ARTERIAL SWITCH OPERATION (ASO)

Surgical Specialty:	Cardiothoracic Surgery
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Background:

- General Considerations
  - Transposition of the great arteries (TGA) encompasses a group of conditions involving ventriculoarterial (VA) discordances.
  - The most common form is dextro-TGA (d-TGA), which is characterized by concordant atrioventricular (AV) connection and discordant VA connection in which the morphological right ventricle (RV) gives rise to the aorta and the morphological left ventricle (LV) gives rise to the pulmonary artery (PA). It is also known as physiologically uncorrected TGA.
  - The arterial switch operation (ASO) is the gold standard of management for d-TGA. The VA discordance is corrected, resulting in an anatomic repair. It is usually a scheduled operation in the first weeks of life.

- Patient Considerations
  - TGA is commonly prenatally diagnosed with fetal echocardiogram (ECHO).
  - TGA refers to a spectrum of lesions, which include the aforementioned d-TGA, double outlet right ventricle (DORV), Taussig-Bing malformation (sub-pulmonary artery VSD), and the more rare, congenitally corrected transposition of the great arteries (ccTGA).
  - d-TGA produces two parallel circulations. It is incompatible with life unless an associated connection exists between the right and left side of the heart (i.e. ventricular septal defect (VSD), patent foramen ovale (PFO), atrial septal defect (ASD), or patent ductus arteriosus (PDA)) [1,4]
  - If there is a restriction to inter-circulatory mixing, which occurs in d-TGA with intact ventricular septum (IVS), systemic oxygenation will be low and result in low arterial saturation. This can be alleviated by establishing a more patent connection between the two systems. Maintaining a PDA with prostaglandin E_1 (PGE_1) infusion and/or emergent balloon atrial septostomy (BAS) are the most common ways to ensure mixing. If the patient is clinically unstable, mechanical ventilation, extracorporeal membrane oxygenation (ECMO), and emergent surgical intervention might be pursued. [1,4]
  - Congestive heart failure can be present in the setting of a large communication between the right and left heart, most commonly a large VSD. This causes an increase in inter-circulatory blood flow and over time can result in LV dysfunction and

pulmonary arterial hypertension (PAH). In this scenario, the patient may require diuretics, pulmonary vasodilators, or low-dose inotropes prior to surgical intervention. [1,4]

- LV mass and function are key indicators for the timing of surgical intervention. Training the LV to perform as the systemic ventricle might be required in the setting of low birth weight, sepsis, or prematurity that delays definitive surgery. This is achieved with a staged approach of initial PA banding followed by ASO. [1,4.]
- Delineation of the coronary artery anatomy is vital to prevent any narrowing or distortion after re-implantation of the coronary arteries to the neo-aorta. The large majority of d-TGAs (70%) have normal coronary anatomy but the remainder have significant variabilities. [1,4]
- For TGA with VSD and severe left ventricular outflow tract obstruction (LVOTO) other surgical options, such as a Rastelli or Nikaidoh procedure, are more appropriate [1,4]

Anesthetic Planning:

- Pre-Anesthetic Evaluation
  - Complete medical history and physical exam
    - Other cardiac anomalies: VSD, LVOTO, pulmonic stenosis (PS), PDA, PFO
    - Prior interventions: BAS, ECMO
    - Cardiorespiratory status: degree of inter-circulatory mixing (restrictive vs. unrestrictive), mechanical ventilation, and settings
    - Medications: most notably PGE_1 infusion and any side effects, pressors, inotropes, diuretics, sedation
  - Labs: complete blood count, complete metabolic panel, coagulation studies, type & screen
  - Imaging:
    - Antenatal ECHO
    - Transthoracic ECHO at birth: confirm the type of TGA, establish coronary artery anatomy, LV size and function
    - Cardiac catheterization: may be performed in conjunction with BAS or when further anatomy detailing is needed; seldom performed independently.
    - Electrocardiography (EKG): right axis deviation and right ventricular hypertrophy
    - Chest radiograph (CXR): “egg-shaped” heart, narrowed superior mediastinum, increased pulmonary vasculature markings
- Specific or Unique Room Set-up Requirements
  - Airway
    - Proper laryngoscope and correctly sized, cuffed ETT
    - Nasal intubation is preferred in some centers as a more stable airway and mitigates oral aversion [1]
  - Vasoactive agents (institutional practices may vary)[2]
    - Inotropes: Epinephrine (0.02-0.05 mcg/kg/min IV)
    - Inodilators: Milrinone (0.25-0.5 mcg/kg/min IV)
    - Pressors: Vasopressin (0.2-0.4 milliunits/kg/min IV), calcium chloride (5 -10 mg/kg/hr IV). Can also consider Phenylephrine (0.1-0.5 mcg/kg/min IV) Dopamine (5 -10mcg/kg/min IV)
    - Pulmonary dilators: Nitric oxide (iNO) might be needed for CPB separation in the setting of pre-existing PAH

