Reoperation for neoaortic root pathology after the arterial switch operation†

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Abstract

OBJECTIVES: To evaluate incidence and results of surgical intervention for neoaortic root pathology following arterial switch operation (ASO) for transposition of the great arteries (TGA).

METHODS: Between April 1996 and August 2013, 12 patients underwent reoperation for neoaortic root dilatation (ARD) and/or neoaortic valve regurgitation (AR). Maximal aortic sinus and annulus diameter Z-scores were recorded. Original diagnoses were TGA/IVS (6), TGA/ventricular septal defect (VSD) (4) and Taussig–Bing anomaly (2) with ASO at a median age of 0.1 (range: 0–10.6) years. Age at ASO, VSD and complex TGA were reviewed as possible risk factors for reoperation.

RESULTS: Twelve patients with tricuspid neoaortic valves underwent 15 root operations; indications were root dilatation (4) and root dilatation with AR (8). Median age was 18.0 (3.0–29.0) years at first reoperation. Median aortic root Z-score at reoperation was 6.33 (range: 3.84–12.15). Procedures were: Bentall procedure (6), aortic valve replacement (2), neoaortic valve plasty (1), supracoronary tube (1) and switch-back operation (2). Mean follow-up was 7.0 ± 5.7 years and complete. No mortality occurred. One patient had two reoperations for primary diagnosis or other risk factors. Redo neoaortic surgery can be performed with low risk taking into account the specific anatomy of the neoaortic root and valve. No risk factors for reoperation could be identified.

CONCLUSIONS: After ASO, surgery for neoaortic root pathology may become necessary when follow-up is long enough and regardless of primary diagnosis or other risk factors. Redo neoaortic surgery can be performed with low risk taking into account the specific technical difficulties.

Keywords: Arterial switch operation • Transposition of the great arteries • Neoaortic root dilatation • Neoaortic regurgitation • Reoperation

INTRODUCTION

Since the introduction in 1975, the arterial switch operation (ASO) has been considered to be an anatomical or ‘corrective’ procedure. After initial modifications, short- and mid-term results improved so much that hopeful expectations were created for the long term. Overall survival and functional status are satisfactory in all larger series. However, it has become clear that a certain and increasing subset of patients will be in need of late reoperations, concerning mainly right-sided and, to a lesser extent, pathology of the neoaortic root and valve [1–8]. The need for reintervention on the coronary arteries is not non-existent but seems very limited at this time. The reported incidence of reoperative procedures for neoaortic root pathology is still low [5, 6, 9] and the development of neoaortic valve regurgitation (AR) and neoaortic root dilatation (ARD) is considered by some authors to be stable over time [9, 10]. On the other hand, there are a growing number of reports where AR and/or ARD are considered to be progressive over time and where concerns are expressed about the need for reoperation in the future [3, 11–14]. Some have reported an incidence as high as 5% in a larger series with up to 25 years of the follow-up [2]. From our own cohort it was established in 2009 that ARD is present in two-thirds of patients, emphasizing the need for careful follow-up [15]. Since then, we have observed an increased incidence of reoperations for neoaortic root pathology. Besides this, histopathological studies revealed structural changes in the neoaortic, originally pulmonary root, which might explain root dilatation at a later age [15, 16]. From this information and from the observation that for several large cohorts follow-up duration is now exceeding 20 years, one may expect an increase of neoaortic root surgery in the near future. Therefore, we...
have evaluated incidence and results of surgical intervention for neoaortic root pathology after ASO, as well as possible risk factors in our centre and we will discuss the indications and technical aspects of the procedures.

**METHODS, PATIENTS AND PROCEDURES**

From 1977 to the present, 391 patients underwent ASO at Leiden University Medical Centre. Between April 1996 and August 2013, 9 patients (2.3%) from this cohort underwent 10 reoperative procedures for neoaortic root pathology. Before 1996, no surgical reinterventions for this indication could be traced. Within the same timeframe, 3 patients were referred from other centres to undergo 5 neoaortic root procedures. From these 12 patients, data on root and annulus diameters, Z-scores as well as the operative procedures and results were retrospectively analysed.

