VALVELESS OUTFLOW RECONSTRUCTION USING AUTOLOGOUS TISSUE AS A POSTERIOR WALL FOR PULMONARY ATRESIA WITH VENTRICULAR SEPTAL DEFECT

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Various extracardiac valved conduits have been used since 1966 to correct right ventricle to pulmonary artery discontinuity [1]. Although a Dacron conduit with porcine heterograft once replaced the homograft as the procedure of choice [2], neoimtimal peel formation and early degeneration and calcification of the porcine valve in children revived the use of the homograft [3, 4]. Although satisfactory long-term survival has been obtained with cryopreserved homografts [5, 6], the rate of reoperation due to first conduit failure was as high as 66% after 15 years, and even higher after a first failure [5]. In contrast, reoperation for Fallot’s...
tetralogy repaired with a transannular patch is much less frequent than that for the Rastelli procedure [7, 8]. We describe the surgical strategy used to treat pulmonary atresia (PA) with ventricular septal defect (VSD).

**Patients and Methods**

From August 1997 to 1999, 10 consecutive patients with PA and VSD underwent valveless outflow reconstruction. Their ages ranged from 1.3 to 11.5 years (mean ± standard deviation, 4.7 ± 3.1 yr); three patients were less than 2 years of age. The male to female ratio was 1:4. Previous palliation included a central shunt through a median sternotomy in five patients, done at this hospital and a Blalock-Taussig shunt in four patients, done at other hospitals prior to referral to this hospital. In all patients with a central shunt, the exposed area was covered with a surgical membrane (Gore-Tex, Flagstaff, AZ, USA). In one 4-year-old patient with multiple major aortopulmonary collateral arteries (MAPCA), a central shunt was performed first (Fig. 1). Transient left pleural effusion for 1 week in this patient was probably due to increased pulmonary blood flow via the dual supply to the left lung. MAPCAs were coil embolized during three admissions in the next 2 years (Fig. 2). The aortic oxygen saturation increased from 84.9% to 87.6%, and the McGoon ratio increased from 1.9 to 2.3 after central shunting and coil embolization.

All patients underwent ultrafast computerized tomography (CT) to determine the definitive status of residual collaterals and pulmonary arteries. Six patients had natural coarctation of the left pulmonary artery near the ductal insertion site, three of whom underwent a patch repair with a central shunt at the first palliation (Fig. 1). The other three patients were managed during total correction as described below. Four patients had a kinked left pulmonary artery caused by a previous shunt. After surgical correction, all patients underwent follow-up ultrafast CT.

**Operative technique**

The substernal structures including the left anterior descending coronary artery were identified by CT before surgery. Under endotracheal general anesthesia and through a median sternotomy, the substernal tissue was dissected free, layer by layer. The Gore-Tex membrane was extracted and the shunt dissected. After aortic and bicaval cannulation, the shunt was clipped and divided. Cardiopulmonary bypass was then begun, with moderate hypothermia. Blood cardioplegic solution was infused through the aortic root after aortic cross clamping. The pulmonary artery was opened after removal of the distal shunt and the stenotic part was opened (Figs. 3A and 4A). After longitudinal ventriculotomy, the perimembranous ventricular septal defect was repaired with a continuous Dacron patch. All pulmonary arteries except two were directly connected to the right ventricle with a 6-0 synthetic absorb-
Fig. 3. Operative procedures used in patients without a stenotic orifice of the right pulmonary artery or with adequate tissue for a direct connection. A) The central shunt is sutured proximally, the distal pulmonary artery is incised after removal of the shunt until the natural or acquired stenotic site of the left pulmonary artery is cut open; the right ventricle is opened and extended distally until the atrial fibrous portion; and the annulus is opened if present. B) The right ventricle and pulmonary artery are connected transversely. C) A transannular patch of fresh pericardium is used to cover the subpulmonary outflow tract, without insertion of a valve. Ao = aorta; LA = left atrium; LPA = left pulmonary artery; LV = left ventricle; RA = right atrium; RV = right ventricle.

able suture (Maxon Davis-Geck, Cyanamid, Hampshire, UK) continuously in a transverse fashion (Fig. 3B). The posterior ridge was smoothed if present.

Figure 4 shows the common wall technique used to correct the stenotic right pulmonary artery where there was inadequate pulmonary arterial tissue for a direct connection — ie, with a long atrial fibrous cord. The ascending aorta was used to augment the pulmonary artery as the common wall, after the adventitia had been cleaned. By suturing both cut margins of the cutback right pulmonary artery to the posterolateral wall of the aorta (Fig. 4B), the orifice of the right pulmonary artery was enlarged. The suturing was then continued horizontally to the fibrous roof of the right ventricle or left atrial appendage, which was covered with the thickened visceral pericardium reactive to the previously implanted Gore-Tex membrane, until the left pulmonary artery was reached. The upper portion of the right ventriculotomy was extended and sutured horizontally to smooth out the posterior portion. In all patients, the caudal edge of the left pulmonary artery was sutured directly to the left edge of the ventriculotomy. Finally, a piece of fresh pericardium was harvested and sutured to cover the right ventricular outflow tract (Figs. 3C and 4C). Injury to the proximal right coronary artery was carefully avoided during stitching. The aortic cross clamp was released after deairring and closure of the interatrial communication. The right ventricular portion and then the right atrium were closed. The patient was weaned from bypass after transesophageal echocardiography and pressure measurements.

