Intramural coronary arteries and outcome of neonatal arterial switch operation

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Abstract

Objective: To evaluate the impact of coronary patterns with intramural arteries on the outcome of arterial switch operation (ASO) in neonates with transposition of the great arteries (TGA).

Methods: Between 1987 and 2008, 919 neonates underwent ASO for TGA. Forty-six (5.0%) had intramural coronary arteries. Intramural course involved the left main coronary artery in 28 of the 46 cases (61%), the left anterior descending artery in 12 patients (26%), the right coronary artery in three and both right and left coronary arteries in three cases. Various techniques were used to manage the coronary arteries: ASO without coronary relocation in one, ASO with coronary transfer as a single coronary button in nine and ASO with coronary transfer as two separate buttons in 36 patients (additional pericardial patches were implanted to orientate the coronary button in nine cases or enlarge the coronary ostium in three cases). The intramural course was unroofed in most cases (after 1995).

Results: There were 13 deaths (28%): two intra-operative, nine before discharge from the hospital and two after discharge; during the same period, overall mortality in the 873 neonates with other coronary patterns was 3.9%. Actuarial survival at 10 years was 71\%/7%. Most deaths (11/13, i.e., 85%) were related to coronary complications. No time—trend effect was noted regarding mortality. Non-fatal coronary lesions were detected in eight patients (three with clinical evidence of myocardial infarction and five without). Five patients underwent re-operation for coronary revascularisation. Actuarial freedom from coronary events at 10 years was 46\%/10%. After a mean follow-up of 8.3\%/4.8 years, left ventricular function was normal in 97% of the survivors; minor ischaemic sequelae were present in two patients.

Conclusions: Coronary patterns with intramural arteries remain associated with high coronary mortality and morbidity following neonatal ASO, even in the current era. The association of slit-like deformation of the ostium, stenosis of the intramural course and abnormal angle of take-off might explain the difficulty in coronary transfer. The technique of coronary transfer should be individually adapted to each anatomical situation. The place of patch ostioplasty of the intramural artery remains to be determined.

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Keywords: Transposition of the great arteries; Arterial switch operation; Intramural coronary arteries

1. Introduction

Arterial switch operation (ASO) has become the treatment of choice for neonates with transposition of the great arteries (TGA). The operation is currently carried out with low mortality and morbidity rates. Successful transfer of the coronary arteries into the neoaortic root represents the key point of the procedure. Various technical modifications have been described to allow adequate coronary transfer in all coronary patterns. There remains, nevertheless, a risk of early and late coronary complications, particularly in patients with unusual coronary anatomy. Among unusual coronary patterns, the presence of intramural coronary arteries has been associated with an increased risk of coronary complications in most surgical series [1—5], whereas, in other series, this was not the case [6—8], particularly with increasing surgical experience [9,10]. However, available data regarding this coronary anatomy are limited and few studies have addressed this issue specifically [11—15]. The present study was undertaken to evaluate the impact of coronary patterns with intramural arteries on the early and late outcome of neonatal ASO.

2. Materials and methods

2.1. Study design

Between January 1987 and December 2008, 919 neonates underwent ASO at Sick Children’s Hospital, Paris. The
Pediatric Cardiac Surgery database was reviewed to find the reports of the patients who had coronary arteries with an intramural course. Permission to perform health-records review was obtained from the Paris V University Ethics Committee. The need for individual consent was waived.

2.2. Study population

Forty-six patients (5.0% of the entire population) were identified. There were 35 boys and 11 girls. Mean age at operation was $8.0 \pm 6.7$ days (range: 2—31 days). Mean weight was $3.1 \pm 0.3$ kg (range: 2.2—3.9 kg). Forty-two neonates (91%) had TGA with intact septum and four had TGA with ventricular septal defect. Associated anomalies included aortic arch obstruction (three), bicuspid pulmonary valve (three) and right ventricular hypoplasia (in one patient with aortic arch obstruction). Antenatal diagnosis of TGA was available in 15 cases (32%). Thirty-two patients (70%) underwent Rashkind procedure and 40 neonates (87%) received prostaglandin infusion, preoperatively.

