"Reverse Blalock-Taussig shunt": Application in single ventricle hybrid palliation

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Objective: Retrograde aortic arch malperfusion after ductal stenting can be life-threatening after univentricular hybrid palliation. Arch perfusion can be maintained with a main pulmonary artery to innominate artery shunt placed during the stage I procedure: a "reverse Blalock-Taussig shunt."

Methods: A retrospective review of 37 infants who underwent hybrid palliation from January 2004 to March 2010 was performed. The infants were divided into 2 groups, those with (group I, n = 16) and those without (group II, n = 21) a reverse Blalock-Taussig shunt.

Results: At the initial palliation, no differences were found in the demographics, systolic or diastolic pressures, or ventricular or atrioventricular valve function between the 2 groups. Group I had more infants with aortic atresia ($P < .01$) and smaller ascending aortas ($P < .01$). Before stage II, the retrograde aortic Doppler flow velocity increased in group I ($P < .01$) and was unchanged in group II. The reintervention rates before stage II were similar between the 2 groups. Before stage II, the ventricular end-diastolic pressure, left and right pulmonary artery pressures and diameters, and mixed venous and arterial saturations were similar between the 2 groups. The complication rates between the 2 groups were not significantly different, although a nonsignificant trend toward more neurologic complications was noted in group I. The Kaplan-Meier survival estimate at 1 year was similar between the 2 groups (63% for group I vs 71% for group II).

Conclusions: The presence of a reverse Blalock-Taussig shunt was not associated with more adverse events than those without. Gradual retrograde arch obstruction occurs commonly in palliated infants with aortic atresia. A reverse Blalock-Taussig shunt might play an important role to address the potential of retrograde obstruction, augmenting arch blood flow. (J Thorac Cardiovasc Surg 2013;146:352-7)

The so-called hybrid palliation (bilateral pulmonary artery [PA] bands and a ductal stent) has emerged as an alternative to Norwood palliation for infants with hypoplastic left heart syndrome or its variants.[1-3] The potential, but unproved, advantage of hybrid palliation is the avoidance of circulatory bypass and aortic arch reconstruction in the neonatal period, shifting such procedures to later in life. A potential problem with this strategy is either immediate or delayed obstruction in the aortic isthmus after ductal stent deployment. This obstruction can compromise retrograde aortic arch flow, which supports, in the extreme case of aortic valvar atresia, the cerebral and coronary perfusion. A potential solution is the placement of a main PA to innominate artery shunt, analogous to a Blalock-Taussig (BT) shunt, which we have designated the "reverse BT (revBT) shunt."[4] This connection can provide a source of blood flow to the ascending aortic arch if the retrograde arch flow from the isthmus becomes compromised. Few centers perform a revBT shunt during hybrid palliation, and little is known regarding the outcomes and potential advantages and disadvantages of the procedure. In the present study, we reviewed our experience during hybrid palliation in those infants with and without a revBT shunt.

METHODS

A retrospective chart review was conducted of all infants with hypoplastic left heart syndrome or 1 of its variants, who had undergone hybrid single ventricle palliation from January 2004 to March 2010. The Research Ethics Board at the Hospital for Sick Children approved the study, and patient and family consent was waived owing to the retrospective nature of the study. The form of surgical palliation (hybrid [with or without a revBT shunt], Norwood, or primary transplantation) was discussed at an interdisciplinary conference after presenting the options to the family. No specific decision-making protocol was applied for the form of surgical palliation. The revBT shunt was placed after PA banding, avoiding the pulmonary valve ring to the innominate artery using a 3.5-mm polytetrafluoroethylene graft. The use of the revBT shunt was approved by the Surgical Innovations Ethics Committee, and the experimental nature was explained to each family.[3]

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Abbreviations and Acronyms
AVVR = atrioventricular valve regurgitation
BT = Blalock-Taussig
ECMO = extracorporeal membrane oxygenation
PA = pulmonary artery
PVR = pulmonary valve regurgitation
revBT = reverse BT

