International Journal of Cardiology Sciences

ISSN Print: 2664-9020
ISSN Online: 2664-9039
Impact Factor: RJIF 5.42
IJCS 2024; 6(2): 129-135
www.cardiologyjournals.net
Received: 05-06-2024
Accepted: 14-07-2024

Ranin Hamdy Elshafey
Department of Cardiovascular Medicine, Faculty of Medicine, Tanta University, Tanta, Egypt

Sameh Samir Khalil
Department of Cardiovascular Medicine, Faculty of Medicine, Tanta University, Tanta, Egypt

Raghda Gohnaimy EL Sheikh
Department of Cardiovascular Medicine, Faculty of Medicine, Tanta University, Tanta, Egypt

Hanan Kamel Kassem
Department of Cardiovascular Medicine, Faculty of Medicine, Tanta University, Tanta, Egypt

Magdy Mohamed EL Masry
Department of Cardiovascular Medicine, Faculty of Medicine, Tanta University, Tanta, Egypt

Corresponding Author:
Ranin Hamdy Elshafey
Department of Cardiovascular Medicine, Faculty of Medicine, Tanta University, Tanta, Egypt

Patients with transposition of the great arteries treated with arterial switch repair: Long-term results

Ranin Hamdy Elshafey, Sameh Samir Khalil, Raghda Gohnaimy EL Sheikh, Hanan Kamel Kassem and Magdy Mohamed EL Masry

DOI: https://doi.org/10.33545/26649020.2024.v6.i2b.74

Abstract

Background: The preferred surgical technique for great artery transposition is arterial switch surgery. Its result is not without unfavourable events, nevertheless. The work's objective was to assess the incidence and outcome of neo-pulmonary and neo-aortic valve disorders, incidence of coronary disease and branch pulmonary artery disease. Also to assess systemic ventricular function.

Methods: A retrospective study of one hundred people with large vessel transposition (D-transposition) (TGA) was conducted among those who underwent ASO with LeCompte Manoeuvre. All patients were subjected to electrocardiogram, full trans thoracic echocardiographic examination, peripheral pulmonaries and coronary arteries and computed tomography/ magnetic resonance imaging.

Results: There was no correlation between left ventricle global longitudinal strain (LVGLS) and age at time of ASO. Age and sex did not significantly correlate with LVGLS. There was significant relation between LVGLS and type of TGA, ventricular septal defect (VSD). Forty patients developed significant pulmonary stenosis (PS), 16 patients have moderate to severe aortic regurgitation, 21 patients have right ventricle (RV) dilatation, 6 patients have RV systolic dysfunction, 4 patients have LV systolic dysfunction, and one patient has significant aortic root dilation. Between the groups under study, there is a substantial difference (p<0.001).

Conclusions: There is great long-term survival following ASO. The majority of patients are developing into healthy adults, but a few percentage require reoperation for PS, neoaortic root dilatation, and neoaortic valve regurgitation. This is especially true with increased follow-up.

Keywords: Outcome, transposition, great arteries, arterial switch repair, aortic regurgitation

Introduction

Transposition of the great arteries (TGA), which makes up 5–8% of all congenital heart defects at birth [1], is the most common cyanotic congenital heart defect. Approximately two-thirds of patients exhibit no major associated anomalies, while one-third display anomalies. Ventricular septal defects (VSD) and pulmonary or sub-pulmonary stenosis are commonly associated with abnormalities [2].

The frequency of diagnosing TGA before birth is on the rise. Without treatment, roughly 30% of infants with TGA do not survive the first week of life, and 90% do not survive the first year [3]. The arterial switch operation (ASO), introduced by Jatene in 1976 [4], represents a breakthrough in the treatment of Transposition of the Great Arteries (TGA). By reattaching the aorta and PAs to their correct ventricles via the ASO procedure, normal circulation is reinstated. Today, ASO and the LeCompte Maneuver are used together, bringing the main pulmonary artery (MPA) and the pulmonary bifurcation in front of the aorta [5]. ASO leads to excellent long-term results, with patients enjoying a long-life expectancy, maintained LV function, and an acceptable quality of life. Though long-term results are positive for ASO patients, they typically experience lower fitness levels than healthier individuals. Pulmonary stenosis, right ventricular dysfunction, aortic regurgitation, and coronary artery abnormalities can impact exercise capacity [6]. Among late complications following ASO (abdominal aortic surgery), PS (pseudoaneurysm) is the most common and is often a result of altered loading conditions via AR (aortic regurgitation) and the development of a gothic arch [7]. Furthermore, recent studies have indicated that CA abnormalities [8], decreased CA vasoreactivity [9], reduced coronary flow reserve, proximal intimal proliferation [10], and reversible myocardial perfusion defects are present in patients who have undergone ASO, and suboptimal coronary perfusion could lead to chronic ischemia, causing LV damage and remodeling. Long-term outcome data are currently insufficient [11].

