ECHOCARDIOGRAPHIC SHORT-TERM FOLLOW UP OF CHILDREN WITH TRANSCATHETER CLOSURE OF PATENT DUCTUS ARTERIOSUS


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Abstract

Background: Patent ductus arteriosus (PDA) can be treated by transcatheter device closure. This study is our experience in Tanta and Benha University Hospitals.

Aim: Initial experience with transcatheter closure of (PDA) using different types of devices. To evaluate the feasibility, efficacy and safety of transcatheter closure of PDA in pediatric age group patients on basis of short-term follow up.

Patients & Methods: This prospective observational study included 26 children with PDA; 21 female and 5 males with age 30.2 ± 27.6 months, weight 12.8 ± 6.6 Kg and body surface area 0.54 ± 0.2m². Aortic angiogram was performed to evaluate the duct size and shape for appropriately choosing the occluder type and size. A second aortic angiogram was performed 10 min after device deployment. Every patient had echocardiographic assessment before and after ductus closure. Follow up was done 24 hour, 1 week and 3 months post-intervention. Evaluation included immediate and remote complications, residual shunt, Left ventricle dimensions, left atrium / aorta ratio and pressure gradient along descending aorta and left pulmonary artery.

Results: No complications like thrombus formation, blood loss or infective endocarditis in any case were reported after successful ducts closure. Complete ductus closure was achieved in 77% of cases by 24 hours post-intervention, and in 96.15 % after three months. The left side dimensions had significantly decreased; the left ventricular end diastolic diameter (LVEDd) decreased from 33.28±4.92 mm pre-intervention to 26.54±4.53 after 3 months (P<0.001) while LA/AO ratio decreased from 1.36±0.30 pre-intervention to 1.13±0.15 after 3 months (P<0.001). No cases of obstruction along descending aorta or left pulmonary artery were reported.

Conclusion: Our experience with transcatheter closure of PDA is effective and safe with good short-term outcome. Transcatheter closure of PDA in infants and children is a feasible, effective and safe modality of treatment. 2D echocardiography is a useful available tool for evaluation of the patients after transcatheter PDA closure.
Introduction
Patent ductus arteriosus constitute nearly 5% - 10% of all congenital heart disease. Some infants may have symptoms such as tachypnea, tachycardia and difficulty in feeding. The presence of volume overloading of the left atrium and left ventricle is an indication for closure of the defect. The risks of endocarditis, aneurysm of PDA, and pulmonary vascular disease are also indications for closure. Surgical ligation of patent ductus arteriosus (PDA) was first reported in 1939 by Gross. Within few decades, PDA was the first example of congenital heart disease to be treated by transcatheter closure. The percutaneous technique was first described by Porstman et al. at 1967. Many devices were used through the last decades but some devices are in common use like Flipper detachable coils, Gianturco coils, Amplatzer Duct Occluder (ADOI) and (ADOII) and the Nit-Occlud Coils (NOC) (PFM). Pharmacological closure of a PDA can be done in premature infant using indomethacin and ibuprofen.

Aim of the work
This study is carried out to evaluate the safety and efficacy of transcatheter PDA closure in pediatric age group on basis of immediate and short-term echocardiographic follow up.

Patients and Methods
That is a prospective observational study that included 26 patients of pediatric age groups who were previously diagnosed to have PDA and suitable for percutaneous transcatheter closure. They were selected from Tanta & Benha University Hospitals during the period from December 2012, going through 2013 and 2014. The procedure was performed in a cardiac catheterization unit at Tanta University Hospital. Both sex (male and females) were included. All the studied cases were subjected to thorough history taking, thorough clinical examination and Two-dimensional and Doppler Echocardiography.