The position of the great arteries (aorta in relation to pulmonary artery) was direct anterior in 70% (32/46), anterior and rightward in 20% (9/46), side by side in 8.7% (4/46) and anterior and leftward in 1.3% (1/46). Coronary anatomy was determined according to the description available in the operative reports. The various coronary patterns are summarised in Fig. 1. In most cases, the intramural course involved the left main coronary artery (28/46, i.e., 61%) or the left anterior descending artery (12/46, i.e., 26%). The right coronary was involved in three patients (6.5%). In the last three cases, two arteries had an intramural course (right and left coronary arteries in two, right and left anterior descending in one). In most cases, there were two coronary ostia, often close to each other. Only one patient had a single coronary ostium (with intramural right and left coronary arteries). In all cases, the ostium of the intramural artery was close to the posterior valvular commissure.

2.3. Surgical treatment

Between 1987 and 2006, all operations were performed by the same surgeon (PRV); subsequently, two surgeons were involved (OR and PRV).

The basic technique used for arterial switch has been reported previously [2]. The Lecompte manoeuvre was used in all cases. Associated procedures included VSD closure in four patients and aortic arch enlargement in three. Externally, it was usually difficult to recognise an intramural coronary artery because the involved artery might emerge from the aortic wall in a more-or-less normal position. After incision of the ascending aorta, the coronary ostia and a potential intramural course were identified before complete transection, to avoid inadvertent section of the intramural artery. Coronary management was achieved using different techniques.

2.3.1. ASO without coronary transfer

In one patient (with intramural left coronary artery and both arteries originating from the same sinus), ASO was performed without coronary relocation, as described by Moat and collaborators [16]. An aortopulmonary fenestration was created with an autologous pericardial baffle to allow coronary artery perfusion with blood from the neoaorta.

2.3.2. ASO with a single coronary button

In nine patients, there were either a single ostium (one patient) or two ostia, which were judged too close to be separated. Coronary transfer was achieved using a single button. The posterior aortic valvular commissure was detached from the aortic wall, taking care to leave the cusps and commissure intact. Both coronary ostia were excised 'en bloc', the single button including the whole intramural segment. In most cases (actually since 1995), the intramural course was unroofed. The single coronary button was sutured to the rim of the transected pulmonary artery, leaving the coronary ostia in their normal anatomic relationships to prevent kinking of the arteries. An anteriorly placed pouch of fresh autologous pericardium was sutured to the coronary button and incorporated in the neoaortic anastomosis.

2.3.3. ASO with two separate coronary buttons

In the remaining 36 patients, there was enough tissue separating the two ostia, and coronary transfer was carried out using two separate coronary buttons.
After detachment of the valvular commissure, excision of both coronary ostia as a single button and unroofing of the intramural segment as described above, the coronary disc was divided into two separate buttons and the coronary arteries were mobilised separately in the standard fashion. Each coronary button was reimplanted into the neoaorta using various techniques, which evolved with time.

In the early part of the series, the two coronary buttons were reimplanted directly into punch holes or vertical incisions made in the neoaortic root and the intramural segment was not unroofed (eight patients). During a short period of time (four patients), both coronary ostia were reimplanted side by side, as previously described [17]. Since 1995 (24 patients), the intramural segment was routinely unroofed and the coronary buttons were reimplanted using medially hinged trapdoor incisions; in nine of these patients, additional pericardial patches were used to achieve adequate orientation of the intramural artery; finally, in three patients in whom the intramural coronary segment was severely stenotic, immediate coronary patch angioplasty was performed using fresh autologous pericardium or pulmonary arterial wall.

2.4. Follow-up and data analysis

Follow-up data were obtained during a 3-month closing interval (April 2009—June 2009). Information was obtained for all patients (100% complete).

The surviving patients had an annual examination by the referring cardiologist; it included clinical assessment, electrocardiogram (ECG) and echo-Doppler evaluation. Most patients had coronary exploration by coronary angiography and/or multislice computed tomographic angiography.

Data were described as frequencies, medians with ranges and means with standard deviations. Estimates of time-related survival and freedom from coronary events were calculated using the Kaplan—Meier method. All analyses were performed using SPSS for Windows version 13.0 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Intra-operative results

After aortic unclamping, coronary perfusion was inadequate in 13 patients (28%) and coronary reimplantation sites were revised immediately. Details of coronary revision are presented according to the initial surgical management in Table 1.

