Optimal Graft Size of Modified Blalock-Taussig Shunt for Biventricular Circulation in Neonates and Small Infants

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SUMMARY

The modified Blalock-Taussig shunt (mBTS) is one of the most important palliative procedures in congenital heart surgery. However, in neonates and small infants, operative mortality and morbidity due to excessive pulmonary blood flow or shunt failure remains high. In this study, a small shunt graft (3.0-mm diameter) was estimated to determine the optimal shunt graft size of BTS as an initial palliation for ultimate biventricular circulation. Eighteen patients weighing an average 3.5 kg who underwent mBTS from July 2004 to January 2013 at our institute were reviewed. We divided the study cohort into two groups: group S ($n = 10$) included patients with 3.0-mm diameter shunt grafts, and group L ($n = 8$) included patients with 3.5-mm diameter shunt grafts. There were no hospital deaths or shunt occlusion in either group. One group L patient (12.5%) had cardiogenic shock due to excessive pulmonary blood flow. There were no differences in postoperative arterial oxygen saturation (SaO_2) between the groups. There were no differences in body weight at intracardiac repair (ICR) between the groups. During the interstage to ICR, body weight gain was significantly greater in group S than in group L ($P = 0.008$). The small shunt graft (3.0-mm diameter) in BTS was safe, provided adequate pulmonary blood flow, and led to significant weight gain between mBTS and ICR for ultimate biventricular circulation in neonates and small infants with low body weight. (Int Heart J 2015; 56: 533-536)

Key words: Palliative procedures, Congenital heart disease, Small shunt graft

Systemic-pulmonary arterial shunts were developed in 1945 by Blalock and Taussig and later by Potts and Waterston.¹⁾ The potential disadvantages of these shunts include excessive volume load, acute thrombosis, and low diastolic blood pressure, leading to coronary insufficiency.^{1,2)} The mortality and morbidity of a modified Blalock-Taussig shunt (mBTS), particularly in neonates and small infants, remain high because of excessive pulmonary blood flow or shunt occlusion.³⁻⁵⁾ Dirks and colleagues reported that low body weight and bigger shunt size/kg body weight were factors associated with postoperative mortality.⁶⁾ In contrast, Myers and coworkers reported good outcomes with the use of 3.5- and 4.0-mm shunts and shunt reintervention using 3.0-mm shunts was common.³⁾ Thus, while small shunts have a tendency to cause shunt thrombosis,⁷⁾ large shunts may lead to pulmonary over-circulation and volume overloading of the heart.⁶⁾

We have attempted to reduce graft sizes to prevent pulmonary over-circulation. In particular, in patients with biventricular physiology who have forward pulmonary blood flow from the main pulmonary artery, a small BTS would be beneficial to prevent excessive pulmonary blood flow. In the present study, we investigated the impact of shunt size on postoperative outcomes in patients who underwent biventricular repair.

METHODS

Patient characteristics: The records of 18 patients (15 males and 3 females) who underwent mBTS as an initial palliation for ultimate biventricular circulation between July 2004 and January 2013 at our institute were retrospectively reviewed. The average body weight at mBTS was 3.5 ± 0.8 kg. We performed mBTS in symptomatic patients with hypercyanotic spells, and in asymptomatic patients who had suspected pulmonary artery isolation. Patients with univentricular physiology were excluded. In patients with univentricular physiology in the absence of pulmonary blood flow from the main pulmonary artery, a small shunt may not be estimated to prevent excessive pulmonary blood flow.

We divided the study cohort into two groups of patients who underwent BTS: group S ($n = 10$) included patients who received 3.0-mm polytetrafluoroethylene (PTFE) shunt grafts, and group L ($n = 8$) included patients who received a 3.5-mm diameter shunt. The demographic data are shown in Table I. The age at mBTS was younger in group S than in group L (group S, 32.9 ± 26.5 days; group L, 81.5 ± 57.0 days; $P = 0.03$). There was no difference in body weight at mBTS between the two groups (group S, 3.4 ± 0.6 kg; group L, 3.7 ± 0.9 kg; $P = 0.52$). Two patients in group S and 4 patients in group L had patent ductus arteriosus (PDA; $P = 0.2$).

