**Case Report**
Volume 9:2, 2023

**Journal of Vasculitis**

**ISSN: 2471-9544** **Open Access**

# Percutaneous Patent Ductus Arteriosus (Pda) Closure: When and How to Close Coil *vs*. Occluder "Step By Step" Cases Report

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## Abstract

**Background:** The PDA defines the pathological persistence after the birth of a fetal physiological communication between the aorta and the pulmonary artery frequently encountered in preterm infants and whose clinical and hemodynamic consequences depend on the importance of the shunt directly bound to the diameter of the canal. Percutaneous closure is the most frequent management modality with excellent immediate and long-term results (two modes of closure: using coil or Occluder). The surgery that remains reserved for complex anatomies or associated with other surgical congenital anomalies.

**Case presentation:** We detail in this document the two methods of percutaneous closure step by step illustrated by pediatric cases. The first case concerns a 7 years old girl of 17Kg weight with history of heart murmur that presented in the TTE a PDA estimated at 1mm with LV dilation. The second case concerns a 12 years old girl of 30 kg weight with also history of heart murmur that presented on TTE a PDA of 4.5mm with LV dilation.

**Therapeutic intervention:** In the first case, we perform a closure with coil 5/5 by a unique femoral arterial approach as a standardized attitude in our center avoiding an additional venous access. For the second case, we opted for a closure with prosthesis N° 6/8 by a double femoral approach (arterial and venous access).

**Outcomes:** The follow-up was favorable for both patients, with total sealing of the defect immediately after the procedures that persist on the 6 months control.

**Conclusions:** The closure of PDA in children is a challenging procedure whose safety requires a good pre- and perprocedural evaluation allowing the right choice of the method and size of the closing device. The respect of the different closure stages and the critical perprocedural ultrasound and angiographic control reduce the rate of complications making this technique accessible and safe. In our series of 108 PDA closures by Coil in children the unique femoral arterial approach is the standardized attitude in the first line in all patients avoiding an additional venous access, which allows the Coil release in the basic technique while the arterial access allows opacification and measurement of the channel. The unique arterial approach has reduced the risk of local complications at the puncture site and the duration of procedure without difference in closure efficiency and embolization risk. In our series of 92 PDA closures by Occluder in children the double femoral approach is the standardized attitude for all patients, the venous access allows the device release while the arterial access allows opacification/ measurement of the channel and control device deployment.

**Keywords:** PDA • Congenital heart disease • Percutaneous closure • Coil • Occluder

**List of abbreviations:** LV: left ventricle; NSAIDs: Non streoidal anti-inflamlatory drugs; PA: pulmonary artery; PDA: Persistent ductus arteriosus; TTE: Transthoracic echocardiography; Vmax: Maximum velocity; WU: Wood unity

## Introduction

PDA is a persistence of the fetal connection between the aorta and pulmonary artery after birth [1]. Shunting in the PDA is left to right (from aorta to pulmonary artery: (Figure 1) [1,2]. It represent 5 to 10% of congenital heart anomalies, with sex ratio male: female at 1:3 [2]. PDA is very common among premature infants (present in about 45% with birth weight < 1750 g and in 70 to 80% with birth weight < 1200 g) [3]. About 1/3 of PDAs will close spontaneously, Portsman, et al. introduced Transcatheter closure in 1967 using the conical Ivalon plug [1,3].

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**Received:** 06 February, 2023; Manuscript No. JOV-23-88749; **Editor Assigned:** 09 February, 2023; PreQC No. P-88749; **Reviewed:** 25 February, 2023; QC No. Q-88749; **Revised:** 02 March, 2023, Manuscript No. R-88749; **Published:** 31 March, 2023, DOI: 10.37421/2471-9544.2023.9.174

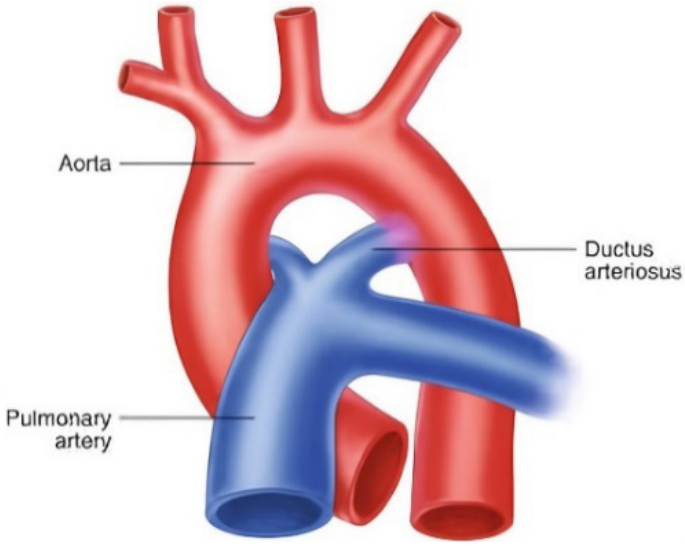


**Figure 1.** Persistent ductus arteriosus [1].

## Case Presentation

### Embryology

The aortic arches (6 pairs) appear at the 4th week of amenorrhea [3]. Arch VI gives the proximal portion of the pulmonary artery (PA) and the ductus arteriosus [3]. Ductus arteriosus is a normal connection between PA and aorta;it is necessary for fetal circulation [3]. At birth, rise in $PaO_2$ and decline in prostaglandin cause its closure within the first 15 hours of life [4]. If this normal process does not occur at least at 1 month, it is a PDA (Figure 2) [5]. Physiological consequences depend on ductal size [3,4]: A small ductus rarely causes symptoms but may cause infective endocarditis [3,5]. A large ductus is responsible of a large left-to-right shunt causing left heart enlargement and elevated pulmonary resistance, leading to Eisenmenger syndrome [4,6].

### Anatomic classification

Krichenko classification is based on angiographic finding with six types (Figure 3) [7].

**Type A:** Conical ductus, is the most common anatomical shape with large aortic ampulla and constricted PA end, it is easily sealed by classic PDA closure device.

**Type B:** Window ductus with a small length and large pulmonary end, its closure require a special device (or atrial septal defect closure device).

**Type C:** Tubular ductus, without any constriction and variable length, the closure is difficult and call for a special device.

**Type D:** Saccular ductus, with wide center and constricted aortic and PA ends, the closure is possible and easy with special device.

**Type E:** Elongated ductus, with very long and constricted PA end, usually sealed with coils.

**Type F:** Fetal type ductus, only in prematurely born, it is long, large and tortuous, the closure require at first-line medication.