Mean ischaemic time was 104 ± 30 min. Two patients could not be weaned from bypass and died in the operating room (one after coronary revision). The sternum was left open in 20 patients. One patient (after coronary revision) left the operating room under extracorporeal membrane oxygenation (ECMO) support.

Table 1
Intra-operative coronary revision (according to initial management).

<table>
<thead>
<tr>
<th>Year</th>
<th>ASO number</th>
<th>Intramural CA</th>
<th>Initial management</th>
<th>Surgery at revision</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>418</td>
<td>LMCA</td>
<td>Single button</td>
<td>Two separate buttons</td>
<td>Alive</td>
</tr>
<tr>
<td>2003</td>
<td>613</td>
<td>LMCA</td>
<td>Single button</td>
<td>Extensive dissection of CAs</td>
<td>In-hospital death (hour 1)</td>
</tr>
<tr>
<td>2004</td>
<td>674</td>
<td>LAD</td>
<td>Single button</td>
<td>Hood enlargement</td>
<td>In-hospital death (hour 6)</td>
</tr>
<tr>
<td>2008</td>
<td>913</td>
<td>LMCA</td>
<td>Single button</td>
<td>Hood plication</td>
<td>Alive</td>
</tr>
<tr>
<td>1998</td>
<td>20</td>
<td>LMCA</td>
<td>Direct reimplantation</td>
<td>Aortic sinus resection</td>
<td>Intra-operative death</td>
</tr>
<tr>
<td>1991</td>
<td>74</td>
<td>LMCA</td>
<td>Direct reimplantation</td>
<td>PA lengthening</td>
<td>Late death (day 105)</td>
</tr>
<tr>
<td>1992</td>
<td>114</td>
<td>LAD</td>
<td>Direct reimplantation</td>
<td>Aortic sinus plication</td>
<td>Alive</td>
</tr>
<tr>
<td>1995</td>
<td>231</td>
<td>LAD</td>
<td>Side by side</td>
<td>Mammary bypass to LAD</td>
<td>Alive</td>
</tr>
<tr>
<td>1994</td>
<td>199</td>
<td>LMCA</td>
<td>Trapdoor incision</td>
<td>Patch augmentation</td>
<td>Alive</td>
</tr>
<tr>
<td>2002</td>
<td>552</td>
<td>LMCA</td>
<td>Trapdoor incision</td>
<td>LMCA patch angioplasty</td>
<td>Alive</td>
</tr>
<tr>
<td>2006</td>
<td>762</td>
<td>LMCA</td>
<td>Trapdoor incision</td>
<td>Patch augmentation</td>
<td>Alive</td>
</tr>
<tr>
<td>2007</td>
<td>799</td>
<td>LAD</td>
<td>Trapdoor incision</td>
<td>LAD patch angioplasty + mammary bypass</td>
<td>Alive</td>
</tr>
<tr>
<td>2008</td>
<td>888</td>
<td>LMCA</td>
<td>Trapdoor incision</td>
<td>LMCA patch angioplasty + ECMO</td>
<td>In-hospital death (day 16)</td>
</tr>
</tbody>
</table>

CA: coronary artery; LMCA: left main coronary artery; LAD: left anterior descending artery; PA: pulmonary artery.

Table 2
Coronary-related deaths (11 patients).

