Impact of Shunt/Pulmonary Artery Ratio on Outcomes in Modified Blalock-Taussig Shunt Patients

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Abstract

Background: The modified Blalock-Taussig shunt (mBTT shunt) is a critical procedure for managing congenital heart defects by improving pulmonary circulation. Traditionally, shunt size is determined based on patient weight and standard guidelines. However, recent evidence indicates that the shunt size relative to the pulmonary artery diameter (S/PA ratio) may be a more accurate predictor of outcomes. This study evaluates the impact of the S/PA ratio on mortality and other clinical outcomes in patients undergoing the mBTT shunt. Methods: This retrospective study analyzed the medical records of 36 patients who underwent mBTT shunt at Soetomo General Academic Hospital between 2021 and 2023. Data on demographics, clinical characteristics, procedural details, and outcomes were collected, focusing on variables such as age, weight, McGoon ratio, pre- and post-operative SpO2 levels, and S/PA ratio. Statistical analyses included Chi-square tests for categorical variables and independent t-tests for continuous variables, with a p-value of <0.05 considered significant. Results: The cohort had a mean age of 54.81 months and a mean weight of 12.18 kg. Preoperative SpO2 averaged 71.44%, improving to 79.26% post-operatively. Patients with an S/PA ratio >1.00 had a significantly higher mortality rate (37.5%) compared to those with an S/PA ratio <1.00 (7.7%) (p = 0.029). These patients also experienced longer ICU stays (4.92 vs. 2.06 days, p = 0.005) and more ventilation days (3.40 vs. 1.68 days, p = 0.047). The hospital stay was also extended in the higher ratio group (8.60 vs. 5.50 days, p = 0.076). No significant differences were observed in pre- and post-operative SpO2 levels or inotropic use. Conclusion: A higher S/PA ratio is associated with increased mortality, longer ICU and hospital stays, and greater ventilation needs following the mBTT shunt. These findings suggest that optimizing shunt size relative to pulmonary artery diameter could lead to better outcomes. Further research is needed to confirm these results and refine surgical strategies for enhanced patient care.

Keywords: mBTT shunt, S/PA ratio, congenital heart defects, pulmonary circulation, surgical outcomes

Significance | This study showed the importance of the S/PA ratio in predicting mortality and recovery outcomes post-modified Blalock-Taussig shunt.

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Introduction

The modified Blalock-Tausig-Thomas shunt (mBTT shunt), an evolution of the original Blalock-Taussig shunt (BT shunt), is a crucial palliative procedure used to treat congenital heart defects, particularly cyanotic heart diseases. This intervention, first performed in 1944 by Dr. Helen Taussig, Dr. Alfred Blalock, and Mr. Vivien Thomas, initially aimed to alleviate cyanosis by improving pulmonary artery flow (Duncan et al., 2022; Frakes & Richardson, 2021). Over time, the procedure has been refined to the mBTT shunt, which employs an interposition

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polytetrafluoroethylene (PTFE) graft instead of directly connecting the subclavian artery to the pulmonary artery (Miyaji et al., 2015; Johnson & Chinn, 2019). This modification allows for better regulation of blood flow, preserves upper limb circulation, and simplifies the takedown procedure, addressing the limitations of the original technique (Alahmadi & Bishop, 2023; Patel et al., 2018).The success of the mBTT shunt is influenced by multiple factors, including the size of the shunt and the dimensions of the pulmonary artery (Smith et al., 2020; Hsu et al., 2017). Traditionally, shunt size has been chosen based on patient weight and standard surgical guidelines (Gleason et al., 2014; Rosenthal et al., 2011). However, recent evidence suggests that the ratio of shunt size to pulmonary artery diameter (S/PA ratio) could be a more precise predictor of surgical outcomes (Tian et al., 2020; Zhu & Song, 2023). A larger shunt relative to the pulmonary artery may improve pulmonary blood flow but also carries risks such as increased mortality and postoperative complications (Chen et al., 2016; Farooqi et al., 2022). Conversely, a smaller shunt might reduce these risks but may not provide sufficient pulmonary circulation (Hernandez & Chen, 2021; Maheshwari et al., 2013). Thus, the S/PA ratio is emerging as a key factor in optimizing shunt size to balance benefits and risks (Vanderlaan & Barron, 2023; Yuan et al., 2009).