The study aimed to assess the frequency and impact of neo-aortic and neo-pulmonary valve disease, the incidence of coronary disease and branch pulmonary artery disease. Also to assess systemic ventricular function.

Patients and Methods

100 D-TGA patients who had ASO using the LeCompte Manoeuvre were included in this retrospective research. The study was carried out between February 2022 and November 2023 with permission from Tanta University Hospitals' Ethical Committee (approved code: 35086/12/21), located in Tanta, Egypt. The patients gave their informed written permission.

Patients on TGA who had undergone atrial switch surgeries were excluded.

Every patient had a comprehensive history taking, clinical assessment, and radiological evaluation [12 lead Electrocardiogram (ECG), full trans thoracic echocardiographic examination with special attention to the left ventricular (LV), aortic valve, coronary arteries, peripheral pulmonary, and any required computed tomography (CT) or magnetic resonance imaging (MRI) to evaluate branch PAs and coronaries]. Ultrasound equipment manufactured by General Electric (GE Healthcare) was used to do echocardiography. The standards and guidelines provided by the European Society of Echocardiography for assessing valve stenosis and regurgitation provide the foundation for valvular disease diagnosis at our facility [12, 13]. For this study, the following data were collected: MPA, left and right pulmonary artery pressure gradients, tricuspid regurgitation (TR) gradient, left ventricular (LV) ejection fraction (LVEF), and RV fractional area change values.

Aortic regurgitation

In our study, we classified AR into trace, mild, moderate, and severe. Grading of AR [12]. Depending on the severity of AR, regurgitation can be classified as trace, mild, moderate, or severe. Trace is everything but subdued. The LV size is typically normal when the AR is mild. The recognised cut-off values for non-significant LV enlargement are LV end-diastolic diameter ≤56 mm, LV end-diastolic volume <82 mL/m², LV end-systolic diameter <40 mm, and LV end-systolic volume <30 mL/m² [13]. Significant aortic root dilatation is defined as aortic root size at z-score of 2.5 or higher, measured by TTE and CMR.

Cardiac magnetic resonance imaging

1.5 Tesla Philips Healthcare scanner was used for CMR imaging. The CMR examination yielded the following data points: peak velocities across the aortic and pulmonary valves, stroke volumes for the MPA, LPA, and RPA, LVEF, RVEF, AR, and EDV/ESV ratios for the RV (all indexed for body surface area). RV and LV volumes were indexed using body surface area. Three distinct forms of TGA exist: basic TGA, TGA with ventricular septal defect, and TGA with coarctation.

Assessment of left ventricle function

Impaired LV function is determined visually or < 53% by modified Simpson plane. GLS was estimated for all patients with 2 D speckle tracking. The apical four-, two-, and three-chamber views of grayscale left ventricular images were obtained from patients' electronic records on the Pacs system for STE analysis. The aortic valve was observed closing in the apical three-chamber view. For each echocardiographic view, we acquired four successive end-expiratory cardiac cycles employing a harmonic imaging technique with a frame rate faster than 50 Hz. 2D speckle tracking software was employed offline to trace the endocardial surface throughout the cardiac cycle. Adjustments to the region of interest and tracking were performed as required, both manually and automatically. Apical views were utilized to assess longitudinal peak systolic strain at the basal, mid, and apical wall segments. The mean global longitudinal strain percentage was reported. A typical GLS level for a healthy person is approximately -20%, but it decreases with aging and is slightly higher in women [14]. Figure 1.

