, and re-operation for re-replacement of degenerated biological valve substitutes [2]. Recently, Elkins and associates demonstrated the safety and effectiveness of combined aortic root autograft replacement in combination with ascending aorta replacement for patients with aortic valve disease and ascending aorta aneurysm [3]. However, Simon-Kupilik and co-workers evaluated the impact of vascular prostheses on aortic root wall stress in an in vivo study and described a significant increase in native aortic root wall stress and aortic root distension after supracommissural replacement of the ascending aorta [4]. Several studies demonstrated, that pulmonary autografts dilate when the Ross procedure is performed as aortic root replacement [5–8]. The dilation of the pulmonary autograft is probably the most common cause of autograft failure following Ross operation [5,8]. Thus, replacement of the ascending aorta in combination with the Ross procedure — performed as aortic root replacement — may have an effect on autograft root dimension, distensibility, and valve function. The purpose of this study was to evaluate the influence of prosthetic ascending aorta replacement on autograft size, distensibility and valve function.

2. Methods

2.1. Patients

Between April 1996 and June 2001, 40 patients underwent Ross operation at our institution as complete root replacement. In 28 of these patients the ascending aorta was
found to be within the normal range (Ross group = R group). Twelve patients presented with ascending aortic aneurysm or dilation and received simultaneous supracommissural replacement of the ascending aorta with a vascular prosthesis (Ross and ascendens aorta replacement group = R/A group). The mean follow-up for all patients was 21 ± 8 months. Patient characteristics and operative data are depicted in Table 1.

2.2. Surgical techniques

All surgical procedures were performed using moderate hypothermic (30°C) cardiopulmonary bypass and antegrade cold blood cardioplegia was used for myocardial protection. Pulmonary autografts were implanted using the full root replacement technique. In patients with dilation or aneurysm formation of the ascending aorta (40.2 ± 6.1 mm) a replacement using a noncompliant Dacron velour prosthesis was performed. Thereby, the diameter of the prosthesis did not exceed the diameter of the aortic annulus. The proximal suture line was sewn 5–8 mm apart from the autograft sinotubular junction of the autograft. In four patients a partial aortic arch replacement was performed during moderate hypothermic circulatory arrest with selective antegrade cerebral perfusion with cold blood. A reduction of the aortic annulus by placation of intercommissural tissue was performed in 17 patients (R group, n = 11; R/A group, n = 6).

2.3. Echocardiographic data acquisition and measurements

Echocardiography was performed with a Hewlett-Packard Sonos 5000 system with 2.5-MHz ultrasound transducers during routine follow-up examinations, with the patient in the left lateral decubitus position. A modified ECG lead I was continuously recorded. Blood pressure was measured by cuff sphygmomanometry (Dinamap, Siemens). Echocardiographic measurements were performed while blood pressure was constant. Root dimensions were measured by two independent observers from video-recorded studies and the average value of five consecutive beats in sinus rhythm were taken. The diameters of the aortic root at the annular level, the sinuses of Valsalva, and the commissures were determined using the leading edge method. To evaluate the reproducibility of echocardiographically determined aortic root diameters video-recorded studies of ten patients were measured twice within 2 weeks. The range of variation of the measured diameters was 2–5.3%. Maximum velocities across the aortic valve were obtained by continuous-wave Doppler using the apical 5-chamber view showing the aorta and left ventricular outflow tract. Aortic regurgitation was assessed by color-flow Doppler techniques in standard transthoracic views and graded using the ratio of jet height/left ventricular outflow tract height as follows: grade I, 1–24%; grade II, 25–46%; grade III, 47–64%; grade IV, >65%.

2.4. Calculations

The following formulas were used to calculate: (1) The peak systolic pressure gradient across the aortic valve (modified Bernoulli equation)

$$ \Delta P \ [\text{mmHg}] = 4 \times v^2 \ [\text{m/s}] $$

where $v$ presents the peak systolic velocity across the aortic valve; and (2) the percent change in radius (PCR)

$$ \text{PCR} \ [%] = (\Delta R \ [\text{mm}] \times 100)/R \ [\text{mm}] $$

where $\Delta R$ presents the difference between the largest and smallest diameter and $R$ is the average diameter.

2.5. Statistical analysis

Categorical data are given as total numbers and relative frequencies; continuous data are given as mean ± SD. Group comparison was made with the use of unpaired t-test for continuous variables. For ordinal data the $\chi^2$ test was performed. A $P$-value of less than 0.05 was considered statistically significant. Software (SPSS for Windows 8.0; SPSS Inc., Chicago, IL) was used for statistical analysis.

3. Results

Postoperative hemodynamic measures and valve function data are shown in Table 2. At postoperative follow-up examination the functional status as well as the hemodynamic data. Autograft valves showed excellent function with low autograft valve pressure gradients. The vast majority of patients revealed a fully competent aortic valve, only one patient the in R-group showed an aortic regurgitation grade II.