The mBTT shunt remains a critical option for patients with certain congenital heart anomalies where complete repair is not feasible at the time of surgery (Lee et al., 2018; Karmarkar & Omer, 2021). This includes conditions such as hypoplastic left heart syndrome, congenitally corrected transposition of the great arteries, and severe cases of tetralogy of Fallot (Martin et al., 2021; Rodriguez et al., 2023). These conditions often require initial palliative surgery to ensure adequate pulmonary blood flow and promote pulmonary artery development before a more definitive repair can be performed (Schwartz et al., 2019; Taylor & Ahmed, 2022). Other congenital lesions that may benefit from the mBTT shunt include various forms of right ventricular outflow tract obstruction and pulmonary atresia (Küçük et al., 2016; Need et al., 2000; Yamamoto et al., 2017).

Understanding the impact of the S/PA ratio on clinical outcomes is essential for optimizing the mBTT shunt procedure (Singh et al., 2019; Zang & Xue, 2022). While mortality is a significant concern, other factors such as ICU stay duration, ventilation requirements, and overall recovery time are also critical to evaluate the comprehensive success of the intervention (Nakai et al., 2020; Osman et al., 2021). By analyzing these parameters in a cohort of patients undergoing the mBTT shunt, researchers aim to gain insights into how shunt size relative to pulmonary artery diameter affects both survival and postoperative recovery, ultimately contributing to improved surgical strategies and patient care (Wilson et al., 2016; Zhang et al., 2022).

2. Materials and Methods

2.1 Study Design and Participants

This retrospective cohort study was conducted at Soetomo General Academic Hospital, analyzing the medical records of 36 patients who underwent the modified Blalock-Taussig-Thomas (mBTT) shunt procedure between 2021 and 2023. The study aimed to evaluate the impact of the shunt size relative to pulmonary artery diameter (S/PA ratio) on clinical outcomes. Patients included in the study were those undergoing mBTT shunt as their initial palliative procedure for congenital heart defects.

2.2 Inclusion and Exclusion Criteria

Inclusion criteria were patients who received the mBTT shunt as their first palliative intervention. Exclusion criteria included patients with non-cardiac comorbidities that could significantly affect mortality, as well as those with incomplete medical records.

2.3 Data Collection

Data collected for analysis included patient demographics (age, weight, sex), clinical characteristics (McGoon ratio, pre- and post-operative oxygen saturation [SpO2] levels), procedural details (shunt size, pulmonary artery diameter, S/PA ratio, surgical approach, cardiopulmonary bypass [CPB] use), and postoperative outcomes (mortality, ICU stay duration, ventilation days, hospital stay length, and postoperative complications).

2.4 Surgical Procedure

All mBTT shunt procedures were performed under standardized conditions. Shunt size was determined based on both patient weight and pulmonary artery size. The shunt was placed using either the right or left subclavian artery, with procedural variations noted for each case.

2.5 Statistical Analysis

Data were analyzed using Chi-square tests for categorical variables and independent t-tests for continuous variables. The primary outcomes analyzed included mortality, ICU stay duration, ventilation needs, and overall recovery time. The S/PA ratio was treated as a categorical variable, with comparisons made between patients with ratios greater than or less than 1.00. A p-value of <0.05 was considered statistically significant.

2.6 Ethics Statement

This study was conducted in accordance with the ethical standards of Soetomo General Academic Hospital and adhered to the principles outlined in the Declaration of Helsinki. As this was a retrospective study, formal patient consent was waived, but patient anonymity and data confidentiality were strictly maintained throughout the research process. The study protocol was reviewed and approved by the hospital's Institutional Review Board (IRB), ensuring compliance with ethical guidelines.

