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Early and Midterm Results of the Arterial Switch Operation: A 9-Year, Single-Center Experience

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ABSTRACT

Background: The arterial switch operation (ASO) has become the surgical approach of choice for transposition of the great arteries. The aim of this paper was to describe the outcomes in patients who underwent arterial switch operation and to analyze the predictors of in-hospital mortality and further need for reoperation at a single-center institution. We reviewed our 9-year experience with arterial switch operation (ASO) for transposition of the great arteries (TGA) or Taussig-Bing anomaly (TBA) to assess the early and midterm outcomes.

Methods: Between January 2007 and May 2016, 34 consecutive patients who underwent ASO for TGA with IVS; and TGA with ventricular septal defect (VSD); and double outlet right ventricle (DORV) with subpulmonary VSD at our institution were included in this retrospective study. The same surgeons operated on all patients. Patients' charts, surgical reports, and echocardiograms were retrospectively reviewed. Median follow-up time ranged from 1 to 9 years, 54.2 (0.4-108) months.

Results: There were 2 (5%) in-hospital deaths. Late death occurred in 1 (2.9%) of 32 survivors. One patient (2.9%) required reintervention. The freedom from reintervention rate was 95.9 ± 1.8% at 9 years. Two patients (3.9%) developed moderate neoaortic regurgitation during the follow-up and one patient underwent reoperation mainly for neopulmonary artery stenosis. The analysis showed that weight, cross-clamp (CC) time, cardiopulmonary bypass (CPB) time, and age of operation are strong predictors for mortality.

Conclusion: ASO remains the procedure of choice for the treatment of various forms of TGA with acceptable early and midterm outcome, and can also be performed with a low risk of early mortality and satisfactory midterm outcomes even in a small-volume center. Early and midterm survival is excellent after arterial switch operation.

INTRODUCTION

TGA is a life-threatening healthy defect which requires rapid cardiac surgery. In the past decades the arterial switch operation (ASO) has become the preferred surgical procedure for transposition of the great arteries (TGA) and double outlet right ventricle (DORV) with subpulmonary ventricular septal defect (VSD) (Taussig-Bing anomaly [TBA]). In 1975, Jatene et al developed ASO, the most widely used approach [Jatene 1976]. It involves translocating the pulmonary artery and aorta and reimplanting the coronary arteries in the neoaorta. The so-called Lecompte maneuver may be performed to place the main pulmonary artery bifurcation anterior to the ascending aorta [Lecompte 1981]. Early and midterm results appear favorable, although identified complications include neoaortic insufficiency and neopulmonary stenosis [Blume 1999; Legendre 2003; Losay 2001; Kempny 2012; Tobler 2010]. The purpose of the present study was to review the short and midterm outcome in terms of mortality and freedom from reoperation in patients undergoing ASO at a single institution.

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METHODS

We included all patients with TGA or DORV with subpulmonary VSD who had an ASO between January 2007 and May 2016. A total of 34 consecutive patients were included in the study. Patients with various forms of TGA undergoing REV, Rastelli operation, Senning procedure, and Fontan operation were excluded from this study. Patient characteristics are shown in Table 1. For 34 patients, including 24 males and 10 females, the median age at the time of surgery was 22.67 ± 75.75 days (range, 3-450 days). The initial diagnosis was TGA with IVS in 17 (50%) patients, TGA with VSD in 13 (38%) patients, and DORV with subpulmonary VSD in 4 (11%) patients. 12 (35%) patients received balloon atrial septostomy.

Preoperative Assessment and Management

All patients underwent preoperative echocardiography. 35% of them underwent balloon atrioseptostomy. Prostaglandin infusion before surgery was administered in 56% of cases.

Surgical Techniques

After a standard median sternotomy, a large pericardial patch was harvested and fixed with a glutaraldehyde solution. Cardiopulmonary bypass (CPB) was instituted using bicaval cannulation. Surgery was performed in moderate hypothermia. Myocardial protection was achieved by application of multidose selective antegrade blood cardioplegia. After dividing the ascending aorta above the sinuses, a cardioplegic solution was infused directly into the coronary artery using a small coronary catheter. The coronary artery buttons were excised from the aortic sinuses. The coronary arteries were then mobilized for some distance and allowed to reside on

Table 1. Patient Characteristics

Age at operation	22.67 ± 75.75	range, 3-450
Male, n	24	
Female, n	10	
Weight	3248 ± 487.95	range, 2000-4200
Previous interventions, n		
Pulmonary banding	1	2.9%
Atrial septectomy	12	35%
Modified BT shunt	0	0%
TGA pathology, n		
TGA+VSD	13	38%
Taussing-Bing, n	4	11%
TGA+ASD, n	17	50%
Coronary pattern (Yacoub), n		
A	30	88%
B	1	2.9%
C	1	2.9%
D	2	5.8%
E	0	
F	0	
Intramural	2	5.8%

Data are presented as the mean ± SD where indicated. BT indicates Blalock–Taussig; TGA, transposition of the great arteries; VSD, ventricular septal defect; ASD, atrial septal defect.

