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Arterial Switch Operations for Single Coronary Artery Ostium or Intramural Coronary Artery

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Background Successful transfer of the coronary arteries is the most critical step during arterial switch operations for patients with transposition of the great arteries with a single coronary artery ostium and/or intramural coronary arteries. Various techniques have been reported and the present study was an evaluation of them in 10 neonatal patients.

Methods and Results Coronary artery transfers are achieved by implantation of coronary buttons to the previously anastomosed neo-aorta using pericardial or pulmonary artery hood techniques. One patient died perioperatively because of myocardial malperfusion. Following prolonged mechanical ventilation, another died from sepsis on the 28th postoperative day. Coronary artery perfusion abnormality was not observed in the remaining patients.

Conclusions Transfer of the coronary button by the pericardial or pulmonary artery hood augmentation technique to the previously anastomosed neo-aorta is a practical, easy and convenient combination of methods for the treatment of these patients. (*Circ J* 2004; **68:** 1179–1183)

Key Words: Arterial switch; Intramural coronary artery; Single coronary ostium; Translocation

Recently, the arterial switch operation has become the first line surgical procedure for the correction of transposition of the great arteries (TGA)[1] and the determinants of success are the preoperative left ventricular performance, coronary artery anatomy and the experience of the surgical team. Complex coronary artery anatomy increases the operative risk[1]

Following repair of TGA with the usual coronary artery pattern in which the right and left coronary arteries arise from sinuses I and II respectively, kinking or tension of the coronary arteries is rarely seen; however, the risk increases in TGA with a single coronary ostium or intramural coronary artery patterns.

Methods

We evaluated the translocation techniques used to treat 10 neonatal TGA patients with a single coronary ostium or intramural coronary artery operated in the 2 cardiovascular surgery clinics of Istanbul University.

We preferred to use the Leiden classification to describe the sinuses of Valsalva[2] Demographic data and coexisting cardiac anomalies of the patients are shown in Table 1. A definitive preoperative diagnosis of all the patients was made by transthoracic echocardiography. Only 1 patient underwent preoperative balloon atrial septostomy and there was 1 preoperative diagnosis of a coronary anomaly. All patients received prostaglandin E_1 infusion before the operation. Six patients were transferred to the operating theater under stable hemodynamic and respiratory status, with the remaining 4 patients being operated under urgent conditions.

Surgical Technique

Cardiopulmonary bypass (CPB) was instituted following cannulation of the distal ascending aorta and the superior and inferior vena cavae. Moderate hypothermia (25–28°C) was used during CPB. After division of the ductus arteriosus, the aorta was cross-clamped and hypothermic, hyperkalemic, antegrade blood cardioplegia was infused. After transecting the aorta distally to the coronary artery ostia, the distribution and course of the coronary arteries were evaluated (Table 2).

In 5 patients with a single coronary artery orifice arising from sinus II, a large single coronary button around the orifice of the coronary artery was excised, extending down to the base of the sinus of Valsalva. The initial segment of the right coronary artery, 5–7 mm distal to the bifurcation of the common coronary ostium, was dissected and freed from the epicardium, while the left coronary artery was kept intact.

The neo-aorta was anastomosed to the distal aorta with 7-0 polypropylene running sutures following the Lecompte maneuver before implantation of the coronary button. Because of the size discrepancy between the neo-aorta and the distal aorta, 2 of the patients required partial neo-aortic tissue resection to adjust the 2 aortic ends. Following the aortic anastomosis, the cross-clamp was released, the aorta was distended and the coronary button implantation site was marked. The aorta was cross-clamped again and a vertical incision was made to the predetermined point on the proximal neo-aorta. The lateral side of the coronary

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Table 1 Demographic Data, Aortic Cross-Clamp Times, Cardiopulmonary Bypass Times, Pulmonary Artery Reconstruction Technique and Coexisting Cardiac Anomalies of the 10 Neonates

