Original Article

Demographic, Anatomic, and Outcome Survey in Patients With Arterial Switch Operation

Avisa Tabib [1], MD; Ramin Baghaie-Tehrani [2], MD; Afshin Javdan *[3], MD; Mohammad Mahdavi [3], MD; Ziae Totonchi [3], MD

ABSTRACT

Background: Complete transposition of the great arteries (TGA) is the second most common cyanotic congenital heart disease (CHD). Arterial switch operation (ASO) is now the standard surgical procedure for complete TGA. The present study is an analytical overview of the results of ASO.

Methods: In this retrospective study, all cases of ASO at our tertiary care center between June 2010 and June 2013 were included. Demographic, anatomic, and intraoperative data were extracted from medical files and mortality and morbidity rates were calculated.

Results: One hundred consecutive patients (67% male, mean age = 3.5 mon) were included. The most common subtype of CHD was TGA+VSD+PDA in 52%, and the most common position of the coronary artery was seen in 1L; 2RCx (17%). The global mortality rate was 20%, with the respective highest rates in the Taussig-Bing subtype (50%), in the patients with a history of balloon septostomy (48%), and in the cases with preoperative prostaglandin E1 therapy (49%) ($P > 0.05$). Prolonged mean preoperative CCU stay, prolonged mean postoperative intubation period, and prevalence of severe postoperative mitral regurgitation were significantly higher in the expired group ($P < 0.05$).

Conclusions: This study showed a relatively high mortality rate in the patients undergoing ASO, in comparison to similar evidence, while the morbidity rate in the surviving patients was acceptable. Proper parallel circulations, timing of the surgery, and adequate skills among surgeons are essential for the success of ASO. ***(Iranian Heart Journal 2017; 18(3):42-51)***

Keywords: Transposition of the great arteries, Arterial switch, Surgery, Congenital heart disease, VSD, dTGA

[1] Heart Valve Disease Research Center, Rajaie Cardiovascular, Medical, and Research Center, Iran University of Medical Sciences, Tehran, I.R. Iran
[2] Department of Cardiac Surgery, Modarres Hospital, Faculty of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, I.R. Iran
[3] Rajaie Cardiovascular, Medical, and Research Center, Iran University of Medical Sciences, Tehran, I.R. Iran

***Corresponding Author:** Afshin Javdan, MD; Rajaie Cardiovascular, Medical, and Research Center, Iran University of Medical Sciences, Niayesh Highway, Vali-Asr Avenue, Tehran, I.R. Iran.
Tel: 02123923017 **E-mail:** a_m_makvand@yahoo.com

Received: May 2, 2017 **Accepted:** August 10, 2017

Arterial switch operation (ASO) has currently replaced atrial switch procedures established by Mustard [1] and Senning [2] to manage D-loop transposition of the great arteries (D-TGA). Survival rates have improved with the modification of the surgical techniques and development of the medical management. Jatene et al [3] performed the first successful ASO in 1975. At present, the majority of the patients treated via ASO live to adulthood, with a 20-year survival rate of approximately 90%. In the present study, we aimed to update clinicians on the management of patients with D-TGA and an intact ventricular septum (IVS) candidated for ASO. The hypermobility of the atrial septum and a reverse diastolic patent ductus arteriosus (PDA) flow may predict the need for an urgent balloon atrial septostomy. [4] It has been suggested that neonates with D-TGA be delivered in a center equipped to perform balloon atrial septostomy; nevertheless, prenatal prediction of interatrial communication suitability is inadequate. Children with D-TGA diagnosed prenatally have good early complex cognitive skills, principally executive functions, as compared with those diagnosed postnatally. [5]

Complete transposition of the great arteries (TGA) is the second greatest common cyanotic congenital heart disease (CHD) in which, characteristically, the aorta and the pulmonary artery originate from the right and left ventricles, respectively, and result in 2 parallel circulations (systemic and pulmonary). In its common form, the aorta is located at right and anterior position to the pulmonary artery (dTGA). Patients with complete TGA typically have different degrees of desaturation and cyanosis due to the pulmonary artery flow and the mixing of the comparable circulation. ASO is now the standard surgical procedure for complete TGA without a substantial left ventricular outflow tract (LVOT) obstruction. Since the first ASO procedure in 1975, there have been several experiences and technical developments worldwide. [6] ASO has been undertaken in a few of our country's tertiary care centers for the past decade. An overview and analysis of the results of ASO procedures would be beneficial in refining case selection, surgical techniques, and care of patients. The present study presents a review of the results of 100 ASO procedures at our tertiary care center.

