Evaluation of valved saphenous vein homograft as right ventricle-pulmonary artery conduit in modified stage I Norwood operation

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Abstract

Potential drawbacks from right ventricle-pulmonary artery (RV-PA) conduit in modified Norwood procedure may be regurgitation through the conduit and incision at the systemic ventricle. In order to address the question if valved RV-PA conduit can provide hemodynamic advantages, we retrospectively reviewed the data of patients who underwent modified stage I Norwood operation with either a non-valved ePTFE RV-PA conduit or a valved saphenous vein homograft (SVG). Four patients in each group, both the ePTFE and SVG, were involved in the study and 2 patients in each group eventually died. Conduit regurgitation was seen mild to moderate-to-severe in all patients with ePTFE and mild in one patient with SVG. This regurgitation progressed over the next several months in the ePTFE group. Tricuspid regurgitation became worse in the ePTFE group, whereas it was improved in 2 patients within the SVG group. RV ejection fraction was reduced from 70\% to 55\% to 12\% in the ePTFE group, whereas it was improved from 62\% to 70\% to 2\% in the SVG group postoperatively ($P<0.05$). We conclude that conduit regurgitation may cause RV systolic dysfunction and prolong a functional recovery after modified stage I Norwood procedure. Saphenous vein homograft may be a choice as RV-PA conduit in this procedure.

Keywords: Stage I Norwood procedure; Hypoplastic left heart syndrome; Right ventricle-pulmonary artery shunt

1. Introduction

Significant improvement in peri-operative management by RV-PA conduit as a part of Norwood stage I palliation has been widely accepted in patients with hypoplastic left heart syndrome (HLHS). This is thought to be theoretical with advantages maintaining higher coronary perfusion pressure and lower Qp/Qs [1]. However, potential drawbacks from this RV-PA conduit may be regurgitation through the conduit and systemic ventriculotomy, even if patients have favorable immediate post-operative hemodynamics. A more recent report [2] suggests that neonates having an RV-PA conduit in Norwood procedure may have a relatively lower pulmonary blood flow (PBF), may need more frequent interstage monitoring and evaluation, earlier catheterization and second stage operation. Since 2001, we have applied saphenous vein homograft (SVG) as RV-PA conduit in patients with HLHS [3], and extended the application to patients with other complex cardiac malformations [4]. The benefit of SVG use in Norwood procedure has been also reported from other institutions [5]. In order to address this question, if a valved RV-PA conduit can provide hemodynamic advantages in modified Norwood operation, we retrospectively reviewed the data of our patients.

2. Materials and methods

Permission to perform the medical record review was obtained from the Committee on Human Research at the University of Tokyo, Japan. The medical records were reviewed for preoperative demographic and echocardiographic data, and hemodynamic data. Diagnostic catheterization data were obtained before bi-directional Glenn (BDG) palliation. SVGs were provided by the University of Tokyo Tissue Bank.

2.1. Patients’ profile

From October 2001 to December 2004, 8 neonates, including 4 males with HLHS (n=7) and its variants (n=1), had a modified stage I Norwood procedure at a median age of 8 (5–33) days and a mean weight of 3 (2.6–3.8) kg. These patients included 3 of aortic atresia/mitral stenosis, 3 of aortic atresia/mitral atresia, and 2 of aortic stenosis/mitral stenosis. Two patients had restrictive ASD without pulmonary venous obstruction. The median size of the ascending aorta was 2.55 (1.8–4.3) mm. One patient had a cardiac-type total anomalous pulmonary venous connection. Preoperative ventricular function was assessed echocardiographically as being good in 6 cases and fair or depressed in 2 patients. Tricuspid valve regurgitation (TR) was characterized on a 0 to 4+ grading scale [6]. Briefly, the grading scale was defined as follows: 0, none; 1+, mild; 2+, mild to moderate; 3+ moderate to severe; and 4+, severe. Along this scale, there were non in 1 patient, 1+ in 1 patient, 2+ in 5 patients, and 3+ in 1 patient. Echocardiography data at 3–4 weeks were shown as post-stage I data. Preoperative N$_2$ inhalation was applied in 6 patients (ePTFE; 2, SVG; 4).
2.2. Operative techniques

Following atrial septectomy, the distal end of the RV-PA conduit, either ePTFE (5 mm; 3, 6 mm; 1) or SVG (4 mm; 2, 5 mm; 2), was connected to the confluence of the pulmonary arteries. Arch reconstruction was performed by an end-to-side connection between the aortic arch and the main pulmonary artery. The proximal end of the conduit was beveled and connected to a limited ventriculotomy with resection of subendocardial muscle.

2.3. Data analysis

Data are described as frequencies, medians with ranges, and means with standard deviations as appropriate. Characteristics and hemodynamic data of patients having ePTFE or SVG were compared using a t-test or nonparametric test. All analyses were performed using SPSS 9.0 statistical software (SPSS, Chicago, IL).