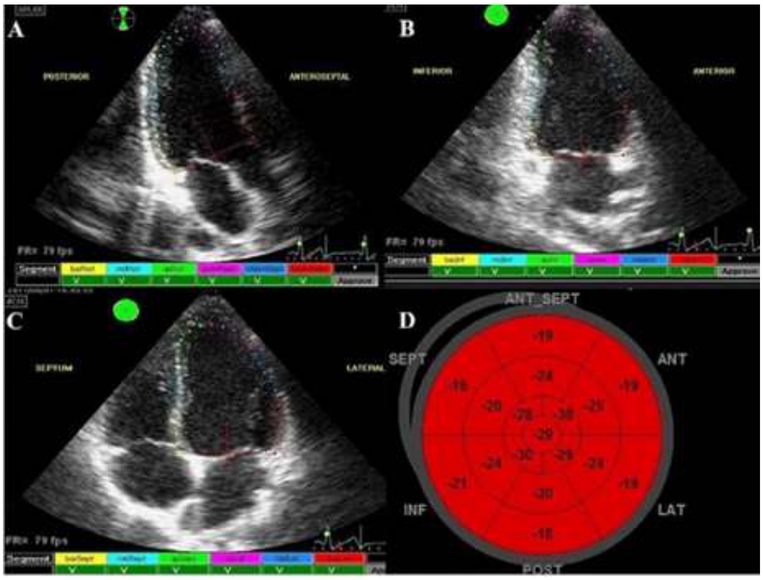

Fig 1: (A) Speckle tracking in 3CH using 2D STI, (B) Speckle tracking in 2CH, (C) Speckle tracking in 4CH, (D) Normal target chart for 2D STI. 2D STI refers to two-dimensional speckle tracking imaging [15]

A measurement of RV function
The right ventricle's free wall and septum exhibit reduced longitudinal and radial functions in RV dysfunction, evident through their inward movement and thickening. We used the reference values for RV dimensions from echocardiogram and CMR. RV dimensions from echocardiogram [14].

Pulmonary stenosis: Significant PS is defined as moderate to severe PS. Types of PS includes valvular, supra valvular and peripheral PS.

Statistical analysis: The statistical analysis was conducted using SPSS v26 from IBM Inc., Chicago, IL, USA. The unpaired Student's t-test was used to compare the means and standard deviations (SDs) of the two groups for quantitative variables. The Chi-square or Fisher's exact test was used to analyze qualitative variables presented as frequency and percentage (%) in the study. The Pearson moment correlation equation was used to calculate the relationship between different variables. A P value less than 0.05 indicates statistical significance.

Results
Demographic data, type of TGA and less common sequalae were presented in this table. Table 1

Table 1: The cases under study are classified based on demographic information, type of TGA, and less frequently occurring complications.

		N=100
Age (Years)		7.04±25.93
Sex	Male	74(74.0%)
	Female	26(26.0%)
Age at time of ASO (days)		5.25 ± 3.28
Rashkind		82(82.0%)
Type of TGA	Simple	74(74.0%)
	TGA/COA	1(1.0%)
	TGA/VSD	21(21.0%)
	TGA/VSD/COA	4(4.0%)
Less common sequalae	BAV	1(1.0%)
	CA obstruction	1(1.0%)
	Moderate PR	1(1.0%)
	Moderate supra valvular AS	1(1.0%)
	Previously medically treated neo-aortic valve infective endocarditis	1(1.0%)
	Severe PR	1(1.0%)

The data is shown as average ± standard deviation or as a percentage. ASO refers to arterial switch operation, TGA stands for transposition of great arteries, COA indicates coarctation, and VSD represents ventricular septal defect. BAV denotes bicuspid aortic valve, PR stands for pulmonary regurgitation, AS refers to aortic stenosis, and CA represents coronary artery.
Transthoracic echocardiogram and MRI parameters were presented in this table. Table 2.

