ORIGINAL ARTICLE

Coronary Re-implantation after Completion of Neo-aortic Reconstruction in Arterial Switch Operation: Accurate Intraoperative Assessment for the Optimal Re-implantation Site

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Abstract

The arterial switch operation (ASO) has evolved into the treatment of the choice for most forms of transposition of the great arteries (TGA). Despite advancement in the technical aspects of the procedure, certain anatomical variations of the coronary arteries are still considered as surgical risks. We have recently employed a novel technique for coronary artery reconstruction in ASO to achieve further improvement of coronary transfer in cases with complex coronary anatomy. The technical key of the procedure is that reconstruction of the coronary arteries is preceded by neo-aortic anastomosis. After neo-aortic reconstruction is accomplished, the neo-aorta is temporarily distended with removal of the cross-clamp. The distended neo-aorta informs us its postsurgical geometry, which facilitates accurate assessment for the optimal site of coronary button transfer. The technique was feasible in 13 of 15 children who were consecutively treated by our group between 2003 and 2008. All patients recovered uneventfully and no coronary perfusion issue has occurred during the follow-up period. However, the complex anatomy of the coronary arteries in two children was not amenable to this technique. One with double loops (1RL; 2Cx) accompanied by side-by-side relationship of the great arteries underwent the open trapdoor technique, while the other with intramural coronary artery underwent the Imai method, that is one of procedure in which the coronary arteries are left *in situ*. The coronary re-implantation after neo-aortic reconstruction is promising to minimize postsurgical coronary ischemia and suitable for most ASO cases. However, various modifications of coronary transfer are required in a few variations of the coronary anatomy and we have to pursue further technical refinement of coronary artery transfer in ASO. (Keio J Med 58 (4) : 227–233, December 2009)

***Keywords*: transposition of the great arteries, arterial switch operation, coronary re-implantation**

Introduction

The arterial switch operation (ASO) is now the surgical treatment of choice for those patients with transposition of the great arteries (TGA). Although the technical refinement and evolving concept of ASO have reduced the postoperative mortality, there is still room for the improvement in this operative procedure. It is the most integral part of ASO to re-implant coronary buttons to the posterior neo-aorta without tension, torsion, or kinking of the coronary arteries. Recently, a technical refinement was discussed in the literature, in which coronary re-implantation after neo-aortic reconstruction yielded better result.[1,2] This technique informs us the postsurgical neo-

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aortic geometry, and facilitates accurate assessment for the optimal site for coronary button transfer. Since we introduced this technique in 2003 to achieve further improvement of coronary transfer in cases with complex coronary anatomy, we have substantiated its technical benefit. Thus, we report here on our results of the technique, and review its feasibility and efficacy for various anatomical variants of the coronary arteries.

Patients and Methods

Patients

Between November 2003 and June 2008, 15 patients with dTGA underwent ASO in our group hospital. Age and weight at the time of operation ranged from 2 to 18 days (median 10 days) and from 2490 to 3650 g (median 3086 g), respectively. The morphological feature of the coronary arteries in those children included the normal coronary arteries (1LCx; 2R) in 8, posterior looping circumflex artery (1L; 2RCx) in 2, and double loops (1RL; 2Cx) in 2. Two patients had single orifice coronary system with posterior looping left coronary artery (2RLCx). Remaining one child showed an intramural course of the left coronary artery that ran between the great arteries (2RLCx). Associated cardiac anomalies comprised ventricular septal defect in 5 children and coarctation of the aorta in one, which were repaired simultaneously.

