PDA (PATENT DUCTUS ARTERIOSUS) DEVICE CLOSURE: CURRENT STATUS

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I ANATOMICAL CLASSIFICATION (KRICHENKO CLASSIFICATION, 1989)

- **Anatomical Basis:** The Patent Ductus Arteriosus (PDA) connects the roof of the main/proximal **left pulmonary artery** to the anterior wall of the **proximal descending thoracic aorta** just distal to the left subclavian artery.
- **Krichenko Angiographic Types (Lateral Aortogram):** Dictates device selection:
- **Type A (Conical — ~65%):** Well-defined aortic ampulla tapering to a discrete constriction at the pulmonary arterial insertion.
- **Type B (Window — ~18%):** Very short, wide, window-like ductus narrowed at the aortic insertion.
- **Type C (Tubular — ~8%):** Tubular configuration throughout its length without any focal constriction.
- **Type D (Complex — ~4%):** Ductus with multiple constrictions and intervening aneurysmal segments.
- **Type E (Elongated — ~5%):** Bizarre, elongated conical ductus with the constriction remote from the anterior tracheal border (characteristic of **premature infants**, often termed **Type F "Fetal/Hockey-stick" ductus** in dedicated premature classifications).

II INDICATIONS AND CONTRAINDICATIONS FOR CLOSURE (ESC 2020 ACHD / ACC-AHA 2018)

- **Class I Indications (Recommended):**
  - **Left Heart Volume Overload:** Evidence of **Left Atrial (LA) and/or Left Ventricular (LV) enlargement** due to significant left-to-right shunting (**Qp:Qs of 1.5:1 or greater**) with **PVR less than 3 Wood Units**, regardless of symptoms.
  - **Symptomatic Patients or Prior Endarteritis:** Congestive heart failure, failure to thrive in infants, exercise intolerance, or a prior episode of **infective endarteritis**.
  - **Modality of Choice: Transcatheter device closure is the Class I treatment of choice** in adults and children when anatomically suitable.
  - **Class IIa Indications (Should Be Considered):**
  - **Borderline PAH (PVR 3 to less than 5 Wood Units):** Closure should be considered when a significant net left-to-right shunt (**Qp:Qs greater than 1.5**) persists.
  - **Small Audible PDA without LV Overload:** Closure is reasonable in a small PDA with an **audible continuous murmur** and normal LV dimensions to eliminate the lifetime risk of infective endarteritis.
  - **Class IIb Indications (May Be Considered):**
  - **Severe PAH (PVR 5 Wood Units or Greater):** May be considered in expert centers only if **Qp:Qs remains greater than 1.5** and **trial balloon/device occlusion** (or targeted PAH medical therapy) confirms a significant drop in PA pressure without a fall in systemic aortic pressure.
  - **Class III (Contraindicated / Harm):**
  - **Eisenmenger PDA: Persistent PVR of 5 Wood Units or greater** with bidirectional or right-to-left shunting (**differential cyanosis and clubbing of the lower extremities/toes**, or resting/exercise lower-limb desaturation).
  - **Silent PDA:** Tiny PDA detected incidentally on color Doppler echocardiography **without an audible murmur**.

III PROCEDURAL TECHNIQUES AND DEVICE SELECTION

- **Vascular Access and Crossing:** Standard **femoral venous** (for antegrade delivery across the right heart and PA into the descending aorta) and **femoral arterial** access (for lateral descending aortography to measure minimal ductal diameter, ampulla size, and length). In premature and small infants, a **venous-only TTE-guided approach** is used to avoid femoral arterial injury.
- **Device Selection by Ductal Morphology:**
  - **Amplatzer Duct Occluder I (ADO I) / Cocoon / Cera Duct Occluder:** Single aortic retention disc with a tapered cylindrical body (sized **2 mm larger** than the minimal pulmonary ductal diameter); the workhorse for **Type A conical PDAs greater than 2 mm**.
  - **Amplatzer Duct Occluder II (ADO II):** Flexible nitinol mesh with **two symmetrical retention discs** and an articulating central waist deliverable through a 4F or 5F catheter from either the venous or arterial side; ideal for **small-to-moderate (<4 to 5.5 mm) Type A, Type C tubular, or Type E elongated PDAs**.
  - **Amplatzer Vascular Plug II (AVP II) or Muscular VSD Occluder:** Multi-lobed or high-radial-strength double-disc devices used for **large tubular Type C PDAs** or **hypertensive adult PDAs**.
  - **Detachable Coils (Flipper / Gianturco):** Used for **very small PDAs (minimal diameter less than 1.5 to 2.0 mm)**.