3. Results

Table 1. Subject Characteristics and Clinical Parameter

Variable	Value	
	Mean	**(±Std Deviation)**
Age (month)	54,8056	(±48,75)
Weight (kg)	12,1806	(±8,27)
McGoon Ratio	1,4284	(±0,29)
SpO2 Pre Operative	71,4444	(±8,33)
SpO2 Post Operative	79,2647	(±3,02)
Variable	**Group**	**N (%)**
Sex	Boy	18 (50)
	Girl	18 (50)
Diagnosis	Univentricular	4 (21.1)
	Biventricular	15 (78.9)
CPB Usage	Yes	20 (55.6)
	No	16 (44.4)
Approach	Sternotomy	35 (97.2)
	Right Sternotomy	1 (2.8)
Shunt Size / Target PA Size (S/PA)	>1.00	8 (22.2)
	<1.00	28 (77.8)
Mortality	Yes	5 (13.9)
	No	31 (75.6)
Procedure	Modified R-BT Shunt	26 (72.2)
	Modified L-BT Shutn	10 (27.8)
Shunt Occlusion	Yes	1 (2.8)
	No	35 (97.2)
Pleural Effusion	Yes	7 (17.1)
	No	29 (70.7)
Donor Artery	a. Innominate	(30 (83.3)
	a. Subclavia Dextra	5 (12.2)
	a. Subclavia Sinistra	1 (2.4)

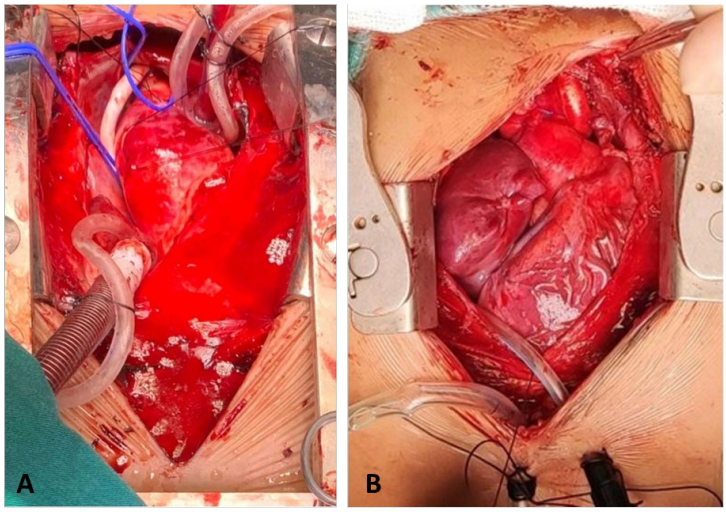

Figure 1. Modified Right- BT Shunt (a) and Modified Left- BT Shunt (b)

Table 2. Clinical Outcomes and Complications by Shunt Size/Target PA Size Ratio

Parameters	Shunt Size / Target PA Size (S/PA) (n)		p value
	<1	>1	
Sex			
• Boy	13	5	0.423
• Girl	15	3	
CPB Use			
• Yes	17	3	0.244
• No	11	5	
Diagnosis			
• Univentricular Heart	3	1	0.581
• Biventricular Heart	9	6	
Approach			
• Sternotomy	27	8	0.588
• Right Thoracotomy	2	0	
Procedure			
• Modified R-BT Shunt	21	5	0.486
• Modified L-BT Shunt	7	3	
Shunt Occlusion			
• Yes	0	1	0.058
• No	28	7	
Pleural Effusion			
• Yes	4	3	0.143
• No	24	5	
Donor Artery			
• Innominate	22	8	0.358
• Subclavia Dextra	5	0	
• Subclavia Sinistra	1	0	
Mortality			
• Yes	2	3	**0.029**
• No	26	5	
Parameters	**Shunt Size / Target PA Size (S/PA) (mean ± SD)**		**p**
	<1	**>1**	
Age (mo)	57.0 (±38.04)	46.87 (78.79)	0.087
Weight (kg)	12.22 (7.37)	12.01 (11.51)	0.777
Pre SpO2	71.03 (8.75)	72.87 (6.97)	0.127
Post SpO2	78.7 (3.08)	81.5 (1.37)	0.941
ICU Stay (days)	**2.06 (0.92)**	**4.92 (3.71)**	**0.005**
Hospital Stay (days)	5.50 (0.92)	8.6 (8.2)	0.076
Ventilation	**1.68 (0.94)**	**3.40 (3.24)**	**0.047**
Inotropes	2 (1.2)	12 (7.9)	0.152