Table 2. Intraoperative Characteristics of Patients

CPB time, min	151.76 ± 60.96	range, 95-355
Cross-clamp time, min	93.67 ± 28.39	range, 55-190
VSD closure, n	17	50%
ASD closure, n	30	89%
Debanding of PA, n	1	2.9%

Data are presented as the mean ± SD where indicated. CPB indicates cardiopulmonary bypass; VSD, ventricular septal defect; ASD, atrial septal defect; PA, pulmonary artery.

Table 3. Neo-Aortic Regurgitation

Mild, n	2	6.4%
Moderate, n	2	6.4%
Severe, n	1	3.2%

the neoaortic root without torsion or tension. The main pulmonary artery was divided at the level of pulmonary bifurcation. After examination of the pulmonary valve, the marking sutures for commissures were inserted at the external surface of the proximal pulmonary root. The distal pulmonary artery was dissected more distally and a Lecompte maneuver was performed. After creation of the coronary buttons, open trap door incisions were made at the site of marking stitches and the coronary buttons were implanted to the incisions using 7-0 non-absorbable monofilament sutures in running fashion. The aorta was then transplanted onto the pulmonary root, using wpolypropylene suture material. The aortic clamp was removed and bleeding controlled along the suture line. The neopulmonary artery root was reconstructed with an autologous pericardial patch and then the root was anastomosed to the distal main pulmonary artery. If there was significant hemodynamic instability during sternal closure, sternal wounds were closed with a latex membrane sewn to the skin edges with a monofilament suture. Intraoperative characteristics are shown in Table 2.

Postoperative Care

Inotropic support was routinely administered with dopamine and phosphodiesterase inhibitor. Other inotropic agents such as epinephrine were selectively used. Full sedation with mechanical ventilation was maintained for at least 24 hours to prevent pulmonary hypertensive crisis. The strategy for postoperative care was the same between groups.

Follow-up

Clinical follow-up data were obtained by means of direct contact with the referring pediatric cardiologist. A complete clinical follow-up was done, including echocardiographic examination.

Statistical Analysis

Statistical analysis was performed by using SPSS 20.0. Descriptive data for continuous variables are presented as mean ± SD, and categorical variables are presented as relative frequencies. Univariate comparisons for categorical variables were performed with the Pearson chi-square test. Univariate comparisons for continuous variables were performed with the Mann-Whitney U test. A P value of less than .05 was considered statistically significant.

RESULTS

Early Outcomes

There were 2 (5%) in-hospital deaths. The first patient was diagnosed preoperatively as having TGA with an intact ventricular septum and a single coronary artery anomaly with intramural course. He died within the first 24 hours after surgery, which was presumed to be caused by low cardiac output. The second patient who had TGA with VSD died of unknown origin of septic shock. He suffered from capillary leak syndrome immediately after the ASO. The patient died of multi-organ failure on the 30th postoperative day.

Five early complications occurred in 34 patients (14%). Two patients (5%) underwent diaphragmatic plication. One patient (2.9%) had a chylothorax that was managed with medical treatment. One patient (2.9%) was reexplored because of

Table 4. Risk Factors for Mortality

	Expired (n = 3)	Alive (n = 31)	*P*
CPB time	261.67 ± 82.21	141.13 ± 48.09	.008
Cross-clamp time	110.0 ± 5.0	92.09 ± 29.26	.068
Weight	2366.66 ± 550.75	3333.87 ± 395.47	.014
Age at operation	24.33 ± 3.78	9.45 ± 7.81	.002
Preterm	3 (100%)	0 (0%)	<.001
Coronary anomaly	1 (33%)	3 (9.7%)	.322

Data are presented as the mean ± SD where indicated. CPB indicates cardiopulmonary bypass.

postoperative bleeding. One patient (0.7%) underwent early reoperation because of pulmonary artery gradient caused by external compression of the hemostatic agents.

