Aortic root translocation (Nikaidoh procedure): Intermediate follow-up and impact of conduit type

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Objective: Aortic root translocation is a promising surgical option for repair of transposition of the great arteries, ventricular septal defect, and pulmonary stenosis. There are little data on the outcomes of this procedure, with no long-term follow-up available. We reviewed our experience with aortic root translocation and the impact of the type of right ventricular outflow tract reconstruction.

Methods: The demographic, procedural, and outcome data were obtained for 32 patients who underwent aortic root translocation from 1997 to 2013 at Boston Children's Hospital. Patients were grouped on the basis of right ventricular outflow tract reconstruction with a valved conduit or a nonvalved anastomosis of the pulmonary artery bifurcation to the right ventricular outflow tract with anterior patch augmentation (transannular patch).

Results: The median age was 7.5 months (16 days to 42 years). Twenty-six patients had valved conduits, and 6 patients had transannular patches. There were no significant differences between groups in baseline and operative characteristics. There was 1 early death (transannular patch group). There were no late deaths during a median follow-up of 20.8 months (1 month to 16.5 years). No patients developed late left ventricular outflow tract obstruction. Transcatheter reintervention was required in 14 patients, 9 with valved conduits (34.6%) and 1 with transannular patch (20%, $P > .99$). Six patients (19.4%) required reoperation, all with a valved conduit ($P = .34$).

Conclusions: Aortic root translocation can be done with low early and late mortality. There was preserved aortic valve function and no left ventricular outflow tract obstruction at late follow-up. The use of a transannular patch had early outcomes comparable to valved conduits, with a trend for fewer late reoperations. (J Thorac Cardiovasc Surg 2015;149:1349-55)

See related commentary pages 1356-7.

The ideal surgical option for the management of dextrotransposition of the great arteries (D-TGA) with ventricular septal defect (VSD) and pulmonary stenosis (PS) is not clear. The currently available surgical options include recruitment of the native left ventricular outflow tract (LVOT) and the arterial switch operation (ASO),[1,2] or non-ASO procedures, including the Rastelli procedure,[3,4] the "réparation à l'étage ventriculaire" (REV),[5-7] and aortic root translocation (Nikaidoh).[8] The presence of severe left ventricular outflow tract obstruction (LVOTO) excludes the ASO as a surgical option.[1] Although results of the Rastelli procedure are encouraging, the long-term outcomes are limited by the late development of left ventricular (LV) dysfunction, progressive development of LVOTO, and reoperations to change the right ventricle to pulmonary artery (RV-PA) conduit with associated risk of damage during sternal reentry,[2,3] particularly because the ventriculotomy in the Rastelli procedure is closer to the midline. Aortic root translocation was first introduced by Bex and colleagues[9] in 1980 and popularized by Nikaidoh[10] in 1984 as an alternative to REV or Rastelli repairs for transposition of the great arteries (TGA)/VSD/PS. The intermediate to midterm results of the Nikaidoh procedure appear superior to the Rastelli procedure in the late development of LVOTO,[1,8,11-13] at the cost of higher technical complexity of the initial operation and longer operative times. The RV-PA conduit can be placed more laterally, potentially reducing the risk of re-sternotomy when it becomes necessary to change the RV-PA conduit.[11]

We previously reported our initial experience using the Nikaidoh procedure, which included 11 patients.[11] The aim of this report is to review our more extensive experience with the Nikaidoh procedure and compare different options of managing the right ventricular outflow tract (RVOT).

MATERIALS AND METHODS

Study Design

This study is a retrospective review of all consecutive patients who underwent aortic root translocation (Nikaidoh procedure) at our institution

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Abbreviations and Acronyms

ASO = arterial switch operation
D-TGA = dextro-transposition of the great arteries
LV = left ventricular
LVOT = left ventricular outflow tract
LVOTO = left ventricular outflow tract obstruction
PS = pulmonary stenosis
REV = réparation à l'étage ventriculaire
RVOT = right ventricular outflow tract
RV-PA = right ventricle to pulmonary artery
TGA = transposition of the great arteries
VSD = ventricular septal defect

between 1997 and 2013. The demographic, procedural, and outcome data were obtained for all patients during the study period. The primary end points included mortality, transplantation, and RV-PA conduit reoperations during follow-up. Clinical or treatment variables were recorded to determine predictors of the outcome measures. The study was approved by the Boston Children's Hospital Institutional Review Board, and individual patient consent was waived.

