# Echocardiographic Midterm and Long-term Outcomes After Arterial Switch Operation for D-Transposition of the Great Arteries: A Single-Institution Experience

Ceres Paulino-Canto, MD | Pacita Jay Lopez Ballelos, MD
Philippine Heart Center, Quezon City, Metro Manila, Philippines

## Abstract

**INTRODUCTION:** Arterial switch operation is the preferred surgical management for D-transposition of the great arteries, but it still has long-term complications, which necessitate continued follow-up of patients. This procedure was first performed in this institution in 1991, and after three decades, there is a need to evaluate midterm and long-term outcomes in this population.

**METHODS:** This is a descriptive study on arterial switch operation patients between January 2010 and March 2019 in this institution. The following parameters were collected through review of charts and online health records (Medtrack): preoperative clinical data, surgical technique and immediate postoperative course and complications, echocardiographic results, and current clinical status. The study was approved by the institutional ethics review board of the hospital.

**RESULTS:** Among the 108 patients included in the study, 35 were long-term patients, and 73 were midterm. A total of 27 patients (25%) were lost to follow-up. Among the remaining patients (n = 81), 76 (94%) were alive. The most common postoperative complications were pulmonary stenosis (n = 11), aortic regurgitation (n = 24), and aortic dilatation (n = 2). One patient had reintervention after surgery for severe pulmonic stenosis. Overall survival function was 93.7% after 5 years (95% confidence interval, 0.81–0.98) and 79.4% after 9 years (95% confidence interval, 0.46–0.93).

**CONCLUSION:** Complications seen in this population are similar to those seen in literature. The overall survival rate after 5 years compares to those of other institutions. However, long-term survival rates were lower, which may be due to poor patient follow-up and a high rate of patient attrition over time. To improve future outcomes, strategies should be implemented to promote continuity of care, and parents should be advised regarding the importance of follow-up.

**KEYWORDS:** arterial switch operation, D-TGA, echocardiography, midterm complications, long-term complications, survival rate

## INTRODUCTION

D-Transposition of the great arteries (D-TGA) is a lesion characterized by ventriculoarterial discordance in which the pulmonary artery arises from the left ventricle and the aorta arises from the right ventricle. It accounts for 3% of all congenital heart diseases and almost 20% of all cyanotic congenital heart defects, with an estimated prevalence of 2.3 to 4.7 per 10,000 live births.[1]

Without treatment, most children with D-TGA die within the first year of life, with 30% mortality in the first week, 50% by the first month, and 90% within 1 year. In infants with ventricular septal defect (VSD), the early survival rate is higher, 91% at 1 month and 33% at 1 year.[2]

During the 1950s, patients with D-TGA were palliated by a Blalock-Hanlon septectomy. This was followed by the atrial switch by Sennings in 1959 and Mustard in 1964. The first successful arterial switch operation (ASO) was reported by Jatene in 1975 in a patient with D-TGA with VSD (D-TGA–VSD).[3]

Anatomic correction in the form of ASO is now the preferred management for D-TGA. This procedure was first performed in this institution in 1991 and has become the procedure of choice for this condition since then.

Most studies report excellent overall long-term results in patients post-ASO. Late deaths were seen in as low as 0.9% to 2.2%,[4–6] with freedom from reintervention at 10 years ranging from 76% to 90% based on several studies.[4,6–8] Most patients have good left ventricular ejection fraction with New York Heart Association (NYHA) functional class I.[7–10] However, there are complications following ASO, which necessitate continued long-term follow-up of patients.

Complications at the right ventricular outflow tract, particularly pulmonary artery stenosis (PS), are the most frequent sequelae of ASO, with an incidence of up to 17%, and are the leading cause of reintervention in this population.[4,13,15]

Aortic regurgitation (AR) is another complication seen in up to 15% of patients.[15] In a study by Losay et al[8] on 1200 patients, 25.6% had mild AR.[9] Hemodynamically significant AR is reported in 4% to 10% of patients, with 2.3% requiring aortic valve replacement.[4,6,9,11,15] Aortic root dilation is a significant risk factor for AR.[11,16] In a study by Co-Vu et al[16] on 124 patients, 66% had *Z* scores more than or equal to 2.5, which increased by 0.08 per year.

In this institution, a study was done by Martinez et al[17] on 58 patients who underwent ASO between 1991 and 2000. Mortality rate was 46.5%, with 31 patients surviving the immediate postoperative course. Twenty-one were included in the study. All of these patients were alive and asymptomatic on follow-up. Other findings include mild to moderate aortic insufficiency in two patients and mild pulmonary insufficiency in one patient.

At present, no further studies have been done on this population. This study therefore aims to determine the clinical and echocardiographic outcomes of patients with D-TGA who underwent ASO in this institution between 2010 and 2019.

## METHODS

The protocol of this study was reviewed and approved by the institutional ethics review board. The investigator requested for the waiver of informed consent because of difficulty of obtaining individual authorization from the research subjects, which was granted by the institutional ethics review board.

*Study Design and Population*

This is a descriptive study that included all surviving pediatric patients aged 0 to 18 years diagnosed with D-TGA who underwent ASO from January 2010 to March 2019 in this institution and who had two-dimensional (2D) echocardiography study within the past year. Patients whose charts were not available for review were excluded from the study.

