A 17-year, single-centre experience with the Ross procedure: fulfilling the promise of a durable option without anticoagulation?\(^1\)

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Received 2 October 2014; received in revised form 14 January 2015; accepted 23 January 2015

Abstract

OBJECTIVES: For adult patients < 60 years with aortic valve disease, the Ross procedure is an attractive alternative to a prosthetic aortic valve. The Ross procedure enables surgeons to achieve a haemodynamically ideal aortic valve replacement. A potential drawback may be long-term durability, which varies considerably between series.

METHODS: Between 1996 and 2014, 209 patients (mean age, 43 ± 10 years) underwent an elective Ross procedure in our department. In 78% (n = 161) of patients a bicuspid valve was found. Patients were examined clinically and with echocardiography during the follow-up. The mean follow-up was 7.9 ± 5 years and was 98% complete.

RESULTS: The 30-day mortality rate was 2.4% (n = 5). The Kaplan–Meier survival rates at 10 and 15 years were 91 and 85%, respectively. In 17 patients (8.3%) the pulmonary autograft had to be reoperated on: 12 of them could be repaired; only 5 patients finally underwent prosthetic valve replacement. The rate of freedom from reoperation for autograft failure was 93% and that from reoperation or moderate autograft regurgitation was 87% at 10 years. Thromboembolic events occurred in 9 patients (0.54%/patient-year) and were mostly related to atrial fibrillation. Endocarditis involving the pulmonary autograft was observed in 6 patients (0.36%/patient-year).

CONCLUSIONS: Pulmonary autograft aortic root replacement to treat patients with severe aortic valve dysfunction is a challenging procedure. The reoperation rate is higher compared with mechanical valve replacement; however, in the majority of patients with reoperations in our series the autograft could be saved. Other valve-related complications are rare.

Keywords: Ross procedure • Aortic valve disease • Outcome

INTRODUCTION

The selection of a suitable device for aortic valve replacement (AVR) must be individualized through consideration of relative advantages and disadvantages. The following has to be considered when selecting a suitable device: durability of prosthesis, flow characteristics, risk of thromboembolism and need for anticoagulation, technical ease of insertion, risk of endocarditis, availability and valve-related noise.

In general, for isolated aortic valve replacement the current clinical practice and recommendation includes a bioprosthetic replacement in patients above 65 years and a mechanical device in patients younger than 65 years of age [1, 2]. Both therapy modalities have their advantages and limitations.

The mechanical prosthesis exposes patients to the cumulative risk of lifelong anticoagulation, restricted haemodynamics, elevated risk for thromboembolism and endocarditis in favour of the defined long-term function of the prosthesis. In comparison, the biological valve does not require lifelong anticoagulation therapy. A major disadvantage is the potential of structural deterioration which may result in dysfunction and need for reintervention. This latter consideration is the main limitation of implanting a biological valve in younger patients [3, 4].

The performance of the Ross procedure in adult patients <60 years with aortic valve disease provides an attractive alternative to a prosthetic aortic valve. The pulmonary root is closer to an ideal substitute than any other current constructed prosthesis. With an almost identical morphology and function compared with the aortic valve, the pulmonary autograft meets almost all conditions for an ideal aortic valve substitute, such as: autograft growth potential in children, freedom from thromboembolism and superior haemodynamics over other current commercial devices. The risk of reoperation and loss of a second native valve is a major drawback of the Ross operation [5, 6].

This paper presents the follow-up results of a seventeen-year experience with the Ross procedure at our institution. The evaluation focuses on the failure mode of the pulmonary autograft,
indications and outcome of reoperation, emphasizing the potential for autograft salvage. The general complication rate and treatment is also described in the current paper.

**PATIENTS AND METHODS**

Between January 1996 and July 2014 a total of 209 patients (median 45y, range 7–64) underwent replacement of a diseased aortic valve using the Ross procedure with the full root replacement technique. Young patients with an active lifestyle were offered the Ross procedure. Many came in with a self-motivated desire or have been referred on the suggestion of their cardiologists. We did not systematically document the major reasons for their decision.