Late Outcomes

Among the 34 patients who survived the initial operation, there was 1 (2.9%) later death. The patient had an unexpected death of unknown cause at 5 months after surgery. The late reintervention was reoperation for neopulmonary stenosis. During follow up, one patient had reoperation for pulmonary stenosis. Reoperation for pulmonary stenosis was observed up to 4 years after surgery. None of the patients needed surgical intervention for aortic regurgitation.

The overall freedom from reintervention rate was 95.9 ± 1.8% at 9 years. Among 32 early survivors, echocardiographic follow-up was completed in 29 patients. The neoaortic regurgitation at the last follow-up is described in Table 3. The aortic regurgitation was mild in 2 patients (6.4%), moderate in 2 (6.4%), and severe in 1 (3.2%). In this study, there was event-free survival for 29 patients.

A linear regression revealed possible association of anatomic and physiologic parameters with mortality. Strong predictors for poor survival are preterm birth (P = .001), weight (P = .001), long CPB time (P = .001), CC time (P = .03) and age at operation (P = .02) (Table 4).

DISCUSSION

Transposition of the great arteries is a congenital heart lesion characterized by a flip in the relationship of the great arteries—the aorta and pulmonary artery—to the right and left ventricles. Transposition of great arteries accounts for 2.6% to 7.8% of all cases of congenital heart disease. It is commonly associated with ventricular septal defect (40% of D-TGA cases), atrial septal defect, atrioventricular valve abnormalities, arch obstruction, abnormal coronary artery patterns, and subaortic or subpulmonary stenosis.

From the early 1960s to the mid 1980s, the Mustard and Senning procedures were the treatment of choice for transposition of the great arteries. The Senning operation resulted in slightly better survival rates than the Mustard operation, though the difference was not significant. However, because of complications such as right ventricular failure, arrhythmias, tricuspid valve dysfunction, baffle related problems, and sudden death, these procedures were replaced by arterial switch operations by the mid 1980s. Since the end of the 1980s, the anatomic correction of TGA (arterial switch) became progressively more reliable. Atrial switch procedure is rarely performed today. As time passed, atrial repair of transposition of the great arteries has been almost entirely replaced by the arterial switch operation. However, the atrial switch operation is not completely obsolete. Between 2007-2016, six patients underwent atrial switch in our institution. There were two in-hospital deaths (1 Senning, 1 Mustard), and one late death (Mustard). Because of these early and midterm results we suggest the arterial switch operation.

The present study shows that ASO can be performed safely, even in a small-volume center. As expected from other reports [Fricke 2012; Roussin 2007] coronary anomalies have usually been considered a strong risk factor; but recently some reports suggest that an unusual coronary anatomy is not a risk factor [Popov 2012; Fricke 2012]. Surgical techniques, technical advances, and current experience may offset the impact of coronary anomalies. We could not determine the relationship between coronary anomalies with mortality. Because there have been many advances in surgical techniques in the past decades, especially in those for coronary transfer, and current experience may offset the impact of coronary anomalies. However, a coronary anomaly can make the procedure more difficult to perform. Postoperative myocardial ischemia is the most lethal complication at early period. Myocardial ischemia is the most common cause of early death. Some recent studies reported that coronary anomaly remains a risk factor for early mortality [Losay 2001; Fricke 2012; Pretre 2001; Prifti 2002]. Earlier reports [Prifti 2002; Wetter 2001] revealed that complex TGA results in a higher mortality rate than simple TGA. In our study we could not determine the relationship between complex TGA and simple TGA with mortality.

The low early mortality (5%) after ASOs found in this study is consistent with the findings of other recent studies of large-volume centers [Khairy 2013; Oda 2012]. Karamlou [Karamlou 2014] and Popov et al [Popov 2012] reported improvement in early outcomes, which were poorer during the initial period [Fricke 2012]. Early mortality in-hospital and cardiac deaths only occurred in 1 patient within the 9 years.

The predictors' analysis for poor operative survival was similar to the reported data [Khairy 2013; Oda 2012]. The intraoperative predictors were CPB time, aortic cross-clamp time, and necessity of associated surgical procedures. ASO has been the treatment of choice for TGA over the past decades because of its excellent survival rate. Our late reintervention rate and freedom from reintervention rate were similar to other centers [Popov 2012; Fricke 2012; Roussin 2007], and the reoperation rate was also comparable to other institutes.

One patient died within 5 months of hospital discharge. Considering the abruptness of the death in this patient, who had no problems during the postoperative hospital course, the cause of death was unknown.

