Outcomes After Anatomic Repair for D-Transposition of the Great Arteries With Left Ventricular Outflow Tract Obstruction

Sitaram M. Emani, MD; Rebecca Beroukhim, MD; David Zurakowski, PhD; Frank A. Pigula, MD; John E. Mayer, MD; Pedro J. del Nido, MD; Tal Geva, MD; Emile A. Bacha, MD

Background—D-transposition of the great arteries (TGA) with left ventricular outflow tract obstruction (LVOTO) may be treated with arterial switch operation (ASO) with or without LVOT intervention, as well as non-ASO anatomic repairs, such as aortic translocation or Rastelli procedure. We evaluated midterm results of repair for TGA/LVOTO at our institution.

Methods and Results—Eighty-eight patients with TGA/LVOTO who underwent anatomic repair were retrospectively reviewed. LVOTO was defined as pulmonary valve (PV) z-score ≤−2.0 or LVOT gradient ≥20 mm Hg in the presence of anatomic subvalvar stenosis. Risk factors for LVOT reintervention were determined by logistic regression. There was no hospital mortality and 1 late mortality. Patients undergoing Rastelli procedure were more likely to require surgical reintervention for LVOTO compared to the other groups (P=0.015). Patients undergoing ASO alone had a higher rate of late LVOT reintervention compared to those who had concomitant ASO/LVOT intervention (P=NS). In those undergoing Rastelli, a larger PV z-score was a predictor of LVOT reintervention (P=0.012). PV z-scores significantly decreased before repair in patients undergoing delayed repair (P=0.005); however, they increased significantly after neonatal ASO (P<0.001).

Conclusions—Patients with TGA/LVOTO who undergo Rastelli repair have a high rate of LVOT reintervention. Higher preoperative PV z-score is a risk factor for reintervention in this group. Patients with mild/moderate LVOTO undergoing ASO alone without LVOT intervention may have an increased risk of LVOT reintervention. In neonates who are candidates for ASO, delay of repair is associated with diminution in size of PV, which may subsequently reduce their suitability for ASO. (Circulation. 2009;120[suppl 1]:S53–S58.)

Key Words: left ventricular outflow tract obstruction ■ surgery ■ transposition of the great arteries ■ transposition of great vessels

Surgical options for patients with D-transposition of the great arteries (TGA) and left ventricular outflow tract obstruction (LVOTO) include arterial switch operation (ASO) and non-ASO anatomic repairs. The Rastelli and aortic translocation procedures, which are the most commonly performed non-ASO anatomic repairs, suffer from need for right ventricular outflow tract (RVOT) reintervention. ASO eliminates the need for prosthetic reconstruction of the RVOT; however, severe LVOT hypoplasia may contraindicate an ASO, or increase the risk of residual LVOTO after ASO.1 LVOTO may result in well-balanced pulmonary and systemic circulations and permit delay of repair. Thus, the timing of repair ranges from neonatal repair to delayed repair in childhood or adolescence. In patients with severe LVOTO, delay of repair necessitates initial palliation with a systemic-to-pulmonary artery shunt.

LVOTO in patients with TGA may be at the valvular or subvalvar level. Valvular obstruction may be attributable to commissural fusion, annular hypoplasia, or leaflet immobility from hypertrophic tissue. Subvalvular obstruction may be attributable to a subaortic membrane or a posteriorly deviated infundibular septum. Atroventricular valvular tissue may contribute to obstruction by abnormal connections crossing the LVOT, or by the presence of accessory tissue that billows into the LVOT during systole.2,3 In the presence of multiple etiologies of obstruction, the contribution from each individual component may be difficult to discern.

A major challenge in management of these patients is the decision regarding the timing and type of operation to perform based on anatomic morphology of the LVOT. Several studies have reported their results with individual operations for TGA/LVOTO, but none has compared the results of ASO-type operations with non-ASO anatomic repairs, or analyzed the effects of delayed repair on the progression of LVOTO. In this study, we compare the preoperative LVOT morphology and mid-term postoperative outcomes of all patients with a diagnosis of TGA/LVOTO who underwent anatomic repair and determine risk factors for progressive LVOTO and reintervention.
Materials and Methods
Echocardiograms, medical records, and operative reports of all patients who underwent anatomic repair of TGA with LVOTO at Children’s Hospital Boston between 1995 and 2007 were retrospectively reviewed. Echocardiograms were reviewed by an independent cardiologist (R.B.) to verify the results. LVOTO was defined as the presence of pulmonary valve (PV) z-score \(< -2.0\) or peak LVOT gradient of \(> 20\) mm Hg in the presence of anatomic subvalvular obstruction on the preoperative echocardiogram. Patients with pulmon-ary atresia and those who underwent single ventricle palliation or atrial switch operation were excluded from the study. This study was approved by the institutional review board at Children’s Hospi-tal Boston.

