Full Length Research

The magnitude of systemic arterial oxygen saturation improvement achievable by a Blalock-Taussig-Thomas shunt: A systematic review

Mark N. Awori*, Jonathan A. Awori, Gilbert Langat and Kimberly Kipkoech

Department of Surgery, School of Medicine, University of Nairobi, P. O. Box 19676-00202, Nairobi, Kenya.

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This study was carried out to determine the magnitude of systemic arterial oxygen saturation (SaO$_2$) improvement caused by a Blalock-Taussig-Thomas shunt (BTTS). PUBMED (PM) and Google Scholar (GS) were searched between 1st January, 1966 and 31st March, 2023. Search terms included: Blalock, Taussig, shunt, pulmonary artery and Tetralogy of Fallot. Only full-text papers that measured pre-BTTS and post-BTTS systemic arterial oxygen saturation were included. Of 153 records retrieved, 12 full-text articles (427 patients) were included in this review. The mean pre-BTTS and post-BTTS SaO$_2$ were 69.9 and 86.9%, respectively. Nine out of 12 studies representing 371 patients (86.8%) had a post-BTTS increase in SaO$_2$ of 20% or less. Available evidence suggests that a BTTS is unlikely to increase the SaO$_2$ by more than 20% in almost 90% of patients. This finding may have important implications for the continued use of BTTS to raise the SaO$_2$ in patients with severe cyanosis.

Key words: Blalock, Taussig, Thomas, arterial, oxygen, saturation.

INTRODUCTION

Since the first report of symptomatic improvement following the creation of a systemic-arterial-to-pulmonary arterial shunt (SAPAS) (Blalock and Taussig, 1945), SAPASs have become an accepted part of the surgical treatment of patients with cyanotic congenital heart disease. The rational for offering a patient a SAPAS is as follows: cyanosis indicates inadequate oxygenation of the blood; creation of a SAPAS will increase pulmonary blood flow and so increase oxygenation of the blood. Unoperated patients with cyanotic congenital heart disease and an arterial oxygen saturation (SaO$_2$) of less than 80% are unlikely to live to adulthood (Poterucha et al., 2016); the inference is that an SaO$_2$ of at least 80% is required for survival. The general aim of the SAPAS, therefore, is to raise the SPO2 to about 80%. In the original description of a SAPAS, the left subclavian artery was anastomosed to the left pulmonary artery; the anastomosis of a subclavian artery to a branch pulmonary artery is known as a ‘classic’ Blalock-Taussig shunt (Blalock and Taussig, 1945). Later, the ‘modified’ Blalock-Taussig was introduced and became more popular. This procedure involves anastomosing one end of a synthetic tube graft to a subclavian artery and anastomosing the other end of the tube graft to a branch pulmonary artery (de Leval et al., 1981). More recently, the Blalock-Taussig shunt has come to be known as...
Table 1. Search strategy.

<table>
<thead>
<tr>
<th>Searches and terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blalock; Taussig; shunt; pulmonary; artery; growth (GS,PM)</td>
</tr>
<tr>
<td>Blalock; Taussig; shunt; tetralogy (GS)</td>
</tr>
</tbody>
</table>

GS = Google scholar, PM= PubMed.

Figure 1. Search flow diagram.

Blalock-Taussig-Thomas shunt (BTTS) (Blake and Yancy, 2022). The basic surgical technique, the principles of peri-operative care, and the operative outcome have essentially remained the same for almost 40 years (Bove et al., 1984). The magnitude of the \( \text{SaO}_2 \) mean increase post BTTS varies between reports; 33% (Bove et al., 1984) and 0% (Sheth and Loomba, 2022). If it were known before hand, that a BTTS would be unlikely to raise the \( \text{SaO}_2 \) to 80% in a particular patient, surgery may not be offered to that patient. The aim of the present review was to determine the magnitude of \( \text{SaO}_2 \) increase that can be expected post-BTTS; this information may improve surgical decision making.

**MATERIALS AND METHODS**

PUBMED (PM) and Google Scholar (GS) were searched between 1st January 1966 and 31st March 2023. The search particulars are shown in Table 1. The “all in title” function was utilised for GS searches and the “title/abstract” function was used for PM searches. The operator “AND” was used for all searches. Titles and abstracts were read; full-text articles were examined if the abstract suggested that there was a possibility that pre-BTTS and post BTTS \( \text{SaO}_2 \) were examined. Only full-text articles that examined pre-BTTS and post-BTTS \( \text{SaO}_2 \) were included. The search flow is as shown in Figure 1.

**RESULTS AND DISCUSSION**

The present search yielded 153 records: 40 full-texts were examined after accounting for duplicate records; 28 of these were rejected. Thirteen full-text articles representing 427 patients were included in this review; the key details of these papers are shown in Table 2 and Figure 2.
Table 2. Full-texts included.

