Late Presenters with Dextro-transposition of Great Arteries and Intact Ventricular Septum: To Train or Not to Train the Left Ventricle for Arterial Switch Operation?

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ABSTRACT

Objective. We report our experience in managing late presenters (older than 4 weeks) with dextro-transposition of great arteries and intact ventricular septum (d-TGA/IVS) in an effort to achieve successful arterial switch operation (ASO) in a third world setting.

Design. We retrospectively reviewed the charts of all late presenters with d-TGA/IVS. Patients were divided into two groups: left ventricular training (LVT) group and non-left ventricular training (non-LVT) group. LVT group underwent pulmonary artery banding and Blalock-Taussig Shunt prior to ASO.

Results. Twenty-one late presenters were included in the study. In LVT group, 11 patients with median age of 6 months (range, 1–72 months) underwent LVT. Later, 8 patients with median age of 9.25 months (range, 1.33–84 months) underwent ASO. Prior to ASO, left ventricle (LV) collapse resolved in all and left ventricle to systemic pressure (LV/SP) ratio was 0.81 (range, 0.76–0.95) in 4 patients. Two patients who had LVT for ≤14 days required postoperative extracorporeal membrane oxygenation (ECMO) support due to LV dysfunction. Seven patients survived to discharge. In non-LVT group, 10 patients with median age of 2.5 months (range, 1–98 months) underwent ASO. Five patients had LV collapse, and median LV/SP ratio was 0.67 (range, 0.56–1.19) in 5 patients. Seven patients needed ECMO support. Seven patients survived to discharge.

Conclusion. Late presenters with d-TGA/IVS, who have LV collapse on echocardiography and/or a LV/SP ratio <0.67 on cardiac catheterization, should be subjected to LVT preferably for duration of longer than 14 days in order to avoid potential ECMO use.

Key Words. Heart Defects; Congenital; Surgery; Transposition of Great Vessels; Ventricles

The arterial switch operation (ASO) remains the preferred surgery for patients with dextro-transposition of great arteries and intact ventricular septum (d-TGA/IVS). It is preferably performed in the first 2 weeks of life while the left ventricle (LV) is still trained to support systemic circulation. In comparison to other corrective surgical options for d-TGA/IVS, ASO has the advantages of maintenance of sinus node function, preservation of the LV as the systemic ventricle and the mitral valve as the systemic atrioventricular valve. Patients with d-TGA/IVS who present beyond the neonatal period have a significant decline in the LV muscle mass (untrained LV) because of the low pressure of the pulmonary circulation against which the LV is pumping, and hence the LV is no longer suitable to handle the high pressure systemic circulation after ASO. It has been reported that the ability of the LV after 2 weeks of age to support the systemic circulation depends on the patency of the ductus arteriosus, the pulmonary vascular resistance, the size of the...
atrial septal defect (ASD), and the presence of left ventricular outflow tract obstruction (LVOTO).³

In order to prepare the LV for ASO, several studies proposed left ventricular training (LVT) with pulmonary artery banding (PAB) to increase the left ventricular after-load, and a systemic to pulmonary artery shunt to improve oxygenation and volume load the LV.³−⁷ Though this concept of LVT has undergone some evolution and was adopted by many centers, the duration of LVT was not standardized. Moreover, no stringent criteria were designed to indicate the optimal preparation of LV for the ASO.

Our institution is located in a region where a significant number of late presenters with different congenital heart diseases are referred. In this study, we report our experience in managing late presenters with d-TGA/IVS in an endeavor to achieve successful ASO.

**Methods**

We retrospectively reviewed the charts of all patients with d-TGA/IVS who were referred to our institution between April 2001 and November 2006. Late presenters with dextro-transposition of great arteries with or without tiny hemodynamically insignificant restrictive ventricular septal defect were included in this review as d-TGA/IVS. We defined late presenters as patients with d-TGA/IVS who were older than 4 weeks at the time of the first surgical intervention. Institutional Review Board approval was obtained for this retrospective study.