Etiology of Obstruction
Preoperative clinical and imaging data were collected in all patients including cardiac catheterization and echocardiographic data, demo-graphic information, and any information regarding before palliative interventions. From the preoperative echocardiogram, the etiology of LVOTO, PV z-score, peak instantaneous LVOT gradient, and associated cardiac anomalies were recorded. The etiology of LVOTO on preoperative echocardiogram was assessed by examining the anatomic structure of the LVOT and the flow acceleration pattern by color Doppler. Valvular obstruction was defined as flow acceler-alation at this level and valvular annular z-score of \(< -2.0\). Obstruc-tion was classified as subvalvular if there was flow acceleration and anatomic narrowing in the subvalvular region and a peak gradient of \(> 20\) mm Hg. LVOTO attributable to abnormal or accessory atri-oventricular valvular tissue or attachments was classified as atrioven-tricular valvular-related LVOTO. Multilevel obstruction was defined as the presence of a combination of \(> 1\) level of LVOTO as defined.

PV Z Score Progression
Patients who had delayed anatomic repair beyond the neonatal period were assessed to determine the progression of PV z-scores during the interim before repair. Only patients who had reliable PV measurements on both the initial postnatal (within 7 days of birth) and prerepair (within 1 month of surgery) echocardiograms were included in this analysis. In patients who underwent neonatal ASO, PV z-score measurements were obtained from the initial postnatal and subsequent echocardiograms after ASO.

Initial Operative Procedure
Operative records were reviewed to determine the type of repair performed. Details of operative procedures were collected, with specific attention to the LVOT interventions performed. For subse-quent analysis, patients were grouped according to the type of operation performed—ASO alone, ASO with LVOT intervention, aortic translocation, or Rastelli. In patients undergoing a Rastelli procedure with Ventricular Septal Defect (VSD) enlargement, the VSD was enlarged along its anterior and superior (infundibul-septum) margins. Relief of LVOT obstruction in ASO patients included neoaoartic valvotomy, resection of accessory Atrioventricu-lar valve tissue, and resection of subvalvar muscle and fibrous tissue.

Postoperative Follow-Up
Clinical status, reoperations, and echocardiographic or catheteriza-tion data at most recent follow-up were obtained from the Children’s Hospital Boston medical record or from the primary referring cardiologist. The most recent echocardiogram was reviewed to determine the LVOT gradient, degree of aortic or neoaoartic valvar insufficiency (AI), and diameter of the neoaoartic root. The number of patients with AI greater than or equal to moderate in severity was reported. Similarly, the number of patients in each group with aortic root dilation beyond a z-score of 3.0 was reported.

Statistical Analysis
Continuous variables that were normally distributed were compared between surgical repair groups using ANOVA, whereas differences in median PV z-scores were assessed by the Kruskal-Wallis test. Preoperative and postoperative changes in PV z-scores were com-pared for ASO patients and those who were delayed using the nonparametric Wilcoxon signed-rank test with an adjustment for baseline z-scores using analysis of covariance.4 Categorical variables and simple binary proportions were evaluated by Fisher exact test for \(2 \times 2\) tables. Kaplan–Meier product-limit estimator was used to evaluate differences in time-related freedom from LV reintervention with 95% CI determined by Greenwood’s formula.5 Univariate analysis was applied for testing associations with LVOT reinterven-tion. A subgroup analysis was conducted on the Rastelli patients to assess the relationship between the preoperative PV z-score and LV reintervention with the OR used to measure the risk. Two-tailed values of \(P < 0.05\) were considered statistically significant. Statistical analysis was performed with SPSS 16.0 (SPSS, Inc, Chicago, Ill).

Statement of Responsibility
The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written.