Patient no.	*Age (days)*	*Weight (g)*	*AXC time (min)*	*CPB time (min)*	*PA reconstruction technique*	*Coexisting cardiac anomalies*
1	*7*	*3,100*	*89*	*115*	*Reconstruction under AXC*	*Perimembranous VSD*
2	*5*	*3,500*	*90*	*120*	*Reconstruction under AXC*	–
3	*12*	*2,900*	*85*	*117*	*Reconstruction under AXC*	–
4	*2*	*3,800*	*95*	*125*	*Reconstruction under AXC*	–
5	*10*	*3,700*	*100*	*127*	*Reconstruction under AXC*	–
6	*12*	*3,800*	*80*	*110*	*Reconstruction after AXC removal*	–
7	*10*	*3,400*	*110*	*140*	*Reconstruction after AXC removal*	–
*8**	*11*	*3,600*	*68*	*300*	*Reconstruction after AXC removal*	–
9	*10*	*3,400*	*70*	*120*	*Reconstruction after AXC removal*	–
10	*3*	*3,200*	*120*	*240*	*Reconstruction after AXC removal*	–

AXC, aortic cross-clamp; CPB, cardiopulmonary bypass; PA, pulmonary artery; VSD, ventricular septal defect.
** This patient died perioperatively.*

Table 2 Coronary Artery Patterns of the 10 Neonates

Coronary artery pattern	*n*
Single coronary artery ostium originating from sinus II	*4*
Two seperate ostia both originating from sinus II	*1*
Single coronary artery ostium originating from sinus I	*1*
Intramural left coronary artery with juxtacommissural ostium and right coronary artery ostium both originating from sinus II	*4*

button was sutured to the vertical incision on the neo-aorta with 7-0 polypropylene. In order to achieve an appropriate deviation and configuration, the anastomosis was completed by pericardial (3 patients) or pulmonary artery (2 patients) patches to cover the defect between the medial side of the coronary button and the neo-aorta (Fig 1), which provides medial rotation of the coronary button. The patch of pulmonary artery was harvested from anterior segment of the residual neo-pulmonary artery after excision of the coronary button.

There was only 1 case of a single coronary artery orifice arising from the sinus I and in this patient, the right coronary artery arising from the sinus I ran towards the right atrioventricular sulcus by coursing in front of the aorta. A large single coronary button was excised, extending down to the base of the sinus of Valsalva. The right coronary artery was freed from the epicardium for its length of 7–8 mm distal to the bifurcation. The initial 4–5 mm segment of the left coronary artery was also freed. The aorta was reconstructed with 7-0 polypropylene sutures after the Lecompte maneuver. The most appropriate location for the proximal coronary artery anastomosis was marked and a vertical incision was made in the neo-aorta. After translocation, because it crossed the aorta anteriorly, the right coronary artery was observed to be overstretched and so in

