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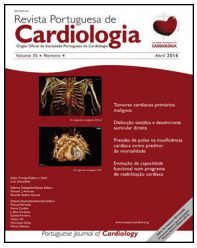

EDITORIAL COMMENT

Percutaneous closure of patent ductus arteriosus: A standard procedure with new perspectives

Encerramento percutâneo de canal arterial persistente: um procedimento padrão com novas perspetivas

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Patent ductus arteriosus (PDA) is one of the most frequent congenital heart defects and may occur as an isolated lesion or in association with others. Its incidence varies from 5% to 10% of all congenital heart disease in term infants,[1] increasing to 20% to 60% in preterm neonates. This is attributable to the lack of normal closure mechanisms due to immaturity in the premature neonate.[2] Most patients have a small to moderate PDA causing restrictive flow with small left-to-right shunt, presenting as symptom-free or with few symptoms. The natural history of these lesions would probably be uneventful, except for the risk of infective endocarditis. Moderate to large PDA will cause an unrestrictive flow, with potential for congestive heart failure (HF) and pulmonary vascular disease. The rational for PDA closure is to prevent late complications such as canaliculitis, HF or Eisenmenger syndrome in late age. Exceptions are neonate or preterm infants with large PDA and the presence of severe pulmonary hypertension.

Since the first successful reports of surgical treatment of a PDA, by Gross and Hubbard in 1939,[3] surgical technique—either ligation of division—has been widely used for large and symptomatic PDA. Although it has been shown that surgery is safe and effective with only occasional complications and some cases of recanalization, pediatric cardiologists have always tried to develop a transcatheter method to close PDA and other anomalies.

The first report on non-surgical closure was by Portsmann et al. in 1967.[4] This investigator along with Rashkind et al.[5] pioneered the development of several PDA closure devices. Due to their efforts, PDA percutaneous occlusion became an effective and safe procedure, and is nowadays the standard method for PDA closure.

After these initial devices, various types of occlusion systems have been developed. Gianturco, Jackson coils (both free and detachable) and similar devices have become an established method for PDA transcatheter closure.[6–9] Since 1992, coils have evolved into the most commonly used devices for small-sized PDA occlusion. The introduction of the Amplatzer® duct occluder family (ADO, Abbott, USA) in 2001, changed the perspective on this procedure, because of increased safety characteristics, like retrievability, repositioning and also the possibility to close defects up to 16 mm in diameter. They are among the most frequently used occluders for large and moderate PDA occlusion.[10–12] Another recent device is the Nit-Occlud® (NOc, pfm, Germany) coil, which was designed specifically for PDA closure. This coil has undergone several modifications since it was first developed, with the latest version in use since 2001.[13,14] Procedures using these techniques were reported to be

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safe and effective, and although complications occur, critical complications are rare.[6–14] Device embolization, the most feared complication, was relatively common in early experience with coils but became rare with the new generation of devices. Reported occlusion rates vary according to operator experience, and post procedure period, from 41% immediately after the procedure to 95 to 100% at three months of follow up.[15–18] Nevertheless, several studies have demonstrated that intermediate and long-term outcomes of percutaneous PDA occlusion with current devices are excellent.[17–19]

In the present study, Sarmento et al.[20] present the results with percutaneous PDA occlusion from a single center for twelve years using at least three different devices. The authors claim to report one of the largest series using the PDA NOc devices, which adds value to the study. In their series, the immediate procedural occlusion rate, assessed by angiography, was high (98.6%), with a low complication rate (1.8%), and a single case of embolization, in line with other reported data.[10,21] The success rate was associated with vascular accessibility, morphology of the ductus, imaging modality, and adequate selection of the device. The study adds no novelty to the technique, but reports on an important case experience at national level. However, the authors fail to explain the set for ''adequate selection of device'' and the criteria for performing coil/device closure. Also, regarding the results, the reported occlusion rate refers to the immediate result, assessed by aortography. The study would be more robust if the authors had described the immediate or 24-hour occlusion rate assessed by echocardiography, which would enable a more accurate assessment and long-term outcomes, as we would expect from a twelve-year retrospective study. Despite these limitations, the study is of value and it gives us the opportunity to discuss issues germane to transcatheter PDA closure, such as indications, selection of devices, expected results and future perspectives.