**Primary surgery**

Original diagnoses were transposition of the great arteries with intact ventricular septum in 6 (TGA-IVS), TGA with ventricular septal defect (VSD) in 4 (multiple VSD’s in 1 and pulmonary stenosis in another 1) and Taussig–Bing anomaly in 2 patients. One patient had previous pulmonary artery banding, 1 had modified Blalock–Taussig shunt and 1 had the Rashkind procedure. One patient underwent the Rashkind procedure and atrial switch with the Mustard technique at the age of 1 month. The ASO was performed at a median age of 0.1 (0.0–10.6) year and in 1 patient at an age of 10.6 years (after previous Mustard procedure).

ASO was always performed using high-flow, moderate hypothermic cardiopulmonary bypass with bicaval cannulation. The ductus arteriosus was ligated before cross-clamping the aorta. After cross-clamping, cold crystalloid (St Thomas II) cardioplegia was administered through the aortic root and subsequently every 30 min through the coronary ostia. The aorta and pulmonary artery (PA) were dissected just above the level of the commissures, after which the coronary arteries were excised as a circular or U-shaped button from the aortic sinus and reimplanted in the corresponding pulmonary sinus with either a button or trap-door technique. VSD closure was carried out through the right atrium, aorta or PA. In patients from the Leiden cohort, the coronary arteries were reimplanted as buttons in all except one. Unfortunately, the operative reports from the other referring centres were lacking or not detailed enough to draw conclusions about coronary anatomy and technique of transfer. The Lecompte manoeuvre was performed in all cases except 2.

**Data collection and definitions**

Patient data and surgical details were collected from surgery reports and local medical records and cardiac surgery database. Follow-up data, such as data on late mortality and reoperation, were obtained from the patients’ (paediatric) cardiologists as part of routine care. No distinction was made between early and late reoperation, as all reoperations were performed after discharge. Age at ASO is grouped into two categories: under and above 365 days. TGA was categorized as TGA-IVS, TGA-VSD, TB and TGA-VSD-P5 but also divided into being either TGA-IVS or complex TGA (all non-TGA-IVS). Neoaortic root pathology is defined as neo-ARD, neoaortic AR or a combination of both.

**Reoperative procedures**

Preoperative magnetic resonance imaging or computed tomography scan was performed in all cases. In case of Lecompte manoeuvre, our approach of the neoaortic root has always been through the main pulmonary artery by cutting it transversely just below the bifurcation at or around the area of the old suture line.

**Statistical analysis**

In this series, statistical analysis was only possible for the 9 patients from the Leiden University Medical Centre cohort (Patients 1–4, 6, 8, 10–12) because from the referring centres the total cohorts are unknown. Statistical analyses were carried out using the SPSS statistical software program for Windows, version 20.0.0 (SPSS, Chicago, IL, USA). Estimates of freedom for reoperation were obtained by means of the Kaplan–Meier method. Univariable Cox regression analyses were used to identify risk factors for aortic root reoperation. Variables tested for their predictive values were age at ASO, VSD and complex TGA. A P-value of <0.05 (two-sided) was considered statistically significant.

**RESULTS**

**Indications for reoperation**

Indications for reoperation and aortic root and annulus root Z-scores are listed in Table 1. In case of neoaortic regurgitation being the main indication for reoperation, symptoms and/or progressive dilatation of the left ventricle formed the indication for surgery.

**Freedom from root reoperation**

Explorative univariable Cox regression analysis revealed that no risk factors for first reoperation after ASO could be identified as the tested risk factors age at ASO (hazard ratio [HR]: 3.08; 95% confidence interval [CI]: 0.61–15.43; P = 0.151), VSD (HR: 1.25; 95% CI: 0.33–4.72; P = 0.739) and complex TGA (HR: 1.21; 95% CI: 0.32–4.54; P = 0.780) were all statistically not significant. Estimated freedom from root reoperation for the Leiden cohort at 5, 15 and 25 years was 99.3, 97.3 and 95.0%, respectively (Fig. 1).

**Reoperative procedures**

Paediatric patients that presented primarily with neo-AR and mainly annular dilatation underwent aortic valve replacement with a mechanical valve when an adult size valve could be placed (Patients 2 and 3). For younger patients or patients with a smaller annulus, repair of the neoaortic valve or ‘switch-back’ procedures were performed (Patients 4 and 5). During the switch-back
procedure, the neopulmonary, originally aortic valve, was used as an autograft for aortic root replacement after which the right ven-
tricular outflow tract and pulmonary artery were reconstructed with a pulmonary homograft [17].