Results
Patient Characteristics
Eighty-eight patients underwent anatomic repair of TGA/ LVOTO between 1995 and 2007 at Children’s Hospital Boston (Table 1). On the echocardiogram before repair, a VSD was present in 78 of 88 (89%) of patients, with multiple VSD being present in 4 of 88 (3%). Other associated anomalies included the presence of a cleft mitral valve in 3 patients (3%) and patent ductus arteriosus in 28 (32%). A balloon atrial septostomy was performed in 33 patients (37%) before repair. Usual coronary pattern was present in 64 of 88 (72%) of patients. Twenty-one patients (24%) had undergone place-ment of a modified Blalock-Taussig shunt as an initial palliative procedure before repair.

Operative Procedures
Preoperative characteristics and LVOT morphology of pa-tients undergoing each type of repair are shown in Table 1. The median preoperative PV z-score was higher in patients undergoing an ASO alone or ASO/LVOT intervention com-pared to those undergoing aortic translocation or Rastelli \((P < 0.05;\) ANOVA). The mean preoperative LVOT gradient was significantly lower in patients undergoing ASO alone compared to other operative procedures \((P < 0.05)\). Similarly, the proportion of patients with subvalvular and multilevel obstruction was lowest in patients undergoing ASO alone compared to other operative procedures \((P < 0.05)\). Fifteen patients in the ASO/LVOT intervention group had bicommissural PV, but none had unicommissural PV morphology. In this group LVOT intervention included PV commissurotomy in 3, balloon dilation of the PV in 1, leaflet debridement in 1, subvalvar membrane or muscle resection in 15, resection of accessory atrioventricular valve tissue in 7, and division of accessory atrioventricular valve to LVOT chordal attachment in 1 patient. VSD enlargement at the time of Rastelli procedure was performed in 11 of 21 patients. There was no operative mortality this cohort of patients.

Recent Clinical Status
At median follow-up of 7.6 years (range, 1–14 years), there has been 1 late mortality in a patient who underwent the Rastelli operation. This patient required bone marrow trans-plan-tation for leukemia and died secondary to complications
of graft versus host disease. Reoperation for LVOTO was required in 8 of 88 (9%) of patients (6 Rastelli, 2 ASO alone; Tables 2 and 3). Reoperation for RVOT reconstruction was required in 17 of 88 patients, all of whom had RV-to-pulmonary artery conduit placement after aortic translocation or Rastelli procedures (Table 2).

PV Z Score Progression Before Definitive Repair
Thirteen patients who had delayed anatomic repair were assessed to determine the progression of PV z-scores during the interim before repair. Of the 13 patients, 7 required initial palliation with systemic to pulmonary shunt. Six patients eventually underwent Rastelli operation; however, 7 patients underwent aortic translocation procedure. The median age of definitive repair in these 13 patients was 216 days (range, 95 days–3 years). Median PV z-score on the initial postnatal echocardiogram was $-3.0$ (range, $-4.2$ to $-1.7$), whereas the median z-score on the echocardiogram before repair was $-4.0$ (range, $-5.9$ to $-1.2$), representing a significant decline ($P=0.005$; Figure 1A). Two additional patients who were not included in this analysis had PV z-scores between $-2$ and $-3$ with antegrade flow on the initial postnatal echocardiogram, but progressed to atresia (no antegrade blood flow across PV) immediately before repair. In 15 patients who underwent neonatal ASO with or without LVOT intervention, median PV z-score on initial postnatal echocardiogram was $-2.0$ (range, $-3.0$ to $-1.5$), and the median neoaortic valve z-score (expressed as PV z-score for equivalent comparison) on follow-up echocardiogram was $0.2$ (range, $-1.8$ to $3.5$; $P<0.01$, Figure 1B). Analysis of covariance confirmed that the significant difference in PV z-score changes (initial versus recent) between the neonatal ASO group and the delayed group ($F=44.01; P<0.001$) was not related to the initial postnatal PV z-scores ($P=0.87$).