Percutaneous PDA occlusion is indicated for lesions presenting with suggestive continuous murmur, confirmed by echocardiography. Ductus with absence of these typical findings, so-called 'silent ductus', should not be occluded, although controversy exists with some authors recommending occlusion.[22] Small size PDA without significant left ventricle overflow should be treated to prevent infective endocarditis. Medium and large size defects, which present significant left-to-right shunt, are treated to prevent HF and pulmonary vascular occlusive disease.

Adequate patient age and size have been an issue, and indications have evolved over time and with new and innovative PDA occluding devices. Until recently, transcatheter PDA closure was considered the procedure of choice for infants $\geq$6 kg and adults. Although an exact lower weight limit has not been set for a safe occlusion, only a few studies have reported results in neonates and infants below this weight threshold.[23–25] Recently, these limits have been exceeded with the release of the new miniaturized devices adequate for premature infants under 1.5 kg. There is an ongoing prospective trial to compare the classic surgical approach to percutaneous PDA occlusion in preterm infants over 700 g and three days old, using the Amplatzer® Piccolo Occluder, an evolution of the Amplatzer® additional sizes (ADO AS) family devices.[26] These advances, although with promising early and mid-term results, need to be confirmed in randomized controlled trials before they can become a standard of care.

Patent ductus arteriosus is an uncommon anomaly in adults, but in this age group they present several pathological changes, such as tortuosity, calcification, friability, aneurysm formation and ductal shortening.[27] A calcified duct is more fragile and difficult to cross and the treatment option was surgery with cardiopulmonary bypass, to overcome complexity and complications. However, the development of new occlusion devices that can be deployed on the arterial side have enabled percutaneous occlusion in adult patients.[28,29] Treatment selection must, however, be made on an individual bases, especially in heavily calcified and fragile ducts. Although there are no specific guidelines for device selection, it seems logical that a less rigid device such as ADO II, ADO II AS, vascular plugs and PDA NOc would cause less shear stress on these fragile walls.

Based on personal experience,[9,12] most PDA can be occluded using a percutaneous approach, keeping in mind that the selection of patients and devices remains the major factor for success and effectiveness, so it is important to take into account patient characteristics, PDA shape, size and minimal diameter. Small to very-small PDA (<2.5 and 1.5 mm in diameter respectively, with continuous murmur) can easily be occluded, regardless of their shape, using detachable coils, which are a cheap and effective choice. Device selection for conical PDA is broader, as either coils or ADO devices and similar can be used depending on the size and minimum diameter of the PDA. Although there is no exact threshold, the latter are usually used to occlude PDA over 2.5 mm in diameter. The PDA NOc devices are recommended, in most studies, to occlude small to moderate PDA, as shown by the authors of this study report. ADO devices are used with greater efficiency in ductus of a larger diameter or morphology that is unfavorable to occlusion with coils.

Complete PDA occlusion and absence of complications are the expected results of percutaneous PDA occlusion. Residual shunting is more common with coils and when it occurs, it has to be treated with repeated procedures, as it may lead to endocarditis or to hemolysis. Device embolization is rare and also more frequent with coils, with an occurrence rate <1%. Device-induced pulmonary branch stenosis or aortic coarctation is rarely seen, although Döppler flow acceleration without invasive gradient may occur, it might resolve spontaneously with growth. Aortography, before and after releasing the implanted device, is the method selected to evaluate immediate result, but echocardiography is more adequate for post-procedural assessment and quantification of incomplete occlusion and late complications. We should however point out, that when using coils, we would recommend continuing catheterization until complete ductal closure is documented by angiography, because of increased risk of embolization and hemolysis. Vascular injury from the delivery system is another feared complication, especially in small infants. Nevertheless, this is rarely seen with experienced operators, also taking into account the evolution in downsizing delivery sheaths over the last five decades.

Finally, transcatheter PDA closure stands as the standard treatment in most cases. Coils and ADO devices or similar are the most frequently used closure devices worldwide. This

approach is feasible, effective and safe with current devices and techniques leading to excellent outcomes. Future perspectives foresee the evolution of techniques to address more challenging cases, such as preterm and low birth weight infants and complex cases in adults, with high occlusion rate and few complications. During the past 50 years, we have witnessed a remarkable evolution in techniques, devices and delivery systems, so we can only anticipate further improvements in transcatheter PDA closure.

Conflicts of interest

The author has no conflicts of interest to declare.

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