The decision to train LV or not prior to ASO was based largely on the presence of LV collapse on echocardiography and left ventricle to systemic pressure (LV/SP) ratio of less than 2/3 (0.67) by cardiac catheterization; however, this ratio was not rigorously followed as not all the patients were fully studied by cardiac catheterization due to various clinical and financial reasons. The LV/SP ratio was never reported previously as a strict value; however, our group adopted a ratio of 2/3 (0.67) in most of our study cases to decide if LV training was required.

**Echocardiography**

Subjects underwent two-dimensional and Doppler echocardiographic examinations by the use of an HP Sonos 5500 ultrasound system (Agilent Technologies, Andover, MA, USA) and a variety of transducers appropriate for body size. Studies were performed on all patients at the time of admission to establish the diagnosis with focus on the presence of ASD, patent ductus arteriosus (PDA), left ventricular outflow tract, LV collapse, dilatation of the right ventricle (RV), and other associated congenital heart anomalies. Left ventricular collapse was identified when the ventricular septum was deviated towards the lateral wall of the LV in apical 4 chambers view or when there was a D-shaped LV in the parasternal short axis view. Follow-up echocardiographic studies were performed after LVT just prior to discharge from the hospital, and before ASO to evaluate the PAB gradient in the LVT group. Left ventricular mass indices were not included in this study due to significant interoperator variability.

**Cardiac Catheterization**

Cardiac catheterization data before LVT and before ASO were collected including LV and systemic or aortic pressures. The pressure readings were expressed as LV/SP ratio. Cardiac catheterization was not performed when the financial coverage was insufficient, and when the treating physicians believed echocardiography provided adequate and relevant data. Sixteen cardiac catheterizations were performed; 12 patients had their cardiac catheterization studies done before any surgical interventions, and 4 patients after LVT.

**Surgical Procedure**

In general, the operative technique and anesthesia protocol were similar in all cases. Using Teflon tape material, PAB was performed through median sternotomy with the aim to achieve an intraoperative LV pressure (measured by direct manometry and expressed as percentage) ≥0.67 of the systemic pressure, and polytetrafluoroethylene (Gore-Tex; W.L. Gore & Associates, Flagstaff, AZ, USA) tube was constructed as a Blalock-Taussig Shunt (BTS) between the innominate artery and pulmonary artery. Established intraoperative LV pressure percentage of the systemic pressure and the size of BTS tube were documented. Chest was left open in case of LV dysfunction or potential band adjustment, and delayed chest closure was performed. ASO was done using cardioplegic arrest and moderately hypothermic cardiopulmonary bypass. Great arteries were switched with Lecompte maneuver, ASDs were closed, and coronaries were re-implanted using buttonhole or trapdoor techniques. Associated repair was done for aortic coarctation, total anomalous pulmonary venous drainage (TAPVD), and the resection of LVOTO was performed when necessary. Extracor-
poreal membrane oxygenation (ECMO) support was utilized for LV dysfunction after ASO when indicated. Postoperative intensive care unit (ICU) stay and surgical length of stay in the hospital (LOS) were documented.

Study Groups
The patients were divided according to the discretion of the treating physicians into two groups: LVT group (11 patients) and non-LVT group (10 patients). The presence of LV collapse, unrestrictive ASD with or without LV/SP ratio <0.67 were the persuasive signs to pursue LVT for the presumably untrained LV. In the LVT group, cardiac catheterization was performed in 7 patients before PAB and BTS, and in 4 out of 8 patients before ASO. In the non-LVT group, 5 patients had cardiac catheterization before ASO. In this study, all data values are expressed as numbers, percentages, medians, and ranges. Comparison between the 2 groups (LVT and non-LVT) was done by using paired \( t \)-test as well as repeated-measures ANOVA, to evaluate the association with the following clinical parameters at the time of ASO: age, weight, LV collapse and LV/SP ratio pre-ASO, post-ASO ECMO use, ICU stay, LOS, and mortality. A \( P \) value of less than 0.05 was accepted statistically significant. Statistical analysis was performed using software (SPSS version 12; SPSS; Chicago, IL, USA).