*Primary Outcome Measures*

Echocardiographic findings in patients who underwent ASO, including valvular insufficiency or stenosis, ventricular function, and other residual lesions, were the primary outcome measures in this study.

*Study Maneuver*

All pediatric patients who fit the criteria were listed based on the surgical census available at the Department of Thoracic and Cardiovascular Surgery.

Patients were grouped into D-TGA with intact interventricular septum (D-TGA–IVS) and D-TGA–VSD. Details such as anatomy, surgical technique and immediate postoperative course, and complications and current clinical status as seen at the outpatient department were obtained from the patient charts and online records (Medtrack).

Outcomes were defined as midterm in patients 1 to 5 years postprocedure and long-term in patients who underwent the procedure after more than 5 years.

Survival rates at 5 and 9 years were determined. Incidence of reoperation and reintervention was noted. Reoperation was defined as an operation on the heart or great vessels performed after the ASO at any time after operation, excluding exploration of bleeding, closure of open chest, wound debridement, mechanical circulatory support, and pacemaker replacement. Reintervention encompassed catheter-based procedures performed after ASO.

Preoperative and postoperative echocardiographic results performed within the past year and at least 1 year after surgery were reviewed. The following results were documented:

(1) Left ventricular end-diastolic volume (mL)
(2) Left ventricular ejection fraction (%)
(3) Left ventricular end-diastolic diameter (cm)

(4) Left ventricular mass/body surface area (g/m$^2$)
(5) Right ventricular fractional area change (%)
(6) Neovalvular pathology (aortic and pulmonic regurgitation or stenosis), categorized under mild, moderate, or severe
(7) Aortic valve annulus and *Z* score

*Sample Size*
A minimum of 56 patients was required for this study based on 17.4% prevalence of significant pulmonary stenosis among patients who underwent ASO,[5] 5% level of significance, and 10% desired half-width of the confidence interval.[18]

*Statistical Analysis*
Descriptive statistics was used to summarize the demographic and clinical characteristics of the patients. Frequency and proportion were used for categorical variables, median and interquartile range for non–normally distributed continuous variables, and mean and SD for normally distributed continuous variables. Kaplan-Meier survival function analysis was used to determine the survival rate of the patients from discharge. All statistical tests were two-tailed tests. Shapiro-Wilk test was used to test the normality of the continuous variables. Missing values were neither replaced nor estimated. Null hypotheses were rejected at 0.05 $\alpha$ level of significance. STATA 13.1 (StataCorp, College Station, Texas) was used for data analysis.

## RESULTS

During the specified time period, there were 182 patients who underwent ASO in this institution (Figure 1). Among these patients, 49 died with an immediate postoperative mortality rate of 26.7% (49/182).

A total of 108 patients were included in the study. Of these, 35 were long-term patients, and 73 were midterm. A total of 27 patients (25%) were lost to follow-up. Among the remaining patients (n = 81), 76 (94%) were alive, and only 47 of these patients had recent 2D echocardiography done in our institution.

Among the patients included in the study, D-TGA–IVS (65%) was more frequently seen than D-TGA–VSD (35%) (Table 1). Age at surgery was performed later in patients with D-TGA–VSD with a median of 82.5 days compared with patients with D-TGA–IVS with a median of 23 days. Twenty patients had balloon atrial septostomy, and 2 patients had pulmonary artery banding prior to surgery.

Preoperative 2D echocardiography findings (Table 2) show that 18% (n = 19) of patients had no interatrial communication, and 73% (n = 79) had a patent ductus arteriosus. Less common findings were coarctation of the aorta (n = 3), right ventricular outflow tract obstruction (n = 3), and pulmonary stenosis (n = 7).

Postoperative 2D echocardiography (Table 3) shows mild pulmonary stenosis in 19% (n = 7) of patients with D-TGA–IVS and 19% (n = 3) of patients with D-TGA–VSD. Moderate pulmonary stenosis was found in one patient (1.9%) with preoperative diagnosis of D-TGA–IVS. Coarctation of the aorta was seen in one patient (1.9%) and dilated sinus of Valsalva in 2 patients (3.8%), all with preoperative diagnosis of D-TGA–VSD.

Majority of the valvular insufficiency noted postoperatively was mild, predominantly AR, which was found in 44% (n = 23) of all postoperative patients, pulmonary regurgitation (PR) in 27% (n = 14), and tricuspid regurgitation in 25% (n = 13). There was one patient (1.9%) with moderate AR, 2 patients (3.8%) with moderate PR, and one (1.9%) with severe tricuspid regurgitation.