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Table I. Patient Characteristics and Diagnoses

Variable	Group S (<i>n</i> = 10)	Group L (<i>n</i> = 8)	<i>P</i>
Body weight at BTS (kg)	3.4 ± 0.6	3.7 ± 0.9	0.52
Age at BTS (days)	32.9 ± 26.5	81.5 ± 57.0	0.03
Diagnosis			
TOF	2	2	0.81
DORV	8	6	0.81
PDA	2	4	0.20

BTS indicates Blalock-Taussig shunt; TOF, tetralogy of Fallot; and; PDA, patent ductus arteriosus.

Table II. Comparison by Univariate Analysis of the Postoperative Results Between Group S and Group L

Variable	Group S (<i>n</i> = 10)	Group L (<i>n</i> = 8)	<i>P</i>
Postoperative SaO ₂ after 72 hours (%)	88.5 ± 3.9	89.2 ± 3.7	0.74
Maximum catecholamine index	4.5 ± 1.0	8.3 ± 4.8	0.03
Age at ICR (days)	173.7 ± 41.1	363.1 ± 161.3	0.002
Body weight at ICR (kg)	6.0 ± 0.6	6.3 ± 1.5	0.61
SaO ₂ before ICR (%)	88.2 ± 6.6	84.4 ± 4.1	0.17
Interval between BTS and ICR (days)	140.8 ± 36.0	281.6 ± 118.9	0.003
Body weight gain during the interstage (g/day)	18.2 ± 5.8	10.1 ± 5.4	0.008
Graft index* (mm ² /m ²)	34.8 ± 4.1	45.2 ± 7.7	0.002

*Graft sectional area divided by body surface area was defined as the graft index. SaO₂ indicates arterial oxygen saturation; ICR, intracardiac repair; and BTS, Blalock-Taussig shunt.

Operative procedure: In our series, mBTS was performed via a median sternotomy in all patients. Five patients underwent cardiopulmonary bypass (CPB) because arterial oxygen saturation (SaO₂) could not be maintained above 65% under a partial pulmonary clamp. We performed anastomosis between the brachiocephalic artery and left or right pulmonary artery under innominate vein using a PTFE graft. A vascular clip was used to close a PDA in 5 patients (83%). The criterion of PDA interruption was that SaO₂ could be maintained at > 85% when the PDA was temporarily clamped. We performed intracardiac repair (ICR) after BTS if the pulmonary artery index (PAI) exceeded 200 mm²/m², and the left ventricular end-systolic volume index (LVESVI) exceeded 70% of normal.

Parameters evaluated and statistical analysis: The postoperative courses and short- and mid-term results were compared between the groups. Age, body weight, body weight gain during the interstage to ICR, catecholamine index, and SaO₂ after mBTS were evaluated. The graft sectional area divided by the body surface area was defined as the graft index. Continuous variables are presented as the mean and standard deviation. Student's test or Welch's test was used to compare continuous variables. Frequencies were calculated for categorical variables with percentages. The χ^2 test or Fisher's exact test was used to examine the associations of categorical variables. Competing outcomes at 1 year were calculated separately for group S and group L and are presented in a graphic format. Factors associated with hospital mortality were analyzed using univariate analysis. The associations between the graft index and body weight gain, and interval during the interstage to ICR were assessed using simple regression analysis. Values of *P* < 0.05 were considered to indicate statistical significance.

RESULTS

There were no hospital deaths or shunt occlusions in either group. One patient (12.5%) in group L had cardiogenic shock due to excessive pulmonary blood flow. There were no differences in postoperative SaO₂ after 72 hours between the two groups (group S, 88.5 ± 3.9%; group L, 89.2 ± 3.7%; *P* = 0.74). The maximum catecholamine index was significantly greater in group L than in group S (group S, 4.5 ± 1.0; group L, 8.3 ± 4.8; *P* = 0.03). The age at ICR was significantly younger in group S than in group L (group S, 173.7 ± 41.1 days; group L, 363.1 ± 161.3 days; *P* = 0.002). There was no significant difference in body weight at ICR between the groups (group S, 6.0 ± 0.6 kg; group L, 6.3 ± 1.5 kg; *P* = 0.61). The interval between BTS and ICR was greater in group L than in group S (group S, 140.8 ± 36.0 days; group L, 281.6 ± 118.9 days; *P* = 0.003). There was no significant difference in SaO₂ before ICR between the two groups (group S, 88.2 ± 6.6%; group L, 84.4 ± 4.1%; *P* = 0.17). During the interstage to ICR, body weight gain was significantly greater in group S than in group L (group S, 18.2 ± 5.8 g/day; group L, 10.1 ± 5.4 g/day; *P* = 0.008).