Results
From April 2001 to November 2006, 21 patients with d-TGA/IVS were referred to our institute for surgical intervention at an age older than 4 weeks. The patients’ characteristics and their relevant clinical and investigational data are presented in Tables 1 and 2 for the LVT and non-LVT groups, respectively. The median age was 5 months (range, 1–98 months) and median weight was 4.7 kg (range, 2.5–19 kg). Seven patients were 6 months of age or older, and 3 patients were older than 12 months. Thirteen patients were males. The median oxygen saturation was 70% with a range of 35% to 85%. Seventeen patients had previous balloon atrial septostomy and 1 patient (#7) underwent surgical atrial septectomy (Table 1). Three patients (#14, #15 and #17) presented to us without septostomy and had adequate oxygen saturations (Table 2). Reasons for delayed referral included: socioeconomic, lack of access to tertiary care facility, neonatal tetanus, and sepsis.

The initial echocardiographic findings showed nonrestrictive ASD and good ventricular function in all patients. Fifteen patients had LV collapse. Seven patients had PDA, 3 patients had LVOTO (one was functional caused by RV dilatation, and 2 were anatomically related to subpulmonary ridge), 2 patients had coarctation of aorta, and 1 patient had a TAPVD.

LVT Group
Eleven patients underwent LVT with PAB and BTS (Table 1). The median age was 6 months (range, 1–72 months) and the median weight was 5.4 kg (range, 2.8–17.2 kg). Two patients were over 12 months of age (42 months and 72 months). The median \( \text{SpO}_2 \) was 63% with a range of 35% to 79%. Echocardiographic assessment showed 3 patients with PDA, but LV collapse and good ventricular function were present in all patients. In 7 patients, the median LV/SP ratio obtained by cardiac catheterization was 0.48 (range, 0.31–0.72).

The most commonly used BTS size was 5 mm (range, 4–6 mm) and the median intraoperative established LV pressure measured by direct manometry was 67% of systemic pressure (range, 55–114%). Five patients had an open chest for a median duration of 2 days (range, 1–2 days) due to LV dysfunction and potential PAB adjustment. One patient (#3) needed tightening of the PAB and 1 patient (#4) needed shunt revision because of thrombosis. The median ICU stay was 5 days (range, 0.5–13 days). One patient (#1) died immediately after LVT. He had an additional coarctation that was repaired 1 week prior to LVT, but he developed acute myocardial dysfunction few hours post-LVT and died presumably due to underestimated residual coarctation and acute ventricular strain. The median PAB gradient prior to discharge from the hospital was 45 mm Hg with a range of 25 to 65 mm Hg. Two patients in this group were lost to follow-up.

Eight patients in this group underwent ASO after LV training. The median age and weight at the time of ASO were 9.25 months (range, 1.33–84 months) and 7.1 kg (range, 2.8–19.2 kg), respectively. The median duration of LV training until ASO was 24.5 days (range, 11–361 days). Prior to ASO, the median PAB gradient was 65 mm Hg (range, 35–99 mm Hg) with resolution of LV collapse in all patients by echocardiographic assessment. Cardiac catheterization was performed in 4 cases and showed median LV/SP ratio 0.81 with range of 0.76 to 0.95. Postoperatively, the median ICU stay was 4.5 days (range, 0.5–35 days).
### Table 1. LVT Group Data