- Monitors
  - Pre-ductal and post-ductal oxygen saturation probes
  - Two temperature probes to measure peripheral and core temperatures (nasopharyngeal and rectal)
  - $ETCO_2$
  - EKG
  - Triple transducer
    - CVP from central line or PICC if in situ
    - ABP from arterial line
      - Can measure aortic root pressure directly if needed, post-bypass
    - LAP, depending on center and surgeon preference, from a left atrial line placed by the surgeon for monitoring post-bypass
  - Near-infrared spectroscopy (NIRS) – cerebral and somatic
  - Intraoperative echocardiography
    - TEE vs epicardial depending on patient and institutional practice
- Lines/Invasive monitoring
  - Two-large bore peripheral IVs
  - Double-lumen central line
  - Arterial line
  - Intracardiac line placed by surgeon
- Blood Availability
  - Red blood cells (RBCs), fresh frozen plasma (FFP), platelets, cryoprecipitate
  - Perfusion will use blood products to prime the pump.
  - Antifibrinolytics per institutional practice: tranexamic acid (TXA) pre-CPB, CPB prime, and post-CPB
  - Discuss with the surgeon the need for other procoagulants (prothrombin complex concentrate, Factor VII)
- ICU Bed Availability
  - Necessary: Preferably a cardiac intensive care unit

Intraoperative Considerations:

- General
  - Cyanotic patients are prone to coagulopathy (polycythemia)
  - Maintain PDA with PGE_1 in ductal-dependent circulation until the patient is effectively on CBP
- Induction
  - Intravenous: fentanyl (narcotic choice may vary by institutional practice) 1-5 mcg/kg IV, etomidate, ketamine
    - Aim for hemodynamic stability. Maintain heart rate, contractility, and preload to maintain cardiac output, ventricular performance, and perfusion of end organs.
- Positioning
  - Supine
  - Shoulder roll to elevate chest for surgical intervention. Monitor for movement or dislodgment of ETT during and after placement.
  - Proper padding, to avoid pressure injury
- Maintenance
  - Institutional practices vary, but most advocate a balanced technique of inhalational agent and opioids.

        - Total fentanyl dose varies from 30-100 mcg/kg.
        - If no vaporizer is available on the CPB circuit, be sure to administer IV anesthetics during this phase.
    - Hemodynamic goals
        - Pre-bypass: optimize inter-circulatory mixing
            - Avoid increases in pulmonary vascular resistance (PVR) that can decrease pulmonary blood flow and reduce inter-circulatory mixing.
                - Elective hyperventilation of the patient is one strategy.
                - Increase FiO_2
                - Avoid acidosis
            - Maintain SVR, particularly in relation to PVR.
        - Post-bypass: maintain cardiac output with low LAP, avoiding pulmonary hypertension
            - Goal LAP between 5 to 8 mmHg
                - Judicious fluid boluses, given in 5-10 mL/kg aliquots to avoid cardiac distention.
- Surgical Considerations
    - Delayed chest closure for bleeding or dilatation/inflammation of the heart
- Emergence/Disposition
    - Early extubation is less likely in small neonates
    - Sedation to avoid agitation immediately post-op that may cause harm to the patient by dislodging lines/drains/airway
        - Dexmedetomidine 0.2-1 mcg/kg/hr IV
        - Fentanyl 1-5 mcg/kg/hr IV infusion with prn bolus
        - Morphine 0.05-0.1 mg/kg/hr IV infusion with PRN bolus
        - Acetaminophen 10-15 mg/kg IV Q-6 hours
- Post-op Care Concerns
    - Bleeding: multiple arterial anastomoses
    - Ventricular dysfunction
    - Arrhythmia: temporary pacing wires placed by the surgeon
    - Pulmonary hypertension: availability of inhaled nitric oxide

Case-Specific Complications/Pitfalls

- A high index of suspicion for coronary insufficiency as a cause of LV dysfunction is appropriate.
    - A rapid increase in LAP, systemic hypotension, and EKG changes should prompt evaluation with transesophageal echocardiography (TEE). [3]
    - Evaluate coronary blood flow, regional wall movement abnormalities
- With VSD closure, heart block can occur - use temporary pacing wires
- Late complications include PA and right ventricular outflow tract (RVOT) stenosis, aortic valve insufficiency, and coronary artery obstruction.

References

1. McEwan A, Manolis M. Anesthesia for Transposition of the Great Arteries. In: Andropoulos DB, Stayer S, Mossad EB, eds. *Anesthesia for Congenital Heart Disease.* 3rd edition. John Wiley & Sons, Inc. 2015 pp. 542-561.
2. McEwan A, Rolo VL. Anesthesia for Children Undergoing Heart Surgery. In: Coté CJ, Lerman J, Anderson BJ, eds. *A Practice of Anesthesia for Infants and Children.* 6th edition. Elsevier. 2019. pp 413-415.
3. DiNardo JA, Shukla AC, McGowan Jr. FX. Anesthesia for Congenital Heart Surgery. In: Davis PJ, Cladis FP, Motomoya EK, eds. *Smith's Anesthesia for Infants and Children.* 8th edition. Elsevier. 2011 pp. 622-627.
4. Nasr, V, DiNardo JA. *The Pediatric Cardiac Anesthesia Handbook*. 1st edition. John Wiley & Sons Ltd. 2017 pp147-160

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