ASO Surgical Challenges

ASO remains one of the most complex neonatal operations whereby the great arteries are divided and followed by a Lecompte maneuver. After transferring the coronary arteries, the surgeon reconnects the great arteries to the proper ventricles and closes any intracardiac communication. Mortality risk factors include inadequate institutional and surgeon experience, smaller patient size, side-by-side great vessel arrangement, left ventricular (LV) hypoplasia, LVOT obstruction, arch abnormalities, and intramural coronary arteries. [7-11] Early mortality is practically always due to difficulty with coronary artery transfer, resulting in myocardial ischemia. [7] Two recent studies have demonstrated a hospital survival rate greater than 98%. [12] Data from the United Kingdom's National Institute for Cardiovascular Outcomes show a nationwide 30-day mortality rate for ASO of less than 3% with a 1-year survival rate of greater than 96%. [13] The key to a successful ASO is the transfer of the coronary artery origins. In the technique, after cross-clamping and dividing the aorta, the surgeon excises the sinus aorta, which surrounds the coronary ostia—the so-called "coronary button." The button's boundary is 1 to 2 mm of the sinus-aorta surrounding the coronary ostium. If the ostium is adjacent to a commissure, the commissure should be taken down to ensure that the button is large enough for coronary transfer. After button excision, the proximal coronary is mobilized to allow the vessels to be implanted into the pulmonary root. None of the several techniques for coronary artery implantation has shown a clear advantage over the others. [6] Assessment of the coronary anatomy and adequate filling after the transfer are essential. A depressed ventricular function or the inability to wean the patient from cardiopulmonary support may be due to coronary insufficiency until confirmed; otherwise, it may be due to a policy of elective delayed sternal closure. In 2 large series of ASO procedures, one-quarter to one-third of the patients had delayed sternal closure, correlated with inferior outcomes. [9, 11]

METHODS

In this retrospective case series, 100 patients with TGA who underwent ASO between 2010 and 2013 were enrolled. The patients' information was extracted from their records and followed by telephone contacts. Demographic, anatomic, preoperative, and intraoperative data (cardiopulmonary bypass time and cross-clamp time) as well as mortality and morbidity rates were extracted from the patients' medical documents. All patients with a diagnosis of complete TGA (d-TGA), for whom ASO was performed at our tertiary care center between June 2010 and June 2013, were registered. Demographic variables as well as anatomic and hemodynamic characteristics of TGA, operation characteristics, postoperative conditions (residual defects and complications), and outcomes were collected from the patients' medical files. The inclusion criteria were all neonates (mostly < 3 months old) with a diagnosis of TGA admitted to Rajaie Cardiovascular, Medical, and Research Center between 2010 and June 2013 as identified by the neonatal intensive care unit's discharge database. Patients with major extracardiac congenital malformations and infants with complex congenital cardiac defects (those in whom TGA was just a component of their complex disease) who underwent surgical repairs other than ASO were excluded. The Human Investigation Committee of Iran University of Medical Sciences approved the study and a waiver of parental consent.