Technique

Our standard technique is based upon the method reported by University of Michigan group which is detailed as follows (**Fig. 1**).[3] After a standard median sternotomy, a large section of pericardium is harvested for neo-pulmonary artery reconstruction. The coronary artery distribution and the relationship of great arteries are inspected carefully. All patients undergo bicaval and aortic cannulation and are perfused with moderate hypothermia. Cardiac arrest is achieved by the repeated infusion of the cold blood cardioplegic solution with topical cooling. Atrial and/or ventricular septal defects are repaired first in the majority of patients. The aorta is transected approximately 5 mm distal to the level of pulmonary artery bifurcation. The coronary ostia are inspected and coronary buttons are excised. The entire wall of the sinus of Valsalva is removed, which allows as large scallop as possible, preventing coronary arteries from kinking, stretching, and torsion with bulging out after restoring blood pressure. After the excision, slight mobilization is performed to achieve a tension-free anastomosis. The pulmonary artery is then transected just below its bifurcation. We transect the pulmonary artery to keep anterior wall somewhat taller than posterior wall, keeping the suture line of the neo-aorta away from the re-implanted coronary buttons. The point where the anterior commissure attached to the vessel wall is marked with a suture exteriorly. LeCompte maneuver is then performed and the distal aorta is anastomosed to the proximal pulmonary artery with a single running suture. Following completion of the neo-aortic anastomosis, the cross-clamp is temporarily removed so as to distend the sinus of Valsalva of the neo-aorta. Removal of the aortic cross-clamp facilitates identifying the optimal location of each coronary anastomosis, since it allows the neo-aorta to distend and tell us its postoperative composition. An oblique incision is made in the left anterior facing sinus of the neo-aortic root to accommodate the left coronary button. The aortic cross-clamp is left off until the incision is begun, closing the valve and protecting it from injury, and then re-applied to avoid further bleeding. The previously placed marking sutures also serve as a guide to location of the valve commissures. The left coronary button is held next to the openings in the neo-aorta in tension-free position to be certain that no twist occurs during the anastomosis. The button is anastomosed with a running suture. In a similar fashion, the right coronary button is re-implanted (**Fig. 2**). Both anastomosis were made into a trap door type of configuration by extending the superior margin of the opening medially. Finally, reconstruction of the neo-pulmonary artery is begun by repairing the defects left after coronary artery excision. For this repair, a large quadrangular-shaped patch of the autologous pericardium is now preferably utilized, because it

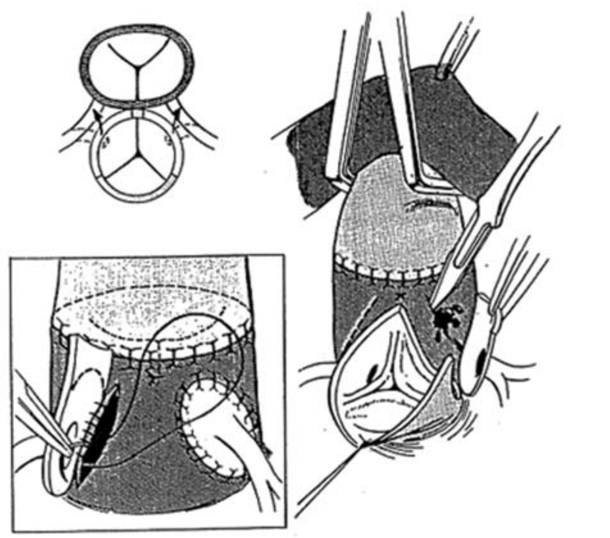

Fig. 1 The left coronary artery is implanted after an oblique incision is made in the left anterior sinus of Valsalva of the neo-aorta. The cross-clamp is removed during the incision to close the neo-aortic valve and protect it from injury. The same procedure is repeated for the right coronary artery.
(Reprinted from Bove EL. Current technique of the arterial switch procedure for transposition of the great arteries. Journal of Cardiac Surgery, Volume 4, Page 197, (1989) with permission from Blackwell Publishing.)