<table>
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<tr>
<th>No</th>
<th>Sex</th>
<th>Age (mo)</th>
<th>Wt (kg)</th>
<th>SpO₂ %</th>
<th>Add Diagnosis</th>
<th>PDA</th>
<th>LV Collapse</th>
<th>Intraop LV/SP Ratio</th>
<th>Open Chest</th>
<th>ICU Stay (day)</th>
<th>PAB Gradient (mm Hg)</th>
<th>LVT Duration (day)</th>
<th>Age (mo)</th>
<th>WT (kg)</th>
<th>ECMO</th>
<th>LOS (day)</th>
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</tr>
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<td>30</td>
<td>13</td>
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<td>72</td>
<td>17.2</td>
<td>79</td>
<td>LVOTO (dilated RV)</td>
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<td>0.72</td>
<td>65</td>
<td>No</td>
<td>1</td>
<td>61</td>
<td>361</td>
<td>84</td>
<td>19.2</td>
<td>53</td>
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</tr>
<tr>
<td>11</td>
<td>M</td>
<td>6</td>
<td>4.5</td>
<td>40</td>
<td></td>
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<td>0.4</td>
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<td>10</td>
<td>64</td>
<td>Lost to F/U</td>
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LVT, left ventricular training; Echo, echocardiography; Cath, cardiac catheterization; ASO, arterial switch operation; WT, weight; SpO₂ %, Oxygen saturation; Add, additional; PDA, patent ductus arteriosus; LV, left ventricle; LV/SP, left ventricular to systemic pressure; Intraop, intraoperative; ICU, intensive care unit; PAB, pulmonary artery band gradient; ECMO, extracorporeal membrane oxygenation; LOS, surgical length of stay in the hospital; CoA, coarctation of aorta; ND, not done; F/U, follow-up; CA, coronary arteries; LVOTO, left ventricular outflow tract obstruction; RV, right ventricle.
Patients #3 and #9 needed prolonged ventilation for respiratory reasons with the latter finally needing a tracheostomy. Two patients (#3 and #8), who had LV training for ≤14 days, required ECMO support for LV dysfunction during the immediate postoperative period. Patient #3 developed severe pulmonary congestion and LV failure in ICU and was put emergently on ECMO support and survived to discharge. Patient #8 had an intramural coronary and died on ECMO support from myocardial ischemia and ventricular dysfunction. Seven patients (88%) in this group survived to discharge from the hospital.

Non-LVT Group

Ten patients underwent ASO without LV training. The median age and weight were 2.5 months (range, 1–98 months) and 3.6 kg (range, 2.5–19 kg), respectively. The median and range of SpO₂ were 72% and 40–85%, respectively. Echocardiography showed LV collapse in 5, LVOTO in 2, PDA in 4, and good ventricular function in all patients. Cardiac catheterization was performed in 5 patients and showed median LV/SP ratio of 0.67 and a range of 0.56 to 1.19. At the time of ASO, 2 patients had resection of LVOTO, and 1 had repair of aortic coarctation and TAPVD. The median ICU stay was 6 days with a range of 0.5 to 40 days. Seven patients (70%) survived to discharge from the hospital.

In this group, ECMO support was required in 7 patients due to postoperative poor LV function. Four patients survived the successful ECMO weaning to discharge. Patient #13 had LV collapse and LV/SP ratio of 0.67 and was considered for LV training, but due to significant RV dysfunction, it was decided to proceed with ASO. Patient #15 with LV collapse and LV/SP ratio of 0.56 was planned to have LV training but for an unclear reason, probably the presence of subpulmonary ridge, the surgeon decided to proceed with ASO intraoperatively. Patient #21 did not have cardiac catheterization before ASO. She had LV collapse but good function and the decision was taken not to train LV. Patient #17 with LV/SP ratio of 0.67 but no LV collapse could not be weaned off bypass, and, needed ECMO support because mitral regurgitation with severe pulmonary congestion and could not be weaned from bypass. Mitral valve was replaced and he was successfully taken off ECMO after 12 hours in spite of significant bleeding.

Three patients died while on ECMO support. Patient #12 had LV/SP ratio of 1.19 and no LV collapse; however, pulmonary hypertension was
believed to be the major contributor to poor outcome. Patients #19 and #20 did not have cardiac catheterization before ASO; however, their ECMO support requirement was primarily due to LV dysfunction.