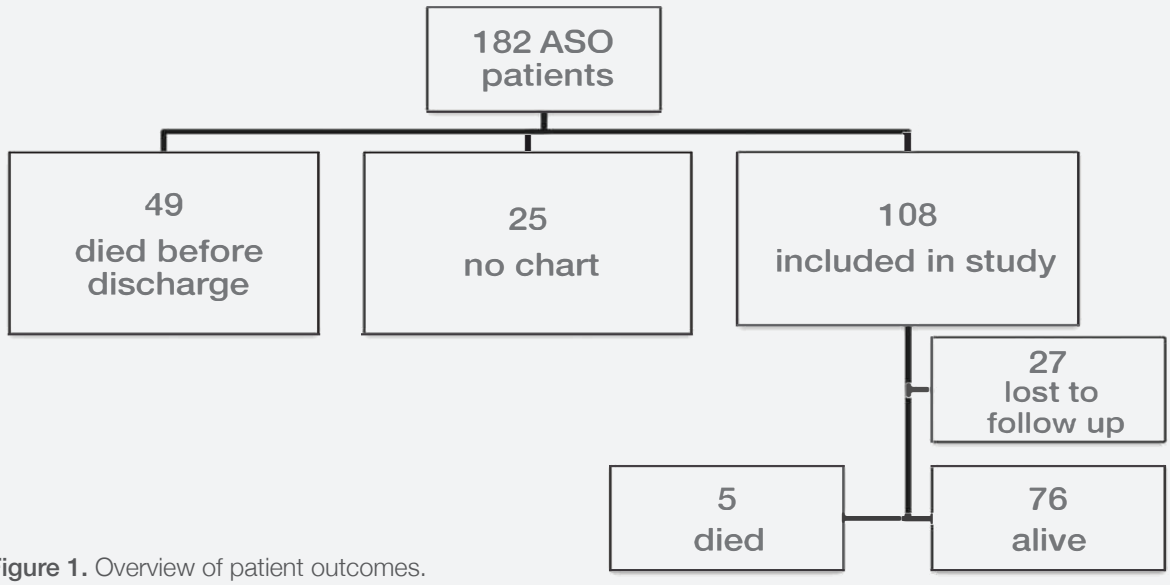


**Figure 1.** Overview of patient outcomes.

**Table 1.** Demographic Data and Preoperative Characteristics of Patients Who Underwent Arterial Switch Operation

| | Total (n = 108) | D-TGA–IVS (n = 70 [65%]) | D-TGA–VSD (n = 38 [35%]) |
|---|---|---|---|
| | Frequency (%) or Median (IQR) | | |
| Age at surgery, d | 35.5 (16–78) | 23 (13–38) | 82.5 (36–2188) |
| Sex | | | |
| Male | 81 (75) | 53 (75.71) | 28 (73.68) |
| Female | 27 (25) | 17 (24.29) | 10 (26.32) |
| Weight, kg | 3.4 (3–3.95) | 3.2 (3–3.5) | 3.85 (3.3–4.4) |
| Height, cm | 52 (47–58) | 50 (46–54) | 55.5 (51–60) |
| BSA | 0.22 (0.2–0.24) | 0.21 (0.2–0.22) | 0.24 (0.22–0.27) |
| Preoperative procedure | | | |
| None | 82 (76.64) | 50 (72.46) | 32 (84.21) |
| Balloon arterial septostomy | 20 (18.69) | 18 (26.09) | 2 (5.26) |
| PA banding | 2 (1.87) | 1 (1.45) | 1 (2.63) |

*BSA=body surface area; IQR=interquartile range; PA=pulmonary artery; D-TGA–IVS=D-transposition of the great arteries with intact interventricular septum; D-TGA–VSD=D-transposition of the great arteries with ventricular septal defect.*

**Table 2.** Preoperative Two-Dimensional Echocardiographic Parameters

| | Total | D-TGA–IVS (n = 70) | D-TGA–VSD (n = 38) |
|---|---|---|---|
| | Frequency (%), Mean ± SD, or Median (IQR) | | |
| Interatrial communication | | | |
| None | 19 (17.92) | 1 (0.47) | 18 (47.37) |
| PFO | 65 (61.32) | 49 (72.06) | 16 (42.11) |
| ASD | 9 (8.49) | 6 (8.82) | 3 (7.89) |
| BAS | 13 (12.26) | 12 (17.65) | 1 (2.63) |
| Presence of PDA | 79 (75.24) | 61 (91.04) | 18 (47.37) |
| Aortic arch anomalies | | | |
| None | 100 (95.24) | 66 (98.51) | 34 (89.47) |
| Coarctation of the aorta | 3 (2.86) | 0 | 3 (7.89) |
| Right-sided aortic arch | 2 (1.90) | 1 (1.49) | 1 (2.63) |
| RVOT obstruction | | | |
| None | 102 (97.14) | 66 (98.51) | 36 (94.74) |
| Mild | 2 (1.90) | 1 (1.49) | 1 (2.63) |
| Moderate | 1 (0.95) | 0 | 1 (2.63) |
| Pulmonary stenosis | 7 (6.67) | 3 (4.48) | 4 (10.53) |
| TV annulus, cm | 1.29 ± 0.30 | 1.26 ± 0.28 | 1.34 ± 0.32 |
| AV annulus, cm | 1.17 ± 0.29 | 1.11 ± 0.23 | 1.29 ± 0.34 |