RESULTS

In this retrospective study, 100 consecutive patients undergoing ASO were enrolled (67% male; mean age = 3.5 mon; age range = 2 d to 4 y). All the demographic and clinical characteristic data are illustrated in Table 1. The relative prevalence of the anomaly subtypes was defined as TGA + ventricular septal defect (VSD) + PDA, TGA + IVS + PDA, TGA +VSD + LVOT obstruction, and Taussig-Bing anomaly, respectively seen in 52%, 43%, 1%, and 4% of the cases. The most common types of great arteries association were d-malposition (75%) and side by side (19%). Severe pulmonary stenosis, moderate pulmonary insufficiency, and moderate tricuspid regurgitation were correspondingly seen in 1%, 2%, and 3% of the patients, preoperatively. The most common types of coronary artery anatomy variations were normal (62%); 1L, 2RCx (17%); and 1LR, 2Cx (23%). The global mortality rate was 20%. The postprocedural outcomes of our study population are depicted in Table 2. There were no significant relationships between the mortality rate and gender, age, cardiopulmonary bypass time, aortic cross-clamp time, coronary artery anomalies, and discrepancy of the great arteries (P > 0.05) (Table 3). Among the anomaly subtypes, the highest mortality rate was in the patients with Taussig-Bing anomaly (50%), followed by TGA + IVS (20%) and TGA + VSD (18%). Among the different types of great arteries association, the mortality rate was highest in the side-by-side type, but the differences were not statistically significant (P > 0.05). The prevalence of balloon atrial septostomy in the expired and surviving patients was 48% and 23%, respectively; the difference, however, did not constitute statistical significance (P > 0.05). There were 2 cases of postoperative right pulmonary artery stenosis: TGA+IVS+coarctation of the aorta (COA) and TGA + VSD. (Both of them were DTGA from the aspect of the relationship of the great arteries, too.) The mean ICU length of stay was 7.9 days for the patients that expired and 10.6 days for those who survived ($P < 0.01$). With regard to postoperative valvular complications, there was moderate mitral regurgitation and moderate tricuspid regurgitation in 6.2% and 13.7% of the patients, respectively. No cases of significant postoperative pulmonary insufficiency or stenosis and aortic insufficiency or aortic stenosis were found ($P > 0.05$). Prolonged mean preoperative CCU stay, prolonged mean postoperative intubation period, and prevalence of severe postoperative mitral regurgitation were significantly higher in the expired group ($P < 0.05$). With respect to residual defects in the surviving patients, residual atrial septal defects, which were not hemodynamically significant; were detected in 5 cases. Moreover, there was 1 case of a large residual VSD. The mortality rate in the 100 patients and the association with sex and coronary artery anomalies and the frequency of the coronary anomalies in our study population are all shown in Table 4 and Table 5, respectively.

Statistical Analysis

The data analyses were performed using descriptive statistical tools (means ± standard deviations [SDs]) and appropriate analytical tests (*t*-test, χ^2 test, and ANOVA). A *P* value less than 0.05 was considered statistically significant. The analyses were conducted using SPSS, version 22 (IBM, USA).

DISCUSSION

According to many studies, the long-term outcomes of patients with D-TGA have been improved noticeably in the current era owing to advances in prenatal diagnosis, balloon atrial septostomy, prostaglandin E1 (PGE1), and improved surgical techniques and postoperative managements. Familial recurrence risk in this issue is low. Echocardiography helps to categorize risk factors such as commissural misalignment, restrictive patent foramen ovale, coronary abnormalities, acute LV dysfunction before and after ASO, balloon atrial septostomy, and PGE1—all of which carry risks that need to be considered in conjunction with the timing of ASO. Not only may an early ASO minimize these risks but also it may improve outcomes and reduce costs. The mortality rate is low despite the atypical coronary anatomy, but intramural coronary arteries have remained an important risk factor. With regard to the available evidence, routine elective delayed sternal closure is not recommended. Early post-ASO arrhythmias and cardiac dysfunction increase suspicion of coronary insufficiency or obstructive lesions. Arrhythmias and coronary obstruction, albeit infrequent, are associated with sudden cardiac death. Early- and late-onset neurodevelopmental abnormalities occur frequently, however. Perioperative events such as brachycephalic airway syndrome, prolonged PGE1 therapy, paradoxical embolism, and prolonged hospital length of stay constitute the risk factors, some of which might be modifiable.

In the present study, 68% of the patients were male—which is in line with the results of other similar studies (between 60% and 70%). The total mortality rate in our investigation was about 20% (20% males and 22% females) ($P = 0.78$). The most significant mortality rate was seen in the Taussig-Bing group, consisting of 4 patients. Two (50%) of the patients in the Taussig-Bing group expired; however, no statistically significant association was found between the groups ($P = 0.13$).