### Table 1. Preoperative Characteristics of Patients Undergoing Biventricular Repair

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ASO Alone (n=35)</th>
<th>ASO/LVOT Intervention (n=20)</th>
<th>Aortic Translocation (n=12)</th>
<th>Rastelli (n=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, days, median (IQR)</td>
<td>7 (4–17)</td>
<td>45 (7–150)</td>
<td>158 (99–500)</td>
<td>258 (150–483)</td>
</tr>
<tr>
<td>Female, N (%)</td>
<td>14 (40)</td>
<td>9 (45)</td>
<td>4 (33)</td>
<td>11 (52)</td>
</tr>
<tr>
<td>LVOT gradient, mm Hg</td>
<td>$17 \pm 13^*$</td>
<td>$44 \pm 19$</td>
<td>$45 \pm 20$</td>
<td>$52 \pm 21$</td>
</tr>
<tr>
<td>Preoperative Blalock-Taussig Shunt</td>
<td>1 (3%)</td>
<td>4 (20%)</td>
<td>5 (41%)</td>
<td>11 (52%)</td>
</tr>
<tr>
<td>LVOT etiology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valvar</td>
<td>28 (80%)</td>
<td>15 (75%)</td>
<td>12 (100%)</td>
<td>20 (95%)</td>
</tr>
<tr>
<td>Unicommissural or bicommissural PV</td>
<td>$-1.5 (-2.6$ to $-1.9)^\dagger$</td>
<td>$-1.5 (-3.0$ to $-1.5)^\dagger$</td>
<td>$-2.7 (-4.0$ to $-0.5)$</td>
<td>$-2.9 (-6.4$ to $-1.0)$</td>
</tr>
<tr>
<td>Thickened leaflets</td>
<td>7</td>
<td>15</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Hypoplastic annulus</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Subvalvar</td>
<td>15 (43%)</td>
<td>15 (75%)</td>
<td>12 (100%)</td>
<td>19 (90%)</td>
</tr>
<tr>
<td>Postdevelopmental conal septum</td>
<td>6 (40%)</td>
<td>9 (60%)</td>
<td>9 (75%)</td>
<td>12 (57%)</td>
</tr>
<tr>
<td>Subpulmonary conus</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Bilateral conus</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Diffuse hypoplasia LVOT</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Subvalvular membrane</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AV valve-related</td>
<td>5 (14%)</td>
<td>8 (40%)</td>
<td>1 (14%)</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Attachments to LVOT</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Accessory leaflet tissue</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Multilevel</td>
<td>13 (37%)$^*$</td>
<td>15 (75%)</td>
<td>12 (100%)</td>
<td>18 (86%)</td>
</tr>
</tbody>
</table>

AV indicates atrioventricular; IQR, interquartile range.
$^*$ $P<0.05$ compared to other groups.
$^\dagger$ $P<0.05$ compared to aortic translocation and Rastelli groups.

### Table 2. Clinical and Echocardiographic Status at Recent Follow-Up

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ASO Alone (n=35)</th>
<th>ASO/LVOT Intervention (n=20)</th>
<th>Aortic Translocation (n=12)</th>
<th>Rastelli (n=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median follow-up time, yr, median (IQR)</td>
<td>8.7 (4–12)</td>
<td>4.4 (2.8–9.5)</td>
<td>4.3 (2.3–9.1)</td>
<td>7.8 (6–12)</td>
</tr>
<tr>
<td>AI $\geq$ moderate</td>
<td>3/35 (8%)</td>
<td>2/20 (10%)</td>
<td>1/12 (8%)</td>
<td>0/21</td>
</tr>
<tr>
<td>Aortic root dilation Z $&gt;3$</td>
<td>4/35 (11%)</td>
<td>3/20 (14%)</td>
<td>3/12 (25%)</td>
<td>3/21 (14%)</td>
</tr>
<tr>
<td>Postoperative LVOT gradient (mm Hg)</td>
<td>9.6 (1.2)</td>
<td>10 (3.3)</td>
<td>4 (2.1)</td>
<td>$12 \pm 4^\dagger$</td>
</tr>
<tr>
<td>LVOT reinsertion</td>
<td>2/35</td>
<td>0/20</td>
<td>0/12</td>
<td>6/21$^*$</td>
</tr>
<tr>
<td>RVOT reinsertion</td>
<td>0/35</td>
<td>0/20</td>
<td>5/12</td>
<td>12/21</td>
</tr>
</tbody>
</table>

AI indicates aortic insufficiency.
$^*$ $P<0.05$ compared to other groups.
$^\dagger$ $P<0.05$ compared to aortic translocation ($\chi^2$ analysis).
Table 2 shows the mean LVOT gradient and number of patients with moderate to severe AI and aortic root dilation at recent follow-up. There was a small but statistically significant difference in mean LVOT gradient between patients in the aortic translocation compared to the Rastelli group. There was a trend toward higher incidence of postoperative AI in ASO groups compared to non-ASO groups, but this difference was not statistically significant. There was no significant difference in incidence of aortic root dilation between the groups.