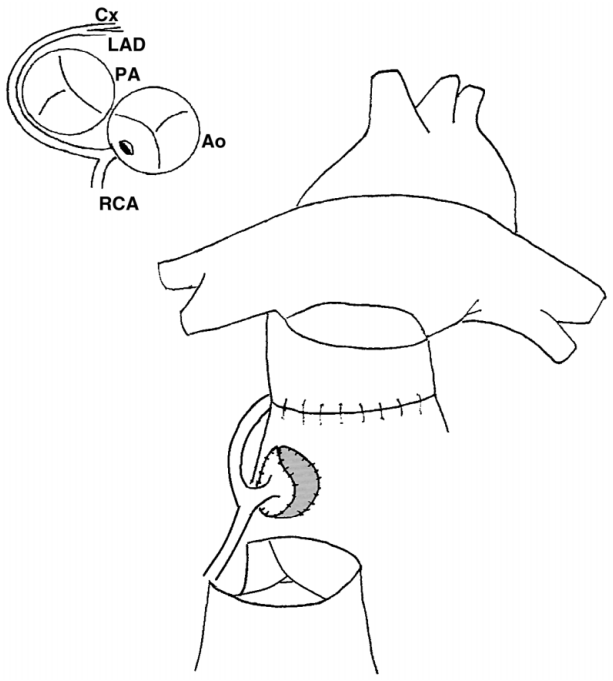


Fig 1. Schematic illustration of coronary translocation in patients with a single coronary artery ostium originating from sinus II. Coronary button reconstruction is made to the previously anastomosed neoaorta. The shaded areas are the pulmonary or pericardial patches used as hoods.

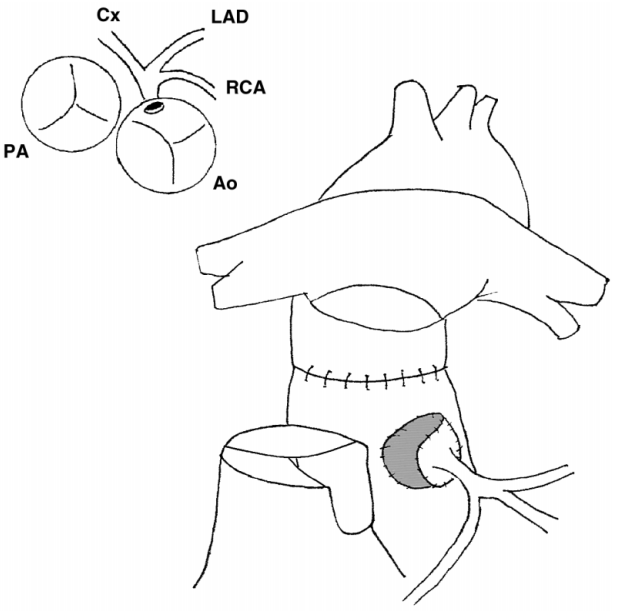


Fig 2. Schematic illustration of coronary translocation in a patient with a single coronary artery ostium originating from sinus I. The shaded area is the pulmonary arterial segment that is used in the medial site of the anastomosis.