<table>
<thead>
<tr>
<th>Year</th>
<th>ASO number</th>
<th>Intramural CA</th>
<th>Time of death</th>
<th>Cause of death</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>14</td>
<td>LMCA + RCA</td>
<td>Intra-operative</td>
<td>Myocardial ischaemia</td>
</tr>
<tr>
<td>1988</td>
<td>20</td>
<td>LMCA</td>
<td>Intra-operative</td>
<td>Myocardial ischaemia (after revision)</td>
</tr>
<tr>
<td>2003</td>
<td>613</td>
<td>LMCA</td>
<td>Hour 1</td>
<td>Myocardial ischaemia</td>
</tr>
<tr>
<td>2005</td>
<td>674</td>
<td>LAD</td>
<td>Hour 6</td>
<td>Myocardial ischaemia (after revision)</td>
</tr>
<tr>
<td>1988</td>
<td>23</td>
<td>LMCA</td>
<td>Day 3</td>
<td>Myocardial ischaemia — arrhythmia</td>
</tr>
<tr>
<td>2005</td>
<td>693</td>
<td>LMCA</td>
<td>Day 5</td>
<td>Myocardial ischaemia on ECMO (after re-operation at day 5)</td>
</tr>
<tr>
<td>2000</td>
<td>477</td>
<td>LMCA</td>
<td>Day 13</td>
<td>Sudden death</td>
</tr>
<tr>
<td>2008</td>
<td>888</td>
<td>LMCA</td>
<td>Day 16</td>
<td>Sudden death (after revision)</td>
</tr>
<tr>
<td>2008</td>
<td>889</td>
<td>LMCA</td>
<td>Day 18</td>
<td>Sudden death (after re-operation at day 1)</td>
</tr>
<tr>
<td>2001</td>
<td>510</td>
<td>RCA</td>
<td>Day 51</td>
<td>Sudden death</td>
</tr>
<tr>
<td>1991</td>
<td>74</td>
<td>RCA</td>
<td>Day 105</td>
<td>Myocardial infarction (after revision)</td>
</tr>
</tbody>
</table>

CA: coronary artery; LMCA: left main coronary artery; LAD: left anterior descending artery; RCA: right coronary artery.
3.2. Early results

Eleven neonates died before discharge from the hospital. All deaths but two were related to coronary complications (Table 2). The two non-coronary deaths were due to hypoplasia of the right ventricle (one) and systemic candidiasis (one).

Two patients required early re-operation for acute myocardial ischaemia 1 day and 5 days after surgery. Both underwent patch angioplasty of the left main coronary artery. Both died despite ECMO support. Another patient with simple TGA underwent coarctation repair 21 days after arterial switch.

Other early complications included mediastinitis (two), phrenic nerve palsy (one) and chylothorax (one). Mean times of ventilation and intensive care unit (ICU) stay were $114 \pm 17$ h and $7.5 \pm 4.8$ days, respectively.

3.3. Late results

Two patients died after discharge from the hospital: sudden death (presumably due to myocardial ischaemia) at 51 days, myocardial infarction at 105 days. There was no mortality after 3 months. The overall mortality was 28% (13/46). The number of patients per periods of 4 years and the number of deaths are shown in Fig. 2; there was no significant decline in mortality with time. Actuarial survival ($\pm$ standard error) at 10 years was $71 \pm 7\%$ (Fig. 3).

The 33 survivors were followed up for $8.3 \pm 4.8$ years. Twenty-nine patients (88% of survivors) underwent at least one coronary evaluation (coronary angiography in 23, multislice computed tomographic angiography in six). Coronary evaluation was undertaken because of ECG and/or echocardiographic findings of myocardial infarction in three patients and as a routine procedure in 26. The first evaluation was performed after a median interval of 11 months (range: 0.5—72 months) after arterial switch. Coronary anatomy was normal in 21 patients and coronary lesions were demonstrated in eight patients, including the three patients with clinical signs of myocardial infarction.

Five patients with coronary lesions in whom thallium myocardial perfusion imaging showed myocardial ischaemia during exercise or after injection of dipyridamole underwent late re-operation. Mean age at re-operation was $6.2 \pm 3.5$ years. Four patients underwent patch angioplasty of a stenosed/obstructed artery (left main coronary artery in two patients, left anterior descending artery in two). One patient with obstruction of the left main stem underwent a mammary bypass. There was no mortality. Patency of the coronary revascularisation was demonstrated in all patients.

At last follow-up, all survivors were leading a symptom-free normal life. Left ventricular function was normal in 32 patients (97%). Minor ischaemic sequelae were noted in two patients (segmental hypokinesia in one and mild mitral insufficiency in one).