The study cohort comprised 36 patients with a mean age of 54.81 months (±48.75) and a mean weight of 12.18 kg (±8.27). The average McGoon ratio, which assesses the size of the pulmonary artery relative to the aortic diameter, was 1.43 (±0.29). Preoperative oxygen saturation (SpO2) had a mean value of 71.44% (±8.33), while post-operative SpO2 improved to a mean of 79.26% (±3.02). The sex distribution was evenly split, with 18 boys (50%) and 18 girls (50%). Diagnostically, the majority had biventricular hearts (78.9%), whereas 21.1% had univentricular hearts. The use of cardiopulmonary bypass (CPB) was reported in 55.6% of cases. Surgical approach was predominantly sternotomy (97.2%), with only one patient undergoing right sternotomy (2.8%) (Table 1, Figure 1)).

Regarding shunt size relative to the target pulmonary artery (S/PA ratio), 22.2% of patients had a ratio greater than 1.00, while 77.8% had a ratio less than 1.00. Mortality occurred in 13.9% of the cases, and the procedure type included Modified R-BT Shunt (72.2%) and Modified L-BT Shunt (27.8%) (Fig.1). Shunt occlusion was rare, occurring in only 2.8% of cases, while pleural effusion was noted in 17.1% of patients. The primary donor artery was the innominate artery in 83.3% of cases, with the subclavian dextra used in 12.2% and the subclavian sinistra in 2.4%. These parameters provide a comprehensive overview of the clinical characteristics and procedural details pertinent to the cohort studied (Table 1).

The study analyzed 36 patients who underwent mBTT shunt, with a focus on the relationship between the S/PA ratio and various clinical outcomes (Table 2). Among the cohort, the S/PA ratio was categorized into two groups: ratios greater than 1.00 and ratios less than 1.00. Notably, higher S/PA ratios (>1.00) were associated with increased mortality, with 37.5% of patients in this group experiencing death compared to only 7.7% in the lower ratio group ($p = 0.029$). This suggests that a higher S/PA ratio may contribute to an increased risk of mortality following the procedure.

In terms of postoperative recovery, patients with higher S/PA ratios had significantly longer ICU stays, averaging 4.92 days compared to 2.06 days for those with lower ratios ($p = 0.005$). Additionally, the need for mechanical ventilation was greater in the higher S/PA ratio group, with an average of 3.40 days of ventilation compared to 1.68 days in the lower ratio group ($p = 0.047$). These findings indicate that a higher S/PA ratio may be associated with more severe postoperative complications requiring extended ICU care and respiratory support.

Hospital stay duration also trended longer for patients with higher S/PA ratios, averaging 8.60 days compared to 5.50 days for those with lower ratios ($p = 0.076$), though this result did not reach statistical significance. No significant differences were observed in pre-operative SpO2 ($p = 0.127$) or post-operative SpO2 ($p = 0.941$) between the two groups, suggesting that oxygenation improvements were similar regardless of the S/PA ratio. The use of inotropes did not differ significantly between groups ($p = 0.152$), indicating that shunt size relative to pulmonary artery diameter may not significantly impact the requirement for cardiac support.

4. Discussion

This study explored the impact of the shunt size relative to target pulmonary artery size (S/PA ratio) on mortality and other clinical outcomes in patients undergoing modified Blalock-Taussig shunt (mBTT shunt) procedures. The results suggest that a lower S/PA ratio (less than 1.00) is associated with better clinical outcomes, including reduced mortality and fewer complications, while a higher S/PA ratio (greater than 1.00) is linked to increased risk and longer recovery times (Amelia et al., 2023; Rana et al., 2011).