The remainder of adolescent and adult patients underwent root replacement by the Bentall procedure with a mechanical valve except for 1 patient who received a supracoronary tubular prosthesis for repair of sinotubular junction (Patient 6). The possibility of a valve-sparing procedure was considered in most cases, but not performed in this series for several reasons that will be discussed later.

**Follow-up**

Mean follow-up was 7.0 ± 5.7 years. No early or late mortality occurred. No thromboembolic or anticoagulation-related complications were registered. After single AVR, no root aneurysms developed at a later stage. All patients are in good clinical condition. Four patients needed multiple reoperative procedures as given in Table 2.

For Patient 5, the initial result of the switch-back procedure was good. For unknown reasons, the autograft failed within 1 year. The aortic valve showed fibrosis and retracted cusps and had to be replaced by a 21 mm bileaflet mechanical prosthesis. At the latest follow-up, this patient is doing well. The other switch-back procedure (Patient 4) is still showing good autograft function at the latest follow-up. The aortic homograft in pulmonary position failed after 4.8 years and was successfully replaced by a pulmonary homograft.

Patient 1 with the Elkins annuloplasty had recurrence of severe neoaoartic regurgitation and needed a reoperative procedure after 6 years. Aortic valve replacement with a 21 mm St Jude bileaflet prosthesis and mitral valve plasty were performed with good result.

Patient 10 developed an endocarditis of the Bentall prosthesis 15 months postinitial root reoperation and needed replacement with a Medtronic Freestyle stentless bioprosthesis (Medtronic, Inc., MN, USA). Unfortunately, recurrence of infection led to a third root reoperation 2 weeks later; in which a mechanical Bentall St Jude 25 mm (St Jude Medical, Inc., MN, USA) was implanted. After 1 year of antibiotic treatment, the patient has recovered completely and is now doing well.

**DISCUSSION**

Until 2009, only 1 adolescent patient (16 years) who needed reoperation for AR was identified out of the Leiden cohort of 39 patients who underwent an ASO between 1977 and 1989 [15]. The same report concluded that ARD was present in two-thirds of patients, and moderate AR was observed in 15%, emphasizing the

<table>
<thead>
<tr>
<th>ASO</th>
<th>Diagnosis</th>
<th>Age (days)</th>
<th>Age (years)</th>
<th>Procedure</th>
<th>Main indication</th>
<th>BSA*</th>
<th>Aortic root diameters (mm)</th>
<th>Aortic root (Z-score)</th>
<th>Aortic annulus diameters (mm)</th>
<th>Aortic annulus (Z-score)</th>
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<tbody>
<tr>
<td>1</td>
<td>TGA</td>
<td>4</td>
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<td>AVP</td>
<td>ARD + AR</td>
<td>0.93</td>
<td>29</td>
<td>4.64</td>
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<td>5.25</td>
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<td>7.9</td>
<td>AVR</td>
<td>ARD + AR</td>
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<td>46</td>
<td>12.15</td>
<td>26</td>
<td>7.62</td>
</tr>
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<td>101</td>
<td>16.0</td>
<td>AVR</td>
<td>ARD + AR</td>
<td>1.87</td>
<td>40</td>
<td>3.84</td>
<td>32</td>
<td>5.02</td>
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<tr>
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<td>TGA</td>
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<td>8.0</td>
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<td>ARD + AR</td>
<td>0.87</td>
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<td>5.11</td>
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<td>ND</td>
<td>X</td>
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<td>X</td>
</tr>
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<td>SCT + MVP</td>
<td>ARD + AR + MR</td>
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<td>ARD</td>
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<td>54</td>
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<td>32</td>
<td>4.30</td>
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<td>24.0</td>
<td>Bentall</td>
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<td>1.83</td>
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<td>6.16</td>
<td>26</td>
<td>7.52</td>
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<td>ARD + AR</td>
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<td>43</td>
<td>5.65</td>
<td>27</td>
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<td>ARD</td>
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<td>48</td>
<td>7.55</td>
<td>27</td>
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<td>95</td>
<td>13.9</td>
<td>Bentall + Asc</td>
<td>ARD</td>
<td>1.43</td>
<td>49</td>
<td>9.63</td>
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<td>11.39</td>
</tr>
<tr>
<td>12</td>
<td>TGA</td>
<td>3861</td>
<td>22.0</td>
<td>Bentall + PApl</td>
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<td>1.69</td>
<td>47</td>
<td>7.01</td>
<td>30</td>
<td>5.02</td>
</tr>
</tbody>
</table>