*(continuation of Table 2)*

| | | | |
|---|---|---|---|
| PV annulus, cm | 1.13 ± 0.25 | 1.05 ± 0.22 | 1.27 ± 0.25 |
| A:P ratio | 1.06 ± 0.25 | 1.09 ± 0.25 | 1.02 ± 0.26 |
| LV geometry | | | |
| Type I | 23 (34.85) | 13 (29.55) | 10 (45.45) |
| Type II | 38 (57.58) | 27 (61.36) | 11 (50) |
| Type III | 5 (7.58) | 4 (9.09) | 1 (4.55) |
| LVEDD, cm | 2.0 ± 0.5 | 1.78 ± 0.4 | 2.38 ± 0.43 |
| LV size within normal | | | |
| Yes | 74 (70.48) | 52 (77.61) | 22 (57.89) |
| Small | 7 (6.67) | 6 (8.96) | 1 (2.63) |
| Enlarged | 24 (22.86) | 9 (13.43) | 15 (39.47) |
| LV mass, g | 16 (10–27.4) | 12.9 (9.3–19.7) | 27.4 (18.7–33) |
| LV mass index, g/m$^2$ | 71.6 (46–113) | 64.2 (42.4–81) | 106.45 (77.8–105) |
| LVEF, % | 79 (73–88) | 83 (75–90) | 77 (70–79) |
| RFAC, % | 54 (48–67) | 54 (47.5–66) | 54 (49–67) |
| mPAP, mm Hg | 70 (56–78) | 70 (58–78) | 67 (56–78) |
| Coronary artery anomaly | 12 (11.43) | 8 (11.76) | 4 (10.81) |
| Delayed sternal closure | 26 (24.3) | 19 (27.54) | 7 (18.42) |

*A:P, ; ASD=atrial septal defect; AV=aortic valve; BAS,=balloon atrial septostomy; D-TGA–IVS=D-transposition of the great arteries with intact interventricular septum; D-TGA–VSD=D-transposition of the great arteries with ventricular septal defect; IQR=interquartile range; LV=left ventricular; LVEDD=left ventricular end-diastolic diameter; LVEF=left ventricular ejection fraction; mPAP=mean pulmonary artery pressure; PDA=patent ductus arteriosus; PFO=patent foramen ovale; PV=pulmonary valve; RFAC=regional fractional area change; RVOT=right ventricular outflow tract; TV=tricuspid valve.*

Postoperative outcomes (Table 4) show that none of the patients underwent reoperation, and only one patient (1.9%) had reintervention after surgery. Of 81 patients with documented follow-up, 76 (93.8%) were alive. Only one patient (1.9%) was reported to be symptomatic on exertion, and the rest were asymptomatic with NYHA classification class I. This is the same patient who underwent reintervention 49 days after ASO for severe pulmonic valve stenosis. Initial gradient across the valve was 94 mm Hg, which decreased to 41 mm Hg postprocedure. The patient also underwent plication for eventration of the right hemidiaphragm. The patient was then successfully extubated and sent home 2 months after surgery. As of last follow-up, the patient was reported to have occasional episodes of dyspnea on exertion. On 2D echocardiogram, the patient has moderate neopulmonary stenosis with gradient of 54 mm Hg. There is also mild regurgitation at the neoaorta and the neopulmonary arteries and enlargement of the right ventricle. Patient has good biventricular function.

Overall survival function was 93.7% after 5 years (95% confidence interval, 0.81–0.98) and 79.4% after 9 years (95% confidence interval, 0.46–0.93) (Table 5). The survival function between the two groups did not vary significantly (Figure 2).

Among the 35 long-term post-ASO patients, 23 (66%) had an initial diagnosis of D-TGA–IVS whereas 12 (34%) had D-TGA–VSD. Two patients (6%) died postdischarge. One patient had D-TGA–IVS and was operated on at 13 days of life. He was discharged 12 days postoperatively. However, no further follow-up was done after discharge. He died 6 years after surgery, and the cause of death was undetermined. The second patient was operated on at 26 days of life and was discharged 18 days postoperatively. He was readmitted after 3 months because of difficulty in breathing and cyanosis. A 2D echocardiography showed a VSD leak measuring 0.4 cm, fair left ventricular function with LVEF of 50% with high normal LV size, and moderate mitral and tricuspid valve regurgitation with estimated pulmonary arterial pressure of 73 mm Hg. The patient eventually died with cause of death listed as severe pulmonary arterial hypertension.

Of the 73 midterm post-ASO patients, 47 (64%) had D-TGA–IVS, whereas 26 (36%) had D-TGA–VSD. Three patients (4.1%)