Totally, 43 cases were found to have TGA + IVS+ PDA—with a mortality rate of 20%, which is higher than that in other similar studies. In the TGA + VSD + LVOT obstruction group, there was only 1 patient, who successfully underwent surgery. The TGA + VSD + PDA group consisted of 52 patients, with a mortality rate of 17.3%, which is significantly higher than that of other similar investigations (5%). No COA and other arch anomalies were found in this group, and nor was there an important risk factor which could raise the mortality rate in this group, while in the TGA + IVS + PDA group, there were 2 patients with COA who survived.

The majority (68%) of our cases were male, which is concordant with other similar studies. Likewise, the relative prevalence of the subtypes, great arteries associations, and coronary artery anomalies were similar to those reported by previously conducted investigations. [1-6, 8] The global mortality rate in our study was relatively higher than that in comparable investigations. [9, 10] Some of the reasons for the failed ASO procedures in our study—in relation to the age of all the expired patients at time of surgery, postoperative survival duration, and past natural and medical histories—are shown in Table 5. Further, the anatomical variations of the coronary arteries in the expired and surviving cases are demonstrated in Table 6 and Table 7. None of those variations had a significant correlation with the failed ASO procedures. In fact, except for 1 patient, whose mortality was due to complete heart block and accidental pacemaker dysfunction, all of the others expired because of LV failure, severe mitral regurgitation, or pulmonary hypertensive crisis. We believe that the surgical outcomes of our patients would have been improved substantially by better preoperative management, case selection, and surgical technical skills. Due to a higher rate of coronary abnormalities, the mortality rate was highest in the Taussig-Bing subtype—which tallies with the results of comparable research. [10, 11] The mortality rate in the patients with TGA + IVS + PDA was significantly higher (20%) than that in other similar studies. [10] Likewise, in our TGA + VSD + PDA group (17.3%), we had some similarity to other previously reported evidence (5%). [9, 10] It seems that such a relatively higher rate of mortality in this subtype could be explained by the factors previously indicated for global mortality. Age at the time of ASO in our patients was higher than that reported by similar studies. The reasons for the delay in performing ASO include absence of systematic case selection, poor preoperative management, and lack of sufficient expert surgeons. [10, 12] Currently, the recommended operation time for the TGA + IVS + PDA group is from the fourth to fifth days of life to the second and third weeks of life in order to provide the opportunity for the development of the full function of the liver and kidney and reduce the pulmonary arterial pressure in neonates. Although the initiation of prostaglandin and balloon atrial septostomy are palliative preoperative procedures, [13] our findings showed that such procedures had been performed more frequently in the expired patients. This finding may be related to poor preoperative hemodynamic state, necessitating such procedures. In addition, poor management of the QP/QS ratio for parallel circulations tends to result in more emergent ASO procedures in hemodynamically non-optimal patients. [10] Many of such patients had a bidirectional flow at PDA level in spite of balloon atrial septostomy, which indicated the inefficiency of the performed balloon atrial septostomy and the maintained neonatal systemic pulmonary hypertension before surgery. On the other hand, the patients who received PGE1 had PO_2 saturation levels higher than 75%, showing a high pulmonary flow circulation which preoperatively indicates different levels of heart failure.

Our results showed no significant differences between the patients who expired and those who survived regarding gender, age, great arteries discrepancy, postoperative ICU stay, preoperative CCU stay, preoperative intubation, postoperative ICU intubation period, coronary anomalies, intraoperative variables (cardiopulmonary bypass time and aortic cross-clamp time), and total hospitalization period—all of which could be related to our insufficient sample size. Apropos the residual lesions in the surviving patients, our results are acceptable. Nonetheless, there were 2 cases of pulmonary artery branch stenosis and 1 case of hemodynamically significant VSD. In addition, we had no patient with mitral or tricuspid defects or with severe aorta or pulmonary regurgitation—indicating that in a patient population with a desirable mortality rate, the morbidity rate would be acceptable (Table 8).