AR: aortic regurgitation; ARD: aortic root dilatation; ASO: arterial switch operation; Asc: ascending aorta; AVP: aortic valvuloplasty; AVR: aortic valve replacement; MR: mitral regurgitation; MVP: mitral valve plasty; PA: pulmonary artery; PApl: pulmonary artery plasty; PAs: pulmonary artery stenosis; PS: pulmonary stenosis; PTR: pulmonary trunk reconstruction; SCT: supracoronary tube; TGA: transposition of great arteries; VSDcl: ventricular septal defect closure; ND: no data.

BSA: body surface area (Dubois); aortic root Z-score (Boston); aortic annulus Z-score (Boston).
need for careful follow-up. Since then, another 3 adult patients from this cohort and 2 adult patients from referring centres needed reoperative procedures for neoaortic root pathology. The observation of this increasing incidence made us review our complete experience yielding a total of 12 patients who needed re-intervention for neoaortic root pathology.

### Incidence and aetiology of root pathology

Although the overall reported incidence of surgery for ARD and AR after ASO operation is still low at 10 years (2–2.5%) [4, 5, 9, 14], several groups have observed that despite the low incidence thus far, the development of AR and ARD is a time-dependent phenomenon, making strict serial surveillance after ASO mandatory [3, 11–14]. McMahon et al. [18] found moderate neoaortic root enlargement (Z-score 3–4, 9) in 52% and severe root enlargement (Z-score > 5) in 25%. They also demonstrated that the development of significant AR was found to be strongly associated with the development of neo-ARD, which is confirmed by others as well [12, 13]. Schwartz et al. [10] concluded that after ASO significant root dilatation and AR continue to develop over time, but that root dilatation tends not to be progressive during late follow-up. However, in this series the latest follow-up was up to 16 years, while Walter et al. [9] concluded that new AR can develop up to 15 years. In our series, 5 patients needed reintervention for progressive root dilatation and/or AR beyond 20 years of follow-up, indicating that this can occur even after a very long time. The significance of several risk factors on the development of late AR and root dilatation such as previous pulmonary artery banding, age at ASO more than 1 year, presence of VSD and complex TGA has been demonstrated in several studies [3, 5, 9–11, 14], but this finding could not be repeated in other large series [1, 12]. In our series, we also were unable to demonstrate any risk factors for reoperation for neoaortic root pathology.

Nevertheless, it is evident that the presence of a VSD with more arterial root size discrepancy predisposes to both neoaortic valve insufficiency and neoaortic root enlargement [13]. And one can also understand that surgical techniques that affect root geometry or tissue quality, like the use of the trap-door technique or pulmonary artery banding, can predispose to neoaortic root pathology later on. Arch obstruction, another known risk factor for neoaortic root pathology, was not present in our series.

On the other hand, half of the patients in this series had TGA-IVS without any known risk factor. Histopathological studies conducted in our centre revealed that the amount of collagen in the arterial roots was diminished in hearts with TGA when compared with normal hearts and that the anchorage and embedding of both arterial roots in the myocardium was less extensive [16], which may be an explanation for the observed neo-ARD in patients without other risk factors. Earlier, we demonstrated that in the pulmonary artery and sinus of untreated TGA, there is a de-differentiation of smooth muscle cells with increasing age that could not be correlated with altered flow which may provide another explanation for the neo-ARD that has been reported as a late complication of ASO [19]. Comparable dilatation of the pulmonary root in the systemic circulation is seen after the Norwood operation for hypoplastic left heart syndrome [20], indicating that the pulmonary artery placed in the systemic circulation is a risk factor in itself.

In summary, the aetiology of neoaortic root pathology is most probably multifactorial. Besides external risk factors, there are also structural intrinsic problems of the pulmonary root in the systemic circulation. This implies that, irrespective of other additional risk factors, a certain percentage of patients after ASO will develop neoaortic root pathology and that this process is progressive over time. Thus, in conformity with our clinical observations, an increase in neoaortic root surgery after ASO can be anticipated in the future in patients with or without additional risk factors.