Surgical Technique

The decision to perform aortic translocation is based on preoperative echocardiogram, cardiac catheterization in almost all patients, and magnetic resonance imaging in selected patients. Attention is focused on the cause of LVOTO and the conal septal anatomy. Patients with a pulmonary valve *Z* score less than −3 with a large unrestrictive VSD are considered for aortic root translocation procedure.

After midline sternotomy, the aortic root is completely mobilized from the LVOT, roof of the left atrium, and the main and right pulmonary arteries. To avoid coronary kinking, the right coronary artery is skeletonized in its epicardial course from its origin to the right atrioventricular groove and a plane between the left anterior descending artery and RVOT is separated. All the dissection is done before giving heparin, if possible. If hemodynamic instability occurs during dissection, cardiopulmonary bypass is established with high aortic and bicaval cannulation. Myocardial protection is achieved by moderate hypothermia and del Nido potassium-magnesium-lidocaine cardioplegia. The aortic root is harvested from the RVOT similar to harvesting the pulmonary autograft in the Ross procedure, under a crossclamped aorta transected at the mid-ascending aorta. More recently, the aortic root is harvested without applying a crossclamp, using fibrillatory arrest, to keep the aortic root uncollapsed to help delineate the plane for harvesting the aortic root with intact coronaries, as well as to recognize coronary injury and possible coronary kinking earlier. If the coronary anatomy appears unfavorable, coronary buttons are harvested from the right coronary artery alone (partial coronary reimplantation) or both coronaries (full coronary reimplantation). Circular buttons are taken to preserve as much of the native sinotubular junction to avoid late aortic root dilatation.

Depending on the status of native pulmonary valve and annulus, the main pulmonary artery is preserved or completely divided at the valvular level. Any conal muscle causing LVOTO is divided. The VSD is enlarged if found to be restrictive. The aorta is crossclamped (if not done before) and transected at the level of the mid-ascending aorta. The harvested aortic root is moved posteriorly. If the coronary arteries were harvested, the optimal position of the aortic root is determined, using rotation if necessary and appropriate to the coronary anatomy (eg, none with intact coronaries, a 180° rotation with full coronary reimplantation, or a variable amount with partial coronary reimplantation), and the coronary buttons are reimplanted. The LeCompte maneuver is performed, and the aortic anastomosis is completed. The VSD is closed using glutaraldehyde-treated pericardium or a Dacron patch. The superior margin VSD patch sutures essentially run on the anterior suture line of aortic root. The RVOT is managed with RV-PA conduit using a valved homograft in younger infants or a nonvalved transannular patch in older children. To reduce the total cardiopulmonary bypass time and aortic crossclamp time, any additional procedures that do not involve the ascending aorta and root are usually performed using fibrillatory arrest before crossclamping the aorta. The patient is gradually weaned from cardiopulmonary bypass with help of a left atrial line, minimal inotropic support, and nitroglycerin. The adequacy of repair, including both ventricular function and regional wall motion abnormalities, is verified by transesophageal echocardiography, and the electrocardiogram is carefully observed for any ST-segment changes. Because the RV-PA conduit stays well away from the midline in aortic root translocation, an attempt for primary chest closure is made in most patients.

Statistical Analysis

Statistical analyses were performed with SPSS version 21 (SPSS Inc, Chicago, Ill). Data are presented as mean ± standard deviation or median (range) where appropriate. Continuous variables were analyzed with the Student *t* test, or the related samples Wilcoxon signed-rank test when appropriate, and categoric variables were analyzed using the chi-square test or Fisher exact test. Actuarial estimates were calculated using the Kaplan–Meier method, and differences between curves were assessed by the log-rank test. All statistical tests were 2-tailed.