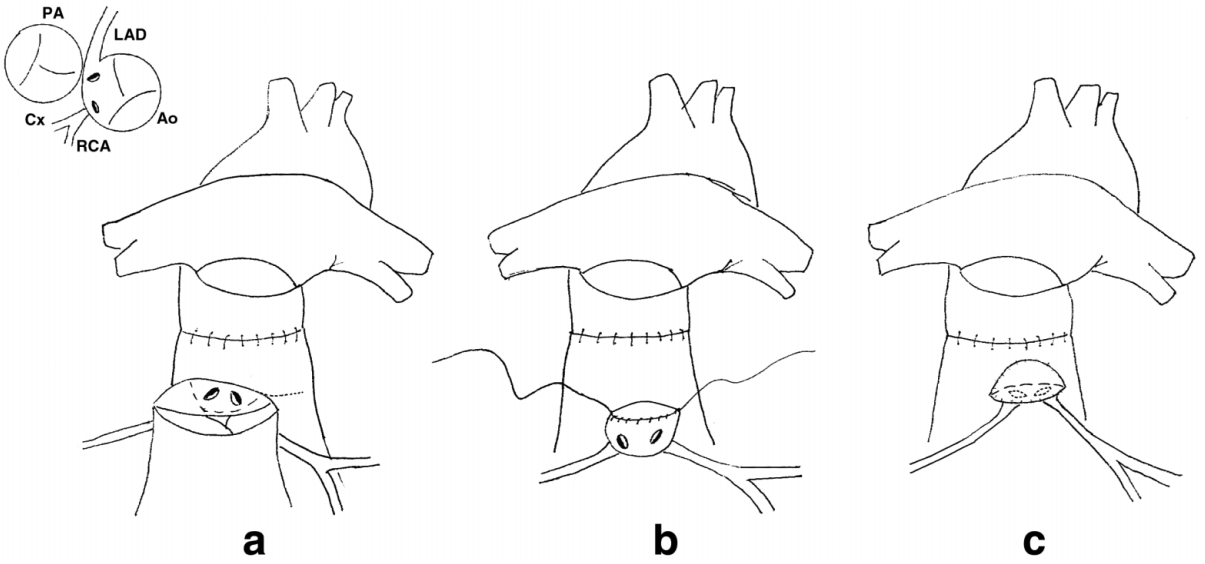


Fig 3. Schematic illustration of coronary translocation in patients with an intramural left coronary artery with juxtacommissural ostium and right coronary artery ostium, both originating from sinus II. (a) Preparation of the coronary button. (b) The superior margin of the coronary button is anastomosed to the caudal margin of the transverse incision on the neo-aorta. (c) Completion of the anastomosis with a pericardial or pulmonary patch.

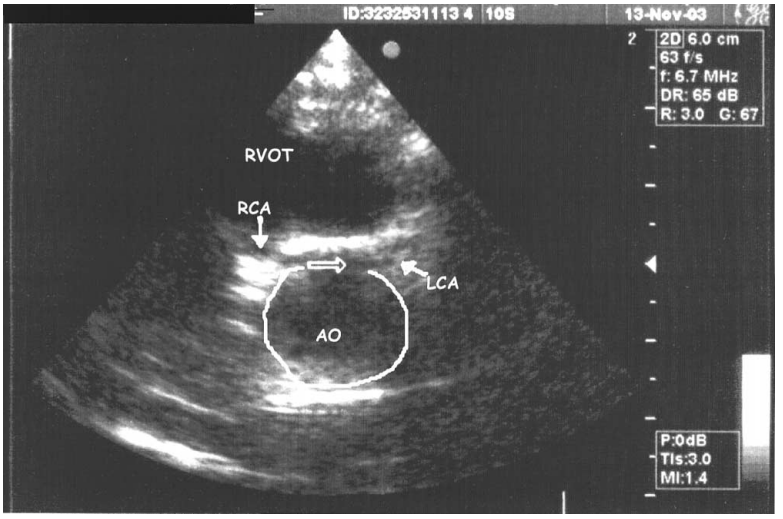


Fig 4. Early postoperative transthoracic echocardiography showing the pericardial cuff (patch) between the neo-aorta and pulmonary artery.

order to avoid the tension on the vessel and to provide an appropriate angle, the margin of the coronary button facing the left coronary artery was anastomosed directly to the neo-aorta using 7-0 polypropylene suture; the remaining medial site of the anastomosis was completed by interposing a pulmonary arterial segment between the medial aspect of the coronary artery button and the neo-aortic incision (Fig 2).

There were 4 patients with an intramural left coronary artery with juxtacomissural ostium and right coronary artery ostium both arising from sinus II. After commissural take-down, a large single coronary button was excised around the orifices of both coronary arteries. Care was taken to prevent rotation of the coronary button. The superior margin of the coronary button was anastomosed to the transverse incision on the neo-aorta. The defect between the inferior and lateral-medial margins and the roof of the coronary button and the neo-aorta was covered with a pericardial patch. Thus, the roof of the implanted coronary artery was constructed by this patch (Figs 3,4).

During the surgical correction, the neo-pulmonary anastomosis was performed under aortic cross-clamp in 5 cases, whereas the anastomosis was completed after removal of the cross-clamp in the other 5 cases. Two separate pieces of fresh pericardium were used to reconstruct the neo-pulmonary artery in 6 neonates and a single piece of pericardium was used in 4 neonates.

Results

The intramural left coronary artery was damaged during the preparation in 2 neonates whose juxtacomissural coronary artery orifices arose from sinus II and so coronary artery bypass procedures between the left internal thoracic and left anterior descending coronary arteries were performed. However, 1 of these patients died in the operating room because of the myocardial ischemia. Coronary artery perfusion abnormality was not observed in any of the other

patients.