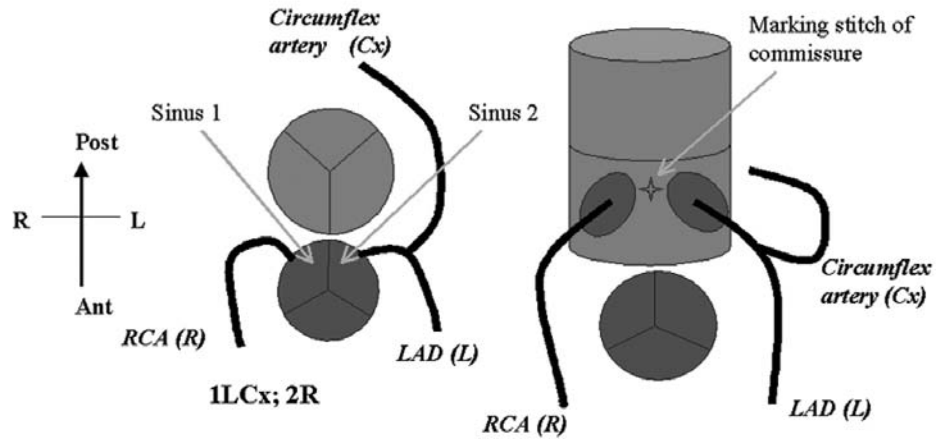

Fig. 2 The schema of coronary transfer after neo-aortic reconstruction in normal coronary artery (1LCx; 2R). LAD: Left anterior descending artery, RCA: Right coronary artery.

provides an adequate tissue for the sinuses of Valsalva and enables to augment the entire anastomotic circumference. The aortic cross-clamp is generally removed during this portion of the operation and systemic rewarming is begun, allowing careful inspection of both coronary suture lines. A left atrial monitoring catheter is inserted and bypass is discontinued in the usual fashion.

Results

There was no hospital death or late death in children who underwent our standard technique, and nobody showed coronary perfusion deficiency during the follow-up period (mean 41 months, 9 ~ 64 months). Re-operation for branch pulmonary artery stenosis was required in one child. Neo-aortic insufficiency of the trace to mild severity was found in 4 children on postoperative echocardiography.

Our standard technique with or without modifications was feasible in 13 of 15 children. In 11 children, the procedure was completed only with minor individual arrangement of adding rotation and/or height control of the coronary buttons. Among those 11 children, one child had major commissural malalignment between the aortic and pulmonary valves. The coronary artery showed the normal anatomy (1LCx; 2R), however, the aorta was slightly deviated leftward, and the pulmonary valve showed a counterclockwise rotation with 15~25 degrees. In order to prevent arterial kinking, we have to move the right coronary button more distally than usual together with a modest counterclockwise rotation. We were able to readily intend the modification with our maneuver (**Fig. 3**).

Major technical arrangements were required in two children. Those two children had single coronary ostium at sinus 2 and posterior looping left coronary arteries, and we completed most of the neo-aortic anastomosis, leaving 5mm region for attaching the coronary button. We had concern that the left anterior descending artery (LAD)/ the circumflex coronary artery (Cx) combination would kink, unless coronary button was transferred above the neo-aortic anastomosis. During the neo-aortic root was filled and dilated, the open area was occluded with forceps to determine the exact place either at or above the neo-aortic suture line. In both cases, coronary buttons were required to be implanted at the level of suture line before finishing neo-aortic anastomosis. Yet, we were able to readily decide optimal site and the open area was used for attaching the coronary button.

Our standard technique was not applicable to two children. One was an 11-days-old boy weighing 3098g. The coronary arteries showed double loops (1RL; 2Cx) with side-by-side great vessels relationship and commissural malalignment, in which the coronary button of the common trunk of the right coronary artery/LAD had to be moved far toward the left, and extreme stretching of the right coronary artery might have ensued. We therefore chose the open trapdoor technique to make a generous trapdoor incision safely in the facing sinus as large as possible, so that the trapdoor was sufficiently expanded toward the right to reduce the transfer distance. Then, a direct anastomosis was done with a running suture. Cx was subsequently implanted into the adjacent facing sinus after neo-aortic reconstruction (**Fig. 4**). On the other hand, our standard technique was readily accomplished in the other case with double loops (1RL; 2Cx) accompanied by anterior-posterior relationship of the great arteries without commissural malalignment. A child with Yacoub type C intramural coronary artery underwent the modified Imai method.[4] This method is one of procedure in which the coronary arteries are left *in situ*. The procedure is applied to children whose coronary orifices are