### Etiology and association

Familial forms are frequent (multigenic) [6,8]. In premature infants, the incriminated causes are hypoxia and pulmonary immaturity. Other causes and associations are described as maternal smoking, prostaglandins, maternal rubella, life at altitude and trisomy 21. Other causes and associations are described as maternal smoking, prostaglandins, maternal rubella, life at altitude and trisomy 21.

### Symptomatology / Clinical examination

**The symptomatology depends on the PDA size:** Small PDAs are usually asymptomatic wile large PDAs are associated with failure to thrive, poor feeding, poor weight gain, frequent respiratory infection, tachycardia and tachypnea [9]. The clinical examination finds a continuous murmur at the upper left sternal border and bounding pulses (Figure 4) [9,10].

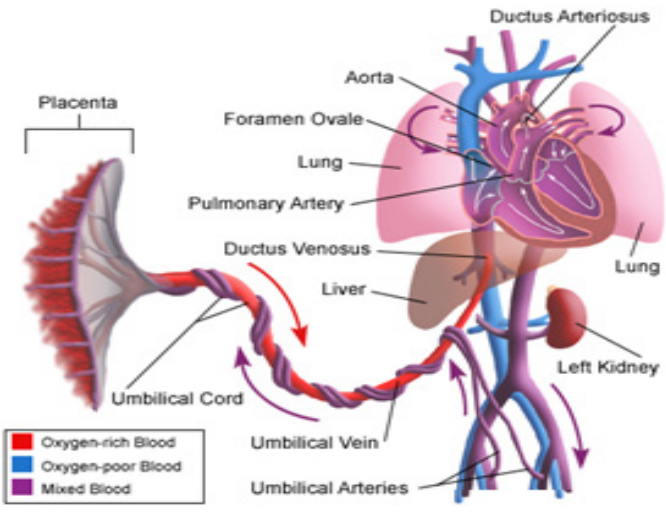


**Figure 2.** PDA and fetal circulation [3].

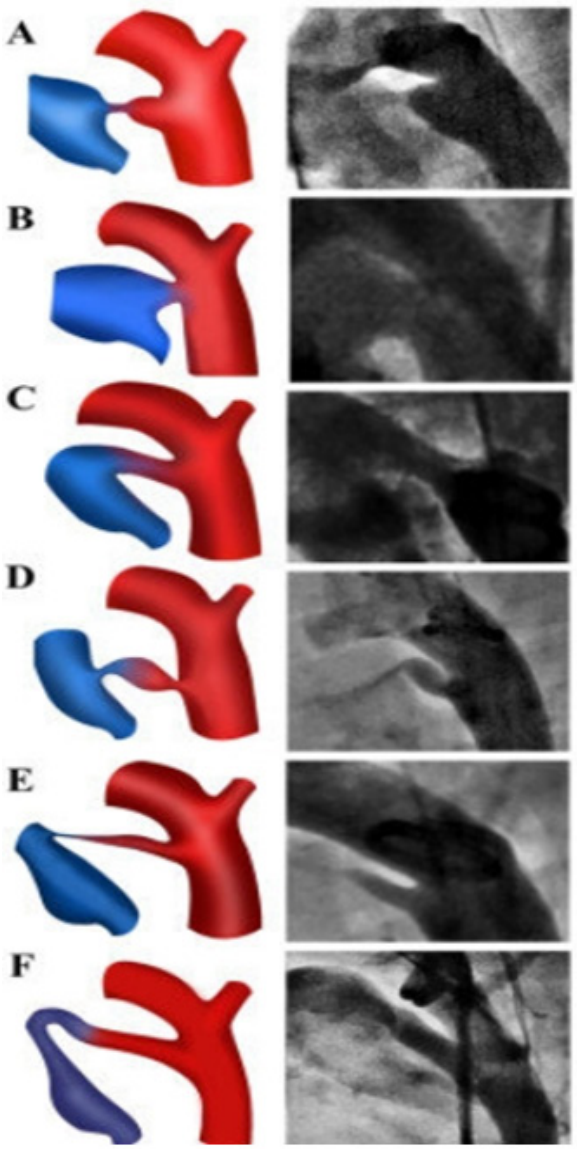


**Figure 3.** Krichenko angiographic classification [7].

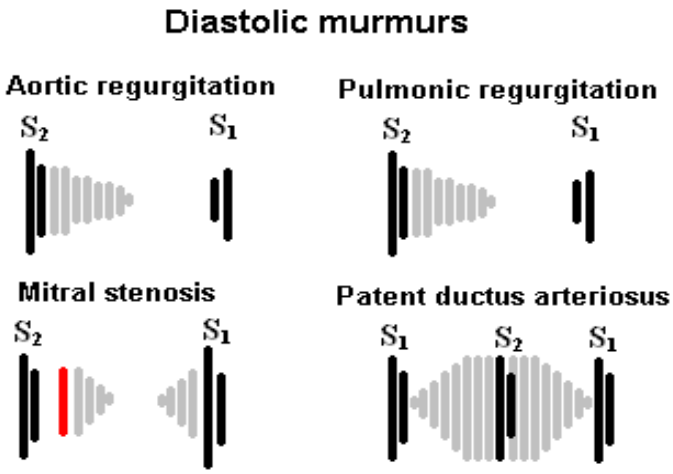


**Figure 4.** PDA murmur [9].

### Clinical forms

The clinical forms depend on the ductus size and the shunt severity [6,9]:

**Large ductus:** Nenatal pulmonary hyper flow with systemic hypo flow progressing to pulmonary arteiolitis after 2 years.

**Intermediate form**: Chronic heart failure.

**Restrictive ductus:** With risk of infective endocarditis.

**Trans-Thoracic Echocardiography role:** TTE makes it possible to identify the PDA, to specify its anatomy and size (correlation index at 0.73 with angiographic measurement) and to quantify the shunt [10]. It also makes it possible to specify the impact on the left cavities size and on the pulmonary pressures [10,11]. The PDA is preferentially visualized in the lest parasternal view with short axis section, showing the aorta in cross section and PA with its division, the Doppler makes it possible to highlight the PDA and to quantify its size on both aortic and pulmonary sides as well as its length [11]. The PDA is also visible in the suprasternal view, showing the aortic arch with, below, the left PA in cross section and the PDA between the two (Figure 5).

## Closure indications and modalities

**Indication:** According to ESC 2020 guidelines for management of adult congenital heart disease, PDA closure is indicated in patients with evidence of left ventricle overload and no pulmonary hypertension (class I) [12]. Percutaneous closure is the method of choice when technically suitable. PDA closure stay indicated in case of pulmonary hypertension with pulmonary resistance of 3-5 WU (Class IIa) or > 5WU (class IIb) and significant left to right shunt. PDA closure is not recommended (Class III) in patient with Eisenmenger physiology. The closure is indicated from the age of 1 year, it is usually performed between 3 and 15 years and remains indicated even in elderly patient.

