SURGICAL PATENT DUCTUS ARTERIOSUS LIGATION

Surgical Specialty:	General, thoracic, or cardiac
Authors:	Jakob Adkins DO, Arpa Chutipongtanate MD Cincinnati Children's Hospital Medical Center, Cincinnati, OH

Background:

- General considerations
  - A patent ductus arteriosus (PDA) occurs when the ductus arteriosus, a normal part of fetal circulation, fails to close. It is the residual vascular structure from fetal circulation that diverts blood from the pulmonary artery to the aorta, to bypass the pulmonary bed in utero. It is typically located between the proximal descending aorta just distal to the left subclavian artery and the main pulmonary artery near the origin of the left pulmonary artery.[1]
  - A large PDA results in increased pulmonary blood flow as PVR begins to decrease; it may lead to congestive heart failure and pulmonary hypertension if left untreated.
  - Open PDA ligation is the definitive treatment when pharmacological treatment with NSAID has failed or is contraindicated, and percutaneous catheter-delivered devices or coils are not an option.[2]
- Patient considerations
  - Disease-specific considerations[1]
    - Pulmonary over-circulation from left-to-right shunting
    - Systemic hypoperfusion from diastolic runoff from the aorta can result in compromised coronary, cerebral, and abdominal organ perfusion. Myocardial ischemia, necrotizing enterocolitis, renal failure, and intracerebral and intraventricular hemorrhage are potential complications.
  - Associated comorbidities/syndromes
    - Prematurity: incidence of 20-60% in preterm infants.[3]
    - Concomitant cardiac abnormalities: a PDA may be associated with almost any other congenital cardiac anomaly except the absence of pulmonary valve syndrome.[1]

Anesthetic Planning:

- Pre-anesthetic evaluation[3,4]
  - Obtain a thorough history, physical exam
  - Optimize comorbid conditions
  - Physical exam: wide pulse pressure, hyperdynamic precordium, coarse continuous machine murmur along the left sternal border that radiates to the back
  - Standard NPO guidelines

    - Fluid status: patients are often on fluid restriction and/or diuretics pre-operatively
    - Additional labs/tests indicated during work-up
        - Transthoracic echocardiogram: assess morphology and size of PDA, shunt direction, arch-sidedness, presence of coarctation, left heart enlargement
        - CBC
        - CXR: normal with small PDA; cardiomegaly and increased pulmonary vascular marking in moderate-to-large PDA
        - EKG: normal or LVH/RVH
        - Type and screen blood group
    - Discussions to have with surgeon/family
        - Operative setting: operating room (OR) vs. ICU
            - Risks of transporting a neonate between locations:
                - Cardiorespiratory instability
                - Accidental endotracheal tube dislodgement
                - Disruption of ventilation
                - Hypothermia
                - Displacement of invasive lines/loss of vascular access
        - Code status
        - Risks of pulmonary or cardiac injury
        - Bleeding risk
        - Risk of recurrent laryngeal nerve injury
- Specific or unique room set-up and/or requirements
    - Airway
        - Secured with an appropriately sized endotracheal tube
            - The patient may already be intubated
        - A NICU ventilator may be required
        - For extreme ex-premies or extremely low birthweight patients, to minimize the risk inherent in transitioning ventilators, consider using a transport ventilator like the Hamilton, both for transporting the patient and for intraoperative ventilation
    - Access
        - Peripheral IV Access
            - At least two large–bore peripheral IVs are ideal
        - Consider central venous access indicated in Complex Cases (central lines may be preferred if the patient has poor peripheral access, is critically ill, or requires continuous inotropic support)
    - Drugs/infusions
        - Consider having epinephrine or dopamine infusions available
        - Continue IV dextrose infusion
        - Calcium bolus available
    - Monitors
        - Upper and lower extremity blood pressure cuffs
        - Pre- and post-ductal pulse oximetry
        - End-tidal CO_2 (ET-CO_2)
        - EKG
        - Core (rectal) temperature
        - Consider an arterial line if comorbidities necessitate
    - Temperature control
        - Set OR/NICU ambient temperature at 28°C
        - Radiant warmer, forced air warmer, or warming pad

        - Blood warmer set available
    - Blood products
        - Packed red blood cells (15mL/kg) available for surgery
        - Maintain platelet count > 50,000

Intraoperative Considerations:

