Review Article

The Blalock and Taussig Shunt Revisited

Abstract

The systemic to pulmonary artery shunts are done as palliative procedures for cyanotic congenital heart diseases ranging from simple tetralogy of Fallots (TOFs)/pulmonary atresia (PA) to complex univentricular hearts. They allow growth of pulmonary arteries and maintain regulated blood flow to the lungs till a proper age and body weight suitable for definitive corrective repair is reached. We have reviewed the BT shunt with its anaesthtic considerations and management of associated complications.

Keywords: *Blalock, complex cyanotic congenital heart diseases, Taussig shunt*

Usha Kiran, Shivani Aggarwal, Arin Choudhary, B Uma, Poonam Malhotra Kapoor

Department of Cardiac Anaesthesia, CTC, AIIMS, New Delhi, India

Introduction

The systemic to pulmonary artery shunts are done as palliative procedures for a variety of complex cyanotic congenital heart diseases. The spectrum may range from simple tetralogy of Fallots (TOFs)/pulmonary atresia (PA) to complex univentricular hearts with major associated surgical problems. The systemic to pulmonary artery shunt provide the first line of management in these critically ill cyanotic neonates. They are less risky and provide regulated blood flow to the lungs allowing growth of pulmonary arteries for future complete repair. The infant also reaches a proper age and body weight suitable for definitive corrective repair.[1]

History

The credit for the evolution of the shunt goes to Helen Taussig, a pediatric cardiologist from John Hopkins. She noticed that several patients with right-sided obstruction, i.e., pulmonary stenosis or PA, cyanosis increased after the closure of the ductus arteriosus. She along with Alfred Blalock, chief surgeon at John Hopkins and Vivian Thomas, a surgical technician decided to use subclavian artery to pulmonary artery connection as a way to augment the pulmonary blood flow.

Since then many modifications to this original operation took place. In 1951, Dubost and Oeconomos reported used lyophilized human vessels as an interposed graft between the subclavian and pulmonary artery.[2] In 1960s, synthetic vascular prosthesis made of nylon, teflon or dacron, a free left subclacvian artery graft or an interposed azygos vein were used as modified Blalock-Taussig shunt (MBTS) when direct end-to-side anastomosis of subclavian and the pulmonary arteries was not possible.[3] In 1970s, the expandable polytetrafluoroethylene (PTFE) has been increasingly used as interposed graft and shown to be patent by clinical angiographic studies.[4]

The main aim of the palliative surgery is to increase pulmonary blood flow in a controlled manner to alleviate cyanosis and improve exercise tolerance in the patients.

Goals

1. Increase blood flow to the lungs in controlled manner – prostaglandin E1 (PGE1) infusion to maintain ductus arteriosus patency, decrease pulmonary vascular resistance (PVR) (avoid hypoxia, hypercarbia, acidosis, sympathetic stimulation)
2. Maintain adequate preload – prevent hemodilution
3. Maintain afterload, i.e., systemic vascular resistance (SVR) and hence the diastolic pressure to maintain coronary perfusion pressure.

Risk Factors

Recent reports regarding the outcomes of modified BT shunt suggest high morbidity

How to cite this article: Kiran U, Aggarwal S, Choudhary A, Uma B, Kapoor PM. The blalock and taussig shunt revisited. Ann Card Anaesth 2017;20:323-30.

Address for correspondence:
Dr. B Uma,
Department of Cardiac Anaesthesia, CTC, AIIMS, New Delhi, India.
E-mail: uma_dilli@yahoo.co.in

Access this article online

Website: www.annals.in

DOI: 10.4103/aca.ACA_80_17

Quick Response Code:

and mortality in neonates. The mortality in single ventricle patients has been reported to be around 15% while in patients with two ventricles it is 3%–5%.[5,6]

Various risk factors have been identified which include:
- Sternotomy[6]
- Anatomic site[6]
- Use of cardiopulmonary bypass (CPB)[6]
- Weight <3 kg[5]
- Preoperative ventilation[5]
- Single ventricle palliation[5]
- PA with intact ventricular septum[5]
- Ebstein's anomaly[6]
- In about one-third of patients, deaths occur in first 24 h postoperatively.[5]

Indications

Palliative shunts are not commonly done for most cases as initial corrective procedures are increasingly performed during infancy. It has mainly been possible due to improved extracorporeal circulation methods, modern perioperative supportive care, and refinements in operative technique.