**Table 3.** Postoperative Two-Dimensional Echocardiography Parameters

| | Total | D-TGA–IVS | D-TGA–VSD |
|---|---|---|---|
| | Frequency (%), Mean ± SD, or Median (IQR) | | |
| Aortic arch anomalies | | | |
| None | 46 (88.46) | 35 (97.22) | 11 (68.75) |
| Coarctation of the aorta | 1 (1.92) | 0 | 1 (6.25) |
| Right-sided aortic arch | 2 (3.85) | 1 (2.78) | 1 (6.25) |
| Dilated sinus of Valsalva | 2 (3.85) | 0 | 2 (12.5) |
| LVOT obstruction | | | |
| None | 48 (92.31) | 34 (94.44) | 13 (87.5) |
| Mild | 3 (5.77) | 2 (5.56) | 1 (6.25) |
| Pulmonary stenosis | | | |
| None | 41 (78.84) | 28 (77.77) | 13 (81.25) |
| Mild | 10 (19.23) | 7 (19.44) | 3 (18.75) |
| Moderate | 1 (1.92) | 1 (2.77) | 0 |
| TV annulus, cm | 1.87 ± 0.41 | 1.76 ± 0.39 | 2.11 ± 0.37 |
| AV annulus, cm | 1.69 ± 0.32 | 1.59 ± 0.27 | 1.91 ± 0.33 |
| AVA Z score | 2.54 ± 1.21 | 2.27 ± 1.11 | 3.12 ± 1.24 |
| PV annulus, cm | 1.33 ± 0.32 | 1.28 ± 0.33 | 1.43 ± 0.30 |
| A:P ratio | 1.28 ± 0.42 | 1.29 ± 0.43 | 1.28 ± 0.41 |
| LVEDD, cm | 2.81 ± 0.75 | 2.62 ± 0.55 | 3.24 ± 0.94 |
| LV size within normal | | | |
| Yes | 37 (71.15) | 29 (80.56) | 8 (50) |
| Small | 2 (3.85) | 2 (5.56) | 0 |
| Enlarged | 13 (25) | 5 (13.89) | 8 (50) |
| LV mass, g | 37.4 (28.4 to 47.6) | 33.2 (24.4 to 39.7) | 52.32 (37.4 to 80.6) |
| LV mass index, g/m$^2$ | 68 (55.5 to 90.2) | 59.2 (48.4 to 78.1) | 90.17 (81.3 to 116) |
| LVEF, % | 70 (63 to 77.5) | 70.5 (63 to 79.5) | 69.5 (64.5 to 74.5) |
| RVEF, % | 52.5 (46 to 58) | 53 (46 to 59) | 52 (39 to 57) |
| mPAP, mm Hg | 20 (20 to 30) | 20 (20 to 29) | 20 (20 to 40) |
| Aortic regurgitation | | | |
| None | 28 (53.85) | 19 (52.78) | 9 (56.25) |
| Mild | 23 (44.23) | 17 (47.22) | 6 (37.5) |
| Moderate | 1 (1.92) | 0 | 1 (6.25) |
| Severe | 0 | 0 | 0 |

*(continuation of Table 3)*

| | | | |
|---|---|---|---|
| Pulmonic regurgitation | | | |
| None | 36 (69.23) | 29 (80.56) | 7 (43.75) |
| Mild | 14 (26.92) | 7 (19.44) | 7 (43.75) |
| Moderate | 2 (3.85) | 0 | 2 (12.5) |
| Severe | 0 | 0 | 0 |
| Tricuspid regurgitation | | | |
| None | 38 (73.08) | 29 (80.56) | 9 (56.25) |
| Mild | 13 (25) | 7 (19.44) | 6 (37.5) |
| Moderate | 0 | 0 | 0 |
| Severe | 1 (1.92) | 0 | 1 (6.25) |
| Mitral regurgitation | | | |
| None | 48 (92.31) | 35 (97.22) | 13 (81.25) |
| Mild | 4 (7.69) | 1 (2.78) | 3 (18.75) |
| Moderate | 0 | 0 | 0 |
| Severe | 0 | 0 | 0 |

*AV=aortic valve; D-TGA–IVS=D-transposition of the great arteries with intact interventricular septum; D-TGA–VSD=D-transposition of the great arteries with ventricular septal defect; IQR=interquartile range; LV=left ventricular; LVEDD=left ventricular end-diastolic diameter; LVEF=left ventricular ejection fraction; mPAP=mean pulmonary artery pressure; PV=pulmonary valve; RVEF=right ventricular ejection fraction; TV=tricuspid valve.*

**Table 4.** Postoperative Patient Outcomes

| | Total | D-TGA–IVS | D-TGA–VSD |
|---|---|---|---|
| Reoperation | 0 | 0 | 0 |
| Reintervention | 1 (0.94) | 1 (1.45) | 0 |
| Patient alive | 76 (70.37) | 53 (75.36) | 23 (62.16) |
| NYHA classification | | | |
| Class I | 75 (98.67) | 52 (98.08) | 23 (100) |
| Class II | 1 (1.33) | 1 (1.92) | 0 |
| Class III | 0 | 0 | 0 |
| Class IV | 0 | 0 | 0 |

*QR=interquartile range; D-TGA–IVS=D-transposition of the great arteries with intact interventricular septum; D-TGA–VSD=D-transposition of the great arteries with ventricular septal defect; NYHA=New York Heart Association.*

died postdischarge, all with an initial diagnosis of D-TGA–IVS. One patient was brought back 1 week after discharge in severe respiratory distress and was diagnosed to have severe pneumonia. The patient died shortly after admission with no repeat 2D echocardiography done. The other two patients were not brought to our institution, and causes of death were undetermined. One was operated on at 26 days of life and was discharged after 22 days. He died 1 month after discharge. Another was operated on at 42 days of life and was discharged 33 days postoperatively. This patient was admitted on the second day of life, but because of positive blood cultures, he needed to be treated for several weeks before clearance was given prior to surgery. Postoperatively, blood and urine cultures were positive for *Enterococcus faecalis*, which again necessitated treatment, hence the prolonged hospital stay. He died 3 months after discharge.