The autograft root size and distensibility at the latest follow-up are depicted in Table 3. Autograft root diameters at the annular, sinus of Valsalva, and sinotubular junction
Table 2
Functional status, hemodynamics, and valve functiona

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th>P-value</th>
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<tbody>
<tr>
<td></td>
<td>R</td>
<td>R/A</td>
</tr>
<tr>
<td>Patients (n)</td>
<td>28</td>
<td>12</td>
</tr>
<tr>
<td>NYHA (median)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>132 ± 22</td>
<td>128 ± 20</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>83 ± 12</td>
<td>79 ± 9</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>74 ± 15</td>
<td>72 ± 11</td>
</tr>
<tr>
<td>AV-PG (mmHg)</td>
<td>2.9 ± 0.7</td>
<td>3.0 ± 1.2</td>
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<tr>
<td>AR grade (n; %)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>23 (83)</td>
<td>9 (75)</td>
</tr>
<tr>
<td>I</td>
<td>4 (14)</td>
<td>3 (25)</td>
</tr>
<tr>
<td>II</td>
<td>1 (3)</td>
<td>3 (25)</td>
</tr>
</tbody>
</table>

a NYHA, New York Heart Association; SBP, systolic blood pressure; DBP, diastolic blood pressure; AV-PG, pressure gradient across the aortic valve; AR, aortic valve regurgitation.

were comparable between groups. The percent change in radius representing of autograft root distensibility did not differ between groups, although the distensibility at the annulus level in group R exceeded the distensibility in group R/A.

4. Discussion

The preliminary results of our study provides some evidence that replacement of the ascending aorta with a noncompliant vascular prosthesis has no impact on midterm autograft root dimension, distensibility and autograft valve function when combined with a Ross operation.

The aortic root has a consistent shape with the largest diameter at the level of the sinus of Valsalva and the smallest diameter at the level of the sinotubular junction. Furthermore, it was previously demonstrated that the diameters of the sinotubular junction and the aortic annulus are related to the size of the aortic valve cusps [9]. This relationship has been also verified for the pulmonary root [10]. Autograft valve regurgitation is frequently caused either by the size mismatch between the aortic annulus and autograft annulus or by dilation of the sinotubular junction [5,10]. Late autograft root dilation at the sinus of Valsalva level is a common finding and has no impact on leaflet coaptation; even when aneurysmatic (> 50 mm) [5–7]. A size mismatch between the aortic and autograft annulus can be solved by reducing the diameter of the aortic annulus. Dilation of the sinotubular junction can be managed by an reduction annuloplasty of the sinotubular junction [10]. However, the latter technique disregards the pathology of the ascending aorta in case of dilation or aneurysm formation. Established risk factors predicting the development of aortic dissection and late aneurysm formation of ascending aorta includes bicuspid aortic valve, younger age at the time of aortic valve replacement, aortic diameter > 40 mm, and fragility and thinning of the aortic wall [11,12]. Taking this knowledge into account it appears to be reasonable to combine the replacement of the ascending aorta with a Ross operation in patients with aortic valve and additional ascending aorta pathology [3]. However, we performed replacement of the ascending aorta even in patients with an aortic diameter < 40 mm to address the dilated sinotubular junction, most of these patients presented with a bicuspid aortic valve. This 'prophylactic' replacement of the ascending aorta in patients with bicuspid aortic valve is based on the knowledge that the ascending aortic pathology in these patients consist of a process similar to cystic medial necrosis and is characterized primarily by an extensive loss of elastic elements within the media [13], which per se carries the risk of late ascending aorta aneurysm formation and aortic dissection.

Replacement of the ascending aorta will prevent the sinotubular junction from dilation with subsequent outward displacement of the autograft valve commissures, which might result in autograft valve regurgitation. Furthermore, the risk of late ascending aorta aneurysm formation or dissection can be prevented. Simon-Kuplik and coworkers recently demonstrated that the replacement of the ascending aorta with a vascular prosthesis results in an increase in aortic root distension, and aortic root wall stress [4]. This increased wall stress may have a detrimental impact on the autograft root. However, in our study we could neither detect any difference in autograft root dimensions nor distensibility in patients with combined ascending aorta and autograft root replacement compared to autograft root replacement alone.

The authors wish to address several limitations. (1) It could be argued that the resolution of the ultrasound technique is not sufficient to define accurate instantaneous movements of the aortic root. The ultrasound technique used in this study operates at a 900-Hz sampling frequency, providing an interval between two consecutive signals of 1.1 ms, which we believe is adequate to define aortic root
motion. However, possibly more accurate techniques, such as high-speed cineradiography [14] or electromagnetic induction [15], are not applicable to humans and could interfere with valve movement. In addition, the echocardiographic technique produced reproducible results with a range of variation of repetitive measured diameters up to 5.3%. However, this could have some impact on the distensibility data. (2) The fact that the aortic root moves during measurement could induce errors. However, these errors would apply to all groups and, therefore, should not affect comparative results. (3) The groups were different in terms of follow-up and age, the follow-up period in the Ross/Ascending group was significantly shorter compared to the Ross group, which may have an influence on the autograft root dimensions that were measured. However, Hokken and coworkers demonstrated that the dimensions of the autograft root increases within the first year and remained unchanged thereafter [7], since we extended our inclusion criteria for the Ross procedure to older patients, we were not surprised to find a higher incidence of dilation of the ascending aorta. However, we do not believe that this fact has any influence on the result of our study. (4) We are well aware that the number of patients studied is small and the follow-up period relatively short. Extended follow-up on a larger patient cohort would help to draw definite conclusion on the effectiveness of the combined replacement of the ascending aorta with autograft root replacement.

In summary, the preliminary results of our study indicates that the combined procedure of autograft root and ascending aorta replacement is an attractive treatment modality for patients suffering from combined aortic valve and ascending aorta pathology. Our results are encouraging, indicating that the replacement of the ascending aorta with a noncompliant vascular prosthesis has no obvious effects on autograft root dimension, distensibility, and autograft valve function.

References