Transthoracic echocardiography was done evaluating the diameter of pulmonary end of the ductus arteriosus. M-mode echocardiography with estimation of left atria/aorta ratio and left ventricular end diastolic dimension was done. In estimation of systolic pulmonary artery pressure, we got the ultrasound beam aligned from the high left parasternal window directly into the mouth of the patent ductus arteriosus, systolic flow velocity was recorded. Applying the simplified Bernoulli equation (ΔP= 4V²), the peak systolic velocity of the patent ductus arteriosus jet was used to calculate the systolic gradient between the aorta and the PA. Subtracting this gradient from the cuff systolic aortic blood pressure yields the PA systolic pressure.
After the procedure, follow up Color-Doppler ultrasound was used to detect and quantify any residual shunt. Doppler ultrasound were used to determine flow and velocity patterns in the descending aorta and left pulmonary artery to rule out obstruction. M-mode echocardiography with estimation of left atria/aorta ratio and left ventricular end diastolic dimension was done comparing the results with that before the procedure.

**PROCEDURE**

All procedures were performed under general anesthesia. Heparin in a dose of 50-100 IU/ Kg body weight and parenteral antibiotics were given to all patients.

Femoral venous and arterial accesses are established. Aortic arch angiography in 30° right anterior oblique (RAO) and straight lateral views is performed. Measurement of narrowest ductal diameter, size of ampulla and length of ductus are measured. All devices included in the study (Amplatzer devices, Nit-Occlude PFM and Nit-Occlud® PDA-R) are deployed using the ante-grade approach. The technique of ADO device deployment is similar to that reported in the literature.® PFM coils were used for patients with small PDAs of 2.5 mm at the narrowest diameter.® Nit-Occlud® PDA-R is deployed as in the manufacturer.® ADO size selected is usually 1-2 mm larger than the duct diameter in children. However, some exceptions to this rule had to be made due to unavailability of the devices at the time of procedure.

Two-dimensional color Doppler echocardiography and descending aortography are performed after device/ coil placement, not released, to document residual shunts, and left pulmonary artery or aortic obstruction. Once optimal position was confirmed, the device/ coil is released. Aortography is performed (10 minutes to allow clotting to occur) carefully, to evaluate the presence of any residual shunt.

**Follow up**

A complete two dimensional and color Doppler echocardiographic studies were performed on all patients at 24 h, 1 week and at 3 month post-procedure. Special attention was paid to residual ductal flow, left pulmonary artery or aortic stenosis, left atrium/aorta ratio and left ventricular function.

**Results**

The age of the studied cases ranged from 6 months to 108 months (9 years) with a mean of 30.2 ± 27.6 month. Their weights ranged from 6 to 33 Kg with a mean of 12.8 ± 6.6 Kg. Their height ranged from 65 cm to 134 cm with a mean of 85.4 ± 18.8 Cm. Body surface area ranged from 0.347 to 1.07 m² with a mean of 0.54 ± 0.2m². Female to male ratio was 4:1.
### Table 1: Data obtained by echocardiography before catheterization represented by mean±SD and range

<table>
<thead>
<tr>
<th>Items</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duct diameter (Pulm. End) (mm)</td>
<td>3.58077±1.03112</td>
<td>1.3 – 6</td>
</tr>
<tr>
<td>LA/AO</td>
<td>1.36±0.30297</td>
<td>1-1.8</td>
</tr>
<tr>
<td>LVEDd (mm)</td>
<td>33.2885±4.9225</td>
<td>26-45</td>
</tr>
<tr>
<td>FS %</td>
<td>37.18077±5.09761</td>
<td>28-47</td>
</tr>
<tr>
<td>LPA velocity (m/s)</td>
<td>1.28654±0.18925</td>
<td>1.2 – 2.2</td>
</tr>
<tr>
<td>Descending AO velocity (m/s)</td>
<td>1.31346±0.1516</td>
<td>1.13- 1.64</td>
</tr>
</tbody>
</table>

**Table (1)** Transthoracic echocardiography showed the diameter of pulmonary end of the ductus arteriosus ranged from 1.3 mm to 6 mm, with a mean of 3.58077±1.03112 mm. M-mode echocardiography showed evidence of left atria, left ventricular dilatation. Increased LA/AO ratio was evident in 12 patients (46%) with a mean of 1.6375±0.19017. The LVEDd was increased in 8 patients 30.8% with a mean of 36.9125±4.31656 mm.