## Modalities

**Medical treatment:** Reserved for heart failure in premature babies (no indication for prophylactic purposes) [13-15]. By NSAIDs, indomethacin, oral or IV paracetamol (Class I).

**Percutaneous closure:** (Figure 6) For weight over 5 Kg (no limit in some centers) [16,17].

Arterial (then venous) approach with 4, 5 or 6 Fr sheath for aortography in profile view (locates measures and classifies PDAs). Coils for PDAs<3mm and Occluder for PDAs>3mm. Coil diameter is equal or superior 2 times the smallest PDA diameter. Occluder size is equal to the smallest PDA diameter + 2 mm (this rule is not applicable for large PDAs). 7 or 8 French introducers are required for 8/6 and 10/8 mm Occluder.

**Contraindications:** Very large PDA or complex anatomy with multiple aneurysm [18].

**Complications:** Anesthesia risk (possible), infectious risk (exceptional), migration risk (rare), thromboembolic risk (rare), traumatic risk (rare but serious) [18,19].

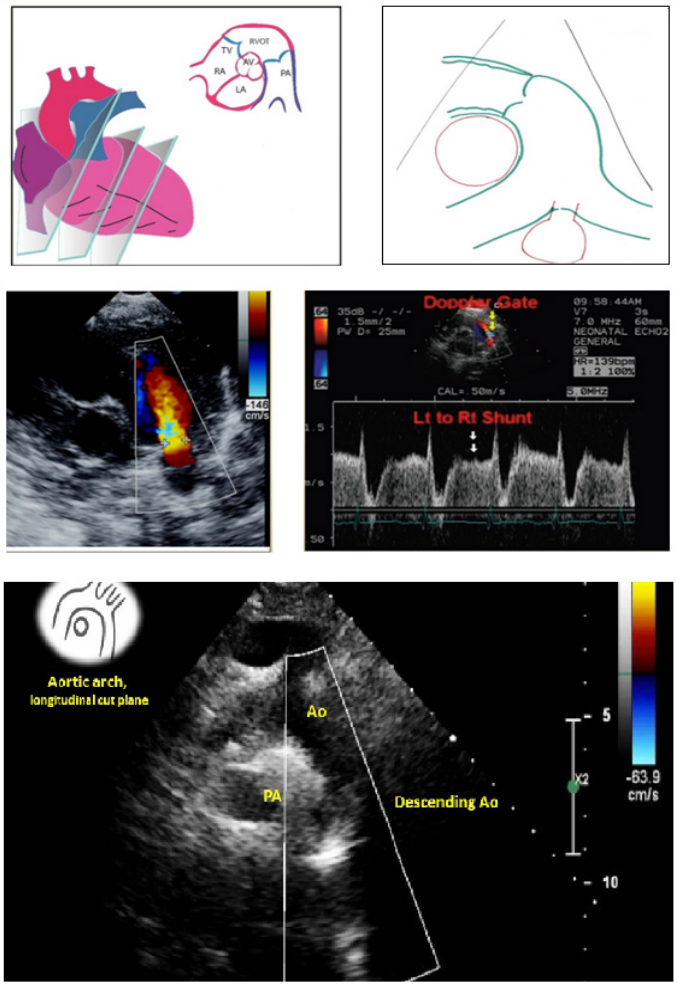


**Figure 5.** Echocardiographic finding in PDA [11].

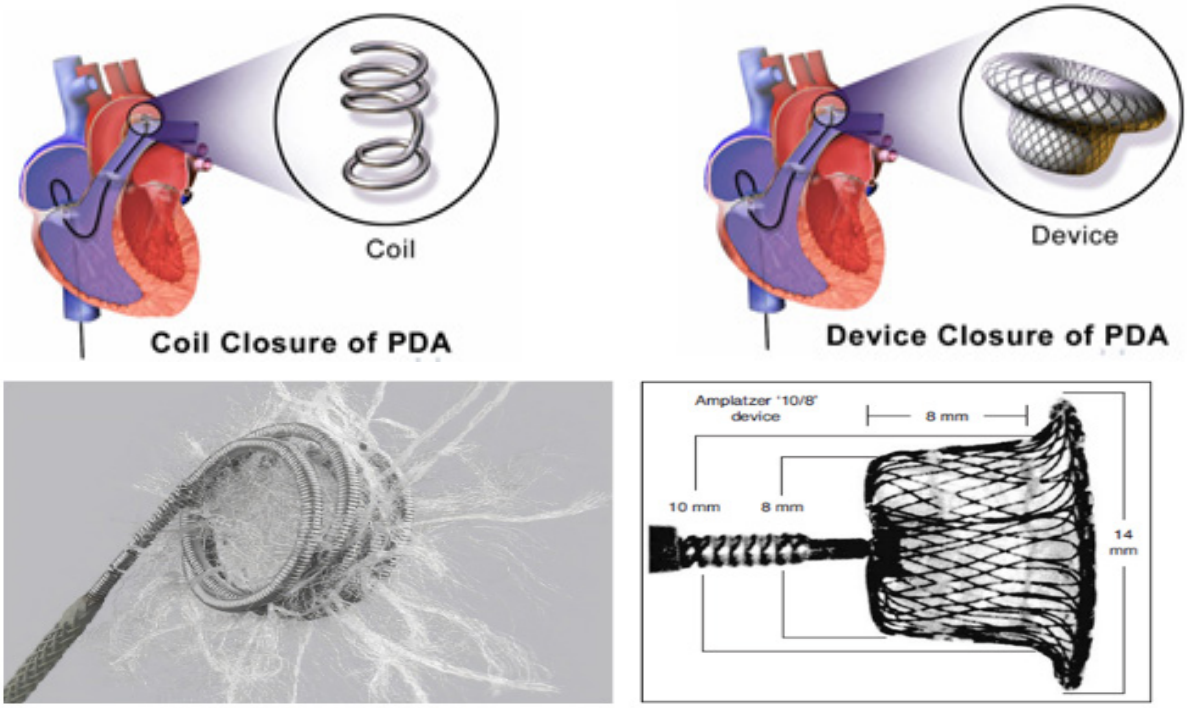


**Figure 6.** PDA devices closure [17].

**Monitoring:** Hospitalization 24-48 hours[17]. Control at Month 1, 3, 6 and 12. Osler prophylaxis for 6 months in case of any bacterial infection.

**Surgical treatment:** Postero-lateral thoracotomy in the 4th left intercostal space by simple ligature (recanalization risk) or section/Suture [20]. In case of percutaneous treatment contraindication or association with operable heart disease (Figure 7). We describe here the percutaneous closure procedures in two children as faithfully as possible with tips and tricks to solve all the difficulties encountered.