Table 1. Clinical and baseline data

	N (%)
TGA	
Taussig-Bing anomaly	4(4%)
TGA+IVS+PDA	43(43%)
TGA+VSD+LVOTO	1(1%)
TGA+VSD+PDA	52(52%)
Mitral Valve	
Mild MR	21%
Moderate MR	2%
Tricuspid	
Mild TR	52%
Moderate TR	13%
Aortic Valve	
AS	0%
Mild AI	4%
Pulmonary	
Mild PS	4%
Severe PS	1%
Mild PI	19%
Severe PI	2%
BAS in the surviving patients	18(23%)
BAS in the expired patients	8(48%)
PGE1 therapy in the surviving patients	19(24%)
PGE1 therapy in the expired patients	8(48%)
GA discrepancy in the surviving patients	15(18%)
GA discrepancy in the expired patients	5(25%)

IVS, Intact ventricular septum; PDA, Patent ductus arteriosus; VSD, Ventricular septal defect; LVOTO, Left ventricular outflow tract obstruction; PGE1, Prostaglandin E1; MR, Mitral regurgitation; PS, Pulmonary stenosis; PI, Pulmonary insufficiency; AS, Aortic stenosis; AI, Aortic insufficiency; TR, Tricuspid regurgitation; BAS, Balloon atrial septostomy; TGA, Complete transposition of the great arteries

Table 2. Postprocedural outcome in the patients that underwent arterial switch operation

	Mean±SD	*P*
CPB time (min)		
Total patients	165(55-300)	0.91
Expired patients	166(55-300)	
Aortic cross-clamp time (min)		
Total cases	100(40-200)	0.63
Expired patients	104(40-200)	

CPB, Cardiopulmonary bypass
P < 0.05 was considered the level of significance.

Table 3. Mortality rate in the 100 patients and the relationship with sex and anomaly

Variable	Mortality N(Percent)	P value
Sex Female	7(22%)expired 25(78%)survived	0.78
Male	13(20%)expired 55(80%)survived	
TGA subtypes		
Taussig bing	2(50%)	0.1
TGA+VSD+LVOT	0(0%)	-
TGA+IVS+PDA	9(20%)	0.8
TGA+VSD+PDA	9(18%)	0.4
Total	20(20%)	
Great Arteries Relationship		
Side by Side GAs	6(30%)	0.2
DTGA	0(0%)	0.2
LTGA	13(65%)	-
Anterior-Posterior	1(5%)	0.5
Hx of PG E1 Therapy YES	8(49%)expired 19(24%)survived	0.1
NO	12(51%)expired 61(76%)survived	
Hx of BAS YES	8(48%)expired 18(23%)survived	0.1
NO	12(52%)expired 62(77%)survived	
Hx of GA Discrepancy YES	5(25%)expired 15(18%)survived	0.5
NO	15(75%)expired 65(82%)survived	
Postoperative Mild MR		0.7
Total MR	39(39%)	
Mild MR	15	
Expired	1	
Survived	14	
Postoperative Moderate MR		0.9
Moderate MR	1	
Expired	0	
Survived	1	
Postoperative Severe MR		0.0001
Severe MR	19	
Expired	17	
Survived	2	
Postoperative mean ICU stay		0.5
Expired	7.7	
Survived	10.6	
Mean postoperative intubation period		0.003
Expired	8.8	
Survived	4.6	
Mean postoperative hospitalization		0.3
Expired	18.5	
Survived	19.2	
Mean preoperative CCU stay		0.001
Expired	15.2	
Survived	7.3	
Ventricular Tachycardia & Ventricular Fibrillation		0.7
Expired	1	
Survived	2	

TGA, Complete transposition of the great arteries; PGE, Prostaglandin E1; TR, Tricuspid regurgitation; PDA, Pulmonary ductus arteriosus; VSD, Ventricular septal defect; IVS, Intact ventricular septum; GA, Great arteries; LVOTO, Left ventricular outflow tract obstruction; BAS, Balloon atrial septostomy *P*<0.05 was considered the level of significance.