The primary finding of our study is that higher S/PA ratios correlate with increased mortality rates. Specifically, the mortality rate was 13.9% overall, with a higher proportion of deaths occurring in the group with an S/PA ratio >1.00 (3 out of 8) compared to those with an S/PA ratio <1.00 (2 out of 28). This significant association ($p = 0.029$) aligns with previous research highlighting that excessive shunt size relative to the pulmonary artery can lead to unfavorable hemodynamic consequences and increased risk of adverse outcomes (Kiran et al., 2017). For instance, a study by Oofuvong et al. (2021) demonstrated that larger shunts relative to pulmonary artery size were associated with higher mortality rates in similar patient populations (Oofuvong et al., 2021).

The analysis revealed significant differences in postoperative recovery times between the two S/PA ratio groups. Patients with an S/PA ratio >1.00 had a mean ICU stay of 4.92 days compared to 2.06 days for those with an S/PA ratio <1.00 ($p = 0.005$). This finding suggests that higher S/PA ratios are associated with more complex postoperative courses, requiring prolonged intensive care. Additionally, hospital stay was longer for patients with an S/PA ratio >1.00, though this difference was not statistically significant ($p = 0.076$). These results are inconsistent with findings from a study by Raja Abou Elella (2014), which found that patients with larger shunt sizes relative to pulmonary artery size had longer hospitalizations but not differs significantly (Elella et al., 2014).

Ventilation requirements were notably higher in the >1.00 S/PA ratio group, with a mean of 3.40 days compared to 1.68 days in the <1.00 S/PA group ($p = 0.047$). This finding underscores the impact of higher S/PA ratios on respiratory support needs, likely due to increased cardiac output and pulmonary circulation challenges. Similarly, the need for inotropic support did not differ significantly between the groups ($p = 0.152$), this finding not in line with the the study from Oofuvong et al. (2021) (Oofuvong et al., 2021).

The analysis of other clinical parameters revealed no significant differences in pre- and postoperative oxygen saturation levels between the two S/PA ratio groups. Preoperative SpO2 was slightly lower in the <1.00 S/PA group (71.03%) compared to the >1.00

S/PA group (72.87%) (p = 0.127), and postoperative SpO2 was also similar across groups (p = 0.941). These findings suggest that while oxygenation might be influenced by shunt size, the S/PA ratio does not significantly impact the overall improvement in oxygen saturation postoperatively. This study is in line with the findings from Miyuki Shibata, et al (2015) that found no differences in postoperative arterial oxygen saturation (SaO2) between the groups (McMullan et al., 2014; Shibata et al., 2015).

Additionally, the use of cardiopulmonary bypass (CPB), surgical approach, shunt occlusion, pleural effusion, and donor artery types did not show significant variations between the S/PA ratio groups. Specifically, CPB usage (p = 0.244) and surgical approach (p = 0.588) were not significantly different, indicating that these factors might not directly influence the association between S/PA ratio and clinical outcomes (Tarca et al., 2023).

5. Conclusion

In summary, our study highlights the critical role of the S/PA ratio in predicting clinical outcomes following mBTT shunt in patients undergoing mBTT SHUNT. A lower S/PA ratio is associated with reduced mortality and shorter ICU stay, while a higher S/PA ratio is linked to increased mortality, prolonged ICU and hospital stays, and higher ventilation needs. These findings suggest that careful consideration of shunt size relative to the pulmonary artery is essential for optimizing patient outcomes and minimizing complications. Further research is needed to validate these findings and explore potential interventions to improve outcomes for patients undergoing mBTT shunt.

Author contributions

M.H.R.W. was responsible for drafting the original manuscript. A.R.H. contributed to the analysis and interpretation of data, while H.S. provided critical feedback and revisions. E.A. assisted with manuscript editing and ensured the accuracy of data presentation. H.D.P. contributed to the overall review and finalization of the manuscript. All authors approved the final version of the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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