## Percutaneous pda closure procedure with coil (step by step)

**Patient information:** Seven years old girl, 17 kg weight followed for heart murmur known since the age of 3 years.

**Clinical findings and diagnostic assessment:** TTE identify a PDA estimated at 1 mm with upper limit size LV without PH (Figure 8).

## Therapeutic intervention

**Material:** 5Fr radial sheath (on the right femoral artery). 0.035" 145 cm J tapped guide wire. 0.035" 145 cm straight guide wire. 0.014" 180 cm Hydrophilic straight guide wire. 5Fr Judkins Right diagnostic catheter. 5Fr Judkins Right Guiding catheter. Coil 5/5 and its Flipper (COOK©). Ultravist 300 contrast.

**Technique:** We started the procedure by sedating the child under Sevoflutane with a mask and monitoring the heart rate, blood pressure and oxygen saturation. Then we proceeded to rigorous disinfection and establishment of sterile fields and punctured the right femoral artery under local anesthesia with Lidocaine 1% using 5F radial sheath then we injected Heparin at dose of 100 units per Kg (1700 units). We then introduced a JR 3.5 5F diagnostic catheter on a 0.035" wire to the aortic isthmus and then we opacified the channel by manual injections of ULTRAVIST 300 contrast to confirm its diameter by angiographic measurement in profile view (1.3 +/- 0.3 mm) (Figure 9). Then we took a JR 4 5F guiding catheter closed by an angioplasty Pyton, we crossed the channel to the pulmonary artery by a 0.014" hydrophilic wire and a 0.035" straight wire used as a body wire to partially engage the PDA The PDA being long with 1.6 mm in diameter, we opted for a coil of 5/5 (5 loops of 5mm) deployed erect in the pulmonary artery after pulling back the guiding catheter, then the central mandrel of the coil is gradually removed to deploy 1.5 loops in the pulmonary artery, 1.5 loops in the channel and 2 loops in the aorta (Figure 10). An echocardiographic control is carried out at this time to confirm the right coil positioning, the channel closure and the absence of arterial clutter on both aorta and PA (V max < 2m/s). We ended up with an angiographic control with contast injection before delivering the coil by the counter-clockwise rotation of the external part of its delivery system (Figure 11). A final angiographic and ultrasound control was carried out 10 minutes later in Cath Lab before the removal of the material and manual compression of the right femoral artery. The procedure skin to skin took 30 minutes. A compressive bandage was placed for 12 hours. The child was monitored in the awakening room for 2 hours at the end of which she returned to the normal hospital bed.

## Follow-up and outcomes

An echocardiographic control was carried out 24 hours later at the end of which the exit was authorized with an antibiotic prophylaxis in front of any septic gesture for 6 months (Figure 12). A clinical and echocardiographic follow-up was performed at 1, 3 and 6 months with total closure of the PDA without residual shunt.