RESULTS

Demographics

A total of 32 patients were included during the study period, with a median age of 7.5 months (range, 1 month to 42 years) and a median weight of 7.7 kg (range, 2.1-48.8 kg). The baseline patient characteristics are summarized in Table 1. D-TGA with VSD was seen in 53% of patients (n = 17). Abnormal coronary anatomy was seen in 3 patients (9%). Eighteen patients had palliative procedures before aortic root translocation, most commonly a modified Blalock–Taussig shunt (16, 50%) or a bidirectional Glenn shunt (3, 9%).

Operative Characteristics

The operative details are summarized in Table 2. A valved RV-PA conduit was used in 26 patients (81%): 19 with an aortic homograft (mean conduit size: 15.7 ± 3.7 mm), 4 with a pulmonary homograft (mean conduit size 21 mm), 2 with a bovine internal jugular vein conduit (Contegra; Medtronic Inc, Minneapolis, Minn), and 1 with the native pulmonary root. A nonvalved transannular patch was used in 6 patients (19%). An atrial baffle Mustard procedure was performed in 5 patients in the setting of anatomic repair of congenitally corrected TGA. Some of these patients have been reported.[14,15] Additional procedures are detailed in Table 2.

Early Outcome

Early outcomes are summarized in Table 3. Thirteen patients were left with an open chest (41%), and 2 patients

TABLE 1. Baseline patient characteristics

Baseline characteristic	Total population	Valved conduit	Transannular patch	*P* value
No. of patients	32	26 (81.3%)	6 (18.8%)	
Age (mo)	7.5 (16 d to 42 y)	6.5 (16 d to 42 y)	8.5 (5-60)	.43
Male patients	22 (68.8%)	16 (61.5%)	6 (100%)	.14
Body weight (kg)	7.7 (2.1-48.8)	6.9 (2.1-48.8)	10.1 (4.7-17)	.24
Body surface area (m^2)	0.39 (0.17-1.46)	0.37 (0.17-1.46)	0.46 (0.28-0.69)	.26
Diagnosis				.83
D-TGA/VSD/PS	17 (53%)	13 (50%)	4 (66.7%)	
DORV/VSD/PS	10 (31%)	9 (34.6%)	1 (16.7%)	
L-TGA/VSD/PS	5 (16%)	4 (14.5%)	1 (16.7%)	
Previous palliation	19 (59.4%)	15 (57.7%)	4 (66.7%)	>.99
mBTS	16 (50%)	12 (46.2%)	4 (66.7%)	.65
Bidirectional Glenn	3 (9.4%)	2 (7.7%)	1 (16.7%)	.48
Pulmonary artery band	2 (6.3%)	1 (3.8%)	1 (16.7%)	.35
Mean LVOT gradient (mm Hg)	60.5 ± 22.3	60.8 ± 24.3	59.2 ± 11.1	.79
Coronary anatomy				
Normal (or usual for TGA)	29 (90.6%)	24 (92.3%)	5 (83.3%)	.48
Abnormal	3 (9.4%)	2 (7.7%)	1 (16.7%)	.48
Left circumflex from RCA	2 (6.3%)	1 (3.8%)	1 (16.7%)	.35
Inverted origin of coronaries	1 (3%)	1 (3.8%)	0 (0%)	>.99
Associated lesions				
Multiple VSDs	4 (12.5%)	2 (7.7%)	2 (33.3%)	.15
Complete common atrioventricular canal defect	2 (6.3%)	1 (3.8%)	1 (16.7%)	.35
Dextrocardia	3 (9.4%)	2 (7.7%)	1 (16.7%)	.38
Situs inversus	2 (6.3%)	2 (7.7%)	0 (0%)	>.99
Heterotaxy syndrome	2 (6%)	1 (3.8%)	1 (16.7%)	.35
Parachute mitral valve	1 (3%)	1 (3.8%)	0 (0%)	>.99