## DISCUSSION

In this study, immediate postoperative mortality rate was 26.7% (49/182). This has decreased from 49% over 20 years

**Table 5.** Survival Function of the Patients After Arterial Switch Operation

| Procedure | Time, y | Died | Survivor Function | 95% CI |
|---|---|---|---|---|
| D-TGA–IVS | 2.647 | 1 | 0.9783 | 0.86–0.99 |
| | 3.981 | 1 | 0.9467 | 0.80–0.98 |
| | 5.786 | 1 | 0.9016 | 0.71–0.97 |
| | 8.992 | 1 | 0.6011 | 0.08–0.90 |
| D-TGA–VSD | 6.479 | 1 | 0.9167 | 0.54–0.99 |
| Total | 2.647 | 1 | 0.9863 | 0.91–0.99 |
| | 3.981 | 1 | 0.9666 | 0.87–0.99 |
| | 5.786 | 1 | 0.9373 | 0.81–0.98 |
| | 6.479 | 1 | 0.9071 | 0.76–0.97 |
| | 8.992 | 1 | 0.7937 | 0.46–0.93 |

*CI=confidence interval; D-TGA–IVS=D-transposition of the great arteries with intact interventricular septum; D-TGA–VSD=D-transposition of the great arteries with ventricular septal defect; NYHA=New York Heart Association.*

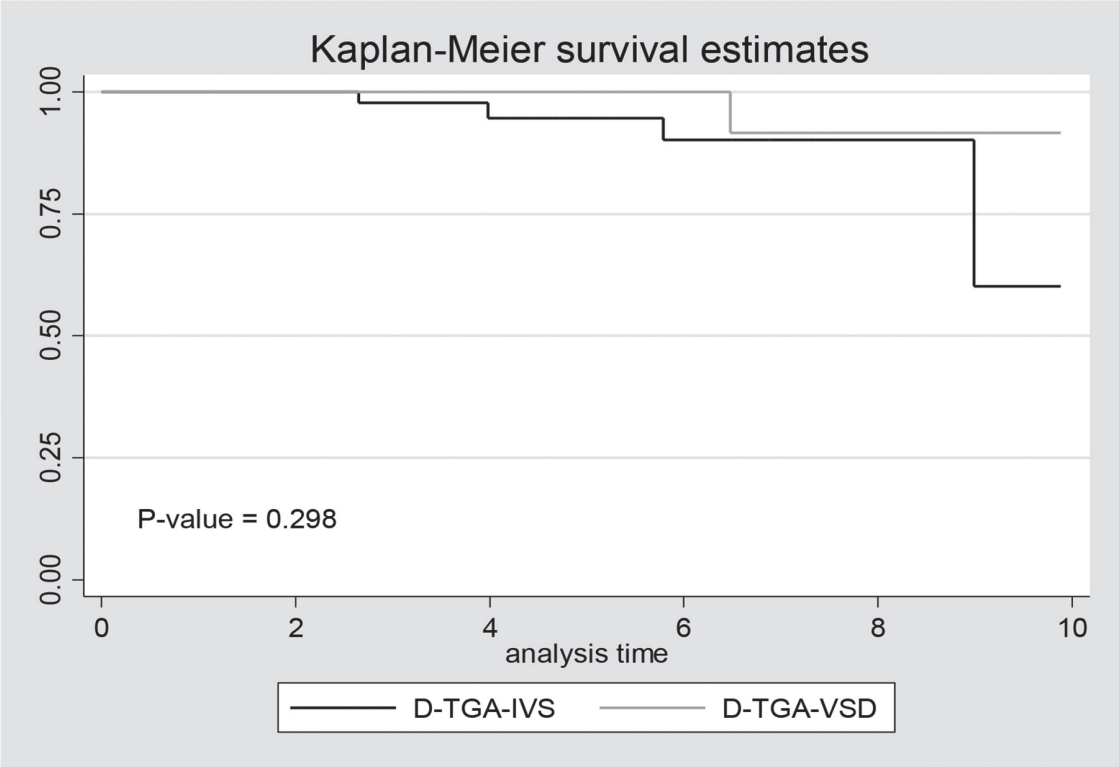


**Figure 2.** Kaplan-Meier survival curves showing overall survival after the arterial switch operation at 1, 5, and 10 years.

ago in this institution (1991–2002).[19] However, this is still high compared with other institutions where mortality rates are now between 1.7% and 12.7%.[20–25] Because of capacity limitations in the operating room and intensive care unit, as well as socioeconomic and geographic factors faced by patients who live in remote provinces, surgery in this institution is performed at a relatively later age compared with others, which may explain this outcome.

Among 108 patients included in the study, 25% (n = 27) were eventually lost to follow-up. Furthermore, only 62% (n = 47) of these remaining patients were able to have a recent 2D echocardiogram done in our institution. Patient attrition and lack of new diagnostics could be attributed to socioeconomic and geographic factors, which make it difficult for the patients to follow up in our institution. After surgery, these patients follow up with specialists in their own provinces to save on travel expenses.

Compared with patients with D-TGA–IVS (median age, 23 days), there was a tendency to operate later on patients with D-TGA–VSD (median age, 82.5 days). Patients with intact ventricular

septum tend to be prioritized over those with VSD under the assumption that the LV geometry of the former decompensates earlier without repair.

None of the patients underwent reoperation in this study. Reoperation for exploration of bleeding, closure of open chest, wound debridement, mechanical circulatory support, and pacemaker replacement were excluded to determine surgical complications directly associated with the patients' preexisting cardiac pathology and exclude outcomes related to the different surgeons' preferences and technique.