The neo-pulmonary artery was anastomosed slightly to the left of the pulmonary bifurcation in 5 of the patients and slightly to the right of the pulmonary bifurcation in 1 in order to avoid compressing the coronary button anastomosis.

Nine neonates were given low-dose epinephrine and moderate-dose dopamine infusions during weaning from CPB. The duration of both CPB and aortic cross-clamping is shown in Table 1.

Signs of coronary perfusion abnormality were not observed on either echocardiography or ECG.

The sternum was closed on the third postoperative day in 2 patients.

The mean intubation time of the patients was 5 days and the range was 2–28 days. Following a prolonged period of mechanical ventilation, 1 patient died from sepsis on the 28th postoperative day.

Discussion

Successful transfer of the coronary arteries is the critical aspect of the arterial switch operations;[1] however, despite high mortality and morbidity rates, the arterial switch operation (ASO) is not considered to be contraindicated in any of the described coronary artery anomalies. Technical difficulties have been overcome by surgical experience and appropriate techniques[3] and as a result, the mortality rate has been reduced to less than 10%.[4]

Although the concept of the repair of TGA has remained unchanged since Jatene, many surgeons have proposed different techniques in order to prevent the occurrence of coronary ischemia.[5,6] An ASO without coronary transfer has been proposed to deal with the single origin or intramural course of the coronary arteries[7] in order to reduce early mortality; however, the continued abnormal course of the coronary persists as a potential nidus for mortality as the patient matures. De Leval et al pointed out that the key point is to take the aorta away from the coronary arteries and pulmonary trunk is brought to them, rather than moving the coronary arteries from the aorta and transferring the coronary scallops to the pulmonary trunk or neo-aorta.[8] The in situ transfer technique proposed by Aubert et al[9] was further developed by Murthy and Cherian.[5] Quaegebeur et al proposed excising appropriate sized segments from the proximal neo-aorta by coronary punch and then anastomosing the mobilized coronary buttons onto these openings.[10] However, despite these modifications, abnormal coronary arterial patterns continue to be a problem for surgeons. In both Aubert's and Murthy's techniques, the coronary artery is left in its original anatomical position and flaps and tunnels are made in the great arteries in such a way that the coronary ostium is committed to the neo-aorta. This avoids problems related to the coronary translocation such as traction and kinking, but late tunnel obstruction and neo-pulmonary artery stenosis because of turbulence in the neo-pulmonary artery remains a concern. In our technique, minimal coronary artery preparation and minimal deviation of the large coronary button through the help of pulmonary or pericardial hoods is necessary for the transfer of the coronary artery. In addition, our technique avoids turbulent flow because there is not a tunnel in neo-pulmonary artery system.

There is debate whether glutaraldehyde-fixed or fresh pericardium is better for pericardial hoods with regard to shrinkage and thickening with sclerosis and the possibility of thrombogenicity. Parry et al did not encounter such problems in their series in which they used glutaraldehyde-fixed pericardial hoods,[11] but in our last 3 cases we decided to use pulmonary artery patches instead of pericardium as hoods. In addition, anticoagulant therapy was administered to all patients postoperatively for the risk of thrombosis.

In 1978 Yacoub and Radley Smith recommended an axial flip-over technique for single coronary ostium repair,[12] and in 1988 Planche et al reported a technique that implied a coronary transfer by rotation of the single coronary button containing the 2 coronary ostia.[13] Recently, they abandoned this technique and decided to use that of Asou et al,[14] which consists of unroofing the intramural course in order to obtain sufficient distance between the 2 ostia to allow a 2-button transfer.