Table 2: Transthoracic echocardiogram and MRI parameters in the studied patients

		N=100
Transthoracic echocardiogram	LVEF (%)	59.12 ± 4.38
	GLS (%)	17.36± 1.12
	RVFAC (%)	43.87 ± 6.81
	MPA gradient (mmHg)	20.96 ± 16.75
	RPA pressure(mmHg)	10.33 ± 3.02
	LPA gradient mmHg)	13.51 ± 3.95
	TR gradient(mmHg)	33.84 ± 13.24
	LVIDd	45.65 ± 4.20
	IVSD (mm)	8.46 ± 0.76
	LVPWd (mm)	7.42 ± 1.10
MRI	LVEF (%)	56.39 ± 2.26
	RVEF (%)	52.51 ± 3.50
	Left EDV index (ml/m^2)	109.4 ± 9.78
	Left ESV index (ml/m^2)	48.36 ± 5.35
	Right EDV index (ml/m^2)	96.99 ± 15.88
	Right ESV index (ml/m^2)	47.65 ± 11.18
	MPA peak velocity (cm/s)	222.6 ± 100.1
	RPA peak velocity (cm/s)	159.1 ± 24.33
	LPA peak velocity (cm/s)	183.7 ± 27.04
	AV peak velocity (cm/s)	114.8 ± 12.40
	LPA stroke volume (ml)	34.58 ± 5.27
	RPA stroke volume (ml)	45.12 ± 5.76
	MPA stroke volume (ml)	82.44 ± 7.90

The data is presented as the mean value plus or minus the standard deviation. IVSd corresponds to the interventricular septal end-diastolic measurement, LPA stands for the left pulmonary artery, LVEF represents the left ventricular ejection fraction, LVIDd refers to the left ventricular internal diameter end-diastole, LVPWd signifies the left ventricular posterior wall end-diastole, LVSF denotes the left ventricular shortening fraction, MPA represents the main pulmonary artery, RPA stands for the right pulmonary artery, RVFAC represents the right ventricle fraction area change, TR corresponds to tricuspid regurgitation, GLS stands for global longitudinal strain, AV signifies the aortic valve, EDV denotes the end diastolic volume, ESV represents the end systolic volume, while MRI stands for magnetic resonance imaging, and RVEF corresponds to the right ventricular ejection fraction.

There was no significant correlation observed between LVGLS and the variables of age and sex. However, a significant relationship was observed between LVGLS and the categories of TGA type, VSD, and Rashkind. Table 3

Table 3: Relation between LV GLS (%) and different parameters

		N	LV GLS (%)	U	P
Age (Years)	18-20	36	17.56 ± 0.67	H=1.670	0.434
	21-29	31	17.23 ± 1.11		
	30-41	33	17.25 ± 1.47		
Sex	Male	74	17.32 ± 1.23	U=960.0	0.987
	Female	26	17.46 ± 0.74		
Type of TGA	Simple	74	17.61 ± 0.70	H=10.043*	0.007*
	TGA/COA	1#	17.50		
	TGA/VSD	21	16.70 ± 1.42		
	TGA/VSD/COA	4	16.08 ± 3.05		
VSD		25	16.60 ± 1.70	U= 538.0*	0.001*
Rashkind		82	17.41 ± 1.10	U= 492.50*	0.007*

The data is shown as mean ± standard deviation. * denotes a significant p-value less than 0.05, #: Not included in the comparison due to a small number of cases (n = 1), U: Mann Whitney test, H: for Kruskal Wallis test, LV: left ventricle, GLS: global longitudinal strain, ASO: Arterial switch operation, TGA: Transposition of great arteries, COA: Coarctation, VSD

There was no correlation between LV GLS and Age at time of ASO. Table 4

Table 4: Correlation between LV GLS and Age at time of ASO

	LV GLS (%)	
	r_s	P
Age at time of ASO (days)	-0.050	0.619

rs: Spearman coefficient, ASO: Arterial switch operation, LV: left ventricle, GLS: global longitudinal strain.

Distribution of the studied cases according to significant PS, AR, RV dilatation, RV dysfunction, LV dysfunction, mortality, arrythmia and re-intervention were presented in this table. Table 5

Table 5: Distribution of the studied cases according to significant PS, AR, RV dilatation, RV dysfunction, LV dysfunction, mortality, arrythmia and re-intervention

		N=100
Significant PS		40 (40.0%)
Types of PS	Valvular	1 (1.0%)
	Supra Valvular	36 (36.0%)
	Peripheral	3 (3.0%)
AR	Mild	60 (60.0%)
	Moderate	13 (13.0%)
	Severe	3 (3.0%)
	Trace	23 (23.0%)
	Neo-aortic root dilation	1 (1.0%)
	RV dilatation	21 (21.0%)
	RV systolic dysfunction	6 (6.0%)
	LV dysfunction	4 (4.0%)
	Arrythmia	1 (1.0%)
	Mortality	1 (1.0%)
	Re-intervention	18 (18.0%)

Data are presented as frequency (%). PS: Pulmonary stenosis, AR: Aortic regurgitation, RV: right ventricle, LV: left ventricle.