In this study, 11 patients (13.6%) developed pulmonary stenosis postoperatively. Pulmonary stenosis is the most frequent complication post-ASO with an incidence of 7% to 40%.[26] Risk is higher in patients with initially small right ventricular outflow tracts[15] and in those who underwent the procedure at an older age.[11] The exact pathophysiology is not well understood, but possible reasons include inadequate growth at the suture lines, the presence of ductal tissue causing narrowing of the left PA, and flow asymmetry after the Lecompte procedure.[20] The risk for stenosis is greatest in the first few years postprocedure and then decreases in time.

Pulmonary stenosis is also the most common reason for reintervention in this population.[4,13,15,26] The only patient who underwent reintervention in this study had severe pulmonary valve stenosis immediately after ASO. He underwent percutaneous pulmonary balloon valvuloplasty with residual gradient of 41 mm Hg. Latest echocardiogram shows moderate pulmonary valve stenosis with a gradient of 54 mm Hg. He is also the only patient who falls under NYHA class II, with reports of dyspnea on exertion. Patients with moderate PS and who are symptomatic have poor overall reoperation-free survival[20] and warrant close follow-up.

Aortic regurgitation was seen in 24 patients, with one graded as moderate and the remainder as mild. Similar results are seen in other studies, where mild AR is seen in up to 25.6% of patients.[8] Unlike PS, it shows a tendency to be progressive.[7,15] In a cohort study by van der Palen et al[27] done on 345 patients who underwent ASO between 1977 and 2015, the occurrence of AR increased long-term after ASO. They confirmed an association with AR in patients with VSD and those who underwent ASO at more than 6 months. The patient with moderate AR had D-TGA–VSD and was 2 years of age at time of surgery. Aortic valve annulus *Z* score was +5.2. These findings imply an increasing need for aortic root and/or valve surgery for this particular patient.

Two patients, both with D-TGA–VSD, were noted to have dilated sinus of Valsalva on postoperative echocardiogram. The neoaortic valve and sinus are larger than normal in post-ASO patients.[28] In the same study by van der Palen et al, findings showed a rapid increase in neoaortic sizes in the first year after ASO, after which the growth rates were comparable to normal from 2 to 18 years of age, but at higher *Z* score levels.[27] Presence of VSD and male sex were found to be independent risk factors for aortic root dilatation. Both patients had only mild aortic insufficiency and were asymptomatic, but they should be followed up closely to measure the aortic root and check for progression of aortic insufficiency.

Postoperatively, one patient was noted to have recoarctation. This patient had end-to-end anastomosis done along with ASO, but on latest echocardiogram, there was a gradient of 68 mm Hg at the descending aorta with a *Z* score of –3.5 at the narrowest segment. In a cohort study done on 715 patients by Michalak et al,[29] reintervention and reoperation were mostly related to pulmonic stenosis and recoarctation of the aorta. In another study, reintervention was significantly more frequent in patients with aortic arch obstruction.[30] Thus, closer monitoring of this subgroup of patients is also warranted.

Insufficiency of the neopulmonary valve is not as common post-ASO, with incidence between 4.3% and 6.6% for moderate PR.[2,5] The risk for PR increases with increasing age at surgery. Patients who developed moderate PR in this study had surgery at 3 months and 2 years of age, respectively, and both had a diagnosis of CHD-TGA-VSD.

All but one patient were asymptomatic and fell under NYHA class I with good biventricular function. These findings are similar to those of other studies[9,10,12] that report good ventricular function and clinical status in the majority of this population.

Overall mortality rate after discharge was 6.2% (5/81), which was higher compared with other studies with mortality between 0.9% and 2.2%.[1,4,13] Overall survival function at 5 years was 93.7%, which was similar to other studies.[20] However, survival after 9 years was at 79.4%, whereas other studies had figures between 88% and 98%.[1,12] Lower long-term survival rates seen in this study may be affected by the high rate of patient attrition over time and lack of patient follow-up as previously mentioned. To improve future outcomes, strategies should be implemented to promote continuity of care, and parents should be advised regarding the importance of follow-up.

## CONCLUSION

Arterial switch operation remains the procedure of choice for the treatment of D-TGA. However, there are complications following ASO, which necessitate continued long-term follow-up of patients. The postoperative complications seen in this study reflect those seen in literature, with the most common being PS, AR, and aortic dilatation.

The overall survival rate after 5 years in this population is similar to those of other studies. However, long-term survival rates were lower, which may be due to poor patient follow-up and a high rate of patient attrition over time. To improve future outcomes, strategies should be implemented to promote continuity of care, and parents should be advised regarding the importance of follow-up.