Echocardiogaphic Assessment

Echocardiography was performed using a Phillips ATL (Advanced Technology Laboratories, Bothell, Wash), Philips IE-33 (Philips Medical systems, Eindhoven, The Netherlands), or Vivid 7 (GE Healthcare, Waukesha, Wis) system. The echocardiograms at diagnosis, immediately after hybrid palliation, before hospital discharge, and before the comprehensive stage II procedure (arch reconstruction and a cavopulmonary connection) were reviewed (n = 27). Digital images were stored and analyzed offline with commercially available software (SyngoDynamics, Siemens Medical Systems, Erlangen, Germany). Ventricular function was graded visually (1, normal; 2, mild impairment; 3, moderate; and 4, severe impairment), and the degree of atrioventricular valve regurgitation (AVVR) and pulmonary valve regurgitation (PVR) was graded (1, none/trace; 2, mild; 3, moderate; and 4, severe) according to the color flow regurgitant jet, as previously described.[5,6] From a suprasternal long-axis view, isthmus flow was measured at the base of the left subclavian artery. The flow profile was outlined manually to measure the maximal flow velocity, and the velocity–time integral, with 3 consecutive heart beats, was measured and averaged. The retrograde/antegrade velocity–time integral ratio was calculated and considered dominantly retrograde if the ratio was >1. The presence of flow in the revBT shunt was determined; however, because of the incident angle, the flow velocity could not be assessed.

Catheterization and Angiography

The invasive hemodynamic studies and angiograms before stage II surgery were reviewed. The diameters of the right and left PAs were measured at the hilum, proximal to the takeoff of the branching vessels. A Nakata index was calculated as the sum of the right and left PA cross-sectional areas indexed to the child's body surface area.[7]

Statistical Analysis

The data are presented as the mean ± standard deviation. Continuous variables were compared using the Mann-Whitney *U* test and Student *t* test. Dichotomous and categorical variables were analyzed using Fisher's exact test and the chi-square test. Paired data were examined using paired 2-tailed *t* tests. Kaplan-Meier curves were constructed to determine the freedom from death or transplantation, and the survival rate was compared between the 2 groups using a log-rank test.

RESULTS

Patient Characteristics

A total of 48 consecutive neonates underwent hybrid palliation. Excluded from the present review were those neonates who underwent hybrid palliation as a bridge to transplantation (n = 7), a salvage procedure during extracorporeal membrane oxygenation (ECMO) support (n = 1) or as an interim procedure before biventricular repair (n = 3). The remaining 37 neonates included in the study cohort were divided into 2 groups: those with (group I) and those without (group II) a revBT shunt. The patient characteristics and diagnoses are listed in Table 1. In group I, 16 neonates underwent palliation at a median age of 6.5 days (mean, 7.4 ± 4.8 days) and median weight of 3.3 kg (mean, 3.2 ± 0.6 kg). The 21 neonates in group II underwent hybrid palliation without a revBT shunt at a median age of 7.0 days (mean, 13.5 ± 24 days) and median weight of 3.2 kg (mean, 3.2 ± 0.5 days). In group II, 4 neonates had aortic atresia; 2 procedures were abandoned because of patient instability during the procedure (electrocardiographic changes of ischemia). The other 2 neonates had an ascending aorta more than 3 mm in diameter and presented early in our experience before the decision to place a revBT shunt in neonates with aortic atresia. No demographic differences were seen between the 2 groups.

Echocardiographic Findings

Not unexpectedly, the group I infants had a significantly smaller ascending aorta (2.4 ± 1.2 mm vs 5.0 ± 1.9 mm, $P < .01$) and more commonly aortic atresia (16/16 [100%] vs 4/21 [19%]; $P < .01$) than those in group II (Table 2). Although all neonates in group I by anatomic definition had retrograde arch flow, 11 neonates (52%) in group II had a dominant retrograde arch flow pattern. No significant difference was found in ventricular function or the degree of AVVR or PVR at the initial examination between the 2 groups.

Interstage Echocardiography: After Stage I and Before Stage II

Echocardiographic studies were obtained before stage II at 186 ± 24 and 198 ± 38 days of age in group I and II, respectively (Table 3). All revBT shunts were patent, as determined by echocardiography or angiography. No significant differences were found in ventricular function, AVVR, or PVR during this period in either group. Before stage I, no difference was found in retrograde flow between the 2 groups; however, in group I, the retrograde arch flow peak velocities increased significantly ($P < .01$). In group II (those with dominant retrograde arch flow, n = 11), no significant increase was seen in the velocity ($P = .30$). In the 3 group II infants (19%) with aortic atresia, the changes in retrograde peak flow velocities were as follows: patient 1, from 0.95 to 2.2 m/s; patient 2, 1.5 to 2.6 m/s; and patient 3, 1.7 to 2.4 m/s. Although the analysis of the entire group showed no statistically significant difference, a clear trend was seen toward progressive arch malperfusion in these infants.

Subsequent Interventions

Intervention on the atrial septum was performed in 10 of 16 (63%) infants in group I and 11 of 21 infants (52%) in group II. No significant difference was seen in the age at intervention between the 2 groups (group I, 52 ± 52 days;