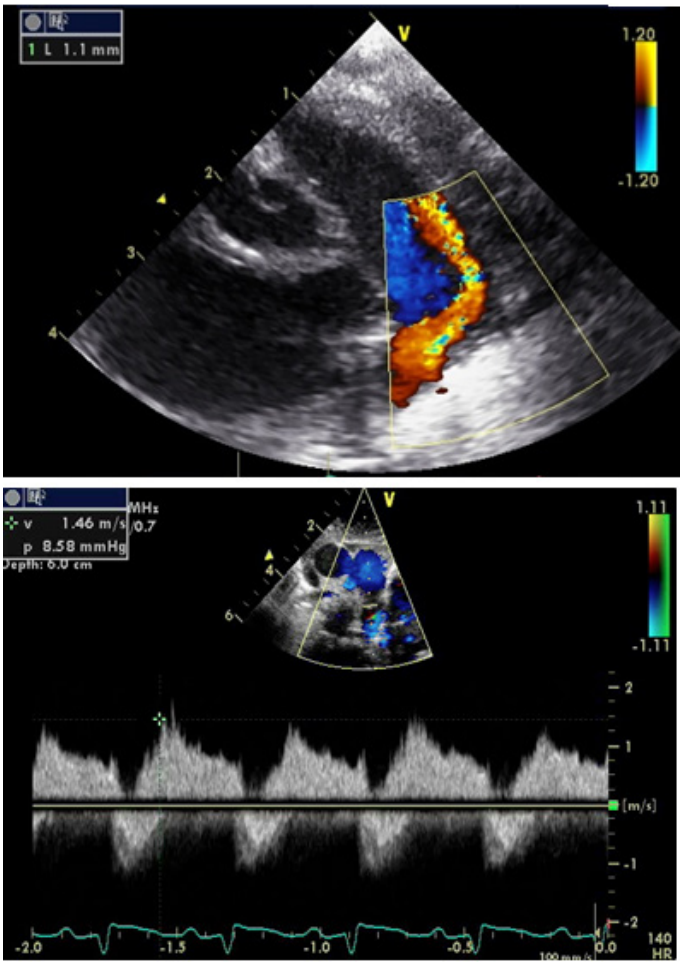


**Figure 8.** First patient echocardiography.

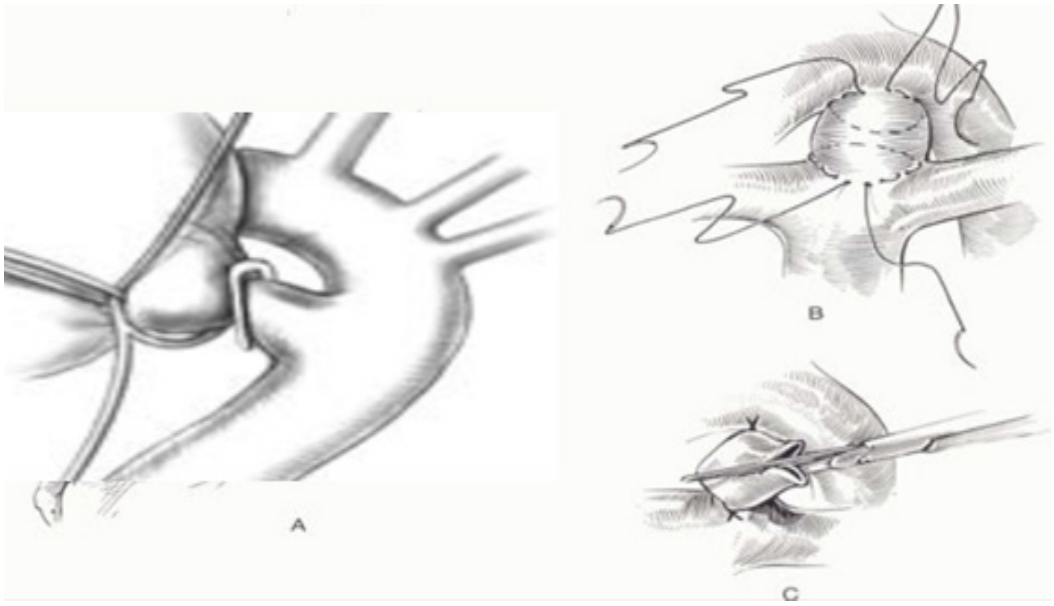


**Figure 7.** Surgical treatment for PDA [20].

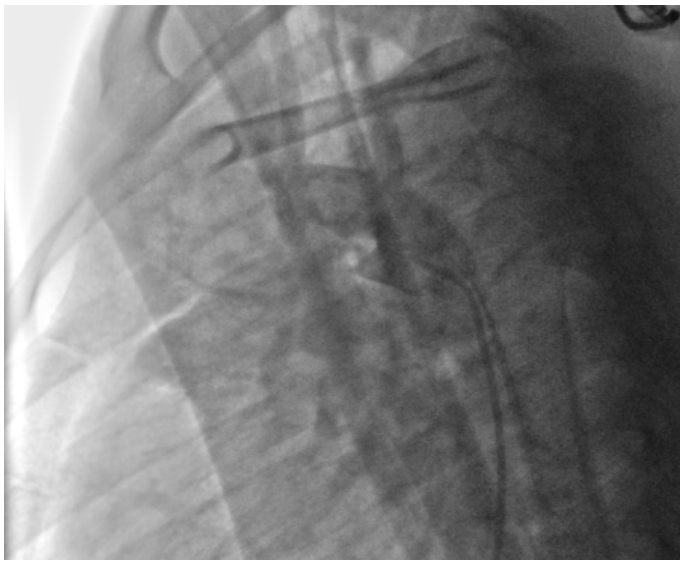

**Figure 9.** PDA opacification in profile view.

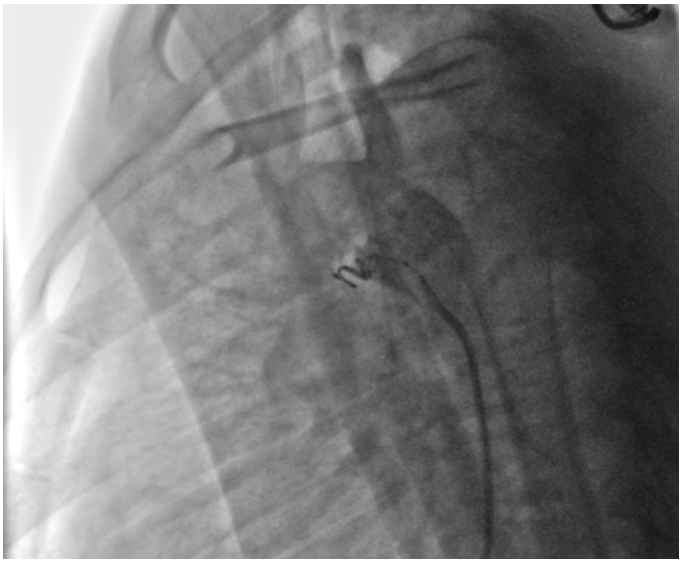

**Figure 10.** Coil deployment.

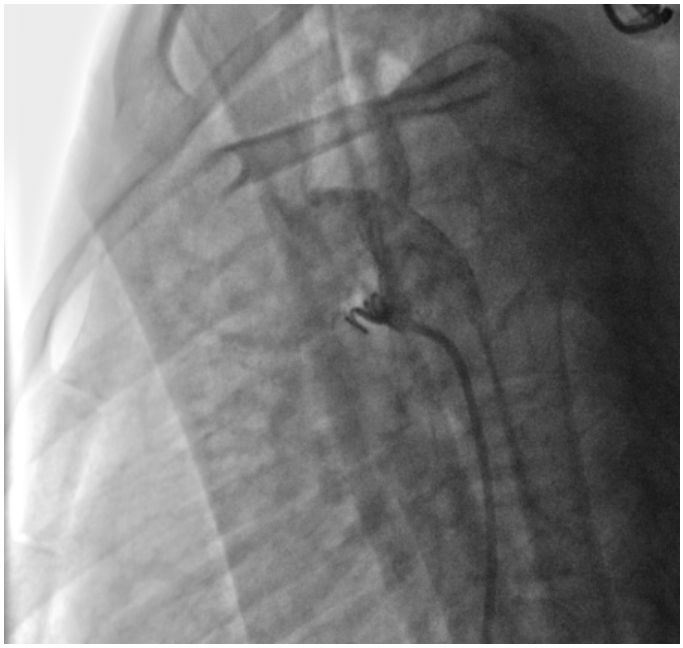

**Figure 11.** Angiographic control after coil delivery.

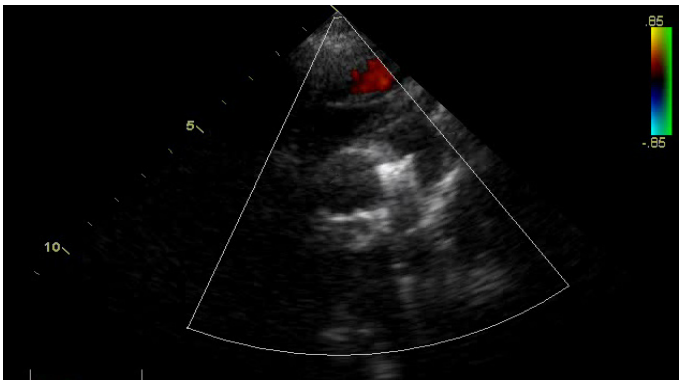


**Figure 12.** Echocardiographic control 24 hours after the procedure.

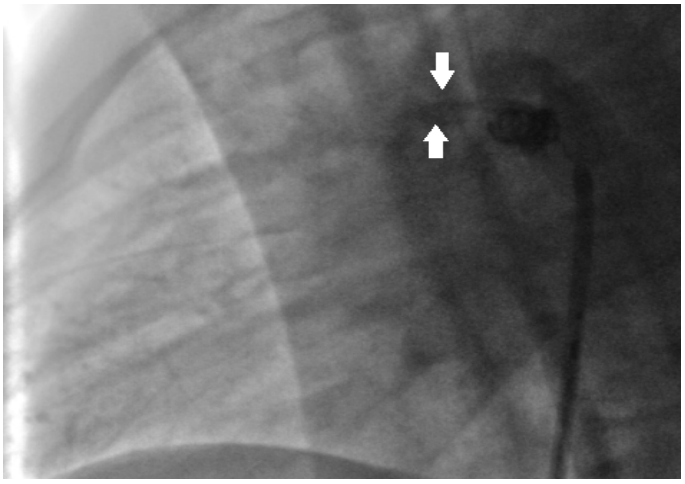

**Figure 13.** Residual shunt after coil deployment.

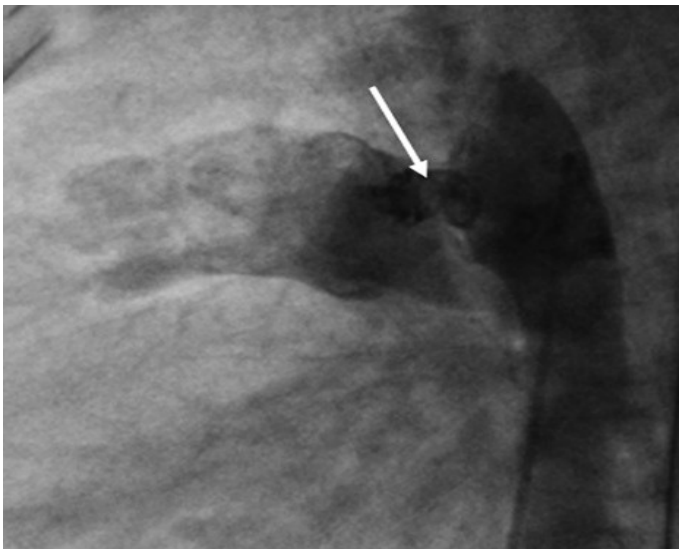

**Figure 14**. Second coil deployment to seal a significant residual PDA shunt after first Coil.

**Discussion:** In our series of 108 PDA closures by Coil in children the unique femoral arterial approach is the standardized attitude in the first line in all patients avoiding an additional venous access, which allows the Coil release in the basic technique [17] while the arterial access allows opacification and measurement of the channel. The unique arterial approach has reduced the risk of local complications at the puncture site and the duration of procedure without difference in closure efficiency and embolization risk. In the case of a minimal residual shunt (restrictive flow > 4m / s) 10 minutes after delivering the coil a control is carried out 24 hours then 1 to 3 months after, spontaneous total closure is seen in 100% of cases in our series (5 cases on 108 children closed by coils) (Figure 13). In the case of a large shunt (non-restrictive flow) after 10 minutes

a second coil can be introduced contralaterally (through the pulmonary artery by a femoral venous access) either immediately or after a period of one month (2 patients in our series required a second coil to close their PDA, one closed immediately, the second 1 month after) successfully in 100% of cases (Figure 14). We do not report in our children's series any cases of coil embolized.