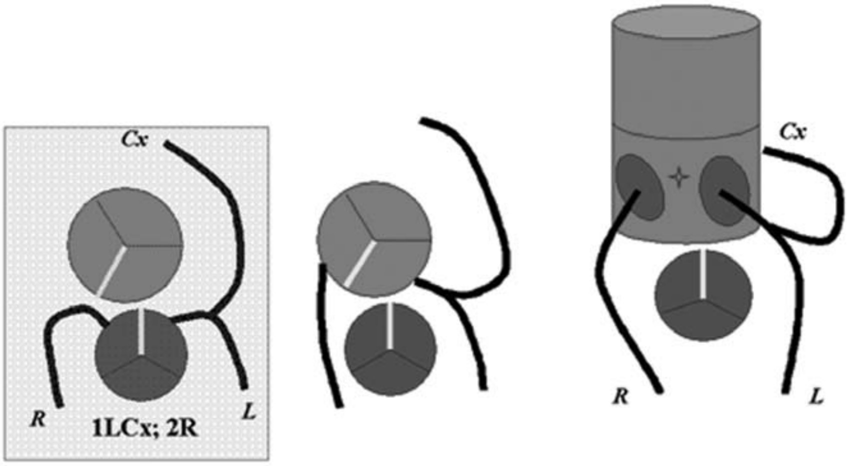

Fig. 3 The schema of coronary transfer in patient with major commissural malalignment of the two arterial valve. Coronary arteries were normal (1LCx; 2R), but the aorta was located left anterior to main pulmonary artery trunk. The pulmonary valve had counterclockwise rotation with 15~25 degree. The right coronary button was required to be transferred more distally than usual and make a counterclockwise twist to prevent kinking.

too close to separate them into two different coronary buttons. In our case, we added a minor modification, i.e., the portion of intramural course was unroofed with taking down the commissure between the facing sinuses to avoid late obstruction.

Discussion

Anatomical variations of the coronary circulation in patients with TGA are common and diverse. Some groups reported no specific relation between the anatomical variations and mortality rates.[1,5] Yet, the recent literature has still implied that certain patterns of origin and distribution of the coronary arteries increase surgical risks and some variations are more problematic than others from a technical viewpoint. Meta-analyses, including the most recent, have revealed that patients with an intramural coronary artery have an approximately five-fold mortality risk as compared with those patients with the usual pattern. The presence of abnormal coronary looping with a single ostium is associated with a three-fold mortality risk.[6] Scheule and colleagues reported that patients with a single right ostium (sinus 2) associated with the posterior looping of left main coronary artery have lower survival than all other subtypes of a single coronary artery.[7] Multivariate analyses showed that coronary events were correlated with only the Yacoub type B (an abnormal course of one or more of the major coronary arteries running between the great vessels with a single coronary ostium) or type C (an abnormal course of one or more of the major coronary arteries running between the great vessels with separated coronary ostia).[8]

On the other hand, many different variations on how to transfer the complex coronary arteries have been suggested in order to achieve better result in ASO. Issues include the height of the implantation site, appropriate angle, and tilt of the coronary buttons. These factors are important to minimize tension, torsion, or kinking of the coronary arteries. Particular attention to the relation between the great vessels and proximal segment of the coronary arteries must also be carefully considered. From their origin from the facing sinuses, the coronary arteries can take a normal course, a looping course, or an intramural course. Posterior looping refers to one or more of the three major arteries running posterior to the pulmonary trunk, while anterior looping refers to an abnormal course anterior to the aorta. With posterior looping there is a shorter distance and an acute turn between the neo-coronary orifice and the coronary artery, resulting in a risk of kinking and/or distortion of the proximal segment of the transferred coronary artery. Conversely, anterior looping results in a greater distance between the neo-coronary orifice and the distal coronary segment and the potential for stretching of the transferred coronary artery or bow stringing as it crosses the neo-pulmonary root. A single coronary artery, in which all three main arteries usually stem from a common arterial orifice in a solitary sinus, is invariably associated with the abnormal looping.