Nevertheless, certain subsets of patients require this initial palliative surgery when cardiac disorders are not amenable to final corrective surgery. The indications can be broadly grouped as under:

A. To increase blood flow to the lungs
   1. Tricuspid atresia and other univentricular conditions where bidirectional Glenn and Fontan shunts can only be performed after the decline in pulmonary vascular resistance which may take months
   2. PA
   3. TOF
   4. Neonatal Ebstein's with functional PA-rare
B. Complete repair not possible
   1. Anatomical-aberrant coronary anatomy left anterior descending coronary artery crosses the right ventricular (RV) outflow tract in TOF (approximately 5%)[7-9]
   2. Physiological-prematurity, intracerebral bleed, or other contraindications to CPB
C. Hypoplastic left heart syndrome
D. To encourage growth of pulmonary arteries
   1. PA
   2. Ventricular septal defect (VSD) with aortopulmonary collaterals
   3. Inadequate pulmonary arteries.

What is an Ideal Shunt?

Features of an ideal shunt are as follows:
- It should be technically simple to perform
- It should provide adequate but not excessive pulmonary blood flow, hence minimize the risk of congestive cardiac failure and pulmonary hypertension
- It should provide good long-term patency
- It should be technically easy to close when repair is completed
- It should result in no residual cardiopulmonary abnormalities after closure.

Types of Shunts

Classic Blalock-Taussig shunt

The classic Blalock-Taussig shunt (CBTS) was the original shunt described by Alfred Blalock and Helen Taussig. The end-to-side anastomosis between the subclavian (or the innominate) and pulmonary arteries is performed. As described by them, the operation was performed on the side opposite to the aortic arch to minimize kinking of the subclavian artery as it crosses over the aortic prominence. In addition, the longer innominate artery reduces kinking of the pulmonary artery.

Surgical approach: Thoracotomy

Advantages:
- Predictability of blood flow, because the subclavian artery diameter prevents excessive blood flow to lungs and hence, congestive cardiac failure
- Unlikely to cause pulmonary vascular disease
- Ease of closure during corrective surgery
- Potential adaptive growth of the anastomosis.

Disadvantages:
- Thrombosis of the shunt due to its size
- Subclavian or the innominate artery have to be sacrificed although it did not appear to have a clearly significant clinical effect[10]
- extensive dissection[10]
- Significant arm ischemia from subclavian artery division was uncommon, although the pulse in the ipsilateral arm was often not felt for days after the operation
- Neurologic disadvantages are rare and include risk of recurrent laryngeal nerve injury, phrenic nerve injury, and Horner syndrome
- Various modifications of systemic-to-pulmonary artery shunt have been described. Among them, the MBTS is the most common type currently in use.

Modified Blalock-Taussig shunt

It is currently most commonly performed procedure. It was first described by Klinner *et al*. in 1962.[11] An interposition PTFE (or Gore-Tex) graft between the subclavian artery and the pulmonary artery is used to prevent sacrificing of the subclavian artery. PTFE conduit is considered ideal.[12] PTFE was found to be superior to Dacron because it has a smaller pore size that limits the tissue ingrowth but allows for fibroblastic incorporation to bind it to surround structures.[13]

Approach: Thoracotomy/midline

Advantages:
- Subclavian artery need not be sacrificed

- MBTS is useful when CBTS cannot easily be performed, such as on the same side as the aortic arch
- Less distortion of pulmonary artery than CBTS
- Future shunt takedown is relatively easy
- Patency rate >90% at the age of 2 years[13]
- Gazzaniga *et al*. advocate using shunts of at least 5 mm, even in small infants as they found that the orifice of the subclavian artery serves to regulate blood flow through the shunt.

Complications:
- Thrombosis
- Leakage of serous fluid through the PTFE in the chest
- Pseudoaneurysm, which can cause massive fatal hemoptysis.[14]

Central shunt

It is the anastomosis between the ascending aorta and the main pulmonary artery using a short PTFE conduit. A central shunt may be especially useful with bilateral small branch pulmonary arteries, a concomitant procedure requiring a median sternotomy, or both.

