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Technical Details of a Novel Surgical Procedure for Construction of the Modified Blalock–Taussig Shunt (UKC's Modification): A Video Presentation

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ABSTRACT

We describe herein the surgical technique on a 2.5-years-old male child weighing 10 kilograms diagnosed with a functionally univentricular heart, disproportionately small right subclavian artery, and hypoplastic pulmonary arteries (Mc Goon's ratio of less than 1.0).5 We interposed a short segment of polytetrafluoroethylene graft between the right brachiocephalic artery and the intrapericardial portion of the right pulmonary artery closest to the bifurcation of the pulmonary trunk on the right side.

Keywords: Surgical procedure, Modified Blalock–Taussig shunt, Complex cyanotic congenital heart disease

INTRODUCTION

Despite advances in the surgical correction of complex cyanotic congenital heart disease, the construction of systemic-to-pulmonary artery shunt remains necessary, mostly as the first stage of palliation.[1-6] Although the traditional modification of the classical Blalock–Taussig (BT) shunt using a polytetrafluoroethylene conduit (W.L. Gore Inc., Elkton, MD, USA) remains the systemic-to-pulmonary artery shunt of choice in our institution, we encountered a subset of patients whom we considered unsuitable for this traditional approach. Patients with a right or left-sided aortic arch and right-sided descending thoracic aorta, those with disproportionately small right and left subclavian arteries, smaller than the proposed size of the synthetic graft, and those with anomalies of systemic venous drainage masking the origin of the great arterial branches constitute the ideal candidates for our suggested modification of the construction of a modified BT shunt.[7]

We did not perform central aortopulmonary shunt in this subset of patients due to the unacceptably high incidence of post-central shunt complications documented in the published literature, namely, congestive cardiac failure, thrombosis, and pulmonary arterial distortion.[3,8,9]

As yet, there is no foolproof formula for choosing an optimal surgical approach, nor is there a given diameter for the shunt in any individual patient. Although an approach through a median sternotomy has been popularized for the construction of central shunts by some investigators, we

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achieved the same objectives by approaching them through thoracotomy.[3,9-11] In patients with double aortic arch, the minor aortic arch was transected and anastomosed to the intrapericardial pulmonary artery.[7]

We approached through a left thoracotomy in all our patients with double aortic arches, in those with the right aortic arch and the right-sided heart, in those with the left aortic arches but right-sided descending thoracic aorta, and in a patient with hemiazygos continuation of an interrupted inferior caval vein, a left superior caval vein, and a right-sided heart.[7]

In addition, in all patients, the shunt was anastomosed to the intrapericardial pulmonary artery due to its wider caliber and the capacity to provide near-uniform flow to both pulmonary arteries, facilitating symmetrical pulmonary artery growth on both sides.

Thus, there were six forces driving our criteria for the selection of the patients, who subsequently entered our group for further study.

Those with anomalies of the aortic arch and its branches.

- The finding of disproportionately small subclavian arteries
- Variations in the morphology of the aortic arch and its branches, and the systemic veins, which in our judgment precluded construction of the modified BT shunt in conventional fashion
- The desire to use a short segment of polytetrafluoroethylene graft
- The desire to place the pulmonary end of the anastomosis onto the pulmonary trunk or its bifurcation to facilitate symmetrical pulmonary artery growth on both sides, and,
- To avoid the use of cardiopulmonary bypass.

In our study group, the pulmonary arterial diameters were following:

- The ratio of diameter of the pulmonary artery to aorta of <0.75
- McGoon's ratio of <1.0
- Nakata's pulmonary artery index of <100 mm^2, <200 mm^2, or <250 mm^2 in patients with tetralogy of Fallot, those future candidates for a Rastelli procedure, or those with a functionally univentricular heart, respectively
- Very small confluent pulmonary arteries in patients below one year of age, the right and left pulmonary arteries ranging from 1 mm to 3 mm in diameter.

Patients with previously placed shunts, pulmonary arterial stenosis at their origin, non-confluent pulmonary arteries, and those undergoing rapid two-stage arterial switch operation were considered unsuitable candidates for our modification of the modified BT shunt.