<table>
<thead>
<tr>
<th>Author</th>
<th>n</th>
<th>Age at BTTS: months</th>
<th>SaO₂ (pre-op/post-op)</th>
<th>SaO₂ difference</th>
<th>Most common/mean shunt size (mm)</th>
<th>Type of CHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guo et al. (2023)</td>
<td>9</td>
<td>15.8 (mn)</td>
<td>70/90</td>
<td>20</td>
<td>6</td>
<td>TET</td>
</tr>
<tr>
<td>Sheth and Loomba (2022)</td>
<td>38</td>
<td>0.5 (md)</td>
<td>89/88</td>
<td>0</td>
<td>4</td>
<td>MCHD</td>
</tr>
<tr>
<td>Lenoir et al. (2021)</td>
<td>64</td>
<td>1 (mn)</td>
<td>76/91</td>
<td>15</td>
<td>4</td>
<td>MCHD</td>
</tr>
<tr>
<td>Zhou et al. (2020)</td>
<td>90</td>
<td>6 (md)</td>
<td>73/88</td>
<td>15</td>
<td>4</td>
<td>MCHD</td>
</tr>
<tr>
<td>Lenoir et al. (2020)</td>
<td>70</td>
<td>1 (mn)</td>
<td>70/90</td>
<td>13</td>
<td>4</td>
<td>MCHD</td>
</tr>
<tr>
<td>Bigdelian et al. (2018)</td>
<td>8</td>
<td>3 (mn)</td>
<td>74.9/89.3</td>
<td>14.4</td>
<td>3.5</td>
<td>MCHD</td>
</tr>
<tr>
<td>Quandt et al. (2017)</td>
<td>28</td>
<td>2 (md)</td>
<td>75/90</td>
<td>15</td>
<td>3.5</td>
<td>MCHD</td>
</tr>
<tr>
<td>Awori et al. (2017)</td>
<td>22</td>
<td>20 (md)</td>
<td>68/89</td>
<td>21</td>
<td>5</td>
<td>MCHD</td>
</tr>
<tr>
<td>Ishikawa et al. (2001)</td>
<td>12</td>
<td>12*</td>
<td>60/75</td>
<td>15</td>
<td>Classic</td>
<td>MCHD</td>
</tr>
<tr>
<td>Gladman et al. (1997)</td>
<td>52</td>
<td>24 (md)</td>
<td>71/86</td>
<td>15</td>
<td>5</td>
<td>TET</td>
</tr>
<tr>
<td>Ul trom et al. (1987)</td>
<td>16</td>
<td>2.4 (mn)</td>
<td>55/84</td>
<td>29</td>
<td>5</td>
<td>MCHD</td>
</tr>
<tr>
<td>Bove et al. (1984)</td>
<td>18</td>
<td>0.5 (md)</td>
<td>50/83</td>
<td>33</td>
<td>5</td>
<td>MCHD</td>
</tr>
</tbody>
</table>

BTTS = Blalock-Taussig-Thomas Shunt; MCHD = multiple types of congenital heart disease; TET = Tetralogy of Fallot; * = all patients under 12 months old; md= median; mn=mean.

Figure 2. Number of patients vs magnitude of SaO₂ increase post-BTTS.

There is evidence that BTTSs do improve the quality of life (Harris et al., 1964). However, when compared with the natural history, BTTSs may not increase longevity (Reid et al., 1973; Samánek, 1992). In current practice, the main indication for a BTTS is to increase a patient’s SaO₂ prior to surgical correction, or as the first step on the Fontan pathway. The present review found that although BTTSs did raise the SaO₂, the magnitude of the increase was not more than 20% in almost 90% of patients; in fact, the mean of the mean increase of the studies included was 17.1%. The highest mean increase in SaO₂ found in this review was 33%; this study represented 4.2% of all patients included in this review (Bove et al., 1984). Only 3 out of 12 studies had a mean SaO₂ rise of greater than 20%; this represented 13.1% of all the patients included in this review. The aim of
performing a BTTS prior to total correction, or as a step on the Fontan pathway, is to ensure sufficient oxygenation of the blood to promote adequate growth of the patient and to minimise the chance of mortality before definitive surgery. In this regard, no target post-BTTS SaO₂ has been identified as reliably achieving these aims. However, patients with un-operated single ventricle arrangements, who have survived into the 5th decade of life, can give us an idea of what this target SaO₂ should be. These unoperated long-term survivors generally have a SaO₂ above 80% and are said to have a ‘balanced circulation’ (Poterucha et al., 2016). A balanced circulation is said to exist when the ratio of pulmonary to systemic blood flow is between 0.8 and 1. When this condition is met, the SaO₂ generally lies between 75 and 80% (Anders, 2021). This implies that the minimum post-BTTS SaO₂ that would promote adequate somatic growth and minimize mortality, prior to definitive surgery, is likely to be 80%. This being the case, and armed with the knowledge that it is unlikely that a BTTS would increase the SaO₂ by more than 20%, it seems that a reasonable SaO₂ threshold for performing a BTTS would be 60%. It is unlikely that patients presenting with a pre-BTTS of less than 60% would benefit, from a survival perspective, from a BTTS. Awori et al. (2023) have already demonstrated that patients with a single ventricle physiology, who present with a pre-BTTS SaO₂ of less than 75%, do not benefit from a BTTS. The findings of the current study suggest that patients with a two-ventricle arrangement who present with a pre-BTTS SaO₂ of less than 60% are unlikely to benefit from a BTTS.

Conclusion

Available evidence suggests that a BTTS shunt is unlikely to raise the SaO₂ by more than 20%. As it is likely that a SaO₂ above 80% is required for a patient to benefit from a BTTS, we suggest that the lower threshold for performing a BTTS, in a patient with a two-ventricle arrangement and who requires a BTTS before surgical correction, appears to be about 60%.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES
