Modified Blalock-Taussig-Thomas Shunt

Surgical Specialty:	Cardiac Surgery
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Background:

- General Considerations
  - Neonates with pulmonary or systemic blood flow restriction due to congenital cardiac anomalies need a shunt that allows blood to flow from one circulation to the other, e.g.ductal dependent circulation via a patent ductus arteriosus, PDA.
  - Examples include tricuspid atresia, tetralogy of Fallot, pulmonary atresia, and hypoplastic left heart syndrome (HLHS). Maintaining ductal patency with prostaglandin E1 infusion to facilitate pulmonary blood flow is a temporizing measure.
  - The modified Blalock-Taussig Thomas shunt (mBTTS) is the most commonly performed palliative shunt to establish reliable blood flow from the systemic to the pulmonary circulation[1]
  - The mBTTS entails anastomosing a tube graft between the innominate or subclavian artery and pulmonary artery and is commonly placed on the right side.[1] Traditionally it was performed via thoracotomy, now it is mostly done via median sternotomy. (See figure)

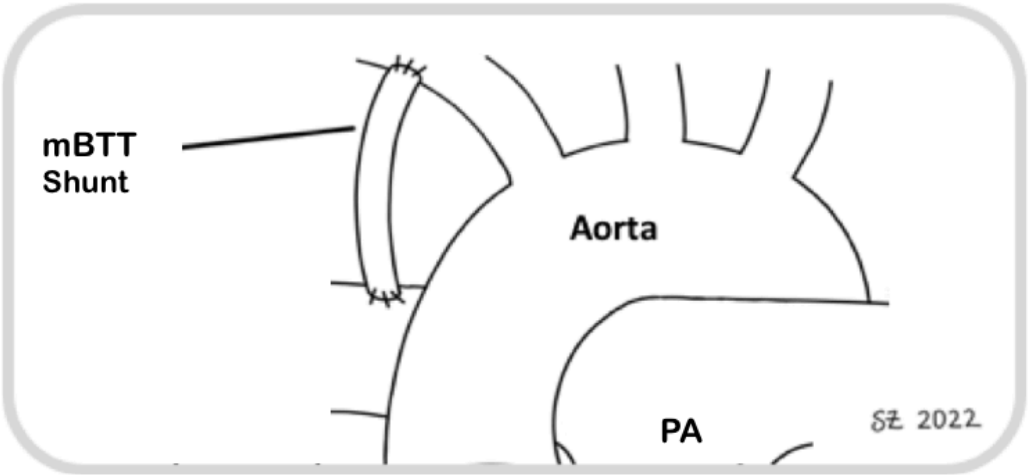

Figure: Modified Blalock Taussig Thomas (mBTT) shunt from the right innominate or subclavian artery to the pulmonary artery. PA =Pulmonary Artery. (Source credit: authors)

- Patient Considerations
    - With inadequate shunt flow or ductal closure, neonates with impaired pulmonary blood flow present with worsening cyanosis and acidosis that progresses to multi-organ failure if uncorrected or unpalliated
    - Patency of the PDA is maintained with prostaglandin E1 (PGE1), which relaxes the vascular smooth muscle of the duct, until the mBTTS is performed (0.01-0.1 mcg/kg/min)
    - Perioperative mortality risk is increased for neonates < 3kg, patients on preoperative mechanical ventilation, single ventricle physiology, and pulmonary atresia with intact septum[2]
    - Diastolic blood pressure (BP) must be adequate to prevent coronary steal and myocardial ischemia
- Associated syndromes
    - Syndromes associated with the cardiac anomalies requiring palliative mBTTS and their associated anesthetic concerns [3,4]
        - Trisomy 21 – Difficult airway, cervical instability, hypothyroidism, airway obstruction, autonomic instability
        - Trisomy 18 – Craniofacial anomalies, difficult airway, pulmonary hypertension, apnea
        - 22q11 deletion – Cleft palate, difficult airway, hypocalcemia, immunodeficiency
        - VACTERL – Difficult airway, tracheoesophageal fistula, renal anomalies
        - CHARGE - Facial and laryngotracheal anomalies, difficult airway
        - Noonan – Facial anomalies, difficult airway, coagulation and platelet defects
        - Turner – Difficult airway, renal anomalies
        - Alagile – Intrahepatic paucity of bile ducts, difficult airway, renal anomalies

Anesthetic Planning:

- Pre-Anesthetic Evaluation
    - Evaluate patient's pertinent history, physical exam findings including NPO status, medications, ventilatory support, vital signs including pre- and post-ductal oxygen saturations, NIRS, vascular access. Laboratory studies may include echocardiography, ECG, CXR, +/- cardiac CT, and catheterization studies
    - It is imperative to review the imaging studies for an aberrant location of the subclavian artery and other extra-cardiac anomalies
    - Pre-operative discussion with surgery/cardiology/ICU teams regarding anticipated surgical approach (thoracotomy vs. sternotomy), the possibility of needing CPB, perioperative airway management, ICU bed availability, and other relevant patient-specific perioperative considerations (e.g. syndrome-related)
    - Discuss the risks/benefits of anesthesia with the family. Verify code status and ECMO option, and consent for blood product transfusion
    - Type and crossmatch, CBC, CMP, coagulation profile
    - Arrange appropriate transport equipment including transport ventilator for patient on mechanical ventilation

- Specific or Unique Room Set-Up Requirements:
    - Additional IV access and line placement as needed. The patient may come intubated -- Set OR ventilator settings similar to the ICU settings

- Airway - Oral/nasal ETT if not intubated
- Specific medications:
  - Induction: Inhalational with sevoflurane. IV typically using ketamine, opioids, paralytic
  - Maintenance: Sevoflurane, fentanyl, dexmedetomidine infusion
  - Vasoactive Infusions may include epinephrine/milrinone/vasopressin/dopamine
  - Pain control and sedation with opioid bolus and infusion, dexmedetomidine infusion, IV acetaminophen
  - Heparin (100 Units/kg before clamping for shunt without CPB and 300 to 400 Units/Kg for shunts performed on CPB)
  - Protamine for heparin reversal
  - Calcium
- Monitors/ vascular access
  - Standard ASA Monitors with 5 lead ECG, NIRS, Arterial BP, CVP, Foley catheter
  - TEE/TTE available
  - Arterial line not typically placed in the same arm as themBTTS side, central venous line, PIV
- Local anesthetic for incision sites and/or regional block for postoperative pain control
- Blood Products - Red Blood Cells which are irradiated in 22q11.2 deletion patients and infants less than 6 months of age, based on institutional practice, FFP, cryoprecipitate, +/- platelets.
- ICU admission for postoperative care

Intraoperative Considerations:

General

- The ultimate goal is to augment pulmonary blood flow (Qp) that is balanced with the systemic blood flow (Qs) with saturation in the range of 75-80% (Qp:Qs=1)
- In a thoracotomy approach, lung retraction is performed for surgical exposure, which impairs oxygenation and ventilation.. It can be managed with intermittent reinflation as allowed. With a median sternotomy approach, the compliance of the lungs increases after opening the chest andventilator settings need to be adjusted accordingly

Induction

- IV induction: Options include etamine, fentanyl, low dose inhalational agents and paralytics with the goal for balanced Qp:Qs and minimizing myocardial depression

Maintenance

- Inhalation and IV agents like opioids, dexmedetomidine infusion, ketamine
- Pain control: Multimodal approach including opioids, ketamine, IV acetaminophen, regional field or nerve block.