Brawn and Mee first reported the trapdoor technique in 1988, which can minimize the rotation angle of a coronary button by transferring the coronary artery to medially hinged "trapdoor" in the neo-aorta.[9] The trapdoor technique was successfully applied to re-implantation of looping coronary arteries, and enabled to avoid arterial kinking or stretching of the transferred coronary arteries.

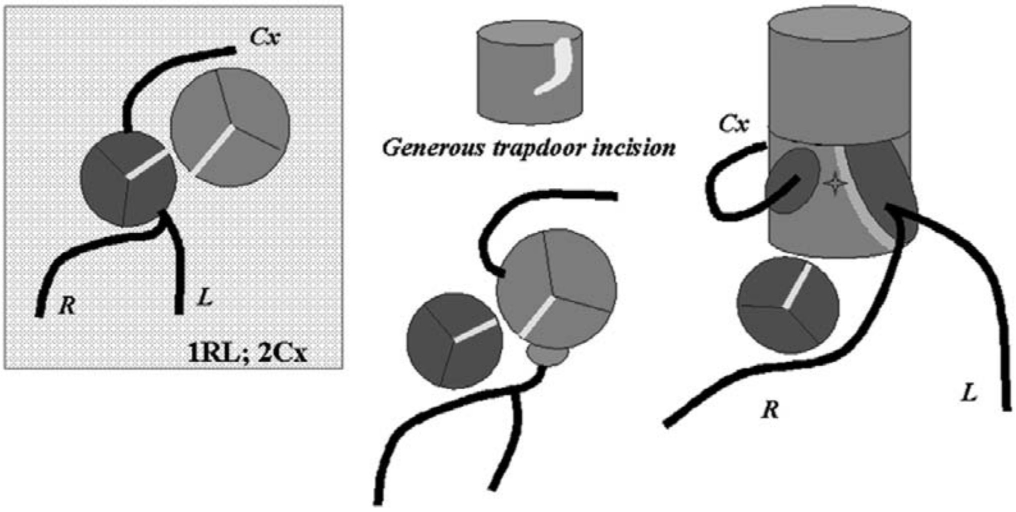

Fig. 4 The schema of coronary transfer in patient with double loops (1RL; 2Cx). Right coronary artery/left anterior descending artery combination must move toward far left due to side by side great vessels relationship and commissural malalignment of the two arterial valves. A generous trapdoor incision in the facing sinus was required before neo-aortic reconstruction in order not to insult neo-aortic valve. A direct anastomosis with a running suture was then done. The circumflex artery was then implanted into the adjacent facing sinus after reconstruction of neo-aorta.

Following the successful large series reported by de Leval[10] and Planché[11] in mid 1990's, the trapdoor technique has gained in popularity. However, even when we utilize the trapdoor technique, it is crucial for surgical success to decide the optimal location for coronary button re-implantation. The critical decision can be facilitated by the neo-aortic distension maneuver technique we described so far. After the neo-aortic anastomosis is completed, the aortic cross-clamp is removed to fill the sinuses of Valsalva of the neo-aorta with blood. This neo-aortic distension maneuver informs us the postoperative geometry of the neo-aorta. Thus, we are able to predict the optimal location for coronary button anastomosis. The technique was first described by Jatene,[12] and later advocated by Pacifico[13] and Bove[3] during 1980's. Since then, a number of series with excellent results have been reported utilizing this technique, particularly in the 21st century. Shukla, *et al*. reported no surgical mortalities in neonates with coronary arteries stemming from a single aortic sinus when a coronary button was translocated after the neo-aortic anastomosis was performed.[14] Brown and colleagues also showed that the technique of completing the neo-aortic anastomosis before selecting the ideal position for a mobilized coronary button significantly decreased the incidence of unsuccessful coronary transfer. They found that coronary artery pattern ceased to be an independent risk factor for surgical mortality after switching to this technique.[2] Chang and Sung, *et al.* reported the comparison of the results between the technique of coronary re-implantation after neo-aortic reconstruction and the open trapdoor technique.[15] They emphasized that coronary re-implantation after neo-aortic reconstruction minimizes coronary artery transfer-related mortality or morbidity. They also emphasized that the technique is particularly beneficial in the management for variations of a single sinus coronary artery.[16] Recently, the University of Michigan group reported the midterm results of coronary re-implantation after neo-aortic reconstruction in 168 patients. They found that the coronary anatomy did not influence surgical mortalities.[1]