All values are reported as mean ± standard deviation, median (range) or number (percentage) unless otherwise noted. *DORV*, Double outlet right ventricle; *D-TGA*, dextro-transposition of the great arteries; *L-TGA*, levo-transposition of the great arteries; *LVOT*, left ventricular outflow tract; *mBTS*, modified Blalock–Taussig shunt; *PS*, pulmonic stenosis; *RCA*, right coronary artery; *TGA*, transposition of the great arteries; *VSD*, ventricular septal defect.

required reexploration for bleeding (6.3%). No patients required extracorporeal membrane oxygenation support. There was 1 early death (3.1%) in an 8-month-old child with heterotaxy syndrome, dextrocardia, congenitally corrected TGA with complete atrio-VSD, and borderline right ventricle hypoplasia. The child underwent anatomic repair (Mustard atrial switch, double patch repair of atrio-VSD, aortic root translocation, and transannular patch for the RVOT reconstruction). Peripheral branch pulmonary artery stenosis with severe pulmonary regurgitation and tricuspid regurgitation developed in the patient, and he underwent early reoperation to place an RV-PA conduit (16-mm Contegra) and tricuspid valve repair. Tricuspid stenosis developed after the reoperation, and he subsequently underwent tricuspid valve replacement with surgical melody valve insertion,[16,17] dilated up to 19 mm. Gram-negative septicemia and multiorgan failure developed, and the patient died on postoperative day 64.

Three patients required early reoperation (9.3%), 1 of whom eventually died of septicemia as described earlier. One other patient presented with moderate aortic regurgitation, which was addressed with reduction of the sinotubular junction, aortic valve commissuroplasty, along with closure of a residual VSD. Another patient had a Mustard baffle leak repaired. Two additional patients required early reinterventions in the catheterization laboratory (6.3%), 1 for superior vena cava stenting for superior vena cava stenosis and 1 for device closure of Mustard baffle leak.

On predischarge echocardiogram, 1 patient had more than mild LVOTO (3.1%), with a 20-mm peak gradient across the LVOT. Residual RVOTO was observed in 8 patients (25%), of whom 7 had an RV-PA conduit and 1 had transannular patch. One patient had moderate aortic insufficiency (3.1%). Two patients had LV dysfunction without any evidence of coronary ischemia at the time of discharge. A hemodynamically nonsignificant residual VSD occurred in 16 patients (50%).

Follow-up

Among the 31 survivors, the median follow-up was 20.8 months (range, 1 month to 16.5 years). There were no late deaths during follow-up. Good functional capacity was seen in all but 1 patient (96% of patients in New York Heart Association class I or II). Kaplan–Meier estimates of survival are illustrated in Figure 1.

A total of 14 patients (45.2% of survivors) required a reintervention during follow-up. Catheter-based reinterventions

TABLE 2. Operative details

Operative characteristic	Entire sample (N = 32)	Valved conduit (n = 26)	Transannular patch (n = 6)	*P* value
CPB (min)	265.3 ± 76.9	266.5 ± 84.9	260.2 ± 23.5	.56
Aortic crossclamp (min)	134 ± 52	141.9 ± 45.7	99.8 ± 62.9	.14
Fibrillatory arrest time (min)	81.7 ± 60.2	77.2 ± 60.3	102 ± 77.8	.73
LeCompte maneuver	31 (96.9%)	25 (96.2%)	6 (100%)	>.99
RVOT reconstruction				
Valved RV-PA conduit	26 (81%)	—	—	—
Transannular patch	6 (19%)	—	—	—
Management of coronaries				
Full coronary reimplantation	18 (56.3%)	17 (65.4%)	1 (16.7%)	.06
Partial coronary reimplantation	1 (3.1%)	1 (3.8%)	0 (0%)	>.99
Intact coronaries	13 (40.6%)	8 (30.8%)	5 (83.3%)	.03
Root translocation on a beating heart	6 (18.8%)	3 (11.5)	3 (50%)	.06
Additional procedure				
Mustard procedure	5 (15.6%)	4 (15.4%)	1 (16.7%)	>.99
Pulmonary artery plasty	5 (15.6%)	4 (15.4%)	1 (16.7%)	>.99
Mitral valvuloplasty	4 (12.5%)	4 (15.4%)	0 (0%)	.57
Multiple VSD closure	5 (15.6%)	3 (11.5%)	2 (33.3%)	.23
Tricuspid valve repair	3 (9.4%)	2 (7.7%)	1 (16.7%)	.48
Glenn takedown	3 (9.4%)	2 (7.7%)	1 (16.7%)	.48
Complete common atrioventricular canal repair	2 (6.3%)	1 (3.8%)	1 (16.7%)	.35
Pacemaker implantation	1 (3.1%)	1 (3.8%)	0 (0%)	>.99
Enlargement of VSD	1 (3.1%)	1 (3.8%)	0 (0%)	>.99
Anomalous pulmonary venous return repair	1 (3.1%)	1 (3.8%)	0 (0%)	>.99

