Echocardiographic Short-Term Follow up of Children after Transcatheter Closure of Patent Ductus Arteriosus

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Abstract:

Background: Patent ductus arteriosus constitutes 5-10% of all the congenital heart diseases. Volume overloading of the left side of the heart, risks of endocarditis, aneurysm of patent ductus arteriosus (PDA), and pulmonary vascular disease are indications for closure of the defect. **Purpose:** Evaluation of the efficacy and safety of PDA device closure in the paediatric age group patients. **Methods:** This prospective observational study included 26 children with a mean age of 30.2 ± 27.6 months and a mean weight of 12.8 ± 6.6 kg. Echocardiographic follow up was done at 24 hour, 1 week and 3 months post-intervention. Evaluation included assessment of residual shunt, left ventricle dimensions, left atrium/aorta ratio and velocity along descending aorta and left pulmonary artery. **Results**: Three different devices were used; the Amplatzer duct occluder (ADO-I) and its delivery system, PFM Nit-Occlud and Nit-Occlud PDA-R. All the patients were discharged safely from hospital after 24 hours of admission. Complete ductus closure was achieved in 77% of cases by 24 hours post-intervention, and in 96.15 % after three months. The left ventricular end diastolic diameter (LVEDd) Z score decreased from 2.13±2.37 pre-intervention, to 0.65±1.8 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). Although the LV showed decrease in systolic function (FS), all the patients showed improvement in symptoms. No significant obstruction along the descending aorta or left pulmonary artery was reported. No complications like thrombus formation, blood loss or infective endocarditis, in any case, were reported.

Conclusion: Trans-catheter closure of PDA is effective and safe with rapid reversal of the left sided overload. Similar studies with long term follow up are needed for further evaluation of the LV systolic function pattern.

Key Words: PDA, device closure, trans-catheter, echocardiographic, short term.

Introduction

Patent ductus arteriosus constitutes 5-10% of all the congenital heart diseases. Volume overloading of the left side of the heart, risks of endocarditis, aneurysm of PDA, and pulmonary vascular disease are indications for closure of the defect (1). Surgical ligation was first reported in 1939 by Gross (2). Within few decades, PDA was the first example of congenital heart disease to be treated by trans-catheter closure by Porstman et al. in 1967 (3). Many devices were used through the last decades. Pharmacological closure of PDA can be done in premature infants using indomethacin and ibuprofen (4).

Aim of the work

This study was carried out to evaluate the short-term hemodynamic effect on the left side of the heart after trans-catheter PDA closure using different devices in the paediatric age group.

Patients and Methods

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

This is a prospective observational study that included 26 patients of the paediatric age groups who were previously diagnosed to have PDA and suitable for per-cutaneous trans-catheter closure. They were selected from Tanta & Benha University Hospitals during the period from December 2012 to December 2014.

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, left atrium to aorta ratio and left ventricular end diastolic dimensions (Z score).

After the procedure, follow up color-doppler ultrasound was used to detect and quantify any residual shunt. Doppler ultrasound was 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 the left atrium to aorta ratio and left ventricular end diastolic dimension (Z score) was done comparing the results with that before the procedure.

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

Femoral venous and arterial accesses were right anterior oblique (RAO) and straight lateral views were performed to take the measurement of the narrowest ductal diameter, size of ampulla and length of ductus.

All the devices included in the study (Amplatzer devices, Nit-Occlude PFM and Nit-Occlud® PDA-R) were deployed using the ante-grade approach as in the manufacturers' instructions (5). Descending aortography was performed after device/coil placement, to document residual shunts, and left pulmonary artery or aortic obstruction.

Once optimal position was confirmed, the device/coil was released. Again, aortography was performed 10 minutes later to evaluate the presence of any residual shunt. A complete two dimensional and color-doppler echocardiographic studies were performed on all the patients at 24 hrs, 1 week and at 3 months post-procedure.

Special attention was paid to residual ductal flow, left pulmonary artery or aortic stenosis, left atrium/aorta ratio and left ventricular dimension Z scores. The online tool parameter (Z) was used to calculate the Z score of the LV.

Results

The age of the studied cases ranged from 6 to 108 months (9 years) with a mean of 30.2 ± 27.6 months. Their weights ranged from 6 to 33 kg with a mean of 12.8 ± 6.6 kg. Their height ranged from 65 to 134 cm with a mean of 85.4 ± 18.8 cm and their body surface areas ranged from 0.347 to 1.07m^2 with a mean of 0.54 ± 0.2 m^2. Female to male ratio was 4:1. The measurements are presented, with respect to body surface area, as tables with mean and SD values in table 1.

Three different device types were used; Amplatzer duct occluder (ADO- I) in 18 patients (69.3%), PFM Nit-Occlud in six patients (23 %) while Nit-Occlud PDA-R was used in two patients (7.7 %). Complete PDA occlusion was detected within 10 minutes post deployment in 16 patients (61.538%), demonstrated by aortography, and after 24 hours post-intervention, in 77%, and after 3 months in 96.15% (figure 1). No patients had absent femoral pulsation or needed blood transfusion. All the patients were discharged safely from hospital after 24 hours.