Surgical approach: Midline

Pericardium is incised. Aortotomy is done with an aortic punch device using a side-biting clamp. A short PTFE conduit is used to anastomose the ascending aorta and the main/branch pulmonary artery.

The advantages of this technique are as follows:
- Applicability to small children with small peripheral vessels
- Prevention of distortion of pulmonary arteries
- Provision of equal pulmonary blood flow to both lungs
- Lower occlusion rate (compared with the CBTS or MBTS techniques)
- Avoidance of subclavian artery steal
- Ease of closure during corrective repair.

Disadvantages
a. Entry into the pericardium
b. Inapplicability for patients without a patent ductus arteriosus (PDA) or other source of pulmonary blood flow.

Immediately postoperatively, patients may be anticoagulated with heparin for 24-72 h. Patients may be placed on long-term aspirin therapy for shunt patency maintenance.

A modification of central shunt was described by Waterson *et al*. for patients with PA, VSD, and hypoplastic pulmonary arteries.[15] An end-to-side anastomosis was done between a transected main pulmonary artery and the side of the ascending aorta. They believed that it provides for adequate pulmonary artery growth in patients with small central pulmonary arteries. This shunt has also been termed the Mee shunt after the senior surgeon involved in its description.

Potts shunt

Potts shunt was developed as an alternate to CBTS in neonates. In this, a connection is made between the descending aorta and left pulmonary artery.

Advantages:
a. Easier to perform because does not involve vessels of small caliber, i.e., the subclavian artery
b. Lesser incidence of shunt thrombosis and occlusion.

Disadvantages:
a. High incidence of subsequent pulmonary hypertension
b. Preferential blood flow to one lung with kinking and distortion of the pulmonary artery
c. Technical difficulties during takedown
d. Congestive cardiac failure (20%).[16]

Because of above-mentioned problems, pott's shunt is not routinely performed.

Waterston shunt

It is the anastomosis between the ascending aorta and right pulmonary artery.

Disadvantages are similar as the Potts shunt
1. Excessive pulmonary blood flow,
2. Risk of pulmonary hypertension
3. Congestive cardiac failure (20%).[16]

Therefore, it is also not routinely performed.

Cooley shunt

A newer approach using intrapericardial anastomosis from the ascending aorta to the right pulmonary artery was described.

Surgical approach – Right anterolateral thoracotomy

Advantages:
- Avoidance of mediastinal dissection (decreased risk of bleeding from collaterals)
- Complete repair could be done in through the same incision
- Less technical difficulties during future takedown.

Disadvantages:
- Complex technique
- Improper size anastomosis could lead to heart failure and pulmonary congestion
- Invasion of pericardium leads to higher risk of adhesions in future cardiac repair.

Sano shunt

An anastomosis between the right ventricle–to–pulmonary artery shunt was done to ameliorate disadvantages of BT shunts.[17] A 4-mm nonvalved PTFE graft was used in infants <2.5 kg and a 5.0 mm nonvalved PTFE graft in infants weighing >2.5 kg. It was reported that mortality improved from 62% to 89% after the stage 1 surgeries.[18,19]

Sano shunt was preferred for univentricular conditions such as in Norwood operation.

Disadvantages:

a. Early obstruction (approximately 3 months) as compared to MBTS[17]
b. To overcome complications of ventriculotomy in a systemic ventricle, a valved conduit from the right ventricle to the pulmonary artery was attempted. It was abandoned following high failure rates.

Preoperative Considerations

Patients presenting for surgery may be grouped into:

a. Nonoperated cyanotic patient for BT shunt
b. Patients presenting for BT shunt takedown and subsequent total correction
c. Patients presenting with pulmonary overcirculation for PA banding
d. Patients presenting with shunt thrombosis.