All values are reported as mean ± standard deviation, median (range) or number (percentage) unless otherwise noted. *CPB*, Cardiopulmonary bypass; *RVOT*, right ventricular outflow tract; *RV-PA*, right ventricular to pulmonary artery; *VSD*, ventricular septal defect.

occurred in 10 patients (32.3%), which included RV-PA conduit dilatation or stent placement in 5 patients (16.1%), balloon dilatation of branch pulmonary arteries with or without stent placement in 4 patients (12.9%), ASD closure in 2 patients (6.5%), and tricuspid valve balloon dilatation in 1 patient (3.2%). Among these patients with catheter-based reinterventions, 9 had a valved RV-PA conduit (34.6%) and 1 had transannular patch (20%, $P > .99$).

Six patients (19.4%) required surgical reoperation, all of whom had valved RV-PA conduits. Surgery included RV-PA conduit change in 3 patients, Melody valve (Medtronic Inc) replacement in the RVOT position in 1 patient, tricuspid valve repair and conversion of valved RV-PA conduit to transannular patch in 1 patient, and mitral and tricuspid valve repair with pulmonary valve replacement in 1 patient. There were no perioperative deaths for these reoperations. Two of these patients required a second reoperation, for RV-PA conduit re-replacement with aortic valve repair and right coronary ostium unroofing in 1 patient and for mitral valve replacement with a 19-mm St Jude Inc (St Paul, Minn) mechanical prosthesis and tricuspid valve repair in 1 patient. Overall freedom from reintervention is illustrated in Figure 2. There was not a significant difference when stratified by transannular patch versus RV-PA conduit (log-rank test, $P = .91$; data not shown). Freedom from re-intervention on the RV-PA connection is illustrated in Figure 3 and was better in patients with a transannular patch (no reinterventions), although not to a statistically significant level ($P = .34$). The overall echocardiographic results at latest follow-up are summarized in Table 4.

DISCUSSION

Our study focuses on the early and midterm results of aortic root translocation and the impact of type of RVOT reconstruction. It expands on our previous experience[11] in managing patients with D-TGA/VSD/PS who underwent anatomic repair with aortic root translocation. We report on 32 patients by grouping them by management of the RVOT; 26 patients had a valved RV-PA conduit, and 6 patients had a transannular patch with direct approximation of the pulmonary bifurcation to the RVOT and anterior patch enlargement.[18-20] Reinterventions and reoperations were more frequent in patients with a valved conduit. During a late follow-up extending to 16.5 years, no patients showed LV dysfunction, 2 patients presented moderate aortic insufficiency, 1 patient had aortic valvuloplasty at the time of RV-PA conduit replacement, and no patients presented residual LVOTO. Two patients (1 in each group) presented with mild coronary compression.