Patients were prospectively followed to enter data for the German Ross Registry including serial echocardiographies in our institution at regular intervals: pre- and postoperative, after 1, 2, 5–7 and 10–14 years. On echocardiography pulmonary autograft transvalvular peak gradients were assessed and regurgitation was graded from 0 to 4 (severe). Missing data or visits were completed by retrieving information from external physicians or hospitals involved in the postoperative treatment. Four patients were lost to the follow-up immediately after the operation. The follow-up is thus 98% complete. If the patients showed significant failure of the neoaortic valve on colour Doppler echocardiographic examination, further diagnostic evaluation included magnet resonance imaging (MRI) and when necessary left heart catheterization.

Medical reports of patients who have been reoperated for autograft failure in external clinics were studied. The mean follow-up was 7.9 years (±4.9 years), with a total of 1661 patient-years. The graft failure in external clinics were studied. The mean follow-up time and the median echocardiography was 7.9 years (±4.9 years), with a total of 1661 patient-years. The mean follow-up time and the median echocardiography was 7.9 years (±4.9 years), with a total of 1661 patient-years.

The right ventricular outflow tract was reconstructed with homografts in 113 patients. Grafts were sized with Toronto SPV sizers according to the measured diameter of the pulmonary artery. All of the homografts were cryopreserved, usually of pulmonary origin (n = 108). Only 5 patients received aortic homografts. The homografts were not matched to the blood group of the patient.

Since 2004 we started to implant stentless Medtronic Freestyle xenografts in the right ventricle outflow tract (RVOT) position in 96 patients. The decision was made because of rising costs and lack of availability for homografts and favourable results for xenografts in the RVOT position published in the current literature. Operative data are presented in Table 2.

**Operative data**

The Ross operation was performed in 207 patients with the full root technique; only 2 patients were treated with the subcoronary autograft inclusion. Technical details of the procedure have been previously described [7].

Briefly, in 100 (from 164) patients with bicuspid aortic valve we have inserted the pulmonary autograft in a partial supra-annular position to correct for the geometric mismatch in depth between the base of the non-coronary sinus and the right or left coronary sinus, respectively. To overcome the geometric mismatch between the regular base of the autograft and the irregular base of the bicuspid root, the autograft was implanted supra-annularly only in the centre of the non-coronary sinus. Additional tailoring of the non-coronary sinus by triangular resection was performed in case of dilatation. The non-coronary sinus was reinforced with an autologous pericardial patch to prevent pseudoaneurysm formation after debridement of calcium later in the series and all autografts were covered with a Dacron graft in most recent patients.

In 147 (70.3%) patients Vicryl (n = 99) or Vypro (n = 55) (both Ethicon, Norderstedt, Germany) mesh was used to prevent aortic root dilatation.

The mesh was fixed with two stitches at the base of the non-coronary sinus, and then it was flipped around the aorta and adapted ventrally with slight tension. Thus mesh and aortic wall remnants prevented dilatation of the neoaortic root. Care was taken to avoid any ostial constriction; the small area beneath the coronary ostia was not covered. A Kaplan–Meier analysis was performed to calculate survival and freedom from aortic valve reoperation or replacement. Survival was compared between groups using the log-rank test. The hypothetical survival of the standard population was computed by the life table method, based on age- and sex-specific mortality data of the year 2012 published online by the German Federal Statistical Agency.

**Statistical analysis**

Descriptive statistics were applied to describe the demographic data. The mean and standard deviation were calculated for continuous data with a Gaussian distribution, and the medians with ranges were calculated for skew-distributed data. A Kaplan–Meier analysis was performed to calculate survival and freedom from aortic valve reoperation or replacement. Survival was compared between groups using the log-rank test. The hypothetical survival of the standard population was computed by the life table method, based on age- and sex-specific mortality data of the year 2012 published online by the German Federal Statistical Agency.