Takeuchi and Katogi left the coronary artery in its original anatomical position in their autologous aortic flap technique and a coronary tunnel was created by the distal great arterial wall, thereby avoiding the use of a pericardial patch.[15] These techniques[12,13,15] are technically demanding and also require careful planning. The pericardial or pulmonary artery hood augmentation technique used in our unit does not require as much expertise and skill because there is not as much rotation of the coronary button involved in the translocation of the single coronary artery. It can be performed easily.

In Brawn and Mee's trap door technique,[16] medial angulation of the coronary button is provided by trap-door incisions in the neo-aorta and we consider that our technique with medial pericardial or pulmonary patches provides a similar but augmented effect for the medial angulation of the coronary button.

In technique used by Asou et al,[14] the coronary buttons are reimplanted directly on the neo-aorta as 2 separate buttons, which is advantageous compared with our technique because it avoids the use of hoods; however, in order to divide the 2 adjacent coronary ostia into 2 separate buttons and implant each of them separately onto the neo-aorta, extensive dissection and preparation of the coronary artery and good evaluation of the appropriate site of transfer is necessary. Shukla et al defended the technique of direct coronary button anastomosis to the previously anastomosed neo-aorta in cases with single coronary ostium.[6] In their technique, appropriate transection of the aorta and pulmonary artery has been shown to avoid the necessity of coronary button anastomosis to the neo-aortic suture line. In our study of 10 cases, the technique as described by Shukla et al[6] was used, in which neo-aortic anastomosis was made before the coronary button reconstructions. In addition to this method, we also used the 'hood technique' of pulmonary artery or pericardial patches to the medial margins of the coronary anastomosis in order to reduce coronary tension and to achieve correct angulation.

Scheule and Jonas[17] prefer a direct implantation technique for single coronary ostium arising from the sinus II and for cases of a single coronary artery arising from sinus I and coursing over the aorta anteriorly, they prefer pericardial tube graft interposition between the neo-aorta and the coronary button for reconstruction. We had 1 neonate with this coronary variation and in this particular patient, the tension on the right coronary artery was relieved by introducing a pulmonary artery patch to the medial margin of the neo-aorta and coronary button anastomosis.

We performed posterior commissural take-down in 4 patients with an intramural left coronary artery arising from sinus II and passing between the aorta and pulmonary

artery. In 2 of these cases we damaged the vessel by direct trauma to the left coronary artery during preparation of the intramural segment and we implanted the left internal thoracic artery to the left anterior descending coronary artery of each patient. One of those 2 patients died, but the other survived. These 2 cases underwent surgery early in our experience with the arterial switch operation and the mortality and morbidity were the result of the surgical team's inexperience rather than any technical difficulty of the procedure.

Compression of the large pericardial or pulmonary hood by the reconstructed pulmonary artery immediately after arterial switch or during long-term follow up is also a major concern. In order to avoid undue compression of transferred coronary cuff, roofed with the pericardial sac, it is necessary to realign the pulmonary trunk by changing the position of the anastomosis between the neo-pulmonary artery and pulmonary bifurcation. In patients with a single coronary artery originating from sinus II, the neo-pulmonary arterial anastomosis should be performed laterally towards the left pulmonary artery. For those originating from sinus I and those with hoods placed on the left side of the neo-aorta, the neo-pulmonary anastomosis should be shifted towards the right pulmonary artery.

Neo-aortic reconstruction prior to the coronary transfer[6] is practical and has some advantages, especially in cases with a size mismatch between the great vessels in which the true coronary implantation points may change with the techniques of neo-aortic anastomosis following coronary anastomosis. Shukla et al's technique allows a more accurate determination of the ideal coronary implantation point and in the case of a size discrepancy, partial aortic wall resection from the aortic root prior to the anastomosis is not generally needed with this technique.

In conclusion, the translocation methods used for the correction of TGA with a single or intramural coronary artery are still the subject of debate. We believe that transfer of the coronary button by pericardial or pulmonary artery hood augmentation technique to the neo-aorta anastomosed in advance is a practical, easy and convenient combination of methods.

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