Aortic translocation is a technically demanding operation, with risks of destabilizing the aortic valve or kinking/compressing the proximal coronary arteries. In the Toronto experience, coronary anomalies were the principal reason for favoring a Rastelli procedure.[21] The

TABLE 3. Early outcomes

Outcome variables	Entire sample (N = 32)	Valved conduit (n = 26)	Transannular patch (n = 6)	*P* value
Hospital stay (d)	13 (8-64)	14 (8-49)	11 (8-64)	.87
CICU stay (d)	6 (2-64)	6.5 (2-19)	5.5 (2-64)	.82
LVOTO	1 (3%)	1 (3.8%)	0 (0%)	>.99
LVOT peak gradient (mm Hg)	0.9 ± 3.9	1.14 ± 4.32	*	
RVOTO	8 (25%)	7 (26.9%)	1 (16.7%)	>.99
RVOT peak gradient (mm Hg)	6.1 ± 11.6	6.4 ± 11.6	5 ± 12.2	.87
Aortic insufficiency				>.99
None	24 (75%)	19 (73.1%)	5 (83.3%)	
Mild	7 (21.9%)	6 (23.1%)	1 (16.7%)	
Moderate	1 (3.1%)	1 (3.8%)	0 (0%)	
Mild to moderate mitral regurgitation	1 (3.1%)	1 (3.8%)	0 (0%)	>.99
Mild to moderate LV dysfunction	2 (6.3%)	1 (3.8%)	1 (16.7%)	.35
Residual VSD†	16 (50%)	12 (46.2%)	4 (66.7%)	.65
Complete heart block	4 (12.5%)	3 (11.5%)	1 (16.7%)	>.99
Early reoperation	3 (9.4%)	2 (7.7%)	1 (16.7%)	.48
Early mortality	1 (3.1%)	0 (0%)	1 (16.7%)	.19

All values are reported as mean ± standard deviation, median (range), or number (%) unless otherwise noted. *CICU*, Cardiac intensive care unit; *LV*, left ventricular; *LVOT*, left ventricular outflow tract; *LVOTO*, left ventricular outflow tract obstruction; *RVOT*, right ventricular outflow tract; *RVOTO*, right ventricular outflow tract obstruction; *VSD*, ventricular septal defect. *Too few measures for a meaningful mean. †Residual VSD was defined on the basis of perioperative echocardiography irrespective of size. All patients had Q_P:Q_S less than 1:1.5, the VSDs were hemodynamically insignificant, and no patient required reoperation for residual VSD.

ASO with LVOTO resection is associated with a high rate of aortic insufficiency and reoperations on the aortic valve,[1] although repair is possible with excellent results,[22-26] and REV or Rastelli procedures are associated with a 10% rate of reoperation for LVOTO at 10 years.[1,3,8]

There is great debate on how and when to choose which surgical management option in patients with D-TGA/VSD/PS: ASO with LVOT resection, REV, Rastelli, or aortic root translocation.[1,13,21,27] Yeh and colleagues[8] recently reviewed the available studies on these different approaches, showing that, after taking into account era effects, overall survival was not significantly different between management options. Historically, our institutional approach has been to favor ASO and LVOTO resection when possible. However, we have managed a select number of these patients with aortic root translocation. We previously reported our results comparing these different management strategies, showing that patients undergoing the Rastelli procedure were more likely to require surgical reintervention for LVOTO than other groups ($P = .015$), particularly in patients with a higher pulmonary valve Z score ($P = .012$).

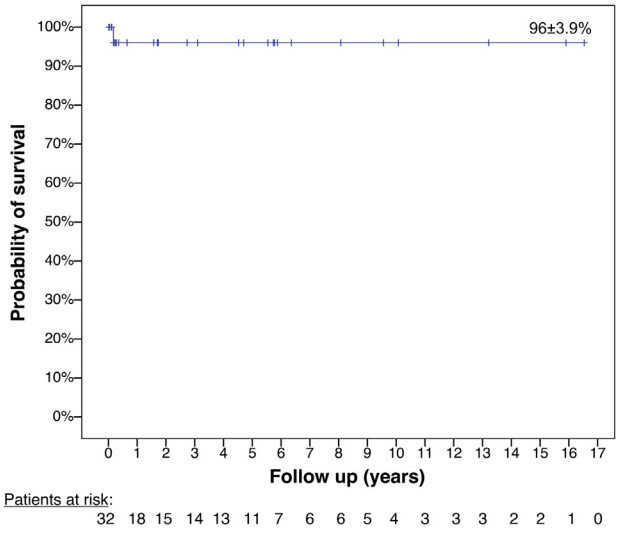

FIGURE 1. Kaplan–Meier survival estimates.