We found that the most common indications for reoperation were pulmonary tract lesions, especially supravalvular pulmonary stenosis, as has also been reported by others [Wetter 2001; Raja 2013]. There are many anatomical and technical factors influencing pulmonary lesions; their incidence varies considerably. We usually reconstructed the neopulmonary root using a glutaraldehyde-fixed autologous pericardial patch. One patient underwent pulmonary tract reoperation mainly because of pulmonary stenosis, and in the early period one patient underwent reoperation because of pulmonary artery gradient caused by external compression of the hemostatic agents. Our recent study showed excellent midterm results with minimal supravalvular pulmonary stenosis. The incidence of moderate and severe neoaortic regurgitation was 9.6%, and aortic valve repair was not necessary for any of these patients. We need long-term follow up to clarify the development of neoaortic regurgitation.

Conclusion

We found good early and midterm outcomes of TGA after ASO up to 9 years of follow up. We find that ASO remains the procedure of choice for the treatment of various forms of TGA with acceptable early and midterm outcomes in terms of overall survival and free reoperation, even in a small-volume center.

REFERENCES

Blume ED, Altmann K, Mayer JE, Colan SD, Gauvreau K, Geva T. 1999. Evolution of risk factors influencing early mortality of the arterial switch operation. J Am Coll Cardiol 33:1702-9.

Fricke TA, d'Udekem Y, Richardson M, et al. 2012. Outcomes of the arterial switch operation for transposition of the great arteries: 25 years of experience. Ann Thorac Surg 94:139-45.

Jatene AD, Fontes VF, Paulista PP, et al. 1976. Anatomic correction of transposition of the great vessels. J Thorac Cardiovasc Surg 72:364–70.

Karamlou T, Jacobs ML, Pasquali S, et al. 2014. Surgeon and center volume influence on outcomes after arterial switch operation: analysis of the STS Congenital Heart Surgery Database. Ann Thorac Surg 98:904-11.

Kempny A, Wustmann K, Borgia F, et al. 2012. Outcome in adult patients after arterial switch operation for transposition of the great arteries. Int J Cardiol PMID: 22884697.

Khairy P, Clair M, Fernandes SM, et al. 2013. Cardiovascular outcomes after the arterial switch operation for D-transposition of the great arteries. Circulation 127:331-9.

Lecompte Y, Zannini L, Hazan E, et al. 1981. Anatomic correction of transposition of the great arteries. J ThoracCardiovasc Surg 82:629-31.

Legendre A, Losay J, Touchot-Kone A, et al. 2003. Coronary events after arterial switch operation for transposition of the great arteries. Circulation 108 Suppl 1:II186-90.

Losay J, Touchot A, Serraf A, et al. 2001. Late outcome after arterial switch operation for transposition of the great arteries. Circulation 104(12 Suppl 1):I121–6.

Oda S, Nakano T, Sugiura J, Fusazaki N, Ishikawa S, Kado H. 2012. Twenty-eight years' experience of arterial switch operation for transposition of the great arteries in a single institution. Eur J Cardiothorac Surg 42:674–9.

Popov AF, Tirilomis T, Giesler M, et al. 2012. Midterm results after arterial switch operation for transposition of the great arteries: a single centre experience. J Cardiothorac Surg 7:83.

Pretre R, Tamisier D, Bonhoeffer P, et al. 2001. Results of the arterial switch operation in neonates with transposed great arteries. Lancet 357:1826-30.

Prifti E, Crucean A, Bonacchi M, et al. 2002. Early and long term outcome of the arterial switch operation for transposition of the great arteries: predictors and functional evaluation. Eur J Cardiothorac Surg 22:864-73.

Raju V, Burkhart HM, Durham 3rd LA, et al. 2013. Reoperation after arterial switch: a 27-year experience. Ann Thorac Surg 95:2105-12.

Roussin R, Belli E, Bruniaux J, et al. 2007. Surgery for transposition of the great arteries in neonates weighing less than 2,000 grams: a consecutive series of 25 patients. Ann Thorac Surg 83:173-7.

Tobler D, Williams WG, Jegatheeswaran A, et al. 2010. Cardiac outcomes in young adult survivors of the arterial switch operation for transposition of the great arteries. J Am Coll Cardiol 56:58-64.

Wetter J, Belli E, Sinzobahamvya N, Blaschzok HC, Brecher AM, Urban AE. 2001. Transposition of the great arteries associated with ventricular septal defect: surgical results and long-term outcome. Eur J Cardiothorac Surg 20:816-23.