Results

All patients survived. Intraoperative transesophageal echocardiography revealed a widely patent right ventricular outflow tract in all patients (Fig. 5). The postoperative systolic right ventricular to aortic pressure ratio was 0.46 ± 0.04 in the operating theater. No patient exhibited a pressure gradient across the annulus. The central venous pressure was low (9 ± 1 mmHg). Follow-up echocardiography twice yearly after surgery revealed trivial tricuspid regurgitation and mild pulmonary regurgitation. Three-dimensional images of the reconstructed right ventricular outflow tract by ultrafast CT are shown in Figure 6. No residual ventricular septal defect was found. All patients were doing well without hepatomegaly at follow-up 18.4 ± 7.4 months after surgery.

Discussion

The surgical approach used to correct PA with VSD in this study included two strategies, a central approach and direct connection of the right ventricle to the pulmonary artery. The central approach has been advocated for PA with VSD and MAPCA [9]. If a peripheral approach, such as a Blalock-Taussig shunt with or without unifocalization is used [10], obstruction of the central pulmonary artery or aneurysmal dilatation of a thin-walled MAPCA might ensue [11, 12]. The resulting uneven growth of the bilateral pulmonary arteries may preclude later total correction. Furthermore, dissection of the peripheral shunt through a median sternotomy is deeper and more difficult than dissection of a central shunt. In our study, the surgical membrane was used to facilitate reentry only. In addition, it was unexpectedly found that the thickened visceral pericardium reactive to the covering
surgical membrane could hold the stitches during total repair. Thus, the visceral pericardium can be used as the natural posterior wall of the right ventricular outflow tract during reentry. This is similar to the conduit bed used during redo Rastelli operation, as previously reported [13]. The left main coronary artery is usually behind the base of the left atrium and can be avoided. The use of a central approach with a covering surgical membrane is, therefore, strongly recommended to prepare a fibrous posterior wall if palliation is deemed necessary. The bite was made deep into the underlying tissue such as myocardium or aorta so that aneurysm formation was less likely to occur. The orifice of MAPCAs will diminish in size after improvement in oxygen saturation. If not, the cardiologist can coil-embolize these MAPCAs without thoracotomy.

The contribution of the Lecompte procedure (or reparation à l’étage ventriculaire, REV) is to connect the right ventricle and pulmonary artery directly without prosthetic material or pericardium [14]. Thus, the malformation can be corrected earlier than with the Rastelli operation. Recently, neonatal correction with REV has been successfully performed on patients with PA and VSD [15]. Of the three patients less than 2 years of age who underwent correction by direct connection in our study, one had not previously undergone palliation. The growth potential after our common wall procedure was expected to be similar to that with neonatal or usual REV [14, 15]. We agree with Metras et al that it is not necessary to mobilize the bifurcation anterior to the aorta for REV [16], as in the Lecompte maneuver for an arterial switch operation [17]. The anterior displacement may totally abolish the functional implication of the natural spiral relationship of the great arteries.

Finally, the pulmonary valve is not absolutely necessary in patients without pulmonary hypertension and tricuspid regurgitation. This has been shown not only in cases after conventional repair of Fallot’s tetralogy [7], but also in cases of Fallot’s tetralogy with absent pulmonary syndrome after valveless repair [18]. It is the outflow tract that requires correction in this disease.
category, not the absence of the valve. We have previously successfully corrected three cases of Fallot’s tetralogy without pulmonary valve insertion. Razzouk et al reported the in situ implantation of a bioprosthetic pulmonary valve that fared better than other modes of the Rastelli operation with a valved conduit [19], probably reflecting that in situ correction of the right ventricular outflow tract is superior to bypass of the subpulmonary outflow through a conduit. Only direct connection with smoothing of the subpulmonary outflow as described here, with or without insertion of the valve, can achieve this goal. Although a pulmonary valve has been implanted after valveless repair [20], these results and others support this valveless option until a redo-free pulmonary valve is available [7, 18]. In short, a central approach with a surgical membrane can prepare the fibrous posterior wall for connection, and a valveless strategy might possibly avoid the need for repeat surgery if the tricuspid valve remains competent, because one competent right-sided valve is adequate for pulmonary circulation without hypertension. Aortopulmonary fistula was not found in our study, though it can occur after common wall repair.

In conclusion, a central approach for palliation and change of PA with VSD into Fallot’s tetralogy at total repair are recommended as surgical strategies. A valveless direct connection or use of a common wall without the Lecompte maneuver can be performed earlier in cases without pulmonary hypertension and tricuspid regurgitation.

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References