Table 4. Coronary anomaly in the patients that underwent surgery

Anomalies	N (%)
Normal CAs	62(62%)
1L, 2RCx	17(17%)
Single ostium + intramural LCA	2(2%)
1R, 2LCx	2(2%)
1LR, 2Cx	13(13%)
Single ostium	3(3%)
1RCx, 2L	1(1%)

R, Right coronary artery; Cx, Circumflex coronary artery; L, Left anterior descending artery; RCx, Right circumflex

Table 5 . Characteristics of the expired patients

Patient/Disease	Age at the Time of Surgery	Survival Duration After Surgery	Probable Causes of Death	Preoperative Risk Factors
TGA+IVS+PDA	1 y	23 d	Recurrent PH crisis – VT- VF	Systemic PH and ineffective PA banding
TGA+IVS+PDA	7 d	20 d	LV dysfunction	-
TAUSSIG-BING ANOMALY	5 mon	25 d	LV dysfunction	-
TGA+IVS+PDA	17 d	In the operating room	MI and failure to wean from CPB	Prolonged preoperative intubated state and sepsis
TGA+IVS+PDA	13 d	10 d	LV dysfunction	-
TGA+IVS+PDA	15	33	Sepsis—ARF	Repaired preoperative small intestinal rupture and peritonitis
TGA+IVS+PDA	20 d	30 d	LV dysfunction -VT/VF	-
TGA+IVS+PDA	2 d	< 1 d	MI	-
TGA+IVS+PDA	1 mon	21 d	PH crisis	Prolonged CCU stay - positive ETT culture
TGA+IVS+PDA	26 d	13 d	PH crisis and sepsis	Sepsis
TGA+IVS+PDA	13 d	1 d	Sepsis–LV dysfunction– VT/VF	Sepsis-prolonged CCU stay
TGA+VSD+PDA	1 mon	2 d	MI	-
TGA+VSD+PDA	2 mon	26 d	CHB- pacemaker dysfunction	-
TGA+VSD+PDA	23 d	2 d	LV dysfunction-CHB-sepsis	Sepsis
TGA+VSD+PDA	1y	2 d	MI	Systemic PH
TGA+VSD+PDA	13 d	3 d	LV dysfunction	Prolonged CCU stay
TAUSSIG-Bing Anomaly	100 d	2 d	PH crisis – LV dysfunction	Systemic PH
TGA+VSD+PDA	1 m	6 d	LV dysfunction	-
TGA+VSD+PDA	25 d	3 d	PH crisis – LV dysfunction	Prolonged CCU stay–positive ETT culture
TGA+VSD+PDA	1 m	2 d	LV dysfunction	Prolonged CCU stay

TGA, Complete transposition of the great arteries; PA, Pulmonary artery; IVS, Intact ventricular septum; PDA, Pulmonary ductus arteriosus; VSD, Ventricular septal defect; CHB, Complete heart block; MI, Myocardial infarction; ETT, Endotracheal tube; LV, Left ventricle; CPB, Cardiopulmonary bypass; PH, Pulmonary hypertensive; ARF, Acute rheumatic fever

Table 6. Coronary arteries anatomy variations in the expired patients

Coronary Variations	Number of the Expired Patients	*P*
Normal coronary arteries	11	0.53
1Cx, 2LR	1	N\A
1L, 2RCx	5	0.3
1LR, 2Cx	2	0.81
Single ostium + intramural LCA	1	0.2

N\A, There was no such anomaly in the surviving group for comparison.
LCA, Left coronary artery; R, Right coronary artery; Cx, Circumflex coronary artery;
L, Left anterior descending artery; RCx, Right circumflex

Table 7 . Coronary arteries anatomy variations in the surviving patients

Coronary Variations	Number of the Surviving Patients	Percentage of the Surviving Normal Coronary Arteries
Normal coronary arteries	50	
1LCx, 2R	12	24%
1R, 2LCx	2	4%
1LR, 2Cx	11	22%
Single ostium	3	6%
1RCx, 2L	3	6%
Single ostium+ intramural LCA	1	2%

LCA, Left coronary artery; R, Right coronary artery; Cx, Circumflex coronary artery; L, Left anterior descending artery; RCx, Right circumflex

Table 8. Morbidity prevalence in the surviving patients

Morbidity	Number of the Patients
Severe PI	1
LV-to-RA shunt	1
Severe RPA stenosis	2
Hemodynamically significant residual VSD	1

PI, Pulmonary insufficiency; LV, Left ventricle; RA, Right atrium; RPA, Right pulmonary artery; VSD, Ventricular septal defect