We have employed this technique as our standard procedure for ASO since 2003. Although our experiences are still restricted to a small number of cases, we also believe that the technique is a safe and promising method to reduce the prevalence of coronary problems after ASO. The technique is indicated for almost all types of the coronary anatomy, even for variations with abnormal looping and/or a single coronary orifice. In posterior looping, we usually twist the coronary button with a modest counterclockwise angle (10~15 degree), so that the coronary artery is medially rotated, and then re-implant the button to more distal and higher position than usual. The maneuver prevents kinking of the transferred coronary artery; however, it may cause another technical problem in that the appropriate implantation site of the buttons would lie at or above the neo-aortic anastomosis. When we encounter the situation, Ugurlucant's modification is utilized.[17] Three to 4 mm suture line of the neo-aortic anastomossi is left unsutured. This open area is occluded with two fine forceps, while the aortic cross clamp is removed to distend the neo-aorta, so that whether the optimal place for the coronary button is either at or above the neo-aortic anastomosis can be accurately determined. Then the open area is used for attaching the coronary button. We successfully utilized this modification in two patients with single coronary ostium of LAD and Cx originating from the right sinus. By using this modified technique, we have not had any concerns about the placement of the coronary button after neo-aortic reconstruction even if the best position was on or above the neo-aortic anastomosis.

An augmentation of transfer distance in anterior looping is generally solved with placing the button in a lower position. However, we were compelled to employ the open trap-door procedure in a child with anterior looping. This patient had double loops (1RL; 2Cx) with side-by-side great vessels relationship and commissural malalignment. The complex anatomical arrangements that may have caused far transfer distance were not amenable to our standard technique. Therefore we selected the open trap-door technique in order not to insult neo-aortic valve, and a generous neo-aortic wall flap was created safely. Commissural malalignment is prevalent in side-by-side great vessels,[18] and it is commonly associated with a variety of anomalous looping courses. The complicated combinations entail a variety of technical modifications to preclude distortion of the transferred coronary arteries.

As mentioned before, the alignment of the commissures of the two arterial valves is also of major surgical significance. Several authors draw special attention to commissural malalignment in TGA. Gittenberger-de Groot, *et al.* reported that the alignment was perfect in two-thirds of cases, and slightly deviated, but adequate for coronary arterial transfer in one-sixth. Major malalignment was found in 19.4% of cases.[19] Kim and colleagues[20] reported that longer transfer distances due to commissural malalignment demanded a variety of techniques to accomplish safe re-transplantation. They were compelled to accomplish more extensive dissection of the coronary arteries than usual in all patients, to re-implant the coronary button to a supra-commissural or juxta-commissural site in some patients, and to transfer two coronary artery systems to the same sinus in others. We experienced one patient with major commissural malalignment, and had to move the right coronary button more distally than usual together with a counterclockwise twist. In this case, our standard method was quite beneficial to decide the optimal height and twist angle of the coronary button. We were able to find out this unusual arrangement easily before implantation during neo-aortic root dilatation. Our standard method would warrant being suitable for variety of commissural malalignment of great arteries.