Forty patients developed significant PS, 16 patients have moderate to severe AR, 21 patients have RV dilatation, 6 patients have RV systolic dysfunction, 4 patients have LV systolic dysfunction, and one patient has significant aortic root dilation. There is a significant difference among the studied groups (p<0.001). Table 6

Table 6: Incidence of different long-term sequalae

Significant PS	Moderate to severe AR	RV dilatation	RV systolic dysfunction	LV dysfunction	Significant A root dilatation	χ^2	p
40 [bc]	16 [a]	21 [a]	6 [abc]	4 [abc]	1 [abc]	84.641	<0.001*
40.0%	16.0%	21.0%	6.0%	4.0%	1.0%		

*Significant p value <0.05, χ2: Chi square test, a: Significant with PS, b: Significant with AR, c: Significant with RV dilatation, PS: Pulmonary stenosis, AR: Aortic regurgitation, RV: Right ventricle, LV: Left ventricle, A: Aortic.

Discussion

Repairing TGA with ASO is widely regarded as the most effective method. Although the long-term survival outcomes are impressive, there can be various complications over time, including RVOT obstruction, pulmonary artery stenosis, aortic root dilatation, worsening aortic regurgitation, and late coronary issues, which may require additional interventions and frequent monitoring [16].

This was in agreement with our results about morphological subtype of TGA, Alkattan *et al.* [17] found simple transposition in 201 patients (65%) and Complex transposition in 108 (35%). Furthermore, a research by Choi and colleagues [18] was carried out to evaluate the long-term results following an arterial switch operation for Simple Complete Transposition of the Great Arteries.

This came in agreement with our results about transthoracic echocardiogram parameters Schuwerk *et al.* [19] According to reports, the biventricular and biatrial function was largely preserved after ASO procedure. The biventricular and biatrial function were evaluated using standard cardiovascular magnetic resonance (CMR). GLS decrease was not caused by surgical or anatomical factors, as per Van Wijk *et al.* [20]. No correlation existed between GLS and demographics, surgical specifics, coronary anatomy, or the presence of a VSD.

In our study, 94% of the patients have overall good RV systolic function. 79% of the patients did not have RV dilatation. Warmerdam *et al.* [21] noticed that the RV function was generally good in the group mentioned earlier. In their study, Taylor and colleagues [22] showed that global RV function was maintained 10 years after ASO.

Regarding AR in our study group, 23 patients have trivial AR (23%), 60% of patients have mild AR, 13% and 3% of patients have moderate and severe AR respectively. One patient does not have AR. In the study conducted by Khairy *et al.* [23] at least moderate neo-AR presents in 3.4%. Nakayama *et al.* [24] carried performed a research to evaluate the results of neo-aortic valve surgery and neo-ar can follow an ASO with risk factors including surgical complications, ischemia, and inflammation. 41 of the 469 patients (8.6%) developed significant AR at a median follow-up of 19.0 years, with a range of 0.1-35.2 years.

Only one patient has significant aortic root dilation and only one patient required Bentall surgery in our study. A study by Verheijen *et al.* [25] examined late follow-up of neo-aortic dimensions and coronary arteries in adult patients who had undergone ASO. The study included 81 patients aged 16 years or older with at least one CTA. Initially, the maximum neo-aortic diameter was measured at 39.2 ± 5.3 mm, and it was found that 35 (43%) patients had neo-aortic dilatation (defined as a neo-aortic diameter of >40 mm). This finding was consistent with the results of Schwartz *et al.* [26], who identified patients that had undergone ASO for D-TGA. The likelihood of remaining free from aortic root dilation was 97%, 92%, 82%, and 51% after 1, 2, 5, and 10 years respectively.