**Patient perspective:** The parents were very satisfied with the result. Their daughter quickly joined school as well as a normal sports activity and social life

**Informed consent:** The parents consented to the sharing and publishing her case and procedure images subject to anonymity

## Percutaneous pda closure procedure with occluder device (step by step)

**Patient information:** Twelve years old girl, 30 kg weight followed for heart murmur known since the age of 8 years.

**Clinical findings and diagnostic assessment:** TTE identify a PDA estimated at 4.5 mm with upper limit size LV without PH (Figure 15).

## Therapeutic intervention

**Material:** (Figure 16) 5Fr radial sheath (on the right femoral artery), 6Fr radial sheath (on the right femoral vein), 0.035" 145 cm J tapped guide wire, 0.035" 260 cm hydrophilic straight guide wire, Two 5Fr Judkins Right diagnostic catheter, 7Fr Delivery system, PDA Occluder N° 6/8 (ANDRATECH©), ULTRAVIST 300 contrast.

## Technique

We started the procedure by sedating the child under sevoflutane with a mask and monitoring the heart rate, blood pressure and oxygen saturation. Then we proceeded to rigorous disinfection and establishment of sterile fields and punctured the right femoral artery under local anesthesia with Lidocaine 1% using 5F radial sheath. We then introduced a JR 3.5 5F diagnostic catheter on a 0.035" wire to the aortic isthmus and then we opaqued the channel by manual injections of ULTRAVIST 300 contrast to confirm its diameter by angiographic measurement in profile view (4.3 +/- 0.4 mm) (Figure 17). Therefore, we planned to implant a 6/8 PDA Occluder that requires a 7Fr delivery system, for that, we punctured the right femoral vein using 6fr radial sheath and injected Heparin at dose of 100 units per Kg (3000 units) then we crossed the right cavities to the pulmonary artery by a JR 3.5 5Fr diagnostic catheter on 0.035" wire. After failing to cross the channel by a straight hydrophilic guide 0.035" because of the smallness of the PDA caliber on its pulmonary side we decided to cross it by its aortic side with the hydrophilic straight 0.035" 260 cm wire that we exteriorized from the left JR 3.5 5Fr diagnostic catheter through the JR 3.5 5Fr diagnostic catheter mounted on the right on which we introduced the delivery system 7F by the right femoral venous access (Figure 18). The delivery system being placed from the femoral vein to the right cavities and then through the canal to the aortic isthmus,