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**Table 2:** Patient characteristics (n = 12) at reoperation after ASO

<table>
<thead>
<tr>
<th>Variables*</th>
<th>First aortic root procedure (n = 12)</th>
<th>Second procedure (n = 4)</th>
<th>Third procedure (n = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>17.0 ± 10.1</td>
<td>12.6 ± 7.6</td>
<td>19.1 ± 5.6</td>
</tr>
<tr>
<td>Time interval (years)</td>
<td>15.8 ± 9.6</td>
<td>12.5 ± 7.3</td>
<td>18.8 ± 5.3</td>
</tr>
<tr>
<td>Hospital stay (years)</td>
<td>9.5 ± 2.4 (6–15)</td>
<td>15.0 ± 17.3 (5–35)</td>
<td>16.5 ± 14.5 (6–27)</td>
</tr>
<tr>
<td>Mortality</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patients</th>
<th>Interval (years)</th>
<th>First procedure</th>
<th>Interval (years)</th>
<th>Second procedure</th>
<th>Interval (years)</th>
<th>Third procedure</th>
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</thead>
<tbody>
<tr>
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<td>AVR + MVP</td>
<td>6</td>
<td>MVR</td>
</tr>
<tr>
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<td>7.9</td>
<td>AVR</td>
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<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>15.7</td>
<td>AVR</td>
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<td>–</td>
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<td>–</td>
</tr>
<tr>
<td>4</td>
<td>8.0</td>
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<td>1.3</td>
<td>AVR</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>6</td>
<td>27.9</td>
<td>SCT + MVP</td>
<td>–</td>
<td>–</td>
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<tr>
<td>7</td>
<td>20.0</td>
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<td>–</td>
<td>–</td>
<td>–</td>
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</tr>
<tr>
<td>8</td>
<td>24.0</td>
<td>Bentall</td>
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<td>–</td>
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<tr>
<td>9</td>
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<td>–</td>
<td>–</td>
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<tr>
<td>10</td>
<td>21.2</td>
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<td>11.5</td>
<td>BentallPApl</td>
<td>–</td>
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</table>

ASO: arterial switch operation; AAR: ascending aorta replacement; AVP: aortic valvuloplasty; MVP: mitral valve plasty; MVR: mitral valve replacement; PApl: pulmonary artery plasty; PS: pulmonary stenosis; SCT: supracoronary tube; TGA: transposition of great arteries; VSD: ventricular septal defect.

*Continuous data are shown as the mean ± standard deviation (range) and categorical data are shown as number (%) or number.
Indications

For patients with neoaortic regurgitation symptoms and/or progressive dilatation of the left ventricle, we formed the indication for surgery in accordance with European Society of Cardiology and American Heart Association guidelines [21]. Rupture or dissection of pulmonary autograft has been reported after the Ross procedure but to date there are no reports of this after ASO. For surgical intervention on neoaortic root aneurysm, international guidelines are based on data for other forms of degenerative aortic or bicuspid aortic valves and intervention is recommended for aneurysm greater than 55 mm [22]. Although this is probably safe with respect to catastrophic events, it has to be noted that less severe root dilatation can significantly contribute to loss of neoaortic valve competence and supravalvar pulmonary stenosis. In the presence of these complications and especially when valve-sparing replacement of the neoaortic root is technically feasible, surgical intervention might be justified in an earlier phase. Even more so as evidence is growing that neo-ARD is progressive over time.

Surgical technique

In case of Lecompte manoeuvre, some centres with larger series propose exposure of the neoaortic root by transversally transecting the right pulmonary artery while at the end of the procedure the right pulmonary artery is reconstructed with a Gore-Tex interposition graft [1, 5]. Our approach of the neoaortic root has always been through the main pulmonary artery by cutting it transversely just below the bifurcation at or around the area of the old suture line, which provides a clear and complete exposition of the complete neoaortic root and coronary arteries, while at the end of the procedure the pulmonary artery can be reconstructed without the need for extra patch material.

In case of smaller children and distinct annular dilatation, AVR alone pointed out to be a good choice since an adult sized prosthesis could be placed and in our series no root aneurysms developed during late follow-up. In smaller children without severe dilatation of the annulus and root, the switch-back procedure can be a good option. Despite early failure in 1 patient, there is preserved function of the aortic autograft in the other growing child after 7 years. However, in this case, failure of the right-sided conduit was the reason for reoperation, comparable with the situation after the Ross procedure. For the grown-up patients, the Bentall procedure may be expected to provide reliable results in the long term comparable with those in the general thoracic population.