There are few patients whose anatomical variations of the coronary arteries do not allow our standard technique as well as the conventional re-implantation procedures, and do demand special technical modifications. The variations are abnormal courses of one or more of the major coronary arteries running between the great vessels, which are commonly associated with ostia close to an aortic commissure and/or intramural course. In particular, the coronary artery variations of Yacoub type B or type C enforce the difficult management. Mee commented that if the ostia are 2 mm or more apart from each other, creation of two separate coronary buttons is feasible, usually requiring taking down the commissure between the facing sinuses. Both coronary arteries can then be handled in the usual way.[4] Inseparable ostia in Yacoub type C as well as a single ostium in Yacoub type B can be managed in two different ways, i.e., transferring a single coronary button upside down[21,22] or the method of coronary artery left *in situ*.[4,23–25] In 1978, Aubert, *et al.* first reported a unique method, in which the coronary arteries are left *in situ* and coronary circulation is restored with creating an aortopulmonary window and suturing a pericardial patch around the coronary ostia.[23] A modification of Aubert's procedure is the Imai method, wherein hinged non-facing aortic sinus wall is used as a baffle instead of pericardial patch. These "coronary arteries left *in situ* procedures" lessen early surgical mortality. However, late right ventricular outflow tract obstruction due to an oversized intra-arterial baffle and late ostial stenosis, especially in cases of the intramural course, remain theoretical hazards that may require future revision. The abnormal course of the coronary arteries left untreated remains as a potential risk for mortality as the child grows. In the case of dividable coronary orifices, the coronary buttons should be translocated in the usual fashion after unroofing the intramural course. Our series included one patient with Yacoub type C coronary arteries, in whom we were compelled to perform the Imai method. In this particular case, the distance between the two coronary orifices was too short to separate them into two buttons. However, we would have performed our standard method if the distance between the orifices were separable enough. Recently, Padalino and colleagues reported on successful coronary transfer in a patient with an intramural origin of both left and right coronary arteries. They created two separated coronary buttons and transferred them after completion of neo-aortic anastomosis.[26] Qamar, *et al.*[1] also successfully treated 12 patients with intramural coronary arteries with using the same technique.

Conclusion

In this manuscript, we reported a simple but uniform technique that permits relocation of the coronary arteries irrespective of their sinusal origin or their epicardial course. The neo-aortic distension maneuver after neo-aortic reconstruction described so far facilitates intraoperative assessment for the optimal positions for coronary button transfer, and our technique enables to minimize major complications in most ASO cases. Although our method is suitable for most ASO cases, various modifications of coronary transfer are required in a few variations of the coronary anatomy and we have to pursue further technical refinement of coronary artery transfer in ASO.