Echocardiography parameters before catheterization are shown in **table 1.** No case had pulmonary hypertension. Three different device types were used; Amplatzer duct occcluder (ADO- I) in 18 patients (69.3%), PFM Nit-Occlud was used in six patients 23 % while Nit-Occlud PDA-R was used in two patients 7.7 %.

Immediate complete PDA occlusion with 10 minutes post deployment was achieved in 16 patients (61.538%) demonstrated by aortography, while by 24 hours post-intervention, complete ductus closure was achieved by 77%, and by 3 months 96.15 % were completely closed.

**Figure 1.** incidence of PDA complete occlusion after the procedure
No patients had absent femoral pulsation and no patients needed blood transfusion. All patients were discharged safely from hospital after 24 hours.

As regards the left atrial and left ventricular dilatation assessed by M-mode echocardiography as a reflection of the volume overload of the PDA on the heart, there was a regression of this dilatation on follow up, table 2.

Table (2): Comparison between echocardiographic data pre catheterization, at one week and 3 months after PDA closure

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre closure</th>
<th>After 1 week</th>
<th>After 3 months</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>P1</td>
</tr>
<tr>
<td>LA/AO ratio</td>
<td>1.36±0.30</td>
<td>1.25±0.2</td>
<td>1.13±0.158</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVEDd (mm)</td>
<td>33.28±4.9</td>
<td>29.23±5.5</td>
<td>26.54±4.53</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FS %</td>
<td>37.18±5.0</td>
<td>34.74±5.7</td>
<td>31.51±5.44</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

P1: Changes between pre closure data and that at one week post closure.
P2: Changes between pre closure data and that at 3 months post closure.
P3: Changes between 1 week post closure data and that at 3 months post closure.

This table shows that LA\AO and LVEDd at 1 week and 3 months were significantly lower than that before catheterization with P<0.001.

No reported partial left pulmonary artery (LPA) obstruction. The mean peak velocity of left pulmonary artery slightly increased from 1.2865±0.1892 m/s preintervention to 1.4780±0.273 m/s at one week, with further slight increase at 3 months 1.505±0.2656. The maximum LPA velocity we recorded was 1.85 m/s in one case (3.8%).

In the current study, no reported aortic obstruction as the maximum peak velocity recorded over the descending aorta was 1.7 m/s in one case. The mean peak velocity over the descending aorta slightly increased from 1.31 m/s preintervention to 1.39 m/s at one week and 1.41 m/s at 3 months post intervention.

Discussion
First transcatheter method was developed by Porstman et al. in late 1960s, followed by Rashkind et al. in late 1970s and these paved the way for the development of a number of other PDA closure devices. Over the last 4 decades, many techniques and devices have been used for patent ductus arteriosus (PDA) occlusion.
Interventionalists in the United States commonly use the Amplatzer Duct Occluder (ADO, AGA Med Corp, MN) and those in Europe use the ADO or the Nit-Occlud Coils (PFM Medical, Germany). In the present study, we tried to evaluate the feasibility, clinical outcome, and safety of transcatheter closure of patent ductus arteriosus (PDA) in infants and children as an initial experience of Tanta and Benha Universities using different devices (Amplatzer Ductal Occluder “AGA Medical Corporation MN”, Nit-Occluder device “PFM Medical, Germany”) and Nit-Occlud® PDA-R.

The present study included 26 patients, who underwent an attempt of transcatheter closure of PDA.