## REFERENCES


1. Reller MD, Strickland MJ, Riehle-Colarusso T, Mahle WT, Correa A. Prevalence of congenital heart defects in metropolitan Atlanta, 1998–2005. *J Pediatr* 2008;153:807.
2. Wernovsky G. Transposition of the great arteries. In: Allen HD, Shaddy RE, Driscoll DJ, Feltes TF, eds. *Moss and Adams' Heart Disease in Infants, Children and Adolescents: Including the Fetus and Young Adult*. 7th ed. Philadelphia, PA: Wolters Kluwer Health/Lipincott Williams & Wilkins; 2008:1039.
3. Jaggers J, Cameron DE, Herlong JR, Ungerleider RM. Congenital Heart Surgery Nomenclature and Database Project: transposition of the great arteries. *Ann Thorac Surg* 2000:69;5205.
4. Villalbaen C, Lafuente MV, Mouratian M, et al. Arterial switch operation: long term outcome. *Rev Argent Cardiol* 2016;84:418–425.
5. Fricke TA, d'Udekem Y, Richardson M, et al. Outcomes of arterial switch operation for transposition of the great arteries: 25 years of experience. *Ann Thorac Surg* 2012;94:139–145.
6. Shim M, Jun T, Yang J, et al. Current expectations of the arterial switch operation in a small volume center: a 20-year, single-center experience. *J Cardiothorac Surg* 2016;11:34–44.
7. Choi BS, Kwon BS, Kim GB, et al. Long term outcomes after an arterial switch operation for simple complete transposition of the great arteries. *Korean Circ J* 2010;40(1):23–30. doi: 10.4070/kcj.2010.40.1.23.
8. Losay J, Touchot A, Serraf A, et al. Late outcome after arterial switch operation for transposition of the great arteries. *Circulation* 2001;104:I-121–126.
9. Xiao, Y. Early and mid-term follow up of patients receiving arterial switch operation: a single center experience. *J Thorac Dis* 2018:10(2);732–739.
10. Grotenhuis HB, Cifra B, Mertens LL, et al. Left ventricular remodelling in long-term survivors after the arterial switch operation for transposition of the great arteries. *Eur Heart J* 2019;20:101–107.
11. Vargo P, Mavroudis C, Stewart RD, Backer CL. Late complications following the arterial switch operation. *World J Pediatr Congenit Heart Surg* 2011;2:37–42.
12. Legendre A, Losay J, Touchot-Kone A, et al. Coronary events after arterial switch operation for transposition of the great arteries. *Circulation* 2003;108 suppl 1:II186–II190.
13. Khairy P, Clair M, Fernandes SM, et al. Cardiovascular outcomes after the arterial switch operation for D-transposition of the great arteries. *Circulation* 2013;127:331–339.
14. Fricke TA, Bulstra AE, Naimo PS, et al. Excellent long-term outcomes of the arterial switch operation in patients with intramural coronary arteries. *Ann Thorac Surg* 2016;101:725–729.
15. Scognamiglio G, Li W. Arterial switch operation for transposition of great arteries: late results in adult patients. Medicine 2013. doi: 10.17987/icfj.v1i1.13.
16. Co-Vu JG, Ginde S, Bartz PJ, Frommelt PC, Tweddell JS, Earing MG. Long term outcomes of the neoaorta after arterial switch operation for transposition of the great arteries. *Ann Thorac Surg* 2013:95;1654–1659.
17. Martinez MS, Balderas JJ, Cases LSR, Lopez WL. Intermediate term survival and functional results of patients after arterial switch operation. Philippine Heart Center. 2000.
18. Peacock JL, Peacock PJ. Research design. In: *Oxford Handbook of Medical Statistics*. New York: Oxford University Press; 2011:60–61.
19. Hernandez RFR, Nuevo J, Cantre T, Casas MLS. Prognostic scoring index to predict outcome of arterial switch operation in Filipino children. *Phil Heart Ctr J.* 2003;10:50–60.
20. Prifti E, Crucean A, Bonacchi M, et al. Early and long term outcome of the arterial switch operation for transposition of the great arteries: predictors and functional evaluation. *Eur J Cardiothorac Surg* 2002;22(6):864–873.
21. Villafañe J, Lantin-Hermoso MR, Bhatt AB, et al. D-Transposition of the great arteries: hot topics in the current era of the arterial switch operation. *J Am Coll Cardiol* 2014;64(5):498–511.
22. Lalezari S, Bruggemans EF, Blom NA, Hazekamp MG. Thirty-year experience with the arterial switch operation. *Ann Thorac Surg* 2011;92:973–979.
23. Feng B, Yinglong L, Hu S, et al. Arterial switch for transposition of the great vessels and Taussig-Bing anomaly after six months of age. *Ann Thorac Surg* 2009;88:1948–1951.
24. Sarris GE, Chatzis AC, Giannopoulos NM, et al. The arterial switch operation in Europe for transposition of the great arteries: a multi-institutional study form the European Congenital Heart Surgeons Association. *J Thorac Cardivasc Surg* 2006;132:633–639.
25. Duncan BW, Poirier NC, Mee RBB, et al. Selective timing of the arterial switch operation. *Ann Thorac Surg* 2004;77:1691–1697.
26. Delmo Walter EM, Miera O, Nasseri B, et al. Onset of pulmonary stenosis after arterial switch operation for transposition of great arteries with intact ventricular septum. *HSR Proc Intensive Care Cardiovasc Anesth* 2011;3(3):177–187.
27. van der Palen RL, van der Bom T, Dekker A, et al. Progression of aortic dilatation and aortic valve regurgitation after the arterial switch operation. *Heart* 2019;105:1732–1740.
28. Hutter PA, Thomeer BJM, Jansen P, et al. Fate of the aortic root after arterial switch operation. *Eur J Cardiothorac Surg* 2001;20:82–88.
29. Michalak KW, Moll JA, Sobczak-Budlewska K, et al. Reoperations and catheter interventions in patients with transposition of the great arteries after arterial switch operation. *Eur J Cardiothor Surg* 2017;51:34–42.
30. Fricke TA, Donaldson S, Schneider JR, et al. Outcomes of the arterial switch operation in patients with aortic arch obstruction. *J Thorac Cardiovasc Surg* 2020;159(2):592–599.