Overall, 17 patients underwent ASO, 8 in the LVT group, and 9 in the non-LVT group (Table 3). Predictably, the age and weight ranges were higher in the LVT group. However, ICU stay and LOS post-ASO were trivially dissimilar. Two patients from the LVT group and 7 from the non-LVT group needed ECMO support. There were 3 deaths in the non-LVT group and 1 in the LVT, and all deaths happened while patients were on ECMO support. Statistical analysis showed no significant difference between the 2 groups (LVT and non-LVT) at the time of ASO with respect to age, weight, LV/SP ratio pre-LVT, ICU stay, LOS, and mortality (Table 3). The use of ECMO support post-ASO was evidently higher among the non-LVT group but it was not statistically significant \( (P = .063) \). However, there was a statistical significant difference \( (P = .017) \) for the echocardiographic disappearance of LV collapse pre-ASO between the 2 groups.

### Discussion

The ASO is the treatment of choice for d-TGA/IVS because it restores near normal anatomy.\(^1,8\) In developed countries, there might be reasons like prematurity, sepsis or other major associated non-cardiac conditions that will cause delay in immediate correction. Unfortunately, in developing countries, late presentation of d-TGA/IVS is not rare, and LVT will always be a surgical option in preparation for ASO. Moreover, the referring centers for late presenters do not have the facility for electrophysiology, interventional laboratory setup, or heart transplantation to handle the well-known long-term complications of the atrial switch operation, and hence, ASO was favored.

The indication for LVT in late presenters has evolved, as ASO has become the accepted treatment for d-TGA/IVS. Criteria for the need for training varied amongst institutions and included age, echocardiographic findings (shape of the ventricular septum, shape of the LV, LV mass and volume, LV diameter, wall thickness, LV mass index, RV/LV wall thickness ratio, LV wall stress), and cardiac catheterization findings.\(^3,7,9,11\) Lacour-Gayet et al.\(^3\) used an age older than 3 weeks, a banana-shaped LV and LV mass index of less than 35 \( \text{g/m}^2 \) as indications for LVT. Nakazawa et al.\(^10\) trained all patients who presented at 2 to 3 months of age.

Both volume overload (provided by BTS or PDA) and pressure after-load (induced by PAB) are required for the LV training. This will reflect on the LV cavity and wall thickness (hypertrophy). Once PAB with or without BTS was performed, various echocardiographic and cardiac catheterization parameters were monitored to assess the preparedness of the LV after training. Corno et al.\(^11\) accepted a reversal of the RV/LV wall thickness ratio from 1.33 ± 0.26 to 0.79 ± 0.08, provided that this was concommitant with an increase in LV diameter and volume. Wernovsky et al.\(^7\) found that LV mass index increased from 46 ± 17 \( \text{g/m}^2 \) to 72 ± 23 \( \text{g/m}^2 \) and that the LV to RV pressure ratio on catheterization increased from 48 ± 8 to 98 ± 19. Jonas et al.\(^6\) found that the LV/RV pressure ratio increased from 0.5 ± 0.08 to 1.04 ± 0.29 on cardiac catheterization. They also found an increase in the LV mass and LV volume, and mass to volume ratio on echocardiography after BTS

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**Table 3. Results of ASO in Both Groups**

<table>
<thead>
<tr>
<th></th>
<th>LVT</th>
<th>Non-LVT</th>
<th>( P ) Value</th>
</tr>
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<tbody>
<tr>
<td>Patients n</td>
<td>n = 8</td>
<td>n = 10</td>
<td></td>
</tr>
<tr>
<td>Age (mo)</td>
<td>9.25 mo (1.33–84)</td>
<td>2.25 mo (1–98)</td>
<td>0.539</td>
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<tr>
<td>Weight (kg)</td>
<td>7.1 kg (2.8–19.2)</td>
<td>3.6 kg (2.5–19)</td>
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<td>LV collapse prior to ASO</td>
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<tr>
<td>LV/SP ratio(_1)</td>
<td>0.48 (0.31–0.72) n = 7</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>LV/SP ratio(_2)</td>
<td>0.81 (0.76–0.95) n = 4</td>
<td>0.67 (0.56–1.19) n = 5</td>
<td>0.573</td>
</tr>
<tr>
<td>Duration of LVT (days)</td>
<td>24.5 days (11–361)</td>
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<tr>
<td>ECMO n</td>
<td>n = 2</td>
<td>n = 7</td>
<td>0.063</td>
</tr>
<tr>
<td>ICU stay</td>
<td>4.5 days (0.5–35 days)</td>
<td>6 days (0.5–40)</td>
<td>0.901</td>
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<tr>
<td>LOS</td>
<td>8.5 days (0.5–54 days)</td>
<td>12.5 days (0.5–57)</td>
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<tr>
<td>Mortality</td>
<td>n = 1</td>
<td>n = 3</td>
<td>0.405</td>
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Data are expressed as median (range).