For each of these, the anesthetic management will depend on:

Patient-related Factors

1. Anatomical diagnosis
2. Age
3. Weight <3 kg
4. Prematurity
5. Coexisting diseases-mostly noncardiac congenital: Tracheoesophageal fistula, anorectal malformation, cleft lip and palate, renal and skeletal pathologies. Down syndrome patients may have atlantooccipital subluxation that warrants airway management precautions
6. Respiratory infections: Effects are more deleterious in patients with pulmonary hypertension or cavopulmonary anastomosis. Risk-benefit ratio is to be discussed with the surgeon when delaying the surgery
7. Exercise tolerance indicated by fatigue, dyspnea on feeding, irritability, and inability to gain weight
8. Medications such as aspirin, warfarin, antidepressants, diuretics, angiotensin converting enzyme (ACE) inhibitors, antiarrhythmics
9. Previous surgeries and length of Intensive Care Unit stay-indicates possible difficult intravenous (IV) access and difficult intubation (? subglottic stenosis)
10. RV function patients with high pulmonary blood flow may present with tachycardia, tachypnea, irritability, cardiomegaly, and hepatomegaly.

Surgical Factors

1. The complexity of the heart lesion determines the duration of the surgery affecting the postoperative outcome. Details such as aortic arch anatomy and possibility of aberrant subclavian artery are important
2. Possible injury to nearby structures during dissection which further complicates the procedure
3. The use of CPB, sternotomy, or thoracotomy changes the anesthetic plan.

Preanesthesia checkup

A detailed history regarding the onset of symptoms, presence of cyanosis, feeding difficulties, sweating on the forehead should be elicited. Medication history must be elicited. Patients with previous BT shunt may be on aspirin, warfarin, diuretics, ACE inhibitors, and antiarrhythmics. The vast majority of newborns have PGE1 infusions running on presentation to avoid the possibility of duct related cardiovascular collapse. The usual dose is 0.01–0.1 mcg/kg/min. Laboratory investigations should be tailored accordingly.

Risk assessment

1. Increased risk of morbidity (mechanical support, reoperation, low cardiac output): Weight <3 kg and preoperative shock
2. Increased risk of mortality: Preoperative acidosis, mechanical support (ventilatory or circulatory), renal impairment, PA with intact ventricular septum and weight <3 kg.

Preoperative orders

1. Psychological preparation: It should be started right after the patient comes to the hospital for surgery. In case of children, counseling of parents is important to:
   - Reduces the child's distress on separation to the operating room
   - Increased child compliance
   - Reduced child anxiety
   - Reduced need for preoperative sedatives
   - Increased parental satisfaction.
2. Preoperative fasting

   Fasting time orders should be clearly written with timing if possible as per ASA guidelines. Dehydration should be avoided in cyanotic patients. If the timing of surgery is uncertain, then an IV line should be placed, and fluids started.
3. Premedication
   - To produce sedation, ease separation anxiety, and facilitate induction of anesthesia (<6 months: Not required)
   - To supplement analgesia and reduce the requirements for general anesthetic drugs
   - To block harmful vagal reflexes
   - To dry secretions in the respiratory tract.

Drugs Used in Premedication

Midazolam

- Produces sedation and anxiolysis
- Increases cooperation
- Does not prolong recovery time
- Smoothens postoperative recovery
- Routes
  - Oral: 0.25–0.33 mg/kg (syrup form)
  - IV: 0.1 mg/kg

- Rectal: 0.4–0.5 mg/kg
- Nasal: 0.2–0.3 mg/kg.

Ketamine

- Produces sedation, anxiolysis, and facilitates induction of anesthesia
- Oral: 5–10 mg/kg
- Rectal: 5–10 mg/kg
- Nasal: 3 mg/kg
- Intramuscular: 2 mg/kg.

Fentanyl

- Oral transmucosal fentanyl citrate
- 15–20 ug/kg: Onset in 20–30 min with 30 min duration of action

4. Continue all cardiac medications on the morning of surgery except ACE inhibitors and diuretics due to their hypotensive effects during anesthetic induction as seen in adult cases
5. Sedation: Sympathetic stimulation due to the crying of an anxious and distressed child can increase oxygen consumption and myocardial work; this might be poorly tolerated in a child with limited cardiac reserve. Midazolam is the preferred premedication to reduce oxygen consumption in the dose of 0.5 mg/kg orally half an hour before surgery. If IV line is present, then, incremental doses of 0.1–0.25 mg/kg midazolam can be given, provided airway and breathing issues are addressed accordingly. Promethazine (5 mg/ml) can also be given in dose of 0.5 mg/kg.