At the 1, 2, 5, and 10-year marks, the probability of being free from moderate or greater aortic regurgitation was 98%, 97%, 96%, and 93%, respectively, while the probability of undergoing neo-aortic valve or root surgery stood at 100%, 100%, 99%, and 95% for the same periods. Previous pulmonary artery banding increases the risk for aortic root dilation. Older age at the time of ASO and the presence of VSD have been linked to unfavorable outcomes. In agreement with our results about significant PS, AR, RV dilatation, RV dysfunction, LV dysfunction, mortality, arrythmia and re-intervention. Khairy *et al.* [23] to assess cardiovascular outcomes after ASO.

6.6% of patients suffered from at least moderate pulmonary regurgitation, and 10.3% from moderate to severe pulmonary stenosis. 28% of patients undergoing arterial switch operations were found to have significant stenosis in the main pulmonary artery and its branches according to a study by Warmerdam *et al.* [21]. Patients with bicuspid neoaortic valves (BNPV) were found to have a higher incidence of aortic regurgitation and dilated neoaort as by Irwin *et al.* [27]. Maeda *et al.* [28] reported a 14-year-old girl's development of supravalvular aortic stenosis as a late complication of atrial septal override (ASO) for transposition of the great arteries (TGA). Hayashi G *et al.* [29] gathered data on arrhythmia occurrence and risk factors from six Japanese institutes, ending the collection in October 2002. Tsuda *et al.* [30] recommended coronary imaging as a prerequisite for competitive sports participation for all patients following ASO.

Vasse *et al.* [31] conducted a retrospective study on sixty-seven patients, in which 9.3% underwent 91 reoperations, with over half of them involving the pulmonary outflow tract. Michalak *et al.* [32] conducted a retrospective study to evaluate the incidence of catheter interventions and reoperations in TGA patients following the ASO, finding that 4.7% of survivors required reoperations. In our study, three out of 100 patients had intervention for a significant difference in lung flow. Thomas *et al.* [33] observed decreased caliber of neopulmonary artery branches unilaterally in three patients and bilaterally in two patients. Rudra *et al.* [34] reported a 5% reoperation rate for the neoaorta based on a 25-year experience with 258 patients at the Cleveland Clinic, which is higher compared to other studies ranging from 1.4% to 2.4% [35, 36]. Our study's shortcomings include its single-center design and somewhat small sample size, limited follow-up period, inclusion of only adult patients, exclusion of the pediatric age group, retrospective design, and missing data due to the patients being referred based on clinical indications, potentially resulting in bias in selection and a rise in the frequency of anomalous discoveries.

We did not directly compare the results obtained from cardiac magnetic resonance imaging with those from 2-D transthoracic echocardiography. While both imaging modalities contribute valuable information, understanding their discrepancies is crucial for optimizing patient care.

Future research should explore concordance and clinical implications arising from differences in MRI and echocardiogram data. We did not consider possible comorbidities that might affect the patient functional class.

Conclusions

Survival rates over the long-term following ASO are outstanding. Most patients are progressing into adulthood in good health, but a few may need further surgery for PS, as well as experiencing neoaortic root dilatation and neoaortic valve regurgitation, particularly with longer-term follow-up. The use of multiple imaging techniques enables the identification of postoperative complications.

No financial support or sponsorship was received, and there are no conflicts of interest.