ASO, arterial switch operation; N, number; LVT, left ventricular training; Non-LVT, no left ventricular training; LV, left ventricle; LV/SP ratio\(_1\), left ventricular to systemic pressure ratio pre-LVT; LV/SP ratio\(_2\), left ventricular to systemic pressure ratio pre-ASO; ECMO extracorporeal membrane oxygenation; ICU intensive care unit at ASO time; LOS, surgical length of stay in the hospital; N/A, not applicable.
and PAB. Nakazawa et al.10 proposed that the LV was prepared when the following criteria were met: LV/RV pressure ratio >0.85, left ventricular end-diastolic volume >90% of normal, LV EF >0.5, and end-diastolic LV posterior wall thickness >4 mm.

Getting the correct band tightness to achieve a balance between adequate after-load for LV training and preventing LV dysfunction after ASO was a commonly reported problem. Ilbawi et al.5 showed that too tight PAB should be avoided. They suggested that a loose band with LV/RV pressure ratio of 0.5 to 0.7 is preferable to a tight band. Lacour-Gayet et al.4 found that a PAB with LV/RV ratio of 65% prevented LV dysfunction. The need for adjusting band tightness was reported by Corno et al.17 and Lacour-Gayet et al.4

When the LV training became an acceptable practice, various investigators worked towards shortening the duration of training. The initial studies advocated months of training and this was progressively shortened to weeks then to days then to intraoperative assessment of the ability of the ventricle to sustain systemic circulation.3–7,9–11 Dabritz et al.9 found that a trial of intraoperative PAB was a reliable indicator as to whether an ASO would be tolerated or not. They found that patients would tolerate ASO by applying PAB for 15 to 30 minutes and achieving a pulmonary to systemic pressure ratio of more than 0.85 without the patient developing failure. Others have argued against the need for LV training even in the presence of LV collapse and advocated doing primary repair up to 6 months of age.12,13

ECMO has been advocated as a means to train the LV with the advantage of being done in the presence of normal oxygen saturations and the ability to control the volume loading of the LV.13,14 Unfortunately, ECMO is highly technical and labor intensive that it puts a strain on staff, laboratory, blood bank, and hospital finance, and is not readily available in most third world situations. The untrained LV may fail after primary ASO and demands weaning off ECMO over several days that ultimately prolongs ICU stay and LOS, and increases the total costs.

In this review, division of the late presenters into 2 groups (LVT and non-LVT) was mainly based on the implemented clinical course for each case. Patients were streamlined into LVT or non-LVT according to the discretion of the treating medical team at the time of admission. However, PAB and BTS were uniformly performed on all in the LVT group. Echocardiography and cardiac catheterization were the only available modalities for diagnostic assessment, and the presence of LV collapse, unrestrictive ASD with or without LV/SP ratio <0.67 were the persuasive signs to pursue LVT for the presumably untrained LV. The LV/SP ratio was never reported previously as a strict value; however, our group felt that a ratio of 2/3 (0.67) is an acceptable and practical one to use. This ratio was adopted in most of our study cases to decide if LV training was not required (Table 2).