- General
    - Anesthetic and physiologic implications of the surgical procedure
        - Successful ligation should result in increased diastolic pressure, decreased heart rate, and transient increase in systolic blood pressure
    - Maintain effective communication between neonatology, surgery, and anesthesia teams
- Anesthesia technique.
    - High-dose opioids and muscle relaxants have long been the cornerstone of anesthetic techniques for surgical PDA ligation in premature patients.
    - Despite concerns about neurotoxicity, ketamine, and halogenated agents are also commonly used as supplemental anesthesia in many specialized centers.
    - Additionally, dexmedetomidine deserves mention in the context of congenital heart surgery, as it has shown potential benefits in improving certain outcomes, possibly by helping to blunt the surgical stress response.
- Induction
    - Depends on the patient, surgical setting, availability of vascular access
        - ICU: opioid technique with fentanyl 2-5 mcg/kg
        - OR: A slow inhalational induction with sevoflurane may be considered in stable, older patients without existing vascular access.
    - Nondepolarizing paralytic: consider rocuronium 0.6-1 mg/kg
- Positioning
    - Most commonly, right lateral decubitus for left thoracotomy incision
    - In the case of right-sided PDA with right aortic arch: left lateral decubitus
- Maintenance
    - Titrate anesthetic as needed throughout the case. Institution-dependent.
        - :One option is a high-dose opioid technique which can blunt the stress response
            - 25 mcg/kg of fentanyl may be used, but up to 100 mcg/kg may be required in a neonate who will remain intubated post-operatively
        - Adjust sevoflurane (in the OR) based on patient response. Patient may not tolerate volatile agent and may demonstrate hypotension
        - Ketamine may be used if patient does not tolerate volatile agent.
    - Maintain paralysis with intermittent rocuronium dosing
- Hemodynamic/physiologic goals [3-5]
    - Maintain cardiac output: optimize preload, and maintain heart rate and contractility.
    - Avoid a decrease in pulmonary vascular resistance (PVR): a decrease in PVR results in an increase in left to right shunt with a decrease in systemic blood flow.
    - Premature and low-weight patients can require unique, precise ventilation that cannot be reproduced with an anesthesia ventilator: use an ICU ventilator or transport ventilator in this setting.
    - Ventilation strategies to maintain PVR
        - Permissive hypercapnia (ET-CO_2 45-55 mmHg)
        - Maintain the lowest tolerated FiO_2 to achieve SpO_2 90-95%
        - Consider a higher PEEP of 5-8 to optimize oxygenation

    - Maintain euvolemia
- Surgical considerations
    - Minimal blood loss is anticipated, unless complications arise
    - Lung retraction can lead to hypercarbia and/or hypoxia
        - Maintain communication with the surgeon
        - intermittent release of retraction may be required
    - The surgeons will test clamp to prevent ligation of the wrong vessel
- Emergence/disposition
    - ICU postoperatively
        - Recover in place for bedside ICU procedures
    - Consider extubation in older, stable patients
    - Sick preterm neonates that failed to wean from the ventilator, necessitating PDA ligation, should remain intubated
- Post-operative pain control
    - Multimodal analgesia
    - Consider nerve block when appropriate
        - Intercostal block/ Paravertebral/Erector Spinae block

Case-Specific Complications and Pitfalls[1,6,7]

- Ligation of incorrect structure
    - Descending aorta: loss of lower extremity BP/pulse
    - Left pulmonary artery: desaturation, decrease ET-CO_2
    - Left mainstem bronchus: desaturation, change in respiratory parameters
- Injury to the recurrent laryngeal nerve: left vocal cord paresis
- Ductal tearing can lead to significant hemorrhage
- Iatrogenic coarctation: check BP in upper and lower extremities to ensure no gradient post-ligation
- Post-ligation cardiac syndrome
    - Elevated risk in neonates < 28 days postnatal age, or < 1 kg
    - Typically presents within 6-12 hours of ligation
    - Hypotension requiring inotropes and failure to oxygenate and ventilate
    - Caused by left ventricular systolic and diastolic failure secondary to increased afterload which the neonatal immature myocardium is unable to adapt eventually leading to pulmonary edema
- Risks of intrathoracic procedure: pneumothorax, hemothorax, or chylothorax
- Pulmonary hypertension

References

1) Jonas R.A. Patent Ductus Arteriosus, Aortopulmonary Window, Sinus of Valsalva Fistula, and Aortoventricular Tunnel. In: Jonas R.A. *Comprehensive Surgical Management of Congenital Heart Disease*. second edition. United Kingdom; CRC Press; 2014: 267-288.
2) Weisz DE, Giesinger RE. Surgical management of a patent ductus arteriosus: Is this still an option?. *Semin Fetal Neonatal Med*. 2018;23(4):255-266. PubMed Link
3) Kritzmire SM, Boyer TJ, Singh P. Anesthesia For Patients With Patent Ductus Arteriosus. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing; August 9, 2022. PubMed Link
4) Joshi RK, Aggarwal N, Agarwal M, Joshi R. Anesthesia protocols for "bedside" preterm patent ductus arteriosus ligation: A single-institutional experience. *Ann Pediatr Cardiol*. 2021;14(3):343-349. PubMed Link
5) Smith A, McNamara PJ, El-Khuffash AF. Non-pharmacological management of a hemodynamically significant patent ductus arteriosus. *Semin Fetal Neonatal Med*. 2018;23(4):245-249. PubMed Link
6) Giesinger RE, Bischoff AR, McNamara PJ. Anticipatory perioperative management for patent ductus arteriosus surgery: Understanding postligation cardiac syndrome. *Congenit Heart Dis*. 2019;14(2):311-316. PubMed Link
7) Nasr. V, DiNardo, J, *Patent Ductus Arteriosus,* The Pediatric Cardiac Anesthesia Handbook 2017, Ch69, Pp69-71.

Reviewed by:

Reviewer #1: Clayre Tanis-Arens, DO, Indiana University School of Medicine

Reviewer #2: Andrew J. Giustini, MD, PhD, Oregon Health & Science University

Reviewer #3: Olga Pawelek, M.D., FASA, The University of Texas Health Science Center at Houston

---

Created: 2/17/25; Last revised: 2/17/25