Investigations

1. Full blood count: Polycythemia increases blood viscosity which leads to thrombosis and infarction in cerebral, renal and pulmonary regions. White blood cell (WBC) count may be increased in cases of respiratory infections. Spuriously, low platelet counts may be observed in cases of polycythemia
2. Coagulation profile: Prothrombin time and partial thromboplastin time (PTT) are usually deranged in a polycythemic patient. Coagulation abnormalities also occur due to platelet dysfunction, hypofibrinogenemia, and factor deficiencies. Preoperative phlebotomy is performed in symptomatic hyperviscosity and hematocrit more than 65%. However, dehydration must be corrected first before deciding about phlebotomy. On the other hand, WBC count and C-reactive protein measurement provide potential diagnosis of infection
3. Serum electrolytes as mentioned earlier should be checked in patients receiving diuretics
4. Electrocardiogram (ECG) may show ventricular strain or hypertrophy
5. Echocardiogram is used for Doppler and color flow mapping, while catheterisation is used for information about pressures in different chambers, magnitude of shunt and coronary anatomy
6. The chest X-ray shows the heart position and size, atelectasis, acute respiratory infection, vascular markings, and elevated hemidiaphragm.

Cardiologist evaluation

The need for cardiologist evaluation depends on the complexity of the lesion. In a patient with a simple or moderately complex lesion that has been completely corrected and is well compensated, a standard preanesthetic visit without cardiology consultation is acceptable. Moderately complex lesions accompanied with the inability to compensate will warrant cardiologist evaluation and optimization, but clearance must always be given by anesthesiologist.

Intraoperative Considerations

Induction

Most induction agents are well tolerated depending on the rate and dose of the drug and whether it is inhalational or IV.

Inhalation induction

It is most commonly used in the absence of IV access. Sevoflurane is the most commonly used inducing agent. However, patients with poor cardiac function, who require inotropes preoperatively, may not tolerate inhalational induction and favor the use of ketamine.

Intravenous

SVR and PVR balance should be considered when using IV agents. Ketamine in the dose of 1–2 mg/kg is the most commonly used inducing agent.

Monitoring

The outcome data in these patients prescribe need for invasive monitoring in addition to routine monitoring so proceed as for a procedure on cardiopulmonary bypass.

1. ECG: Particular attention to be paid to baseline ECG trace to detect rate, arrhythmias and ST changes due to myocardial ischemia
2. Arterial line: It is to be placed on the side opposite to the side of proposed shunt in case of radial artery (i.e., right-sided shunt, so left radial artery and vice versa) or femoral route can be taken. Upper and lower limb pressures can be compared with the use of noninvasive blood pressure to diagnose coarctation that may have been missed. The diastolic pressures are important as they give indication of any coexisting PDA as well as coronary steal resulting in myocardial compromise
3. SpO_2 probe: One should be aware that in right to left shunts pulse oximetry overestimates arterial oxygen saturation as saturation decreases, end-tidal carbon dioxide readings underestimate $PaCO_2$, and discrepancy worsens with hypoxemia. When in doubt, obtain an arterial blood gas (ABG) preoperatively for baseline

4. Near infrared spectroscopy
5. Central venous line: To administer volume and inotropes if required
6. $EtCO_2$ monitoring
7. Temperature probe
8. Baseline ABG and activated clotting time are obtained
9. Urine output.

Position

1. Thoracotomy: For right sided modified Blalock-Taussig shunt, left lateral position and for left sided modified Blalock-Taussig shunt right lateral positions are required
2. Sternotomy: For central shunts.

Perioperative Management

A balanced anesthetic technique, combining narcotic, and inhalational agents supplemented with muscle relaxant is usually undertaken. The ordinary routines such as the use of 100% oxygen, hyperventilation and excessive inhalational agents may decrease PVR, increase Qp: Qs and decrease diastolic pressure with resultant concerns for myocardial ischemia and systemic perfusion. Particular attention to be paid for redo cases as sternotomy may result in excessive blood loss. Adequate blood should always be arranged beforehand.