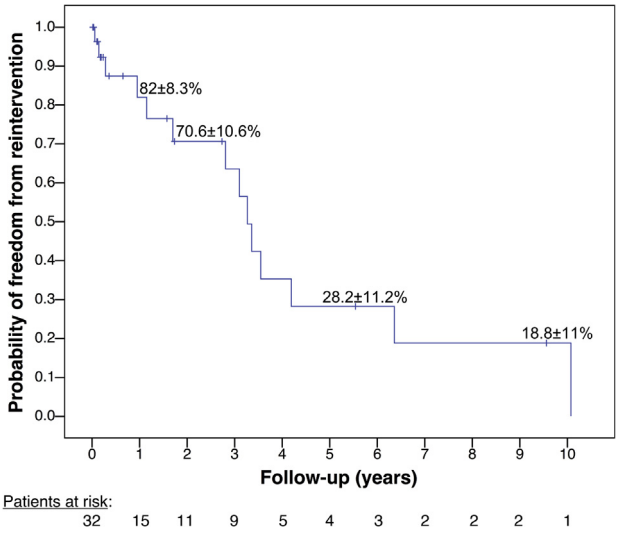

FIGURE 2. Kaplan–Meier estimates of freedom from reintervention among survivors.

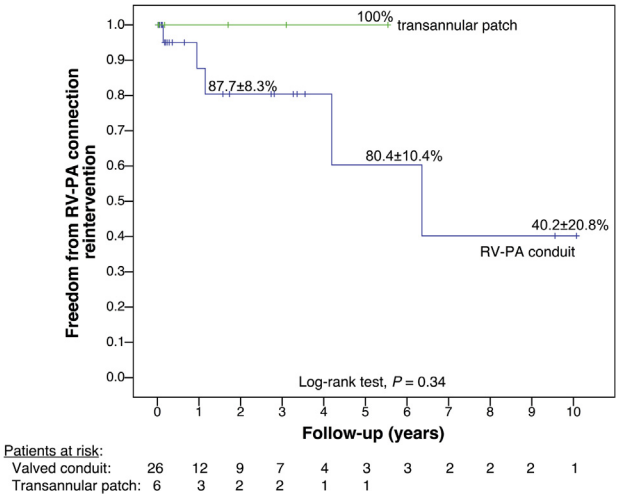

FIGURE 3. Kaplan–Meier estimates of freedom from RV-PA connection reintervention stratified by connection type. *RV-PA*, Right ventricle to pulmonary artery.

The larger pulmonary valve created a longer intracardiac baffle at higher risk of obstruction. By comparison, in the patients reported in this article, 1 patient (3.1%) showed a peak LVOT gradient of 20 mm Hg at discharge, and no patients showed LVOTO at late follow-up.

In perhaps one of the most interesting comparative studies on the subject, Hazekamp and colleagues[28] studied 33 patients with LVOTO in various forms of transposition, of whom 21 had TGA/VSD/PS.[28] They found that ASO and LVOT muscle resection was feasible in 10 of 21 patients (47%). Aortic root translocation or Rastelli was indicated in 9 patients (42%), in whom the authors determined that the Nikaidoh procedure could be performed in 8 of the 9 patients, because 1 patient was not favorable for aortic root translocation, with a large aortic valve, very small LVOT, and large membranous anterior subaortic VSD, which could be more easily repaired with a Rastelli baffle, because root translocation would not provide any significant benefit, because it would be done over a very short distance.