3. Results

Modified ultrafiltration was used in 3 patients and peritoneal dialysis was used in all patients. Nitric oxide was used in 6 patients postoperatively. The delay in chest closure was insignificantly longer in the SVG group.

3.1. Clinical course

In each group, one patient died within 30 days after surgery and another patient died before BDG after the completion of pre-BDG catheterization study. Two patients completed BDG and one of those completed modified Fontan in each group (Fig. 1). Time to BDG was 3 months in the SVG group and 4–6 months in the ePTFE group. Both conduits had stenosis mostly at the proximal anastomosis site.

3.2. Cardiac catheterization and echo data

Cardiac catheterization data were obtained from 6 survivors. Pulmonary vascular resistance (PVR) and PA index were insignificantly lower in the SVG group at pre-BDG evaluation (Table 1). Conduit regurgitation was seen mild to moderate-to-severe (1+ in 1 patient, 2+ in 2 patients, 3+ in 1 patient) in the ePTFE group and no regurgitation was seen in 3 patients, and 1+ in 1 patient in the SVG group for the first month of surgery. This regurgitation progressed over the next few months in the ePTFE group, whereas it remained static in the SVG group. After stage I Norwood palliation, TR became worse in the ePTFE group (1 patient developed 1+, and another patient had aggravation from 1+ to 3+). Interestingly, in the SVG group, 2 patients had improvement of TR (one from 3+ to 0, one from 1+ to 0) (Fig. 2). RV ejection fraction (RVEF) was reduced postoperatively with gradual recovery during the follow-up in the ePTFE group, whereas it was improved after surgery in the SVG group (Fig. 3).

4. Comments

RV-PA conduit as a part of Norwood stage I palliation has been recognized as contributing to postoperative hemodynamic stability and better survival after the surgery [1,7] However, potential drawbacks from this modification are right ventriculotomy and pulmonary regurgitation through the conduit. In a recent study, comparing ventricular function in patients who underwent modified Norwood procedure with either an RV-PA conduit or conventional systemic to pulmonary shunt, ventricular contractility after BDG and Fontan was inferior in patients with an RV-PA conduit [8]. Also, development of TR remains a significant obstacle to successful staged repair in a subset of these patients [6].

4.1. Impact of RV-PA conduit on development of pulmonary vascular tree

Pulmonary blood flow is likely to result in structural changes in vessels. Decreased PBF appears to result in poor

![Fig. 2. Tricuspid regurgitation evaluated by echocardiography. It was improved in the SVG group, whereas there was a trend towards the aggravation in the ePTFE group after the surgery. Pre: preoperative condition.](Image)
development of the pulmonary vascular tree and the wide pulmonary artery pulse pressure in utero is associated with abnormal proliferation of segmental branches seen in patients with absent pulmonary valve [9]. Although PA index does not seem to be different between the groups, pulmonary regurgitation potentially may cause poor development of pulmonary arterial tree. Decreased pulmonary vascular resistance may explain low PBF in the ePTFE group. This is supported by a previous report that patients with RV-PA conduit had significantly lower calculated Qp/Qs, and relatively lower PBF, earlier second stage operation than patients with classical stage I [2]. Inversely, a report by Rumball et al. [10] concluded that RV-PA conduit stimulates better growth of the pulmonary arteries after modified Norwood procedure based on their angiographic findings. Structural abnormalities of pulmonary vascular and lymphatic trees are reported in a subgroup of patients with HLHS and an intact or very restrictive atrial septum [11]. And the fibrous matrix of ventricular myocardium is very different in patients with HLHS with less collagen matrix than normal [12]. In such circumstances, physiological PBF may be critical for establishment of reasonable pulmonary circulation.

4.2. Impact of valved RV-PA conduit on impairment of RV function

Ventriculotomy affects myocardial function immediately after the surgery and even in long term follow-up. A report from one of the pioneer groups of RV-PA conduit suggests deterioration of the ventricular function after the right ventriculotomy in stage I palliation and this might be compensated by hyperkinetic motion in other ventricular segments [13]. Another factor affecting ventricular function is pulmonary regurgitation to cause volume overload for the ventricle. This study demonstrated that cessation of pulmonary regurgitation by valved SVG caused improvement of TR and RVEF in some patients. Ventriculotomy can not be avoided even in SVG, however, it might be effective in reducing volume overload [3,4].

4.3. Benefits and drawback of SVG homograft conduit

There are several advantages in using SVG including better handling, hemostasis and possible resistance to infection. However, this may be against the limited availability and possible degeneration of SVG. Because of limited availability, we could only use 4–5 mm diameters of SVG, this might be related to an earlier second surgical intervention in the SVG group.

In summary, RV-PA non-valved conduit has regurgitation through the conduit and this regurgitation continues for several months after stage I. RV systolic function deteriorated in the non-valved ePTFE group with partial recovery during the follow-up. Both conduit regurgitation and functional deterioration were not essentially seen in SVG.

Based on our data, saphenous vein homograft may be appropriate as RV-PA conduit in modified Norwood procedure. Further investigation would be warranted to lead a conclusion.

References