Some authors reported successful valve-sparing procedures in case of root aneurysm after the ASO [1, 5, 8]. Although we have good experiences with valve-sparing procedures in the congenital and paediatric population, we have taken some caution with this procedure in this population for several reasons. The anatomy of the neoaortic, originally pulmonary valve was considered the main problem since the anterior-located cusps have their insertion deep in the left ventricular outflow tract, with in most cases a distance of almost or even more than 1 cm between the nadir of the cusp and the ventriculo-arterial junction. There were serious doubts whether the annular base could be effectively restored and stabilized with a valve-sparing procedure using the reimplantation technique with a tube or Valsalva graft because it was considered not possible to encase the complete root. Other reasons not to preserve the valve were poor quality of the neoaortic valve, the wish to keep aortic cross-clamp time within safe time limits because of poor left ventricular function and/or concomitant procedures or the wish to provide the most definitive solution in case of technically difficult or hazardous procedures. Nevertheless, in selected cases it still may be a good option with respect to avoidance of anticoagulation and quality of life.

Limitations of the study are its retrospective design and the heterogeneity of the study population. Some data were lacking, especially from patients that were referred from other hospitals.

CONCLUSIONS

At this moment, the reported incidence of surgery for neoaortic root pathology is still low, but it is likely that with ever longer follow-up times the need for surgery for late neoaortic root complications will continue to increase, also in patients without any additional risk factors. Redo neoaortic surgery is technically feasible at a low risk, taking specific technical difficulties into account.

Conflict of interest: none declared.

REFERENCES

I have three questions.

Dr Koolbergen: Yes. It surprised us as well, but in our series, we haven't seen this diagnosis.

Dr Belli: Second question. Almost all adults underwent Bentall. You affirm that root replacement by the reimplantation technique in these conditions can be extremely complex. Did you consider Yacoub’s remodelling technique for valve-sparing root replacement in this population?

Dr Koolbergen: Yes. That’s exactly why I’m now going to explore the Lansac procedure with the Yacoub remodelling technique and an external aortic ring. And I hope with this technique we can sometimes spare the valves in this population.

Dr Belli: And the last question. In your opinion, can we apply guidelines which change from time to time, many defined for Marfan or bicuspid vasculopathies, regarding the root diameter in this condition particularly when aortic valve function is preserved?

Dr Koolbergen: When aortic valve function is preserved, it’s extremely difficult to produce guidelines because you can compare the situation to no other pathologies actually. So you cannot compare to the connective tissue disease group, nor to the group after the Ross procedure. And as far as we know, no section has been mentioned in this group. But, nevertheless, I think we all agree that at a certain point when the aneurysm grows and is progressive, then you need to replace it, especially when it can contribute to a pulmonary branch stenosis as well. Sharp coronary takeoff may be a problem eventually and, of course, eventually the neoaortic valve will start to leak. But for now, we follow the guidelines as used for connective tissue disease to be on the safe side.

Dr F. Al Rashidi (Lund, Sweden): In the paediatric setting from your series, what’s the size of the annulus, because in the previous paper the annulus diameter was quite large. How much do you reduce the annulus until you are satisfied for the paediatric population patients?

Dr Koolbergen: For the paediatric population, of course we always have in the OR our algorithm with the body surface area, and if necessary, we reduce to that size. But I must say that for the children described in this series, not all data on the exact measurements during operation were there. So we only had pre-operative diameters and postoperative measurements.

Dr F. Lacour-Gayet (New York, NY, USA): I have a question about the cause of this aortic root dilatation or regurgitation after arterial switch. It is a matter of concern to observe such important root dilatation following arterial switch. We know some causes: pulmonary artery banding, TGA associated with VSD and TGA-VSD associated with coarctation, as Dr Belli just mentioned. It is obvious that with the very large pulmonary valve in neonates, the pulmonary valve and the pulmonary root are very likely at risk of enlarging even more. So my question is specifically to know whether you are using a trapdoor technique or not in the primary arterial switch?

Dr Koolbergen: No. In the arterial switch operation, we tried to use trapdoor techniques as little as possible. Of course, we know that this has been found to be a cause for this problem in the past. But as far as we know (we did not have all operative reports complete, especially not from the referring centers), trapdoor techniques were only used in two patients.

Dr Lacour-Gayet: Only in two?

Dr Koolbergen: Yes.