PDA Morphology / Clinical Group	Preferred Transcatheter Device	Sizing & Technical Pearl
Type A Conical PDA (>2.0 mm)	**Amplatzer Duct Occluder I (ADO I)**	Select pulmonary end **>=2 mm larger** than narrowest ductal diameter; antegrade venous delivery
Small / Tubular / Elongated PDA (<4–5 mm)	**ADO II** or **Amplatzer Vascular Plug II (AVP II)**	Symmetrical dual discs; low profile via 4F/5F sheath (venous or retrograde arterial)
Very Small PDA (<1.5–2.0 mm)	**Detachable Coils** or **ADO II**	Simple retrograde or antegrade delivery; avoid residual high-velocity jet (hemolysis)
Premature / ELBW Infant (>=700 grams)	**Amplatzer Piccolo Occluder** (FDA approved 2019)	Implanted **completely intraductally** via **4F femoral venous-only TTE-guided** approach (avoids LPA/aortic obstruction)
Large Hypertensive Adult PDA	**Muscular VSD Occluder**	Dual retention discs prevent systemic-pressure embolization into PA

IV THE PREMATURE INFANT PARADIGM SHIFT (AMPLATZER PICCOLO OCCLUDER)

- **The Clinical Problem:** Hemodynamically significant PDA in **extremely low birth weight (ELBW) premature infants** causes pulmonary hemorrhage, prolonged mechanical ventilation, bronchopulmonary dysplasia, and necrotizing enterocolitis; while cyclooxygenase inhibitors (indomethacin, ibuprofen) or paracetamol often fail, surgical thoracotomy ligation carries risks of post-ligation low cardiac output syndrome, **left recurrent laryngeal nerve palsy (vocal cord paralysis)**, phrenic nerve injury, chylothorax, and scoliosis.
- **The Amplatzer Piccolo Occluder Breakthrough (Pivotal Trial, *JACC Cardiovasc Interv* 2020):** A low-profile, symmetrical nitinol device approved for premature infants weighing **as little as 700 grams** (and age >=3 days). Delivered via a **4F femoral venous-only approach under bedside Transthoracic Echocardiography (TTE) and fluoroscopic guidance** (zero arterial access and minimal contrast), the entire device is packed **completely inside the fetal ductus (intraductal placement)** so that neither disc protrudes into the tiny neonatal descending aorta or left pulmonary artery—achieving **95.5 to 99 percent implant success** and rapid ventilator weaning.

V COMPLICATIONS AND OUTCOMES

- **Device Embolization (less than 1 percent):** Embolization into the **Pulmonary Artery** (from undersizing) or **Descending Aorta**; retrieved percutaneously with a gooseneck snare or surgically.
- **Iatrogenic Aortic Coarctation or Left Pulmonary Artery (LPA) Stenosis:** Caused by protrusion of the aortic retention disc into the aortic isthmus or the pulmonary end into the origin of the LPA (especially in infants weighing less than 6 kg). Mandatory pre-release TTE and pullback pressure assessment must confirm no LPA or descending aortic flow acceleration (**Doppler velocity must remain less than 2.0 m/s** without a diastolic tail).
- **Mechanical Intravascular Hemolysis (0.5 percent):** High-velocity residual shunt jet shearing red blood cells against the nitinol/polyester mesh, presenting with hemoglobinuria within 24 hours; managed with hydration, transcatheter coil/plug closure of the residual leak, or device retrieval if refractory.
- **Long-Term Outcomes:** Complete closure rates exceed **98 to 99 percent at 6 to 12 months**, establishing transcatheter occlusion as the definitive gold standard over surgery across virtually all weight and age groups (except giant non-constricting window-type ducts exceeding available device sizes).

KEY REFERENCES

- **Krichenko A, Benson LN, Burrows P, Möes CA, McLaughlin P, Freedom RM:** Angiographic classification of the isolated, persistently patent ductus arteriosus and implications for percutaneous catheter occlusion, *American Journal of Cardiology*, 1989.
- **Sathanandam SK, Gutfinger D, O'Brien L, et al.:** Amplatzer Piccolo Occluder clinical trial for percutaneous closure of the patent ductus arteriosus in patients >=700 grams, *JACC: Cardiovascular Interventions*, 2020.
- **Baumgartner H, De Backer J, Babu-Narayan SV, et al.:** 2020 ESC Guidelines for the management of adult congenital heart disease, *European Heart Journal*, 2020.