Amplatzer duct occluder (ADO-I) and its delivery system was used in 18 patients (69.3%). PFM Nit-Occlud was used in six patients 23 %. Nit-Occlud PDA-R was used in two patients 7.7 %. Our selection for the size of the ADO I was based according to the manufacturer’s recommendation 2 mm more than the minimal diameter of the ductus. As the diameter of the pulmonary end of the ductus measured by angiography ranged from 1 to 4.7 mm (mean = 3.17±0.92 mm), ADO- I size 8/6 was used in 34.615 % of cases (n=9/26) representing the majority of patients, followed by ADO- I size 6/4 in 15.3 % of cases (n=4/26), and ADO- I size 10/8 in 11.5% of cases (n=3/26).

Immediate complete PDA occlusion with 10 minutes post deployment aortography was achieved in 16 patients (61.538%). Trivial residual flow in the left pulmonary artery was seen in 4 patients (15.3%). Foaming in the device was noticed in 6 patients (23 %). At 24 hour follow up by echocardiography 20 patients (76.923 %) had complete closure. while (96.15%) of cases had completely closed PDA at three month follow up echocardiography.

Review of the results of ADO occlusion in several initially published studies demonstrated residual shunts in 5% to 34% post implantation, which decreased to 0 to 3% at follow-up.

No patients had absent femoral pulsation and no patients needed blood transfusion.

All patients were discharged safely from hospital after 24 hours admission. This short hospital stay is one of the advantages of transcatheter PDA closure over the surgical ligation.

As regards the left atrial dilatation assessed by M-mode echocardiography as a reflection of the volume overload of the PDA on the heart, there was a regression of this dilatation on follow up at one week , and three months. LA/AO
ratio decreased from 1.36 to 1.25 at one week, and further decrease to 1.13 at 3 months after successful ductal closure. The mean left ventricular end diastolic diameter (LVEDd) decreased from 33.28±4.92 mm preintervention, to 29.23±5.5 at one week. At 3 months after ductus closure the mean LVEDD was 26.54±4.53.

With doppler echocardiography we compared the peak velocities recorded in left pulmonary artery and descending aorta pre intervention and that at one week and 3 months to detect any obstruction related to the occlusion device. No reported partial left pulmonary artery (LPA) obstruction. The mean peak velocity of left pulmonary artery slightly increased from 1.28±0.18 m/s preintervention to 1.478±0.27 m/s at one week, with further slight increase at 3 months 1.5±0.26. The maximum LPA velocity we recorded was 1.85 m/s in one case (3.8%). Left pulmonary artery stenosis due to protrusion of the device into the proximal left pulmonary artery has rarely been observed in infants and smaller children. Pass et al. (2004) reported two cases of partial obstruction of the LPA seen on follow up (2.7m/s on echocardiography).

An aortic obstruction is a concerning complication of transcatheter PDA closure using ADO. In most patients, obstructions were clinically insignificant, detected only by Doppler echocardiography. Furthermore, blood flow velocities decreased during follow-up. Rarely, significant obstructions were observed in smaller infants with larger PDA, and a device removal was necessary in these patients. In the current study, no reported aortic obstruction as the maximum peak velocity recorded over the descending aorta was 1.7 m/s in one case. The mean peak velocity over the descending aorta slightly increased from 1.31 m/s preintervention to 1.39 m/s at one week and 1.41 m/s at 3 months post intervention.

In the current study no reported thrombus formation, thromboembolism or infective endocarditis in any cases after successful ducta closure. Prophylaxis for infective endocarditis is recommended for 6 months in all patients.

**Conclusion and summary**

Transcatheter closure of PDA in infants and children is a feasible and effective modality of treatment with excellent results, and thus it should be the treatment of choice in infants and children. 2D echocardiography is a useful tool for follow up the patients after PDA closure. No single device can be suitable for closure of all morphologies and sizes of PDAs. Such studies with long term follow up are needed for better evaluation.
References


5. Eun Mi, Eun Songb, and Young Choib (2013): Comparison of oral ibuprofen and intravenous indomethacin for the treatment of patent ductus arteriosus in extremely low birth weight infants. Department of Pediatrics, Chonnam National University Hospital, Chonnam National University Medical School, Gwangju, Korea