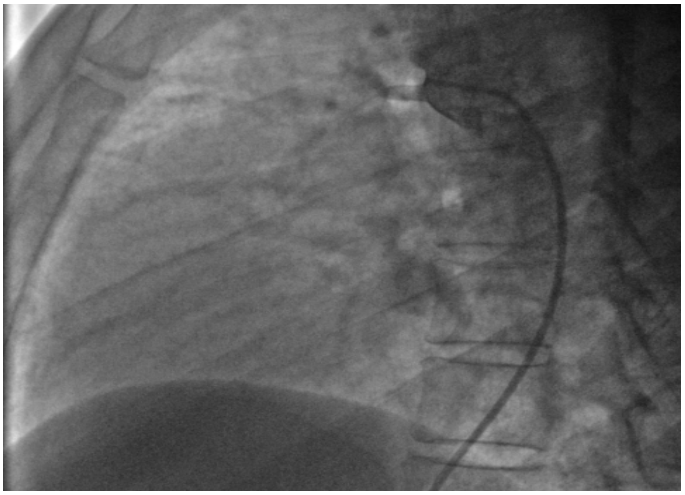

**Figure 17.** PDA opacification and measurement.

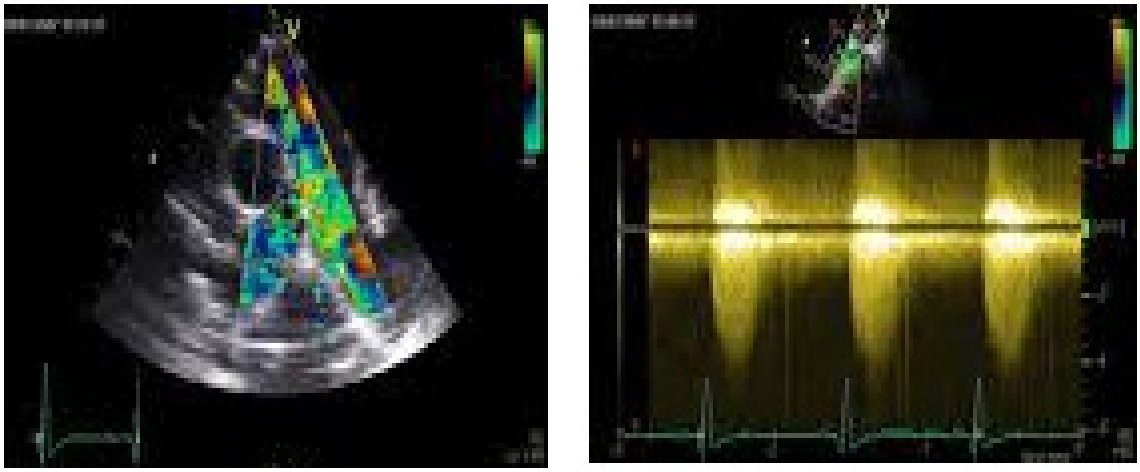

**Figure 15.** PDA in echocardiography.

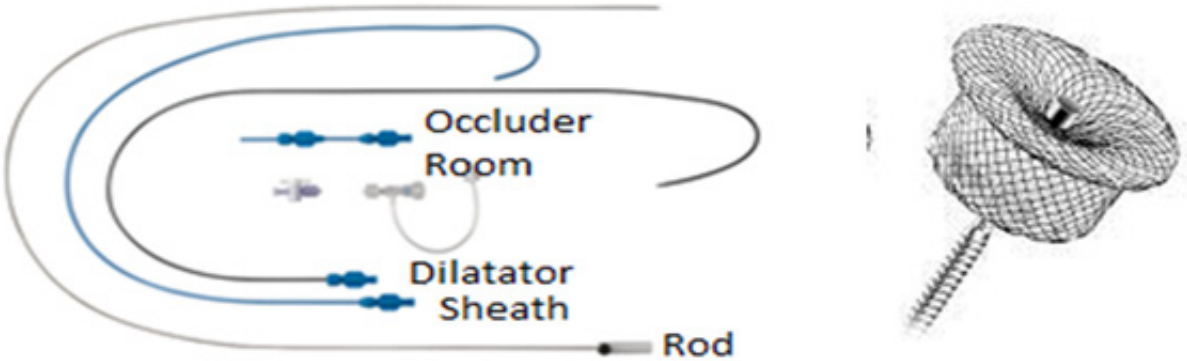


**Figure 16.** PDA delivery system.

the prosthesis is debubbled and fixed by screwing on its rod then mounted in its chamber (room) under serum washing and conveyed to the end of the 7F sheath (Figure 19). We deployed the distal part of the device in the aortic isthmus and pulled back the entire system to the aortic ampulla under angiographic control (Figure 20). A traction was, then, maintained on the rod with removal of the 7Fr sheath until the device was completely deployed into the body of the channel, injections through the JR3.5 5F catheter placed in the aorta were performed close to the device confirming its correct positioning in the aortic ampulla and