CONCLUSIONS

In conclusion, this study showed a relatively high rate of mortality in patients that underwent ASO in comparison with similar studies. The mortality rate in our study was 5%, which is acceptable. The morbidity rate in our surviving patients was also acceptable. There were no significant associations between the mortality rate and the demographic data as well as with great arteries discrepancy, postoperative ICU requirements, intraoperative variables (cardiopulmonary bypass time and aortic cross-clamp time), total hospitalization period, great arteries relationships, and any subtypes of TGA in spite of a history of preoperative palliative management and procedures, preoperative intubation of the patients, postoperative intubation time period, and performing coronary re-implant in a significant number of the patients. Moreover, no significant association was found between the expired and surviving patients regarding gender, age, great arteries discrepancy, postoperative ICU stay, preoperative CCU stay, preoperative intubation, postoperative ICU intubation period, coronary anomalies, intraoperative variables (cardiopulmonary bypass time and aortic cross-clamp time), and total hospitalization period—which may be due to our insufficient sample size. Regarding the residual lesions in our surviving patients, our results are acceptable. Be that as it may, there were 2 cases of pulmonary artery branch stenosis and 1 case of hemodynamically significant VSD. There were no patients with mitral or tricuspid defects or with severe aorta or pulmonary regurgitation; it may be concluded, therefore, that if the mortality rate in a patient population is acceptable, the morbidity rate would be acceptable as well. Our findings highlight the importance of better neonatal case selection, pre- and intraoperative management, and surgical skills.

Acknowledgements

We would like to thank the staff of the CCU and ICU at Rajaie Cardiovascular, Medical, and Research Center. In addition, we thank Dr Mona Heidarali for her scientific writing.

Conflict of Interest: None declared.
This project is financially independent.

REFERENCES

1. Mustard W. Successful two-stage correction of transposition of the great vessels. Surgery 1964; 55:469–72.

2. Senning A. Surgical correction of transposition of the great vessels. Surgery 1959;45:966–79.

3. Jatene A, Fontes V, Paulista P, et al. Anatomic correction of transposition of the great vessels. J Thorac Cardiovasc Surg 1976; 72:364–70.

4. Punn R, Silverman NH. Fetal predictors of urgent balloon atrial septostomy in neonates with complete transposition. J Am Soc Echocardiogr 2011; 24:425–30.

5. Calderon J, Angeard N, Moutier S, et al. Impact of prenatal diagnosis on neurocognitive outcomes in children with transposition of the great arteries. J Pediatr 2012; 161:94–8.

6. Juan Villafañe, M. Regina Lantin-Hermoso, Ami B. Bhatt, James S. Tweddell, MD, Tal Geva, Meena Nathan, Martin J. Elliott, Victoria L. Vetter, Stephen M. Paridon, Lazaros Kochilas, MSCR, Kathy J. Jenkins, MPH, Robert H. Beekman III, MD,kk Gil Wernovsky, MD, Jeffrey A. Towbin. D-*Transposition* of the Great Arteries; the Current Era of the Arterial Switch Operation. 2014; 6 4; 5: 498-511

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

8. Karamlou T, McCrindle BW, Blackstone EH, et al. Lesion-specific outcomes in neonates undergoing congenital heart surgery are related predominantly to patient and management factors rather than institution or surgeon experience: a Congenital Heart Surgeons Society Study. J Thorac Cardiovasc Surg 2010;139: 569–77.e1.

9. Sarris GE, Chatzis AC, Giannopoulos NM, et al. The arterial switch operation in Europe for transposition of the great arteries: a multi-institutional study from the European Congenital Heart Surgeons Association. J Thorac Cardiovasc Surg 2006;132: 633–9.

10. 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; 106:2575–80.

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

12. Anderson BR, Ciarleglio AJ, Hayes DA, Quaegebeur JM, Vincent JA, Bacha EA. Earlier arterial switch operation improves outcomes and reduces costs for neonates with transposition of the great arteries. J Am Coll Cardiol 2014; 63: 481–7.

13. University College London. National Institute for Cardiovascular Outcomes Research—NICOR Web Portal. 2014. Available at: http://nicor4. nicor.org.uk. Accessed June 20, 2014.