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Review

Percutaneous Closure of a Patent Ductus Arteriosus in Preterm Infants

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ABSTRACT

Spontaneous closure rate of ductus decreases as gestational age and birth weight decrease. Therefore, patent ductus arteriosus (PDA) is a very common finding in extremely preterm infants. Most popular questions discussed between neonatologists and pediatric cardiologists are: Whether the ductus is open or not, should we close it or not, when should we close it, and if we have decided to close: should we do it medical, transcatheter or by surgery? In this review we try to clarify patient selection for PDA closure, the main steps of percutaneous PDA closure, device selection, complications, transport, anesthesiology and main trick points in extremely low birth weight infants in the light of our clinical experience and the literature.

Keywords: PDA, percutaneous, preterm, invasive closure

INTRODUCTION

Patent ductus arteriosus (PDA) is an important problem in extremely preterm infants.[1,2] Most popular questions discussed between neonatologists and pediatric cardiologists are whether the ductus is open or not, should we close it or not, when should we close it, and if we close should we do it medical, transcatheter or by surgery? In this review, we tried to clarify, which PDAs should be closed, what are the main points of percutaneous PDA closure and the main trick points in preterm considering our clinical experience and the literature.

Patient Selection and Timing

There is a controversy about the topic how to manage symptomatic PDA especially extremely low birth weight preterm. This patient group needs special care, namely very sensitive hemodynamic status even affected by slight changes. Therefore; extreme caution is required in the manipulation of these babies.

1. Patient selection: PDA closure is a team approach: all patient data should be discussed in a multi-disciplinary team including a pediatric cardiologist, neonatologist, cardiac surgeon and anesthesiologist. Every member of the team should provide their opinion in the patient selection, way of closure, possible complications that they may face. Therefore, main precautions are taken before the procedure and a strategy is decided for every possible nightmare scenario.

The patients who have hemodynamic significant PDAs should be indisputably treated. The term hemodynamic significant PDA is defined as the following:

a) Clinical: PDA is associated with severe bronchopulmonary dysplasia, necrotizing enterocolitis, respiratory distress syndrome, high duration with assisted ventilation, intraventricular hemorrhage, pulmonary hemorrhage periventricular leukomalacia, and renal impairment etc.[3]

b) Echocardiography: Left heart enlargement, increased pulmonary blood flow with a velocity of more than 42 cm/s[4], the flow pattern in the mid-cerebral, mesenteric arteries can be reversed or vanished. Narrowest ductal artery diameter more than 2 mm. LA/Ao >1.4[5].

2. Timing is a controversial issue. Each patient should be evaluated on the basis of own. However; there are reports suggesting closure

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within the first 4-6 weeks. In addition to this, most extremely low birth weight (ELBW) infants with a large PDA were reported that they develop pulmonary hypertension by 8 weeks.

Procedure

The femoral vein or umbilical is accessed with 4F sheath. Arterial injury is a major problem in preterm infants;[6,7] we recommend PDA closure by only venous access. In our previous studies, we described that the major disadvantage of this method is difficulty in visualization with angiography before the release of the device. Nevertheless, good transthoracic echocardiography by experienced staff is very helpful in such circumstances. Also, aortogram can be done through PDA, which can lead to the visualization of the aorta. 50 U/kg heparin was used for heparinisation. Sathanandam et al.[8] reported that heparinized saline flushes can be sufficient to maintain activated clotting time. Therefore, they suggested not using a heparin injection.

Hemodynamic evaluation is not sine qua non-for preterm babies. The most important goal is to complete the procedure as quickly as possible without disturbing the haemodynamic status of the patient. Therefore; we did not perform hemodynamic measurements routinely.

1. Device selection: All the devices used for this age group were off-label. According to our previous experience, we usually prefer only Amplatzer Ductal Occluder II-Additional Size for preterm infants <1 kg. The ones that we have used <2 kg were detachable coils for small ducts (1.5-3 mm) and Amplatzer Ductal Occluder (ADO I, ADO II, ADO II AS) (St Jude Medical, St. Paul, Minnesota) were used for moderate-sized ducts (3-5 mm).

The main factors that help us choose the device are are the size and shape of the ductus and the structures adjacent to the ductus. As we mentioned in our previous reports, we selected the size of the Amplatzer Ductal Occluder after 1-1.5 mm adding to the narrowest diameter of ductus.

In our center from the date July 1997 up till now 609 percutaneous PDA closures were performed. 53 of them were less than 2 kg and 16 of them <1 kg. Coils (Cook Medical, Bloomington, IN) were used in 2 patients, Amplatzer Ductal Occluder was used in 53 patients (2 with ADO I, 8 with ADO II, 43 patients with ADO II AS). We preferred ADO II AS especially for ELBW infants because their retention disks are small and more flexible, which enables delivery from both arterial and venous sides and decreases protrusion risk.

Sathanandam et al.[6], had closed PDA of 55 infants percutaneously. Besides ADO II-AS; they used microvascular plug (MVP; Medtronic), and Amplatzer vascular plug II (AVP II, Abbott). Most common device they used was the MVP (44/55). They preferred MVP while the risk of protrusion of the device to the left pulmonary artery (LPA) and aorta is small and the delivery cable is flexible that makes it easy to manipulate.

The other device they used was AVP-II (3 of 55 patients). However, the authors also state that this device is unideal for preterm infants. Because sheath exchange is required, delivery cable is relatively stiff and cannot be used for 5 mm device.

Sathanandam et al.[8] also reported that the size of the patient is not always a disadvantage. Because: (a) as the patients get smaller length of the PDA gets longer that makes easier to implant the device, (b) the rate of having pulmonary vascular disease in younger patients is low procedure is better tolerated.