3.4. Coronary events

Coronary events occurred in 19 patients (41%) and included coronary-related deaths in 11, coronary lesions with clinical signs of myocardial infarction in three and asymptomatic coronary lesions in five patients. Actuarial freedom from coronary events at 1 year, 5 years and 10 years was $65 \pm 7\%, 53 \pm 9\%$ and $46 \pm 10\%$, respectively (Fig. 4).
Details regarding coronary-related deaths and non-fatal coronary complications are given in Tables 2 and 3. Most probably because of the small number of patients in each group, the incidence of coronary-related deaths and coronary events was not clearly influenced by the coronary anatomy or the initial surgical management (Table 4).

4. Discussion

Adequate transfer of the coronary arteries represents the technical key point of the arterial switch procedure. Coronary transfer is more demanding in some unusual coronary patterns and, specifically, in the presence of intramural coronary arteries. Several surgical series have shown that intramural coronary arteries were associated with an increased early risk [1–5]; this was clearly demonstrated in a meta-analysis published in 2002 [18]. Other reports have noted that increasing surgical experience might mitigate the early adverse outcome [8–10]. It has also been documented that, in the presence of intramural coronary arteries, late coronary complications might occur after an initial straightforward course [14]. The present study shows that, in our total experience with ASO, coronary patterns with intramural arteries are associated with an increased mortality rate (28% vs 3.9% in patients with other coronary patterns), as well as an increased incidence of overall lethal and non-lethal coronary events (41% vs 4.7% in other coronary patterns). Disappointingly, there was no improvement with increasing experience of the surgical team as shown in Fig. 2.

The term ‘intramural coronary artery’ refers to coronary patterns in which there is an intimate relationship between aortic and coronary arterial walls; histologically, the aortic and coronary medial walls are attached without interposed adventitia. Intramural coronary arteries are rare in patients with normal ventriculoarterial connections, but proportionally more common in TGA, with a reported incidence of 3–5%. In most cases, the left main coronary artery or the left anterior descending artery are involved, although the right coronary artery and both arteries might be involved as well. The intramural artery usually originates from the wrong sinus (from the same sinus as the other coronary artery) and courses between the great arteries. Sometimes, the intramural artery originates from its normal sinus but above the sinotubular junction. When both arteries originate from the same sinus, there are usually two distinct ostia, which are more-or-less close to each other; the association of a single coronary ostium and intramural course is rare. Very commonly, the ostium of the intramural artery is in very close relationship to the posterior valvular commissure. It should be pointed out that intramural course and course between the great arteries are frequently associated but are not synonymous; an intramural artery might originate from its normal sinus and have a normal epicardial course; a coronary artery originating from the wrong sinus might course between the great arteries without intramural course. All of these abnormal coronary patterns might complicate coronary transfer during ASO.

The presence of an intramural coronary artery offers several surgical challenges.

(1) The intramural artery might have a more-or-less normal epicardial course and diagnosis by external inspection might be impossible, exposing to the risk of section of the abnormal artery during the aortotomy; it is therefore essential, in all patients, to open the aorta partially in a safe area and to determine the coronary anatomy (number and location of the ostia, relationship with the commissure and the sinotubular junction and intramural course) before transecting the ascending aorta.

(2) Because the abnormal ostium is usually paracommissural, it is necessary to mobilise the posterior valvular commissure from the aortic wall before excising both coronary ostia as a single disc, which includes the whole intramural segment; the commissure must subsequently be resuspended to the pericardial patch used to repair the neopulmonary root. This was not associated with an increased incidence of postoperative pulmonary valvular incompetence.

(3) To carry out the ASO in a more-or-less usual fashion, it is necessary to divide the coronary disc into two separate
When, despite opening of the proximal intramural artery course between the aorta and the pulmonary artery.

After aortic unclamping, any abnormality in myocardial perfusion (as assessed by direct inspection and/or intra-operative echocardiography) should be addressed aggressively by immediate coronary revision; in most cases, patch coronary ostioplasty should restore normal coronary blood flow; in desperate situations, performing a mammary-to-coronary bypass might be life saving.