In the year 2006, we published the technical details and results of further modification of the modified BT shunt on 92 selected patients aged from 7 days to 3.6 years (mean 7.08 ± 6.16 months).[7]

In 2009, we published our results in ATS of the second stage procedures on these patients, demonstrating, in particular, the symmetrical pulmonary artery growth pattern and ease of takedown.[12]

In 2006, we published the technical details and results of further modification of the modified BT shunt on 92 selected, heterogenous cohort of symptomatic cyanotic neonates, infants, and preschool children with cyanotic congenital heart disease. These patients were aged from 7 days to 3.6 years (mean 7.08 ± 6.16 months) not amenable either to primary intracardiac repair or to the construction of bidirectional cavopulmonary connection.[7] These patients had specific anatomic situations contraindicating the usual technique for the construction of the modified BT shunt.[7]

Subsequently, between 2006 and 2022, we performed an additional 82 UKC's shunting procedures in various symptomatic cyanotic patients of the entire cohort. One hundred and ten patients underwent a second-stage operation, with 27 receiving a superior cavopulmonary connection, 29 a total cavopulmonary connection, and 54 proceeding to biventricular repair after a mean interval of 25.8 months. We have 21 patients awaiting their second or final stage palliation.

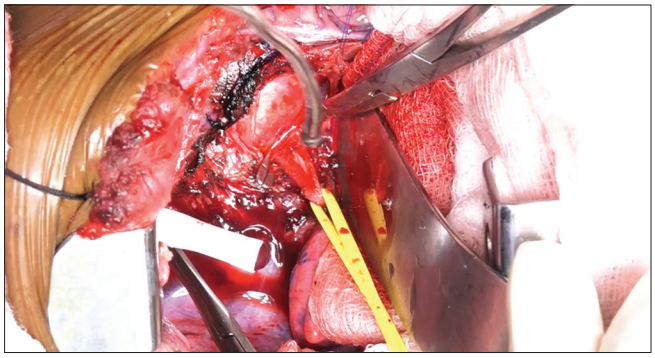
The pulmonary arteries grow as a result of the complex interaction of several factors, such as their initial size, the size of the shunt, and the direction of flow of blood proximal and distal to the site of anastomosis of the shunt.[13-18] We observed adequate growth of the pulmonary arteries, which were symmetrical and compared favorably with other reported series on the central aortopulmonary shunt.[3,8-11] Published literature documents an occurrence of pulmonary artery distortion ranging from zero to one-third in patients with a traditionally modified shunt[2,8,13,14] and from zero to three-fourths of those receiving a classic shunt.[1,6] Should they occur due to their distal location, the distorted arteries are difficult to repair. When observed in our patients, the distortion was easily repaired due to their central location.

We describe here-in the surgical technique on a 2.5-year-old male child weighing 10 kg diagnosed with a functionally univentricular heart, disproportionately small right subclavian artery, and hypoplastic pulmonary arteries (Mc Goon's ratio of <1.0).[5] We interposed a short segment of polytetrafluoroethylene graft between the right brachiocephalic artery and the intrapericardial portion of the right pulmonary artery closest to the bifurcation of the pulmonary trunk on the right side. The postoperative recovery was uneventful.

SURGICAL TECHNIQUES

Patient's position and surgical incision

For modified right posterolateral thoracotomy, the patient is positioned laterally, slightly tilted to the right. The chest is entered through the right fourth intercostal space. To avoid rib fractures posteriorly during opening of retractor blade, the intercostal muscles are divided beyond the skin incision [Video 1].



Video 1: Modified Blalock Taussig shunt (UKC'S Modification).

Exposure of the intrapericardial right pulmonary artery

The first stay suture is placed on the pericardium using No. 1-0 silk suture. The second stay suture is placed on the mediastinal pleura overlying the esophagus. The right lung is retracted inferiorly with a wet sponge for adequate surgical exposure. The right azygos vein is divided in between ligatures.

The right pulmonary artery is identified and looped using a silicone-based elastomer loop. The right pulmonary artery is isolated and dissected intrapericardially. The superior caval vein is dissected and retracted using multiple 5-0 polypropylene sutures.

Exposure of the right brachiocephalic artery

The right subclavian artery is dissected and found to be disproportionately smaller than 4 mm. The vein overlying the base of the right subclavian artery is looped along with the right recurrent laryngeal nerve and ansa cervicalis, and the brachiocephalic artery is dissected.