Conflict of Interest

Not available

Financial Support

Not available

References

1. Medjedovic E, Stanojevic M, Jonuzovic-Prosic S. Transposition of the great arteries. Ultrasound in Obstetrics & Gynecology. 2024;18(2):89-92.
2. Brickner ME, Hillis LD, Lange RA. Congenital heart disease in adults. Second of two parts. The New England Journal of Medicine. 2000;342(5):334-342.
3. Heino A, Morris JK, Garne E, Baldacci S, Barisic I, Cavero-Carbonell C, *et al*. The association of prenatal diagnoses with mortality and long-term morbidity in children with specific isolated congenital anomalies: A European register-based cohort study. Maternal and Child Health Journal. 2024;28(5):1020-1030.
4. Jatene AD, Fontes VF, Paulista PP, Souza LC, Neger F, Galantier M, *et al*. Anatomic correction of transposition of the great vessels. The Journal of Thoracic and Cardiovascular Surgery. 1976;72(3):364-370.
5. Lecompte Y, Neveux JY, Leca F, Zannini L, Tu TV, Duboys Y, *et al*. Reconstruction of the pulmonary outflow tract without prosthetic conduit. The Journal of Thoracic and Cardiovascular Surgery. 1982;84(5):727-733.
6. Jonas K, Jakutis V, Sudikienė R, Lebetkevičius V, Baliulis G, Tarutis V. Early and late outcomes after arterial switch operation: A 40-year journey in a single low case volume center. Medicina (Kaunas). 2021;57(2):56-78.
7. Ntsinjana HN, Biglino G, Capelli C, Tann O, Giardini A, Derrick G, *et al*. Aortic arch shape is not associated with hypertensive response to exercise in patients with repaired congenital heart diseases. Journal of Cardiovascular Magnetic Resonance. 2013;15(5):101-120.
8. Hauser M, Bengel FM, Kühn A, Sauer U, Zylla S, Braun SL, *et al*. Myocardial blood flow and flow reserve after coronary reimplantation in patients after arterial switch and Ross operation. Circulation. 2001;103(14):1875-1880.
9. Gagliardi MG, Adorisio R, Crea F, Versacci P, Di Donato R, Sanders SP. Abnormal vasomotor function of the epicardial coronary arteries in children five to eight years after arterial switch operation: an angiographic and intracoronary Doppler flow wire study. Journal of the American College of Cardiology. 2005;46(9):1565-1572.
10. Pedra SR, Pedra CA, Abizaid AA, Braga SL, Staico R, Arrieta R, *et al*. Intracoronary ultrasound assessment late after the arterial switch operation for transposition of the great arteries. Journal of the American College of Cardiology. 2005;45(12):2061-2068.
11. Pizzi MN, Franquet E, Aguadé-Bruix S, Manso B, Casaldáliga J, Cuberas-Borrós G, *et al*. Long-term follow-up assessment after the arterial switch operation for correction of dextro-transposition of the great arteries by means of exercise myocardial perfusion-gated SPECT. Pediatric Cardiology. 2014;35(2):197-207.
12. Lancellotti P, Tribouilloy C, Hagendorff A, Moura L, Popescu BA, Agricola E, *et al*. European association of echocardiography recommendations for the assessment of valvular regurgitation. Part 1: Aortic and pulmonary regurgitation (native valve disease). European Journal of Echocardiography. 2010;11(3):223-244.
13. Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J, *et al*. 2021 ESC/EACTS Guidelines for the management of valvular heart disease. European Heart Journal. 2022;43(7):561-632.
14. Lancellotti P, Cosyns B. The EACVI Echo Handbook. 2nd ed: Oxford University Press; 2016.
15. Hai PD, Phuong LL, Dung NM, Hoa LTV, Quyen DV, Chinh NX, *et al*. Subclinical left ventricular systolic dysfunction in patients with septic shock based on sepsis-3 definition: A speckle-tracking echocardiography study. Critical Care Research and Practice. 2020;2020:60-75.
16. Kempny A, Wustmann K, Borgia F, Dimopoulos K, Uebing A, Li W, *et al*. Outcome in adult patients after arterial switch operation for transposition of the great arteries. International Journal of Cardiology. 2013;167(6):2588-2593.
17. Alkattan HN, Diraneyya OM, Elmontaser HA, Jaweed J, Alsaiad AM, Arifi AA, *et al*. The behavior of residual pulmonary artery gradient after arterial switch operation: A longitudinal data analysis. Journal of Cardiac Surgery. 2020;35(12):2927-2933.
18. Choi BS, Kwon BS, Kim GB, Bae EJ, Noh CI, Choi JY, *et al*. Long-term outcomes after an arterial switch operation for simple complete transposition of the great arteries. Korean Circulation Journal. 2010;40(1):23-30.
19. Schuwerk R, Freitag-Wolf S, Krupickova S, Gabbert DD, Uebing A, Langguth P, *et al*. Ventricular and atrial function and deformation is largely preserved after arterial switch operation. Heart. 2021;107(20):1644-1650.
20. van Wijk SW, Driessen MMP, Meijboom FJ, Takken T, Doevendans PA, Breur JM. Evaluation of left ventricular function long term after arterial switch operation for transposition of the great arteries. Pediatric Cardiology. 2019;40(2):188-193.
21. Warmerdam E, Magni F, Leiner T, Doevendans P, Sieswerda G, Wijk S, *et al*. Echocardiography and MRI parameters associated with exercise capacity in patients after the arterial switch operation. Journal of Cardiology. 2020;76(1):18-26.
22. Taylor AM, Dymarkowski S, Hamaekers P, Razavi R, Gewillig M, Mertens L, *et al*. MR coronary