Ventilatory concerns

These patients may already have preoperative respiratory infections resulting in high airway pressures and low saturation due to pulmonary congestion and bronchospasm. Further insults are added when surgery requires thoracotomy in right lateral or left lateral positions resulting in one lung ventilation with retractors applied on the exposed lung for a better view of the surgical field. Hyperventilation and high FiO_2 to keep $EtCO_2$ and saturation to acceptable levels may be required during this time.

Before proceeding for anastomosis, heparin is given 3 min before clamping in a dose of 1–1.5 mg/kg IV. ACT is to be maintained >250 s. For BT shunt first, the pulmonary artery branch is clamped. Desaturation is quite frequent during this anastomosis. It requires vigilant monitoring of the blood pressure, any bradycardia occurring due to hypoxia and $etCo_2$ values (low due to decreased pulmonary blood flow). Paradoxically, this may be less of an issue with thoracotomy, as clamping the PA will reduce ventilation-perfusion mismatch.

After the PA end is opened, the clamp is applied on systemic artery-subclavian/innominate of the proposed side or aorta in case of central shunt when the partial aortic clamp is applied. Subclavian artery may easily be confused with PDA. The absence of arterial trace in femoral artery can diagnose this condition. Hemodynamic instability may occur after the shunt is opened due to blood loss, systemic runoff to the PA and subsequent acidosis and ischemia-reperfusion injury occurring from release of metabolites from ischemic limb. Inotropes may be required. As per our institutional protocol, before the release of systemic artery clamp, we start inotropes and administer sodium bicarbonate prophylactically. It is common to see low saturations initially due to high PVR, and pulmonary vein desaturation secondary to lung collapse, hypoxic pulmonary vasoconstriction, and atelectasis. Saturation improves subsequently. At this time, low FiO_2 is preferable. A rise in $EtCo_2$ is noted after the shunt is open. Hemodilution is to be avoided. It is prudent to check ABGs at this time.

Further intraoperative course is guided by ruling out any anatomical issues, i.e., appropriate shunt size and whether prone to any kinking or narrowing. If there are no anatomical issues, a review of the physiological issues should be done-adequate preload, sinus rhythm, good contractility (i.e., good myocardial perfusion), maintenance of SVR and appropriate PVR. Remember that shunt is not the sole determinant of PVR. PVR also depends on changes in lung volume, alveolar oxygenation, pH, and pCO_2. Use of inotropes results in improvement in hemodynamic parameters and oxygen delivery but at the cost of increased consumption.

Postoperative Management

- Postoperative pain is commonly managed with continuous narcotic infusion usually fentanyl at 1 mcg/kg/h
- The decision regarding extubation: This has been attributed to a number of factors:
  - Physiologic vulnerability of the neonates particularly with congenital heart disease
  - There are changes in PVR, SVR, and Qp which occur with lung re-expansion in combination with emergence from anesthesia, transition to postoperative pain regimens, possibility of bleeding, etc. These contribute to the postoperative risk of cardiac arrest.

The incidence of failure to extubate neonates following MBTS was investigated by Gupta *et al*.[20] They found that 27% patients required either reintubation or the instigation of noninvasive ventilation within 96 h. Decreased ventricular function was strongly associated with failure. There was a 13% incidence of diaphragmatic paralysis, all in the group that failed. Postextubation hemodynamics also changed, with an increased heart rate and systemic blood pressure in successful subjects.

Management of Complications

Shunt failure

The immediate postoperative period is the time when the incidence of shunt failure is high. This can present acutely

with precipitously dropping saturations. It might be due to acute shunt failure secondary to the shunt clotting or kinking. This is an emergency and should be addressed immediately.[21-23]

BT shunt thrombosis has been reported to be around 12%.[24] Various studies suggest the use of aspirin or heparin to prevent shunt thrombosis. However, histopathology of shunts electively taken down found 25% had a 50% stenosis at a median age of 8 months.[1,25]

Anticoagulation Management

Heparin should be started as soon as possible in the postoperative period. Patients are usually given heparin during clamping of the artery. Heparin should be restarted if bleeding is not an issue usually after 4 h (chest drains <3 ml/kg/h and postop aPTT is <60 s).