In patients with concordant ventriculoarterial connections, the anomalus origin of one coronary artery from the wrong sinus with an initial intramural course carries a potential risk of acute myocardial ischaemia and sudden death [21]. Several mechanisms have been proposed to explain the pathophysiology of ischaemia in this setting [22]: (1) flap closure of the slit-like opening of the coronary orifice, (2) acute angle of take-off and kinking of the coronary artery as it exits from the aorta, (3) stenosis of the intramural segment of the proximal coronary artery, (4) compression by the aortic commissure and (5) compression as the coronary arteries courses between the aorta and the pulmonary artery. The same mechanisms probably apply to patients with TGA and intramural coronary arteries. Ideally, all these mechanisms should be addressed at the time of surgery to achieve optimal early and late results. For these reasons, conversion to atrial repair (Senning procedure) or ASO without coronary transfer [16,23] might provide satisfactory early results but should probably be avoided because the intramural coronary artery is left intact with a potentially dangerous intramural course between the great arteries. Similarly, coronary transfer using a single-button technique leaves intact the abnormal course between the great arteries and was, in our experience, associated with an increased risk of coronary events.

We, therefore, think that coronary transfer should be performed using two separate buttons, unless there is a single ostium or two ostia very close to each other [12]. Excision of the common wall between the aorta and the coronary artery should be carried out to correct the slit-like opening of the ostium and open the proximal part of the intramural segment; this also facilitates the division into two separate buttons. The coronary button bearing the intramural segment should be reimplanted taking great care to avoid kinking at the site of aortic take-off; this might need the implantation of additional pericardial patches [6,20].

In patients with a concordant ventriculoarterial connection and intramural coronary arteries, patch ostioplasty of the abnormal artery is evolving as the procedure of choice [22]. This technique enlarges a slit-like ostium, augments the diameter of the whole intramural segment and improves the acute angulation at the take-off [19]. The place of this technical solution during ASO remains to be determined, particularly in patients with severe stenosis of the intramural segment. In our experience, 4 of the 6 patients who underwent coronary patch ostioplasty either as a primary procedure or at the time of intra-operative coronary revision had a satisfactory early and late result. If deemed necessary, patch ostioplasty should be performed meticulously using microsurgical techniques; the optimal patch material (fresh autologous pericardium, pulmonary arterial wall and innominate vein wall) remains controversial.

Because of the risk of early and late coronary complications, even after a straightforward initial course, all patients must be followed up very closely. It is our routine practice to evaluate coronary anatomy (by coronary angiography or multislice computed tomographic angiography) first before hospital discharge and, again, before school age. If coronary lesions are detected, myocardial perfusion imaging is performed and re-operation undertaken if needed [24].

5. Conclusions

During ASO, the presence of intramural coronary arteries remains associated with an increased risk of coronary mortality and morbidity. In most cases, coronary transfer as separate buttons with unroofing of the intramural segment should provide adequate coronary perfusion. However, in selected cases, coronary patch ostioplasty might be indicated. Close coronary follow-up is mandatory.

Acknowledgement

We express our appreciation to Corinne Pasquet for secretarial assistance.
References


Appendix A. Conference discussion

Dr V. Tsang (London, UK): The intramural vessel remains a very challenging problem.

I hope you don’t mind if I address the first question to Professor Youhe. Did you know about the intramural vessel before surgery? Was it usually not.

Dr Tsang: Say if you do, how would you prepare yourself mentally to tackle such an issue.

Dr Youhe: Not very well if you look at the results.

Dr Tsang: Would you consider a certain plan when you know about the intramural vessel before surgery? Do you think it would help?

Dr Youhe: I would not like to discuss immediately all the points, but the point we would like to make at the end of this study is that probably the best solution is to enlarge routinely the intramural course with a patch.

This may need some microsurgical techniques, because as you know, the distal artery may be extremely small.

Dr Tsang: I’m sorry to divert. Can I ask another question?

Intramural vessels coming from the adjacent sinus and from the wrong sinus may have different events. Did you find any differences in those patients who have intramural coronary artery from the adjacent sinus with a short course, less angulation, and without a stenotic orifice, compared with those coronary arteries coming from the wrong sinus with a long horizontal intramural course and a stenotic orifice?

Dr Metton: We didn’t find any difference because we have just a few patients with coronary artery coming from two sinuses. In most cases, I think it’s about 33 cases, the coronary artery comes from the wrong sinus with an intramural course between the posterior commissure.