Using a silicone-elastomer vessel loop, the right brachiocephalic artery is looped and pulled up gently from the mediastinal tissues. Care is taken not to injure the right recurrent laryngeal nerve and ansa cervicalis while dissecting the right brachiocephalic artery. Heparin is administered intervenously at a dosage of 100 units/kg.

Selection of an appropriate sized polytetrafluoroethylene graft

A segment of thin-walled polytetrafluoroethylene graft is selected, and the aortic end is beveled to an angle of 45° like a funnel (Bard Peripheral Vascular Inc. 1625 West, 3rd Street, Tempe, AZ, USA).

The graft is irrigated at least 20 times under pressure using heparinized saline and kept soaked until implantation.

Construction of the graft-brachiocephalic artery anastomosis

After placing a side-biting clamp, the graft-aortic anastomosis is performed using a 7-0 monofilament polypropylene suture (Johnson and Johnson Ltd., Ethicon, LLC, San Lorenzo, USA). The clamp is temporarily released to check for adequacy of flow. The graft is irrigated with heparinized saline and trimmed to adequate length.

Dissection and isolation of the intrapericardial segment of the right pulmonary artery

The distal end of the pulmonary artery is looped using a silicone-elastomer vascular loop. The individual pulmonary arterial branches are not dissected to prevent postoperative adhesions. The pulmonary artery on the right side is then clamped proximally near the bifurcation intrapericardially in an oblique fashion to ensure flow continued to the pulmonary artery on the other side through antegrade flow from the right ventricular outflow tract.

The intrapericardial portion of the pulmonary artery close to the bifurcation is preferred for the pulmonary anastomosis due to its wider caliber and the capacity to provide near uniform flow to both pulmonary arteries.

Construction of the graft-pulmonary artery anastomosis

The pulmonary artery anastomotic site is opened between stay sutures without excision. The graft-pulmonary artery anastomosis is performed using a 7-0 polypropylene suture. Before completion of the anastomosis, the graft is irrigated with heparinized saline to remove any debris.

Release of the vascular clamps, vascular loops, and closure of the thoracotomy

Both clamps are removed. The short segment of the polytetrafluoroethylene graft is never clamped. Heparin is not reversed. A small window is created at the bottom of the pericardium to drain out the interpericardial collected serosanguinous fluid. The right lung is properly expanded, ensuring the absence of any atelectatic lung segment.

Following the release of the vascular clamps, it is important to ensure stable hemodynamics and a rise in oxygen saturation. Dopamine at a dose of 5–10 μg/kg/min is electively started on completion of the systemic-to-pulmonary artery shunt. One right pleural angled chest tube is placed. The thoracotomy wound is closed in layers.

Short-and long-term results

An intraoperative thrill was palpable on the pulmonary artery after the procedure. There was rise of systemic arterial oxygen saturation from 68% in the preoperative period to 90% in the postoperative period. At 96 months of follow-up, the child was asymptomatic, in sinus rhythm and no evidence of congestive cardiac failure with New York Heart Association functional class II. Repeat angiocardiography at 96 months follow-up revealed adequate, bilaterally symmetrical growth of the pulmonary arteries with McGoon's ratio greater than 2.0, without distortion of the pulmonary arteries and systemic ventricular ejection fraction of 80%.

The child successfully underwent second-stage, fenestrated, extracardiac total cavopulmonary connection using a 18 mm polytetrafluoroethylene conduit with division of the shunt. The adhesions were minimal at the time of second operation.

CONCLUSION

Patients deemed unsuitable for the construction of the shunt in traditional fashion are considered for our modification.[1] The palliation provided by these shunts is satisfactory, with predictable growth of the pulmonary arteries without significant distortion and easy take-down.[1] Our modification may be considered from the perspective of a complementary technique for central shunting and not a competitive one.

Ethical approval

Since employment of systemic-to-pulmonary artery shunts are essential for cyanotic congenital heart diseases and this modification was published on earlier occasion, Institutional Ethics Committee or the Institutional Review Board approval was not considered essential.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

Poonam Malhotra Kapoor is the member of Editorial Board of the journal.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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