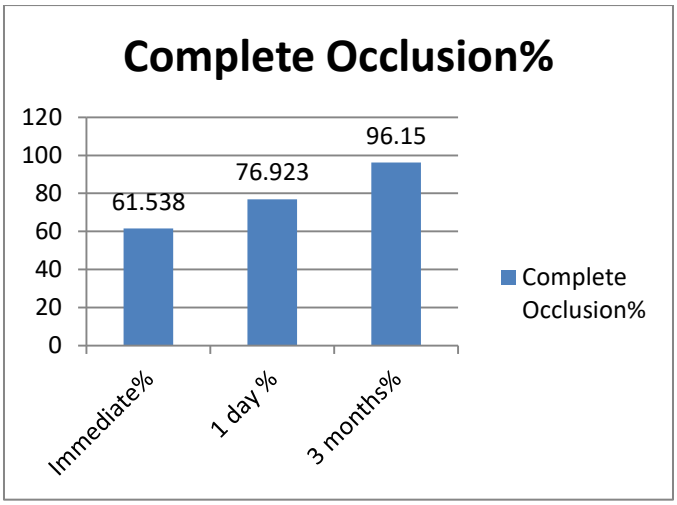

Figure1. Incidence of PDA complete occlusion after the procedure

The mean peak velocity of left pulmonary artery slightly increased from 1.28±0.19 m/s preintervention to 1.47±0.27 m/s at one week, with further slight increase at 3 months 1.5±0.26 m/s which was not significant. The maximum LPA velocity we recorded was 1.85 m/s in one case (3.8%).

As well, in the current study, there was 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 pre-intervention to 1.39 m/s at one week and 1.41m/s at 3 months post intervention.

Table (1): Data obtained by echocardiography before catheterization represented by mean±SD and range

Items	Mean ± SD	Range
Duct diameter (Pulm. End) (mm)	3.58±1.031	1.3 – 6
LA/AO	1.36±0.30	1-1.8
LVEDd (Z score)	2.13±2.37	-0.57 - 9.72
FS %	37.18±5.097	28-47
LPA velocity (m/s)	1.28±0.18	1.2 – 2.2
Descending AO velocity (m/s)	1.31±0.15	1.13- 1.64

Increased LA/AO ratio was evident in 12 patients (46%) with a mean of 1.63±0.19. The LVEDd Z score was increased in 11 patients (42.3%) with a mean of 2.13±2.37 Z score. LA/Ao= left atrium/aorta, LVEDd= left ventricle end diastolic dimension, FS= fractional shortening, LPA= left pulmonary artery.

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

Item	Pre closure	After 1week	After 3months	P-value		
	Mean ± SD	Mean ± SD	Mean ± SD	P1	P2	P3
LA/AO ratio	1.36±0.30	1.251±0.2	1.133±0.158	<0.001	<0.001	<0.001
LVEDd (Z score)	2.13±2.37	0.43±2.3	-0.65±1.8	<0.001	<0.001	<0.001
FS %	37.18±5.0	34.746±5.7	31.51±5.44	<0.001	<0.001	<0.001

FS= fractional shortening, LA/Ao= left atrium/aorta, LVEDd= left ventricle end diastolic dimension

Discussion

First transcatheter method was developed by Porstman et al. in late 1960s, followed by Rashkind et al in late 1970s (6) 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) (3).

In our study, immediate complete PDA occlusion within 10 minutes post deployment aortography was achieved in 16 patients (61.538%). Trivial residual flow to the left pulmonary artery was seen in 4 patients (15.3%). Foaming in the device was noticed in 6 patients (23 %). At 24 hours follow up by echocardiography, 20 patients (76.923 %) had complete closure while 96.15% of cases had completely closed PDA at three months follow up echocardiography. Review of the results of ADO occlusion in a study showed small to trivial shunts in 17% of cases by angiography immediately after implantation and decreased to 11% by echocardiography after 24 hours.

At one-month follow-up, 1% had trivial residual shunts and none at 6-month follow-up (7). In a multicenter USA trial using the ADO device, complete angiographic occlusion was shown in 76% of the patients immediately after implantation, which increased further to 89% on the following day by echo-doppler studies. Complete closure was demonstrated in 99.7% of the patients at one year follow-up (10).

No patients had absent femoral pulsation and no patients needed blood transfusion. All the 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 was achieved at 3 months after successful ductal closure.

The mean left ventricular end diastolic diameter (LVEDd) Z score decreased from 2.13±2.37 pre-intervention, to 0.43±2.3 at one week and to -0.65±1.8 at 3-month follow up. This is similar to the findings of another study (8), that showed that LV end diastolic dimensions also decreased significantly after successful PDA closure; the mean LVED decreased from 40 ± 9 before PDA closure to 36 ± 6 mm one month after closure.

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 the left pulmonary artery slightly increased from 1.28 ± 0.18 m/s preintervention to 1.47 ± 0.27 m/s at one week, with further slight increase at 3 months (1.50 ± 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 (9). Another study (10) reported two cases of partial obstruction of the LPA seen on follow up (2.7m/s on echocardiography).

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 (10). Rarely, significant obstructions were observed in smaller infants with larger PDA, and a device removal was necessary in these patients (11).

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 pre-intervention to 1.39 m/s at one week and 1.41 m/s at 3 months post-intervention.

In the current study, there was no reported thrombus formation, thromboembolism or infective endocarditis in any case after successful ducat closure. Prophylaxis for infective endocarditis is recommended for 6 months in all patients (12).

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. The hemodynamic effects of PDA shunting regress rapidly after ductus closure with significant decreases in the left sided overload indices. 2D echocardiography is a useful tool for follow up after PDA closure. Similar studies with long term follow up are needed for further evaluation of the LV systolic function pattern.

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