angiography and late-enhancement myocardial MR in children who underwent arterial switch surgery for transposition of great arteries. Radiology. 2005;234(2):542-547.
23. Khairy P, Clair M, Fernandes SM, Blume ED, Powell AJ, Newburger JW, *et al*. Cardiovascular outcomes after the arterial switch operation for D-transposition of the great arteries. Circulation. 2013;127(3):331-339.
24. Nakayama Y, Shinkawa T, Matsumura G, Hoki R, Kobayashi K, Niinami H. Late neo-aortic valve regurgitation long after arterial switch operation. The Annals of Thoracic Surgery. 2019;108(4):1210-1216.
25. Verheijen DB, Engele LJ, Egorova AD, Stöger JL, Mertens BJ, van der Palen RL, *et al*. Late follow-up of neo-aortic dimensions and coronary arteries in adult patients after the arterial switch operation. International Journal of Cardiology Hypertension. 2023;14(1):100-120.
26. Schwartz ML, Gauvreau K, del Nido P, Mayer JE, Colan SD. Long-term predictors of aortic root dilation and aortic regurgitation after arterial switch operation. Circulation. 2004;110(11):128-132.
27. Irwin M, Binney G, Gauvreau K, Emani S, Blume ED, Brown DW. Native bicuspid pulmonary valve in D-Loop transposition of the great arteries: outcomes of the neo-aortic valve function and root dilation after arterial switch operation. Journal of the American Heart Association. 2021;10(3):15-26.
28. Maeda T, Koide M, Kunii Y, Watanabe K, Kanzaki T, Ohashi Y. Supravalvular aortic stenosis after arterial switch operation. Asian Cardiovascular and Thoracic Annals. 2016;24(6):578-580.
29. Hayashi G, Kurosaki K, Echigo S, Kado H, Fukushima N, Yokota M, *et al*. Prevalence of arrhythmias and their risk factors mid- and long-term after the arterial switch operation. Pediatric Cardiology. 2006;27(5):689-694.
30. Tsuda T, Bhat AM, Robinson BW, Baffa JM, Radtke W. Coronary artery problems late after arterial switch operation for transposition of the great arteries. Circulation Journal. 2015;79:2372-2379.
31. Vasse S, Martin-Bonnet C, Henaine R. Surgical reinterventions after arterial switch operation for transposition of the great arteries. Archives of Cardiovascular Diseases. 2022;14:251-252.
32. Michalak KW, Moll JA, Sobczak-Budlewska K, Moll M, Dryżek P, Moszura T, *et al*. Reoperations and catheter interventions in patients with transposition of the great arteries after the arterial switch operation. European Journal of Cardio-Thoracic Surgery. 2017;51:34-42.
33. Thomas B, Martins JD, Tavares NJ, Lopes A, Pinto FF, Fragata J. Stenosis of the branches of the neopulmonary artery after the arterial switch operation: A cardiac magnetic resonance imaging study. Annals of Pediatric Cardiology. 2013;6:29-33.
34. Rudra HS, Mavroudis C, Backer CL, Kaushal S, Russell H, Stewart RD, *et al*. The arterial switch operation: 25-year experience with 258 patients. The Annals of Thoracic Surgery. 2011;92:1742-1746.
35. Formigari R, Toscano A, Giardini A, Gargiulo G, Di Donato R, Picchio FM, *et al*. Prevalence and predictors of neoaortic regurgitation after arterial switch operation for transposition of the great arteries. The Journal of Thoracic and Cardiovascular Surgery. 2003;126:1753-1759.
36. Hövels-Gürich HH, Seghaye MC, Ma Q, Miskova M, Minkenberg R, Messmer BJ, *et al*. Long-term results of cardiac and general health status in children after neonatal arterial switch operation. The Annals of Thoracic Surgery. 2003;75:935-943.

How to Cite This Article
Elshafey RH, Khalil SS, EL Sheikh RG, Kassem HK, EL Masry MM. Patients with transposition of the great arteries treated with arterial switch repair: Long-term results. International Journal of Cardiology Sciences 2024; 6(2): 129-135.