**Table 1: Patients’ preoperative data**

<table>
<thead>
<tr>
<th>Patients’ data</th>
<th>Total (n = 209)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>50 (24.0)</td>
</tr>
<tr>
<td>Male</td>
<td>159 (76.0)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>43.1 (±10.2)</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.9 (±0.2)</td>
</tr>
<tr>
<td>Previous operation</td>
<td>17 (8.1)</td>
</tr>
<tr>
<td>New York Heart Association classification</td>
<td></td>
</tr>
<tr>
<td>I, II</td>
<td>113 (54.0)</td>
</tr>
<tr>
<td>III, IV</td>
<td>93 (44.6)</td>
</tr>
<tr>
<td>Unknown</td>
<td>3 (1.4)</td>
</tr>
<tr>
<td>Left ventricle ejection fraction (%)</td>
<td></td>
</tr>
<tr>
<td>&gt;55</td>
<td>157 (75.1)</td>
</tr>
<tr>
<td>41–55</td>
<td>32 (15.3)</td>
</tr>
<tr>
<td>≤40</td>
<td>16 (7.8)</td>
</tr>
<tr>
<td>Unknown</td>
<td>4 (1.9)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>18 (8.6)</td>
</tr>
<tr>
<td>Dominant valvular dysfunction</td>
<td></td>
</tr>
<tr>
<td>Aortic stenosis</td>
<td>106 (50.7)</td>
</tr>
<tr>
<td>Aortic regurgitation</td>
<td>55 (26.3)</td>
</tr>
<tr>
<td>Mixed aortic disease</td>
<td>48 (23.0)</td>
</tr>
<tr>
<td>Aortic valve morphology</td>
<td></td>
</tr>
<tr>
<td>Tricuspid</td>
<td>44 (21.1)</td>
</tr>
<tr>
<td>Bicuspid</td>
<td>164 (78.5)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Aetiology</td>
<td></td>
</tr>
<tr>
<td>Congenital</td>
<td>149 (79.3)</td>
</tr>
<tr>
<td>Degenerative</td>
<td>33 (15.8)</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>19 (9.1)</td>
</tr>
<tr>
<td>Rheumatic</td>
<td>8 (3.8)</td>
</tr>
</tbody>
</table>
Occurrence rates of valve-related complications were calculated \[(\text{number of events/number of patient-years}) \times 100\] for each group. A *P*-value of ≤0.05 was regarded as statistically significant. SPSS 22.0 (IBM, Armonk, NY, USA) was applied for descriptive statistics and the calculation of linearized event rates.

### RESULTS

#### Early and late mortality

The 30-day mortality rate was 2.4% (*n* = 5). The cause of death in 2 of the patients was refractory postoperative low output and multi-organ failure. One early death was related to a coronary ischaemic event and the other one to transfusion-related acute lung injury. Another patient died due to sudden death after discharge. During the late follow-up, 12 patients (5.7%) had died. Among them, there were 5 cardiac-related mortalities due to heart failure, myocardial infarction or sudden death. There were also 4 non-cardiac-related deaths. The reason for death was not found in 3 patients. The Kaplan–Meier survival rates at 10 and 15 years were 91 and 85%, respectively. Survival (all causes) among the 209 patients was compared with the survival of the general German population, matched by each patient’s age, sex and year of operation (Fig. 1). After the initial decrease associated with early hospital deaths, the survival appears to parallel the survival of the matched population up to 10 years. After 15 years difference in survival become slightly more obvious, but still not reaching statistical significance (*P* = 0.15).

#### Autograft reoperation

A total of 18 patients underwent reoperation on the autograft [1.01%/pat. year (95% cardiac index (CI), 0.6–1.7%), 4 of which were done in other institutions. After 14 years of the follow-up (number at risk = 29), the rate of freedom from all autograft reoperations was 80% and that from explantation and replacement of the pulmonary autograft 91% (Fig. 2). Seventeen of the patients who required reoperation of the autograft had originally a bicuspid aortic valve. The mean age was 37 years (+10) at reoperation. Of these 18 patients, 13 required isolated autograft reoperation and 5 required simultaneous reoperation of both the pulmonary autograft and the allograft. Six patients were reoperated for formation of a subannular pseudoaneurysm after a median time of 10 months (range, 3–33) postoperatively with competent valves. Decalcification of the non-coronary annulus had been performed in these patients and the autograft had been positioned supra-annularly in the centre of the non-coronary sinus. At reoperation we mostly found a pseudoaneurysm beneath the autograft non-coronary sinus. These patients underwent resection of the pseudoaneurysm if possible and subsequent reconstruction by closure of the entrance with a pericardial patch or direct suture. One of these patients underwent a second revision within 2 months externally. The aortic valve was replaced by a mechanical prosthesis; nevertheless, aortic regurgitation occurred again and he died from heart failure 8 months later.
Four of the reoperations were due to recurrent (n = 2) or new onset (n = 2) of endocarditis. All of these patients underwent successful autograft repair.