Dr Tsang: About the use of autologous pericardial patch in the ostioplasty, I personally find the autologous pericardial behaviour quite unpredictable. When it is not pericardium, it can behave like anything. What is your preferred choice of patches in such critical reconstruction of the ostium?

Dr Metton: When we do the immediate coronary patch angioplasty, usually we use the fresh autologous pericardium. When we re-operate on a patient, we use saphenous vein.

But we were asking Mr Youhe if we couldn’t use the innominate vein for the first patch angioplasty because the pericardium is sometimes very thick and can be difficult for the end of the coronary artery.

Dr Tsang: This may be a bit provocative. You were suggesting that arterial switch is not a good option in this context. But what you said is based on data of sudden death in the adult patients with normally related great vessels. Does that risk apply to children?

Dr Metton: We have no data to say that arterial switch operation is not indicated with intramural. But we think that similarly to patients with anomalous coronary artery of the wrong sinus, the better option is to avoid leaving the intramural course in place. But we have no data to say that, at least in my experience, my knowledge.

Dr R. Jonas (Washington, D.C., USA): I’d like to provide an alternative point of view. We had the opportunity for quite a few years in Boston to be referred essentially every arterial switch that was being done in the United States and had a very big experience with all sorts of anomalous coronary arteries.

And other than the first year or two, we did not find that intramural coronary arteries were a risk factor. And I would discourage people from trying to place patches within the coronary arteries in the newborn period. I think that would be a mistake.

One thing I’ve learned about unroofing the anomalous coronary in the setting of normally related great arteries is that the tunnel that passes through the commissure is like a cartilaginous tube. Immediately above the commissure, the arterial wall is supporting the entire weight of the valve closure, and I think for that reason it becomes very thickened and noncompliant.

My personal feeling is that is that the mechanism of the ischaemia that one can get in high-demand situations with an anomalous coronary artery.

I would like to suggest that, once you’ve moved an intramural coronary to a noncommissural position where it is not taking the full weight of the valve, there may be remodeling of the wall in that situation and that it will no longer be a high-risk situation.
Getting back to transposition, we have published that the intramural coronary artery is not a risk factor. That was the Boston experience derived from a very large number of cases. We simply handled it as a normal coronary transfer.

So I would discourage taking complex approaches to moving the intramural coronary.

**Dr I. Chiu (Taipei, Taiwan):** I would like to make one comment. I saw most of your cases were transferred by separate technique, just one case have the flap.

Well, the basic principle in coronary transfer I think was proposed by Mr de Leval many years ago in the Journal of Thoracic and Cardiovascular Surgery. We should redirect LV output to the in situ coronary artery. This is the basic principle. We utilized various flaps to achieve this principle and published in the Journal of Cardiac Surgery.

And I advocated yesterday a spiral switch of the great arteries, that is, the application of the transfer of the coronary artery principle to the pulmonary artery.

So I think we encounter a lot of complications early or late after operation. We should stick to the principle of in situ transfer both in coronary artery and pulmonary artery.

**Dr M. Haw (Southampton, UK):** Did you see a drop in the incidence of coronary events once you introduced the patch angioplasty, or did you see any coronary events once you started that technique?

**Dr Vouhe:** There were not enough patients to tell that because I think there are only three patients who had patch as a primary procedure. And the three went well, but it’s too small a patient number.

**Dr Z. Al Halees (Riyadh, Saudi Arabia):** I would like to propose using the autologous pulmonary artery as a patching material whenever it is required. I believe it works quite well, even though Dr Jonas does not agree, even for the coronary augmentation in the neonate.

**Dr E. Belli (Paris, France):** We have the same results that Professor Vouhe has experienced; that intramural, inter-arterial coronary course is associated with significantly higher mortality.

We never use a pericardial patch because we don’t know the behaviour, and you can lose the control of the operation: we believe that you have one bullet to use; after a couple of stitches to suspend the coronary, we don’t go to cross-clamp the aorta to revise the coronaries. In case we have obvious ischaemia and impossibility to wean from bypass, we use internal mammary graft which is, in my opinion, the best option to save the patient.