Freedom From LVOT Reintervention
Eight patients in the entire cohort (9%) required LVOT reintervention consisting of VSD enlargement in 2, subaortic membrane resection in 3, and the Konno procedure in 3 patients. By univariate \( \chi^2 \) analysis, type of operation was a significant predictor of need for LVOT reintervention (Table 3). Kaplan–Meier freedom from LVOT reintervention plot for the entire cohort is shown in Figure 2. Although 2 patients in the ASO alone group required LVOT reintervention, this was not significantly different compared to the ASO/LVOT intervention group. Both patients in ASO alone who required LVOT reintervention had multilevel obstruction on preoperative echocardiogram.

Echocardiographic Follow-Up
Table 2 shows the mean LVOT gradient and number of patients with moderate to severe AI and aortic root dilation at recent follow-up. There was a small but statistically significant difference in mean LVOT gradient between patients in the aortic translocation compared to the Rastelli group. There was a trend toward higher incidence of postoperative AI in ASO groups compared to non-ASO groups, but this difference was not statistically significant. There was no significant difference in incidence of aortic root dilation between the groups.

Risk Factors for LVOT Reintervention Within Rastelli Group
Variables that were evaluated to determine specific risk factors for LVOT reintervention within the Rastelli group included initial PV z-score and performance of VSD enlarge-
ment at the time of Rastelli. Higher PV z-score on the preoperative echocardiogram was an independent predictor of LVOT reintervention (OR = 4.0; \( P = 0.012 \)). Median z-score in Rastelli patients who required LVOT reintervention was −1.6 compared to −3.2 in patients who did not require reintervention.

**Discussion**

This study examines patients with TGA/LVOTO who underwent anatomic repair. Patients with smaller PV z-scores and multilevel LVOTO were more likely to undergo aortic translocation or Rastelli procedures, whereas patients with larger PV were more likely to undergo an ASO-type operation. LVOT reintervention was more common in patients undergoing the Rastelli compared to aortic translocation, with the major risk factor for reintervention in Rastelli patients being a larger preoperative PV z-score. Finally, neonatal ASO was associated with increase in size of the PV, whereas delay of definitive repair was associated with significant reduction in PV annular size in the interim before definitive repair.

Freedom from LVOT reintervention after Rastelli has been previously demonstrated to be \( \approx 84\% \) at 10 years, and recurrent LVOTO is a risk factor for mortality.5,7 These findings have prompted increased utilization of aortic translocation for patients with TGA/LVOTO, and this study confirms a lower incidence of LVOT reintervention in aortic translocation compared to Rastelli.6,8 The low incidence of LVOT reintervention after aortic translocation is likely attributable to the positioning of the aortic valve over the true anatomic LV outflow, resulting in subaortic outflow uncumbered by conus or septal muscle.10 Although previous reports have suggested a high incidence of LVOTO after Rastelli, none has examined PV z-score as a risk factor for reintervention.10–12 In this study, higher PV z-score was a risk factor for LVOT reintervention despite VSD enlargement at the time of Rastelli. The distance between the LV and the aorta determines the length of the intracardiac LVOT tunnel; because the PV lies posterior to the aorta and directly over the LV, a larger PV Z annular size results in further anterior displacement of the infundibular septum and aorta and elongates the LV to aorta distance.

An advantage of ASO-type repairs over Rastelli or aortic translocation is the lack of RVOT conduit and need for conduit reintervention. Previous studies have demonstrated the feasibility of ASO with LVOT intervention in selected patients with TGA/LVOTO, and have suggested that this procedure is underutilized.1,2,11 Increment in the PV dimensions after ASO suggests growth (or stretch) potential of the LVOT when antegrade flow is optimized and results in low postoperative LVOT gradients at mid-term follow up. However, in patients with mild annular hypoplasia and multilevel obstruction, ASO alone was associated with an increased (but statistically insignificant) need for LVOT reintervention compared to ASO with LVOT intervention, suggesting that caution must be exercised in performing ASO alone. Attention to the mechanisms of LVOTO, by preoperative and intraoperative segmental analysis, is critical to determining the candidacy for ASO and type of LVOT intervention required. In this study, an ASO with LVOT intervention was technically successful even in patients with preoperative PV z-scores of −3 and multilevel obstruction. Thus PV z-score as low as −3 may not preclude an ASO with relief of LVOT obstructing lesions when these obstructions are amenable to surgical relief. In this experience LVOT lesions that were deemed amenable to surgical relief included comissural fusion, hypertrophic muscle, membranous tissue, and accessory atrioventricular valvular tissue. Contraindications for ASO/LVOT intervention have included severe valvar dysplasia or unicommissural valve, which are not amenable to simple repair.