Management of heparin therapy

Standard heparin regime for prophylaxis:

Prepare infusion of heparin at 1000 U/kg and start infusion at 10 units/kg/h (0.5 ml/h).[26,27]

Monitoring

A. Clotting profile (apTT, PT, and fibrinogen) is to be monitored
   1. Before commencement of heparin
   2. 4–6 h after starting
   3. 1 h after syringe change
B. Platelet count if drop >50%
   Consider HIT 5–10 days after institution of the treatment
C. Therapeutic range – aPTT (60–90 s)
   - Loading dose not required if recently returned from OR
   - If APTT <50 s bolus of 50 U/kg over 10 min
   - If APTT 50–90 s, infusion at 200 U/kg/h and APTT to be checked after 4 h.

D. Aspirin
   - Aspirin is to be started
   - Chest is closed, and intracardiac lines removed
   - Pacing wires removed
   - Start at 3–5 mg/kg (maximum 75 mg) once daily
   - Continue heparin until the second dose of aspirin is given.

Management of Blocked Blalock-Taussig Shunt

This is an emergency.

Diagnosis: Any patient with a significant drop in saturation with systemic to pulmonary cardiac shunt or inaudible shunt murmur.

If there is any concern regarding surgical repair or deteriorating child despite above interventions, return to the OR should not be delayed.

Management of Pulmonary Overcirculation

BT shunt too big in size leads to excessive pulmonary blood flow and high saturation described as pulmonary overcirculation. This is common if ductus arteriosus is patent and resolves only after its closure.

Diagnosis

- Relatively high saturation
- Chest X ray-edematous lungs
- Low mixed venous saturation
- Rising lactate
- Increase in base deficit
- Relatively low mean blood pressure
- Signs of right heart failure.

Treatment

- Mild form: Fluid restriction, diuretics
- Severe form: Manipulation of SVR and PVR
- Surgical: Pulmonary artery band/clipping.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Gladman G, McCrindle BW, Williams WG, Freedom RM, Benson LN. The modified Blalock-Taussig shunt: Clinical impact and morbidity in fallot's tetralogy in the current era. J Thorac Cardiovasc Surg 1997;114:25-30.
2. Lónyai T, Záborszky B, Kárpáti P. Synthetic vascular prosthesis for Blalock-Taussig anatomosis. Acta Chir Acad Sci Hung 1966;7:361-9.
3. Rodriguez L, Izukawa T, Moës CA, Trusler GA, Williams WG. Surgical implications of right aortic arch with isolation of left subclavian artery. Br Heart J 1975;37:931-6.
4. de Leval MR, McKay R, Jones M, Stark J, Macartney FJ. Modified Blalock-Taussig shunt. Use of subclavian artery orifice as flow regulator in prosthetic systemic-pulmonary artery shunts. J Thorac Cardiovasc Surg 1981;81:112-9.
5. Petrucci O, O'Brien SM, Jacobs ML, Jacobs JP, Manning PB, Eghtesady P. Risk factors for mortality and morbidity after the neonatal Blalock-Taussig shunt procedure. Ann Thorac Surg 2011;92:642-51.
6. McKenzie ED, Khan MS, Samayoa AX, Vener DS, Ishak YM, Santos AB, *et al*. The Blalock-Taussig shunt revisited: A contemporary experience. J Am Coll Surg 2013;216:699-704.
7. Fellows KE, Freed MD, Keane JF, Praagh R, Bernhard WF, Castaneda AC. Results of routine preoperative coronary angiography in tetralogy of Fallot. Circulation 1975;51:561-6.
8. Hurwitz RA, Smith W, King H, Girod DA, Caldwell RL. Tetralogy of Fallot with abnormal coronary artery: 1967 to 1977. J Thorac Cardiovasc Surg 1980;80:129-34.
9. Need LR, Powell AJ, del Nido P, Geva T. Coronary echocardiography in tetralogy of Fallot: Diagnostic accuracy, resource utilization and surgical implications over 13 years. J Am Coll Cardiol 2000;36:1371-7.
10. Moulton AL, Brenner JI, Ringel R, Nordenberg A, Berman MA, Ali S, Burns J. Classic versus modified Blalock-Taussig shunts in neonates and

infants. Circulation 1985;72(3 Pt 2):II35-44.