References

1. Qamar ZA, Goldberg CS, Devaney EJ, Bove EL, Ohye RG: Current risk factors and Outcomes for the arterial switch operation. Ann Thorac Surg 2007; **84**: 871–879
2. Brown JW, Park HJ, Turrentine MW: Arterial switch operation: Factors impacting survival in the current era. Ann Thorac Surg 2001; **71**: 1978–1984
3. Bove EL: Current technique of the arterial switch procedure for transposition of the great arteries. J Card Surg 1989; **4**: 193–199
4. Mee RB: The arterial switch operation. In: Stark J, de Leval M, editors. Surgery for congenital heart defects. 2nd ed. Philadelphia, London, Toronto, Montreal, Sydney, Tokyo: W.B. Saunders, 1994; 483–500
5. Quaegebeur JM, Rohmer J, Ottenkamp J, Buis T, Kirklin JW, Blackstone EH, *et al*: The arterial switch operation J Thorac Cardiovasc Surg 1986; **92**: 361–384
6. Pasquali SK, Hasselblad V, Li JS, Kong DF, Sanders SP: Coronary artery pattern and outcome of arterial switch operation for transposition of the great arteries. A meta-analysis. Circulation 2002; **106**: 2575–2580
7. Scheule AM, Zurakowski D, Blume ED, Stamm C, del Nido PJ, Mayer, Jr.JE, *et al*: Arterial switch operation with a single coronary artery. J Thorac Cardiovasc Surg 2002; **123**: 1164–1172
8. Legendre A, Losay J, Touchot-Koné A, Serraf A, Belli E, Piot JD, *et al*: Coronary events after arterial switch operation for transposition of the great arteries. Circulation 2003; **108**[suppl II]: II-186-II-190
9. Brawn WJ, Mee RBB: Early results for anatomic correction of transposition of the great arteries and for double-outlet right ventricle with subpulmonary ventricular septal defect. J Thorac Cardiovasc Surg 1988; **95**: 230–238
10. deLeval MR, François K, Bull C, Brawn W, Spiegelhalter D: Analysis of a cluster of surgical failures J Thorac Cardiovasc Surg 1994; **107**: 914–924
11. Conte S, Lacour-Gayet F, Serraf A, Bruniaux J, Touchot A, Planché C: Evolving concepts in the surgical management of transposition of the great arteries. Ann Thorac Cardiovasc Surg 1996; **2**: 109–116
12. Jatene AD, Fontes VF, Souza LCB, Paulista PP, Neto CA, Sousa JEMR *et al*: Anatomic correction of transposition of the great arteries. J Thorac Cardiovasc Surg 1982; **83**: 20–26
13. Pacifico AD Stewart W, Bargeron Jr. LM: Repair of transposition of the great arteries with ventricular septal defect by an arterial switch operation. Circulation 1983; **68**[suppl II]: II49–II55
14. Shukla V, Freedom RM, Black MD: Single coronary artery and complete transposition of the great arteries: A technical challenge resolved? Ann Thorac Surg 2000; **69**: 568–571
15. Chang YH, Sung SC, Lee HD, Kim S, Woo JS, Lee YS: Coronary reimplantation after neoaortic reconstruction can yield better result in arterial switch operation: Comparison with open trap door technique. Ann Thorac Surg 2005; **80**: 1634–1640
16. Sung SC, Chang YH, Lee HD, Kim S, Woo JS, Lee YS: Arterial switch operation for transposition of the great arteries with coronary arteries from a single aortic sinus. Ann Thorac Surg 2005; **80**: 636–641
17. Ugurlucan M, Sayin OA, Surmen B, Tireli E: Coronary reimplantation after neoaortic reconstruction in arterial switch operation. Ann Thorac Surg 2006; **82**: 382
18. Massoudy P, Baltalarli A, de Leval MR, Cook A, Neudorf U, Derrick G, *et al*. Anatomic variability in coronary arterial distribution with regard to the arterial switch procedure. Circulation 2002; **106**: 1980–1984
19. Gittenberger-de Groot AC, Sauer U, Oppenheimer-Dekker A, Quaegebeur J: Coronary arterial anatomy in transposition of the great arteries: A morphologic study. Ped Cardiol 1983; **4** (Suppl. 1): 15–24
20. Kim S, Kim W, Lim C, Oh SS Kim Y: Commissural malalignment of aortic-pulmonary sinus in complete transposition of great arteries. Ann Thorac Surg 2003; **76**: 1906–1910
21. Yacoub MH, Radley-Smith R: Anatomy of the coronary arteries in transposition of the great arteries and methods for their transfer in anatomical correction. Thorax 1978; **33**: 418–424
22. Planché C, Bruniaux J, Lacour-Gayet F, Kachaner J, Binet JP, Sidi D, *et al*: Switch operation for transposition of the great arteries in neonates. A study of 120 patients. J Thorac Cardiovasc Surg 1988; **96**: 354–363
23. Aubert J, Pannetier A, Couvelly P, Unal D, Rouault F, Delarue A: Transposition of the great arteries. New technique for anatomical correction. Br Heart J 1978; **40**: 204–208
24. Brown EM, Salmon AP, Lamb RK: Arterial switch procedure without coronary relocation: A late complication. J Thorac Cardiovasc Surg 1996; **112**: 1406–1407
25. Takeuchi S, Katogi T: New technique for the arterial switch operation in difficult situation. Ann Thorac Surg 1990; **50**: 1000–1001
26. Padalino MA, Ohye RG, Devaney EJ, Bove EL: Double intramural coronary arteries in d-transposition of the great arteries. Ann Thorac Surg 2004; **78**: 2181–2183