Hemodynamic/Physiologic goals

- Maintain balanced pulmonary blood flow (PBF) and systemic blood flow with saturation in the range of 75-80% on low FiO2. Manipulate SVR and PVR- titrate with FiO2, ventilation, anesthetic agents (sevoflurane, ketamine, opioids), preload, and vasopressors to facilitate balanced Qp:Qs. Use inotropic support to increase cardiac output and maintain SVR to facilitate PBF and coronary perfusion[4]

- Avoid tachycardia as it reduces diastolic time compromising the coronary perfusion
- Keep MAP greater than 40 mmHg. Be vigilant of coronary artery hypoperfusion to prevent myocardial ischemia, arrhythmia, and cardiac arrest
- Maintain adequate hemoglobin levels for maximizing O2 carrying capacity
- Monitor NIRS closely and keep at baseline

Positioning
- Median sternotomy- supine, with shoulder roll and appropriate padding.
- Thoracotomy- lateral decubitus with thoracotomy side up

Surgical Considerations[1]
- The discovery of aberrant subclavian arteries will impact the surgical plan
- The proximal anastomosis is performed with side clamping of the subclavian or innominate artery and may result in the loss of ipsilateral pulse oximeter/ blood pressure reading
- The pulmonary artery is side-clamped for the distal anastomosis causing hypoxemia. Manage with ventilatory adjustments, vasopressors, and fluids treatment
- Opening the shunt increases arterial oxygenation and decreases systolic and especially diastolic BP (diastolic run-off). It also it acutely increases ventricular volume and myocardial work. This combination can lead to coronary ischemia which can be managed with volume and vasopressors to maintain coronary artery perfusion pressure
- Appropriate shunt size - Usual mBTTS range 3.0-4.0 mm, most commonly 3.5 mm for neonates. A shunt size too small leads to inadequate PBF; too large leads to systemic steal to the lungs, pulmonary over-circulation (SpO2> 85%) leading to pulmonary hypertension, and risk of systemic and coronary hypoperfusion
- Low saturation indicates decreased PBF: shunt size too small, shunt anastomotic stenosis or kinking, low systemic pressure, increased PVR. Rule out mechanical shunt problems, increase systemic blood pressure, decrease PVR, optimize hemoglobin. Transthoracic echocardiography (TTE) may help visualize stenotic shunt flow. Serial ABGs are useful to assess the adequacy of shunt flow
- It is important to confirm the correct ETT position and patency, and rule out endobronchial intubation because failure to do so might lead to unnecessary shunt revision
- High saturation and systemic hypotension suggests that the shunt is too big with pulmonary over-circulation and may require shunt revision
- PGE1 infusion continued or stopped in discussion with the surgeon. Surgeons commonly ligate PDA to decrease additional PBF, instead of waiting for it to close after PGE1 discontinuation
- Platelet transfusion avoided if possible - risk of shunt thrombosis; give RBC as needed
- Adequate preload, sinus rhythm, appropriate PVR and SVR to maintain balanced blood flow

Emergence/Disposition[3,4]
- Transfer to ICU. Stay on mechanical ventilation until hemodynamic stable, with stable saturations of 75-80% on low FiO2, and exhibiting minimal post-operative bleeding

Post-operative Care[3,4]
- Analgesia with opioids, ketamine, IV acetaminophen, regional infiltration on surgical closure and sedation usually includes dexmedetomidine infusion
- Heparin (6-10 U/kg/hour) to maintain shunt patency after minimal concerns for postoperative bleeding. Aspirin after starting enteral feeds

Case-Specific Complications/Pitfalls

- Shunt thrombosis/kinking - presents as worsening hypoxemia (emergency)
- Decreased PVR, pulmonary over-circulation causing pulmonary edema or hemorrhage with resulting systemic under-perfusion
- Decreased SVR, with decreased coronary perfusion pressure, causing myocardial ischemia. It could lead to hypoxemia due to decreased shunt flow
- Phrenic and recurrent laryngeal nerve palsy, Horner's syndrome, and chylothorax

Management goals of patients with mBTTS for Non-Cardiac Surgeries

- Saturation goal of 75-80% AND adequate BP (maintain PVR/ SVR balance). Avoid increases in PVR and/or decreases in SVR resulting in hypoxemia, decreases in PVR leading to systemic underperfusion/coronary artery steal, and myocardial depression.
- Auscultate for shunt murmur – ensure flow present through the mBTTS shunt
- Stand by heparin (100 U/kg) – for emergent dosing with suspected shunt thrombosis

References

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