11. Klinner W, Pasini M, Schaudig A. Anastomosis between systemic and pulmonary arteries with the aid of plastic prostheses in cyanotic heart diseases. Thoraxchirurgie 1962;10:68-75.
12. Gold JP, Violaris K, Engle MA, Klein AA, Ehlers KH, Lang SJ, *et al.* A five-year clinical experience with 112 Blalock-Taussig shunts. J Card Surg 1993;8:9-17.
13. Gazzaniga AB, Elliott MP, Sperling DR, Dietrick WR, Eiseman JT, McRae DM, *et al.* Microporous expanded polytetrafluoroethylene arterial prosthesis for construction of aortopulmonary shunts: Experimental and clinical results. Ann Thorac Surg 1976;21:322-7.
14. Zaki SA, Shanbag P. Pseudoaneurysm following modified Blalock Taussig shunt. Indian Pediatr 2010;47:198-9.
15. Watterson KG, Wilkinson JL, Karl TR, Mee RB. Very small pulmonary arteries: Central end-to-side shunt. Ann Thorac Surg 1991;52:1132-7.
16. Truccone NJ, Bowman FO Jr., Malm JR, Gersony WM. Systemic-pulmonary arterial shunts in the first year of life. Circulation 1974;49:508-11.
17. Sano S, Ishino K, Kawada M, Arai S, Kasahara S, Asai T, *et al.* Right ventricle-pulmonary artery shunt in first-stage palliation of hypoplastic left heart syndrome. J Thorac Cardiovasc Surg 2003;126:504-9.
18. Pizarro C, Mroczek T, Malec E, Norwood WI. Right ventricle to pulmonary artery conduit reduces interim mortality after stage 1 norwood for hypoplastic left heart syndrome. Ann Thorac Surg 2004;78:1959-63.
19. Dragulescu A, Ghez O, Bouvenot J, Guillaumont S, Kreitmann B, Metras D, *et al.* Value of the norwood-sano compared with the classical norwood procedure in hypoplastic left heart syndrome. Arch Mal Coeur Vaiss 2006;99:452-6.
20. Gupta P, McDonald R, Goyal S, Gossett JM, Imamura M, Agarwal A, *et al*. Extubation failure in infants with shunt-dependent pulmonary blood flow and univentricular physiology. Cardiol Young 2014;24:64-72.
21. Williams JA, Bansal AK, Kim BJ, Nwakanma LU, Patel ND, Seth AK, *et al.* Two thousand Blalock-Taussig shunts: A six-decade experience. Ann Thorac Surg 2007;84:2070-5.
22. Schindler M. In: Macnab A, Macrae D, Henning R, editors. Care of the Critically Ill Child. London: Churchill Livingstone; 2002. p. 198-9.
23. Ahmad U, Fatimi SH, Naqvi I, Atiq M, Moizuddin SS, Sheikh KB, *et al.* Modified Blalock-Taussig shunt: Immediate and short-term follow-up results in neonates. Heart Lung Circ 2008;17:54-8.
24. Parry AJ, McElhinney DB, Kung GC, Reddy VM, Brook MM, Hanley FL. Elective primary repair of acyanotic tetralogy of Fallot in early infancy: Overall outcome and impact on the pulmonary valve. J Am Coll Cardiol 2000;36:2279-83.
25. Wells WJ, Yu RJ, Batra AS, Monforte H, Sintek C, Starnes VA. Obstruction in modified blalock shunts: A quantitative analysis with clinical correlation. Ann Thorac Surg 2005;79:2072-6.
26. Monagle P, Chalmers E, Chan A, DeVeber G, Kirkham F, Massicotte P, Michelson AD; American College of Chest Physicians. Antithrombotic therapy in neonates and children: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines (8th edition). Chest 2008;133 6 Suppl: 887S-968S.
27. Andrew M. Anticoagulation and thrombolysis in children. Tex Heart Inst J 1992;19:168-77.