Early postoperative endocarditis occurred twice: one case was reoperated in the acute phase within the first month and the second one 7 months after the first operation. In the latter case, a complete autograft suture dehiscence was observed at revision. Two cases presented with late endocarditis. One of these healed developing a subvalvular dehiscence, which was repaired using an autologous pericardial patch. The second one was a fulminant late endocarditis with Staphylococcus aureus and had a paravalvular abscess that was repaired with radical debridement, with reconstruction with autologous pericardium.

Progressive dilatation of the neoaortic root combined with aortic regurgitation was the main cause for autograft reoperation in 4 patients after a mean time of 14 (±0.3) years. Two of them were reoperated in an external unit; in both the autograft and root was replaced by a Bentall procedure (St.Jude Medical (SJM) 25) and a stentless bioprosthesis (Edwards Prima 27), respectively. The other 2 cases of autograft/ascending aorta dilatation were reoperated at our institution; one autograft could be saved by a David reimplantation; the other one was replaced by a biological valve because the patient was suffering from severe heart failure.

Other reasons for reoperation were due to structural valve deterioration (n = 3) or technical failure (n = 1) (Table 3).

Extensive calcification of all valves was found in a patient receiving immunosupression due to liver transplantation; another patient showed a rupture of the left coronary cusp. The third patient was reoperated in another unit and the operation protocol was not explicit regarding the underlying pathology.

After fourteen years of the follow-up (number at risk = 29), the rate of freedom from all autograft reoperations was 80% and that from explantation and replacement of the pulmonary autograft 91% (Fig. 2).

In univariate risk analysis, no risk factors (age, gender, dominant valvular dysfunction, bicuspid versus tricuspid, autograft wrapping and annulus reduction) were identified that were significantly associated with an increased risk of autograft valve insufficiency (defined as a neoaortic valve regurgitation of at least moderate grade), or dilation of the aortic root >44 mm.

Revision of the RVOT replacement

RVOT replacement was done with homografts in 113 patients (median follow-up of 11 years /range, 0–18 years) and with a Medtronic Free Style Bioprosthesis in 96 patients (median follow-up of 5 years/range, 0–15 years). Ten (4.8%) patients underwent reoperation because of failure of the neopulmonary valve, 5 of them due to endocarditis, the other 5 because of structural degeneration or development of stricture. Percutaneous intervention was performed in 14 patients; 12 of them had received a bioprosthesis and developed early degeneration or stricture at the proximal suture line. As previously reported [8] by our group: patients with bioprostheses in the RVOT position after the Ross procedure showed a significantly higher risk of reintervention or pulmonary valve dysfunction than patients with homografts. The rate of freedom from pulmonary valve failure after 5 years was 97% with homografts versus 73% with bioprosthesis. The main problem in these patients was early development of a stricture at the suture line. As the follow-up is significantly shorter in xenografts (median of 5 years versus median of 11 years in homografts), the question of whether xenografts will develop valve degeneration and wall calcification as in the case of homografts remains open to further investigation.

Clinical and echocardiographic status at follow-up

At the last follow-up visit, 97% of the patients were in New York Heart Association class I or II, and 2.6% of patients (n = 5) were in New York Heart Association class III owing to heart failure.

At the last echocardiographic examination 95% of the patients had minor aortic regurgitation (<Grade II), 5% had moderate aortic regurgitation (Grade II) and so none remained with severe insufficiency. The mean transvalvular gradient was 4.0 (±2.0), while the maximum gradient did not exceed 6.6 (±3.6). The mean calculated aortic valve area was: 3.5 (±0.6) cm².

About 20 patients (10.5%) showed a dilatation of the aortic root or ascending aorta of >45 mm, without significant aortic regurgitation.

After excluding reoperation of the pulmonary autograft for subvalvular pseudoaneurysms, the rate of freedom from autograft reoperation, aortic regurgitation >II and/or aortic root dilatation >45 mm was 92.1% (95% CI, 87.3–96.9) at 10 years and 78.0% (95% CI, 65.6–90.4) at 14 years.