More patients in the ASO group developed neo-AI over time compared to the non-ASO groups, although this difference was not statistically significant. The development of neo-AI after ASO may be attributable to the presence of a morphological PV in the systemic circulation, although the incidence of clinically significant neo-AI in the general ASO population remains low. LVOTO has been shown to be a risk factor for development of significant regurgitation.14 Possible ultrastructural differences between native aortic and pulmonary tissue may result in differential behavior when placed in systemic circulation, or transaortic resection of subvalvular tissue may result in distortion of the neoaortic valve and subsequent development of neo-AI.

In most patients who underwent delayed anatomic repair beyond the neonatal period, progressive diminution in the PV annular size was observed between the initial postnatal echocardiogram and the echocardiogram obtained before definitive repair. This decrease in PV annular diameter occurred regardless of the size of the initial PV on the postnatal echocardiogram, and in a few patients, resulted in near atresia by the time of repair. In contrast, patients who underwent ASO during the neonatal period demonstrated significant increase in neoaortic z-score over time. Although inherent differences in the severity of LVOTO between patients who underwent delayed repair versus neonatal repair may explain the differential growth of the LVOT, multivariate analysis demonstrated the progression to be independent of the initial PV z-score. Antegrade blood flow may provide the stimulus for growth of LVOT structures, and palliative maneuvers such as aorto-pulmonary shunts may lead to a reduction in blood flow through the LVOT.

The relationship between timing of definitive repair and LVOT growth has implications for neonates who are considered candidates for ASO alone or ASO/LVOT intervention based on the initial postnatal echocardiogram. Several patients in the series who were initially considered to be candidates for ASO/LVOT intervention at postnatal echocardiogram eventually underwent either Rastelli or aortic translocation attributable to further deterioration in PV z-score. This anticipated postnatal reduction in PV annulus should be considered in the early postnatal decision-making for the patient with TGA, VSD, and LVOTO, and neonatal ASO with or without LVOT intervention may be preferable to initial palliation or delayed definitive repair as the prospects of ASO diminish over time with the latter approach.

The major limitations of this study include its retrospective design and variable follow-up between groups. Rastelli pro-
cedures were performed early in the series, whereas aortic translocation procedure and ASO with LVOT intervention have been performed predominantly in the more recent years. The impact of surgical era on outcomes was not elucidated, and long-term follow-up is necessary to verify these results.

In conclusion, in this cohort of patients with TGA LVOTO, the Rastelli operation was associated with the highest rate of LVOT reintervention. Larger preoperative PV z-score emerged as a risk factor for LVOT reintervention after Rastelli. ASO/LVOT intervention in patients with moderate LVOTO was associated with excellent relief of LVOTO and reduced need for RVOT reintervention, but may eventually result in a higher risk of neoaortic insufficiency. Delay of definitive repair resulted in progressive diminution in PV size, and repair during early infancy (without initial palliation) may be preferable for patients who are considered candidates for ASO. Most patients with PV z-scores of $>-3$ and resectable LVOT obstruction (commissural fusion, subvalvar membrane or muscle, accessory Atroventricular valve tissue, or chordal attachments) should be considered candidates for an ASO. The LVOT obstruction should be surgically addressed at that time. For PV annular $z$-score $<-3$, unicommissural PV, or unreseactable LVOTO, the aortic translocation is preferred. Palliation with a Blalock-Taussig shunt should be avoided in favor of neonatal repair if the patient is deemed a candidate for ASO.

**Sources of Funding**

The project was funded by the Department of Cardiovascular Surgery at Children’s Hospital Boston.

**Disclosures**

None.

**References**

Outcomes After Anatomic Repair for D-Transposition of the Great Arteries With Left Ventricular Outflow Tract Obstruction
Sitaram M. Emani, Rebecca Beroukhim, David Zurakowski, Frank A. Pigula, John E. Mayer, Pedro J. del Nido, Tal Geva and Emile A. Bacha

_Circulation_. 2009;120:S53-S58
doi: 10.1161/CIRCULATIONAHA.108.843102

_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2009 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/120/11_suppl_1/S53

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in _Circulation_ can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to _Circulation_ is online at:
http://circ.ahajournals.org/subscriptions/