The graft index was significantly greater in group L than in group S (group S, 34.8 ± 4.1 mm²/m²; group L, 45.2 ± 7.7 mm²/m²; *P* = 0.002; Table II). There was a positive correlation between the graft index and interval between BTS and ICR (correlation coefficient = 0.52; *P* = 0.03; Figure 1). There was a slight negative correlation between the graft index and body weight gain (correlation coefficient = -0.24; *P* = 0.34; Figure 2).

Figure 1. Graft index and interval between Blalock-Taussig shunt (BTS) and intracardiac repair (ICR).

Figure 2. Graft index and body weight gain.

DISCUSSION

In spite of the recent progress in the perioperative management of patients with congenital heart diseases, operative mortality and morbidity of BTS, particularly in neonates with low body weight, remain unsatisfactory because of the excessive pulmonary blood flow or shunt occlusion.^{3,8-11} In particular, the mortality of BTS is 5 times higher in patients with a univentricular heart than that in patients with biventricular circulation.^{12,13} Thus, it is becoming increasingly common to follow a protocol that involves only primary repair without the use of palliative shunts. Several investigators have recently insisted that early-stage primary repair is safe and effective, with low mortality.^{14,15} However, this is not universal.¹⁶⁻¹⁸ Others prefer to perform a palliative shunt without CPB in symptomatic patients under a specific age, and primary repair above this age. Also, BTS has advantages in annulus growth and annulus preservation,^{19,20} and has preserved good pulmonary valve function.

The factors associated with adequate pulmonary flow are body weight at mBTS and graft size. There have been a limited number of reports on small shunts (3.0-mm graft); thus, the feasibility of these small shunts has not been widely investigated.²¹ In the present series, we reduced the graft size to prevent excessive pulmonary blood flow and cardiogenic shock. A possible disadvantage of small grafts is shunt occlusion; therefore, in the operative procedure, we placed a BTS at the proximal portion of the brachiocephalic and pulmonary arteries with sufficient anastomosis size, and the median sternotomy approach was selected for all patients. Talwar and colleagues reported that the median sternotomy approach for mBTS was preferable to the thoracotomy approach and had fewer shunt failures.²² Our study revealed that use of 3.0-mm BTS reduced the interval between BTS and ICR and increased body weight gain during the interstage; however, SaO₂ for the small shunt graft was almost the same as that for the larger graft.

In the present study, a 3.0-mm graft BTS was adequate in patients weighing about 3.5 kg. However, in larger patients, the optimal graft size remains controversial. In our analysis of the graft index, an adequate and sufficient graft index seemed to be about 40 mm²/m² (Figures 1 and 2). From this point of view, in patients with a body weight of 4.0 kg, a 3.5-mm graft BTS corresponding to a graft index around 40 mm²/m² would be adequate, and in patients with a body weight of 5.0 kg, a

4.0-mm graft BTS would be adequate.

In the present study, we focused on patients with biventricular circulation. With the forward pulmonary blood flow from the main pulmonary artery, additional pulmonary flow would be beneficial even through a small BTS. In our analysis, there was a positive correlation between the graft index and interval between BTS and ICR. In contrast, there was a tendency towards a negative correlation between the graft index and body weight gain. Thus, a 3.0-mm shunt graft is feasible for patients with pulmonary stenosis (PS) who weigh 3.5 kg.

There are several limitations to this study. First, we did not investigate patients with univentricular circulation. Second, this was a retrospective study, with a limited number of patients and a limited range of patient body weights. A future study with a larger number of cases with various patient demographics is warranted.

Conclusion: A small, 3.0-mm diameter BTS was safe, provided adequate pulmonary blood flow, and led to significant weight gain between mBTS and ICR for ultimate biventricular circulation in neonates and small infants with low body weight.

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