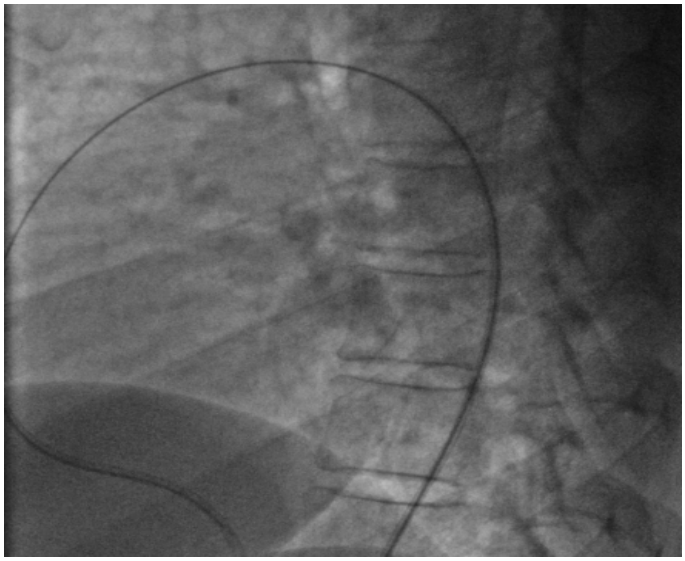

**Figure 18.** Wire crossover from left to right.

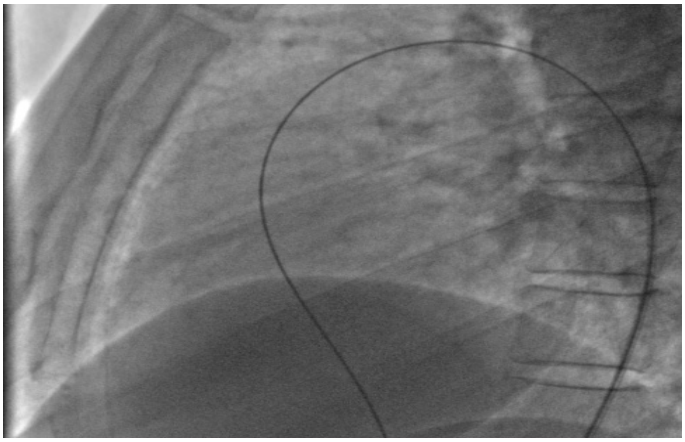

**Figure 19.** Wire externalization.

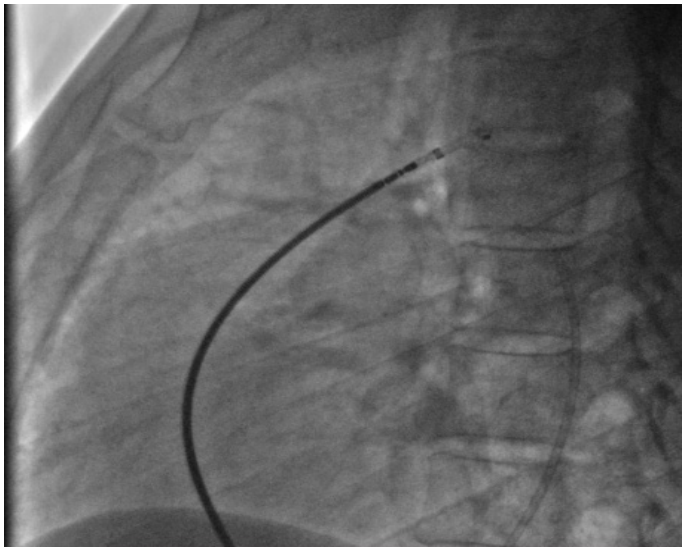

**Figure 20.** Device deployment.

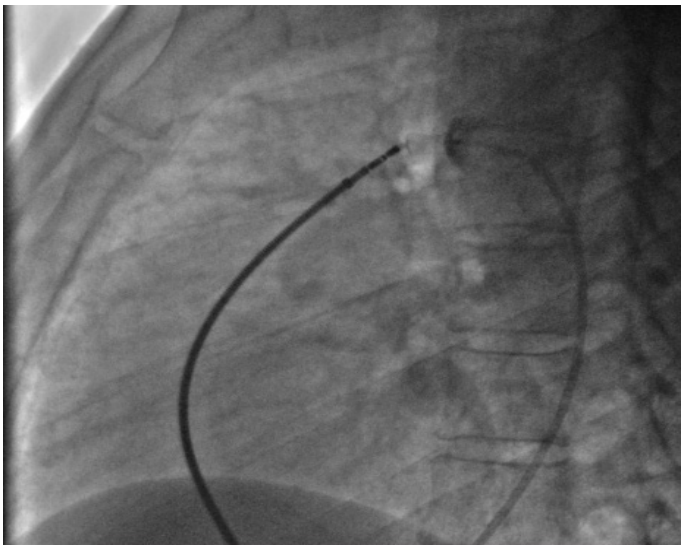

**Figure 21**. Angiographic control and deployment.

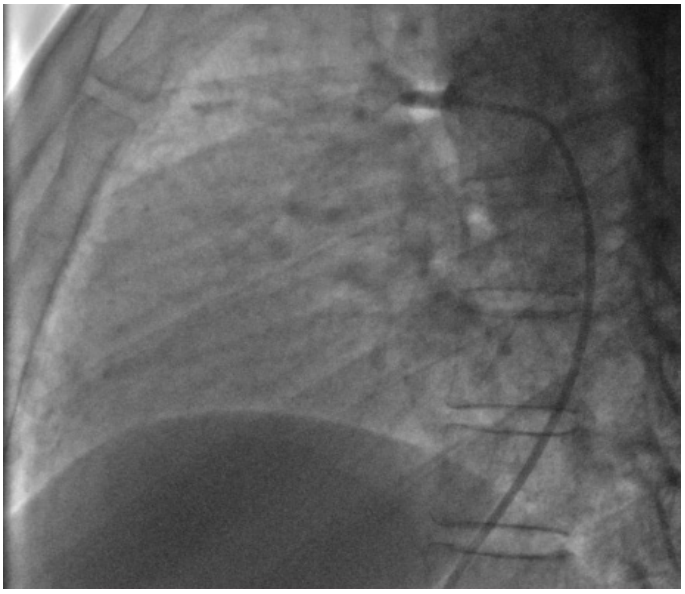

**Figure 22.** Device delivery and control.

absence of residual shunt, comforted by an echocardiographic control (Figure 21). We proceeded to the definitive release of the device by an anti-clockwise rotation of the external part of its rod and we ended up with an echocardiographic and angiographic control with contast injection (Figure 22). A final angiographic and ultrasound control was carried out 10 minutes later in Cath Lab before the removal of the material and manual compression of the right femoral artery and vein. The procedure skin to skin took 40 minutes. A compressive bandage was placed for 12 hours. The child was monitored in the awakening room for 2 hours at the end of which she returned to the normal hospital bed.

**Follow-up and outcomes:** An echocardiographic control was carried out 24 hours later at the end of which the exit was authorized with an antibiotic prophylaxis in front of any septic gesture for 6 months. A clinical and echocardiographic follow-up was performed at 1, 3 and 6 months with total closure of the PDA without residual shunt.

## Discussion

In our series of 92 PDA closures by Occluder in children the double femoral approach is the standardized attitude for all patients, the venous access allows the device release while the arterial access allows opacification/ measurement of the channel and control device deployment [19]. In the case of a minimal residual shunt (restrictive flow > 4m / s) 10 minutes after delivering the device a control is carried out 24 hours then 1 to 3 months after, spontaneous total closure is seen

in 100% of cases in our series (3 cases out of 92 children closed by Occluder). In the case of a large shunt (non-restrictive flow) after 10 minutes a coil can be introduced contralaterally (through the aorta by a femoral arterial access) either immediately or after a period of one month (1 case sealed by a Coil added 3 months avec the first procedure) successfully in 100% of cases. We deplore in our children's series (at the beginning of our experiment) a case of Occluder 6/8 embolization recovered by lassot in a delivery system 12Fr due to mismatch between the size of the channel and the prosthesis.

**Patient perspective:** The parents were very satisfied with the result. Their daughter quickly joined school as well as a normal physical activity and social life

**Informed consent:** The parents consented to the sharing and publishing her case and procedure images subject to anonymity

## Conclusion

The closure of PDA in children is a challenging procedure whose safety requires a good pre- and perprocedural evaluation allowing the right choice of the method and size of the closing device. The respect of the different closure stages and the critical per procedural ultrasound and angiographic control reduce the rate of complications making this technique accessible and safe.

### What we know about it

PDA is very common congenital heart disease. Its closure is most often percutaneous with excellent results in the short, medium and long term. The management of the puncture point in this situation remains delicate and requires great concentration especially in children.

### What this clinical case adds

General anesthesia seems to us to be a reassuring attitude in children. In coil closure procedure the reduction of the approach to a single femoral access by the abundance of venous access reduces the rate of local complications without harming the success rate of the procedure. In the case of a minimal residual shunt (restrictive flow > 4m / s) 10 minutes after delivering the coil or the device a control is carried out 24 hours then 1 to 3 months after, spontaneous total closure is seen in the majority of cases (100% of cases in our series). In the case of a large shunt (non-restrictive flow) 10 minutes after delivering the coil or the device, a coil can be introduced contralaterally to the first access either immediately or after a period of one month allowing closuring successfully de defect in the majority of cases. Procedure videos are available on our YouTube channel:

## Acknowledgements

We thank our paramedics who participated in the percutaneous procedure.

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**How to cite this article:** Zaoui Nassime, Amina Boukabous, Nadhir Bachir and Ali Terki, et al. " Percutaneous Patent Ductus Arteriosus (Pda) Closure: When and How to Close Coil *vs.* Occluder "Step By Step" Cases Report." *J Vasc* 9 (2023): 174.