Other valve-related events

During the follow-up thromboembolic events occurred in 9 patients (0.54%/patient-year) and were mostly related to new onset of atrial fibrillation or heart failure. Endocarditis involving the pulmonary autograft and/or the RVOT substitute was observed in 9 patients (0.54%/patient-year), leading to reoperation in almost all cases, except one, which could be treated conservatively. Bleeding events or valve thrombosis was not observed.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Indication for reoperation</th>
<th>Subannular pseudoaneurysm</th>
<th>Endocarditis</th>
<th>Aortic root dilatation</th>
<th>Other/structural deterioration</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair</td>
<td></td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Valve replacement</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Additional procedure on the ascending aorta</td>
<td></td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Mean time to reoperation in years (y)</td>
<td></td>
<td>1.1 (±1.0)</td>
<td>4.4 (± 6.3)</td>
<td>14.0 (±0.3)</td>
<td>4.8 (±4.3)</td>
<td>5.5 (± 5.9)</td>
</tr>
</tbody>
</table>
The indication for anticoagulation with warfarin was given in 13 patients (6.2%) for atrial fibrillation, reoperation with mechanical valve replacement or deep vein thrombosis.

**DISCUSSION**

The choice for an optimal aortic valve replacement is difficult and getting more and more individualized as reflected in the American College of Cardiology/American Heart Association (ACC/AHA) 2014 Guidelines for the Management of Patients with Valvular Heart Disease: 'The choice of valve prosthesis in an individual patient is based on consideration of several factors, including valve durability, expected hemodynamics for a specific valve type and size, surgical or interventional risk, the potential need for long-term anticoagulation, and patient preference. Specifically, the tradeoff between risk of reoperation for bioprosthetic valve degeneration and the risk associated with long-term anticoagulation should be discussed in detail with the patient' [9].

Indications for bioprosthetic valve placement for a patient of any age includes refusal to take warfarin and 'lifestyle considerations', comprising external factors preventing successful adherence to anticoagulation protocols. For example: limited patient access to monitoring or therapy for financial, social or geographic reasons, a history of drug abuse or non-compliance with drug therapy.

In this context the Ross procedure may offer an attractive alternative to a prosthetic aortic valve, but it is a technically complex operation that changes severe single valve pathology into double valve pathology and its long-term durability is still debated. With the exception of its use in children, where the autograft growth potential is one of the main advantages over prosthetic and homograft valve replacement, this technique remains controversial.

In our series patients with aortic valve disease who were <60 years and who had contraindications for anticoagulant therapy or wished to avoid this therapy were treated by the Ross procedure. The mortality associated with this procedure exceeds that of isolated aortic valve replacement (~1%), but at 2.9% was comparable with a meta-analysis of 39 Ross procedure series published between 2000 and 2008, where the pooled operative mortality in adult patients was 3.2% (95% CI, 1.5–7%) [6].

In retrospect 2 patients should not have been included; one was with severely impaired left ventricular function and coronary anomaly, and another patient was severely obese, diabetic and had massive left ventricular hypertrophy.

However, 10- and 15-year survival rates were comparable with the age- and sex-matched German population, including patients who had reoperations and similar to other published single-centre series [10, 11]. Mokhles et al. [12] published a case-match study of 253 patients who had isolated aortic valve replacement with a mechanical valve and a highly specialized anticoagulation self-management operated in a highly specialized institution (mean age, 48 years; mean follow-up, 6.3 years) and 253 patients who underwent the Ross procedure from the German-Dutch Ross Registry (mean age, 47.3 years; mean follow-up, 5.1 years) showing no difference in survival up to 8 years. On the other hand, the only randomized study comparing the pulmonary autograft with aortic homograft for aortic valve replacement in young patients has clearly shown superior results in favour of the Ross operation [13].

In a meta-analysis of 17 consecutive series of both children and adults, the yearly rate of structural valve deterioration or non-structural valve deterioration for the autograft valve was estimated to be 1.15% (95% CI, 1.06–2.06%) [6].

In our series, with the longer follow-up as published in the meta-analysis, we found a yearly rate of structural or non-structural valve deterioration of 1.1% (95% CI, 0.6–1.7%), being within the lower part of the 95% CI of the pooled series.

Nevertheless, our reoperation on the autograft has to be discussed in particular because of the occurrence of subannular pseudoaneurysms in 6 patients, a complication that was not reported in other series.

Five patients were operated and reoperated on between 1999 and 2003, and 1 case in 2010 because of formation of a subannular pseudoaneurysm. All had a supra-annular position of the autograft in cases of bicuspid valves with left to right fusion. This was done to correct for the deeper position of the non-coronary annulus in the left ventricle outflow tract (LVOT), in few cases the sinus underwent a triangular resection to correct a local sinus dilation [7]. Later this area was reinforced with a pericardial patch or lately all autograft roots were reinforced by a Dacron prosthesis [14].