2. Time and radiation of the procedure: Mean fluoroscopy time and radiation dose is another popular topic in PDA closure of preterm infants. Since the procedure is a bit more complicated than the standard PDA closure; procedure time is expected to be increased so are the fluoroscopy time and radiation dose. However, as we have shown in our previous studies;[9,10] the mean dosage of radiation given for the ones <2 kg was 128.9 (98.5-285.7) cGy/cm^2; in PDA closure <1 kg: was 223±153.8 cGy/cm^2. Mean time of procedure and fluoroscopy were for <2 kg were 44.5±13.1, 13.8±5.6 min, respectively and for PDA<1 kg was median fluoroscopy time: 8.6 min median procedure time 37 min These values are unideal for a “standard PDA closure” in older children; this would be acceptable in the view of the fact that difficult and complicated procedure.

Complications

In our case series no major complication was faced. Minor complications like LPA stenosis and arterial access injuries were seen in a few patients. The peripheral pulmonary artery stenosis (LPA) of 2 patients who spontaneously resolved.

Transport

Transport of these preterm babies should be done carefully because these patients’ hemodynamic status is unstable, they are “fragile”. They are usually intubated and frequently have inotropic support. In our institution, these babies were followed by the neonatal intensive care unit which locates one floor under catheterization lab. Therefore, with only taking elevator for one floor patient can be welcomed to the catheter lab. However, 'operating room is located in a different building, which takes at least 30 minute to reach with a transport vehicle.

Therefore, we follow-up patient in the neonatal intensive care unit at least 1 day before catheterization and perform the closure procedure at the catheter lab. After bleeding control is done in the femoral veins, the patient is transferred back to the neonatal intensive care unit (NICU) with a neonatologist. If the patients are the ones that have been referred from other neonatal centers, they are sent back to their centers after being monitorized for one night in our NICU following closure. There are special considerations during transport that may change the hemodynamic clinical status of the patient, body temperature, ventilation, infusions (inotrops, or fluids). All the staff included in the transport should be experienced, informed about these issues and receive special care and know how to manage any case of trouble. As our institutional policy, we accept patients from all over our country, but if the patients are from different cities, they are

hospitalized one day before in our NICU and after stabilization of their clinical status catheterization is performed. Recently a paper is published by Willis et al.[11] about the transport of ELBW neonates for PDA closure in the catheterization lab. They reported that special attention is required about the body temperature, fluid balance, and hemodynamic status. Briefly, multi-disciplinary team approach is mandatory for the safety of the transport procedure.

Bedside procedures are another popular topic. In many centers surgery is performed successfully at the bedside, which is really comfortable for such extremely risky patients. For percutaneous closure, it is challenging. The procedure can be performed with the guidance of transthoracic echocardiography; In case of any complications, such as embolization, fluoroscopy, a special catheter, or an equipment is required. In such instances, interventionalists feel themselves safe in catheter lab cause accessibility to whatever they need in a limited of time. In our institution since NICU and catheter labs are very close to each other, transport has never been a problem so we were not in need of bedside percutaneous closure.

Anesthesia

The anesthesia of these patients should be different from that of other patients. The metabolism of these ELBW infants is different so their response and tolerance to certain drugs may change such as the neurological consequences of ketamine are questionable, premature babies can react excessively to propofol and sevoflurane, severe hypotension may occur.[12-15] Only deep sedation is enough if the patients are not intubated. If the patients are intubated, only the dosage of their sedative drugs is regulated.

Lönnqvist[16] reported a good review of the anesthesia for extreme premature infants. The authors suggested that getting repeated either arterial or venous blood gas analyses during the case is better than end-tidal carbon dioxide traces to estimate arterial pCO_2 because of the high respiratory rate. Also using balanced intravenous fluid that contains adequate sodium and glucose concentrations, to avoid hypoglycemia, appears more logical than using total parenteral nutrition. Serum calcium levels can be reduced by both sepsis and transfusion of blood product. Thus, small-incremental doses of intravenous calcium can be used to support cardiac output and blood pressure, guided by plasma analyses.[17] Also, all the staff physicians and anesthesia technicians involved in the procedure should be the ones who have experience in extremely low birth weight preterm.

Follow-up

In the follow-up; patients are checked with regular control visits. During each visit, physical examination and transthoracic echocardiography and electrocardiogram are performed. The first visit is planned on the next day, then 1, 3, 6 months after implantation. After 1 year, if there is no additional problem, visits are done annually. In each visit, patients are checked for the position of the device, protrusion to great arteries, residual shunt presence. Previously, we have faced with several adverse effects after ADO implantation. The median follow-up interval of our study was 35 (6.5-20) months.

CONCLUSION

Preterm infants especially less than 1 kg, are extremely fragile, their hemodynamic status can be easily affected by small changes. Therefore, percutaneous PDA closure in this patient group is a completely different issue from the other patients. Actually our center has 22 years' experience in percutaneous PDA closure and we started to perform percutaneous closure in ELBW infants in the last 5 years. Long-term results of percutaneous preterm PDA closure are still unknown, but more data are gathered from the reports published by other experienced centers worldwide. In this review we shared our institutional experience. Not only the procedure itself, but also the transport, anesthesia are really important issues and these patients should be evaluated with a multidisciplinary approach. Moreover, follow-up is also very critical; physician should be aware of complications and check for them in each control visit of the patient.

Briefly, compatible with the literature we believe in that transcatheter closure of PDA in preterm is a safe and also an effective effective method but only in experienced centers with a multidisciplinary approach.

Ethics

Peer-reviewed: Externally peer-reviewed.

Authorship Contributions

Concept: Ö.P., N.N., Design: N.N., Data Collection or Processing: Ö.P., Analysis or Interpretation: Ö.P., Literature Search: Ö.P., N.N., Writing: Ö.P.

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