More recently, Honjo and colleagues[21] from the Toronto group tried to derive retrospectively an anatomic ''LVOT complexity score'' to help in choosing between management options. Although interesting, this complexity score, derived retrospectively on patients whose management was decided traditionally (ie, by preoperative echocardiographic and surgical inspection), would seem to confirm that this esteemed and established program, with no early deaths in their experience, chose the right option for the right patient, with higher LVOT complexity scores in patients with a Nikaidoh

TABLE 4. Follow-up evaluation

Follow-up variable	Value	Valved conduit (n = 26)*	Transannular patch (n = 5)*	*P* value
Follow-up duration (mo)	20.8 (1 wk to 16.5 y)	26.8 (1 wk to 16.5 y)	20.4 (2 wk to 5.5 y)	.36
LV ejection fraction	60.2 ± 5.9	59.9 ± 6.1	62.3 ± 4	.54
RV function				>.99
Normal	25 (89.3%)	22 (88%)	3 (100%)	
Mildly reduced	2 (7.1%)	2 (8%)	0 (0%)	
Moderately reduced	1 (3.6%)	1 (4%)	0 (0%)	
RVOTO	10 (35.7%)	9 (36%)	1 (33.3%)	>.99
Mean RVOT peak gradient (mm Hg)	9.0 ± 14.2	9.3 ± 14.7	6.7 ± 11.5	.81
LVOTO	0 (0%)	0 (0%)	0 (0%)	>.99
Aortic insufficiency				.64
None-trivial	12 (46.2%)	10 (43.5%)	2 (66.7%)	
Mild	13 (50%)	12 (52.2%)	1 (33.3%)	
Moderate	1 (3.8%)	1 (4.3%)	0 (0%)	
RV-PA conduit regurgitation				.64
None-trivial	12 (42.9%)	10 (41.7%)	2 (50%)	
Mild	7 (25%)	6 (25%)	1 (25%)	
Moderate	6 (21.4%)	6 (25%)	0 (0%)	
Severe	3 (10.7%)	2 (8.3%)	1 (25%)	
Coronary compression	1 (3.8%)	1 (4.3%)	0 (0%)	>.99
Mitral insufficiency				>.99
None-mild	30 (96.8%)	25 (96.2%)	5 (100%)	
Moderate	1 (3.2%)	1 (3.8%)	0 (100%)	
Tricuspid valve insufficiency				>.99
None-trivial	9 (33.3%)	8 (33.3%)	1 (33.3%)	
Mild	17 (63%)	15 (62.5%)	2 (66.7%)	
Moderate	1 (3.7%)	1 (4.2%)	0 (0%)	

Variables are presented as mean ± standard deviation, median (range), and number (percentage of survivors). *LV*, Left ventricular; *RV*, right ventricular; *RVOT*, right ventricular outflow tract; *RVOTO*, right ventricular outflow tract obstruction; *RV-PA*, right ventricle-pulmonary artery; *LVOTO*, left ventricular outflow tract obstruction. *Not all echocardiographic parameters were available on follow-up echocardiogram.

procedure than in patients with an ASO ($P = .019$). However, no thresholds of LVOT complexity score were determined to help in choosing management, likely because of the sample size, and it remains to be seen if this LVOT complexity score can be useful in the clinical management of patients in a prospective application of a management protocol based on these scores.[27]

Study Limitations

First, it is a retrospective, single-center, noninterventional study designed to evaluate the outcomes of an established clinical program. All patients were managed as individuals and not according to a treatment protocol, which would have improved our ability to analyze outcomes. Our analyses were limited by the small patient sample, even if this represents one of the largest populations of aortic translocation procedures. Furthermore, the finding of fewer interventions in the transannular patch group may be an artifact of age at repair or duration of follow-up. Finally, the follow-up, although extending to 16.5 years, was limited to a median of just less than 2 years, because a large proportion of the patients underwent operation more recently.

CONCLUSIONS

Aortic root translocation can be performed with low early and late mortality, with extended operative times. There was preserved aortic valve function and no LVOTO at late follow-up. The use of a transannular patch had early outcomes comparable to valved conduits, with a trend for fewer late reoperations during follow-up.

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