Structural deterioration occurred in 3 patients who were susceptible to this by concomitant disease like dialysis-dependent renal failure, former thoracic irradiation or previous rheumatic disease.

Endocarditis was the reason for reoperation of the autograft in 4 patients (0.3%/patient-year), which accounted for 22% of the reoperation rate on autografts and is in parallel with reports on larger series [15]. This rate is about half of the reported rates of 0.7%/year for prosthetic valve replacement [16].

Fourteen years after operation 4 patients required reoperation because of aortic root dilatation. Although this incidence rate was quite low compared with other results, we have to keep in mind that 5% of the remaining population showed a regurgitation of the aortic valve of grade II. Intra-annular position of the autograft and wrapping with remnants of the aortic wall and a resorbable mesh could not prevent, but could reduce the problem of late dilatation [17].

Long-term results after the David procedure showed very stable valve function and a minimal rate of structural valve degeneration. Stiffening of the root does not exert increased stress on the leaflets; at least this does not cause a clinical problem [18]. By this experience autografts are currently wrapped with a Dacron prosthesis to avoid the problem of late dilatation in the future.

Nevertheless, as the avoidance of lifelong anticoagulation was one of the main reasons for performing a Ross procedure in our patients, the main question is: could we fulfill the promise of a long-lasting option without anticoagulation?

Two-thirds (66%) of all reoperations could salvage the autograft, thus retaining the benefits the pulmonary autograft has to offer. In one-third of reoperations a valve replacement was done, mostly in external institutions. Except in cases with structural deterioration we postulate a good chance of preventing a mechanical valve replacement and thus avoid lifelong anticoagulation. Moreover, other valve-related complications are rare, and so we could fulfill the promise of living without anticoagulation in most of the cases. The Ross operation may deserve renewed interest.

**LIMITATIONS**

This is a single-centre experience with evolving techniques. The study design was a prospective follow-up study covering a long period of patient inclusion. Changes in preoperative, operative and postoperative management, evolving surgical techniques
and different replacement of the RVOT valve may have affected the outcome. No randomization or comparison with the eage-
and sex-matched group receiving either mechanical or biological aortic valve replacement was undertaken.

**Conflict of interest:** none declared.

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**APPENDIX. CONFERENCE DISCUSSION**

**Dr A. Franco-Cereceda** (Stockholm, Sweden): I have a number of questions, but in the interest of time I will restrict myself to just a few of them.

First of all, the best way to prevent complications and reoperations is, of course, to operate on the right patient, and you have been doing this now for 18 years and collected quite a substantial experience. How has your prac-
tice changed during these 18 years, specifically, what patients do you now exclude that you included when starting this program? And of course this relates to valve pathology, valve morphology and potentially other risk factors preoperatively.

My second question relates to the fact that in your manuscript you state that approximately 10% of your patients at follow-up have a dilated ascending aorta exceeding 45 mm. You have a large proportion of bicuspid valves in your cohort; do you foresee that you will have a substantial number of reoperations because of this mid-ascending aortic dilatation in front of you? Your patients are young. They have a long life expectancy and a lot can happen during that time. So what will happen with the rest of the aorta? It is not necessarily related to the Ross procedure but it is still very interesting, because with this procedure you have a valve with perfect haemodynamic function.

**Dr Miskovic**: I think with time the indications have changed. When we started with the Ross procedure there were many more patients with aortic re-
gurgitation, but with time this indication for the Ross operation decreased, because in most of the cases you try to reconstruct the aortic valve if it is pos-
sible and you don’t have a stenotic or mixed lesion. So this is one important thing which changed.

We also don’t have rheumatic disease as an indication anymore in young patients who want to be operated without a mechanical valve.

Most middle-aged patients in the Western countries are patients with bicus-
pid valve disease and aortic stenosis when they come to you for aortic valve replacement.

Concerning your second question, yes, we had about 20 patients at last follow-up with an aorta ascending exceeding 45 mm. We often don’t know the exact location of the dilatation, when receiving external echoes, for example if it is the aortic root, or the ascending aorta. We have to wait and see if they develop aortic regurgitation or not. If it is dilatation of the ascending aorta, you have this problem as well in cases of bicuspid aortic valve with a bioprosthesis, because the disposition for this is given anyway.