In spite of the presence of PDA in 33% of our series, we consider that LV volume load with BTS is complementary to the pressure load accomplished by PAB. In our review, 5 of the 11 patients (LVT group) were left with open chests at the time of LVT for potential PAB adjustment. Only 1 patient (3) needed tightening of the band. We believe that LV pressure ≥0.67 (2/3) of systemic pressure by direct manometry was adequate for training, and if this was achieved at the time of PAB, there is no need for delayed chest closure. Intraoperative PAB gradient measurement was not obtained or considered as a part of assessment due to the presence of BTS flow which will augment the pulmonary artery pressure, the expected postoperative LV dysfunction, and the possibility of pulmonary hypertension. Furthermore, there was no direct proportional relation between intraoperative LV/SP ratio and PAB gradient obtained by echocardiography prior to hospital discharge.

Most of our LVT patients had LV collapse without LVOTO and with median LV/SP ratio of 0.53 on cardiac catheterization. From our experience with patients #13, #15, and #19–21, we believe that obtaining a documentation of an increased LV/SP ratio by cardiac catheterization is a reliable measure for the decision to consider LV preparedness. Moreover, the resolution of LV collapse and maintenance of good function together with documentation by cardiac catheterization of an increased LV/SP ratio above 0.67 after LVT were suitable indicators for adequate LVT to sustain systemic circulation after ASO.

Though the outcome of this review supports the need for LVT in the presence of the LV collapse and an LV/SP ratio of less than 0.67, an LV/SP ratio of greater than 1 before ASO may reflect a sign of pulmonary hypertension. This was observed in 1 patient (#12) who had LV/SP ratio of 1.19 and did poorly after ASO. In retrospect, perhaps an atrial switch operation would have been a better option in this case as the LV is better suited to tolerate the pressure load of pulmonary
hypertension. Similarly, despite our disfavor, the atrial switch operation could have been also considered for the complex intramural coronary anatomy that was experienced with patient #8.

In our series, the period of training had a wide range, which covered almost the entire spectrum presented in the literature. The median duration of training was 24.5 days; 4 patients being trained for longer than 1 month. Two patients (#3 and #8) who had LVT for \( \leq 14 \) days needed ECMO support after ASO. Both patients would probably have benefited from a longer duration of LVT. In regard to ECMO use, LOS and survival, the postoperative course of patients (#4, #6, and #10) who had longer LVT (more than 3 months) was much better compared with those who had shorter duration of training. Thus, the duration of the LVT is considered more important in assessing LV preparedness for ASO.

Unfortunately, ECMO is a highly demanding cardiopulmonary support modality, and is not readily available in most third world institutions. The untrained LV needs to be weaned off ECMO over several days and that eventually prolongs hospital stay and increases the expenses. Our need for ECMO support (50%) was higher than what was quoted in the literature, and we believe it was a major postoperative morbidity in our series. In this review, 9 patients (7 of the non-LVT group and 2 from the LVT group) needed ECMO support after ASO, and only 5 of them survived successful ECMO weaning. The demand for ECMO support for postoperative LV dysfunction among non-LVT group (70%) was higher compared with LVT group (25%), and thus we believe the application of LVT in late presenter with d-TGA/IVS will minimize the likelihood use of ECMO support after ASO.

In conclusion, this study supports the notion of considering ASO for patients with d-TGA/IVS in order to maintain LV as the systemic ventricle. In a similar developing country environment, late presenters with d-TGA/IVS, who have LV collapse associated with unrestrictive ASD on echocardiography and/or a LV/SP ratio of less than 0.67 (2/3) on cardiac catheterization, should be subjected to LVT preferably for duration of longer than 14 days. Adequate LVT using PAB and BTS may obviate the need for mechanical support after ASO; however, if the duration of LVT is less than 14 days, the use of ECMO support may be warranted. A combination of relevant echocardiographic and cardiac catheterization data will give the necessary information to guide the management of late presenter with d-TGA/IVS. These findings should be further verified in a larger multicenter prospective study with a long-term follow-up.

Limitations of the Study
This study is limited by the fact that it was retrospective in nature with small patient numbers. Not all the patients had cardiac catheterizations. Cardiac MRI would have helped in providing more refined data in particular concerning ventricular mass to steer the decision-making process.

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