TEHRAN HEART CENTER

Original Article

Transcatheter Closure of Patent Ductus Arteriosus Using the Amplatzer Ductal Occluder: Early Results and Midterm Follow-Up

Mostafa Behjati Ardakani, MD*, Sayed khalil Forouzannia, MD, Majid Dehghani, MD, Mohammad Hassan Abdollahi, MD

Afshar Hospital, Yazd University of Medical Sciences, Yazd, Iran.

Received 10 December 2007; Accepted 16 April 2008

Abstract

Background: *The transcatheter closure of patent ductus arteriosus has advanced rapidly with improvements in device designs. The aim of this study was to analyze the safety, efficacy, and early and intermediate follow-up results of the percutaneous closure of persistent ductus arteriosus (PDA) with the Amplatzer ductal occluder (ADO) in children.*

Methods: *Between May 2004 and March 2007, fifty patients between 7 months and 20 years of age underwent the transcatheter closure of PDA, using the ADO. The mean PDA diameter at its narrowest segment (pulmonary end) was 7.35±2.57 mm (range: 4 to 16mm). Follow-up evaluations were performed via echocardiography at 24 hours, and 1, 3, 6, and 12 months and then yearly after implantation.*

Results: *Successful immediate occlusion of PDA was achieved in 42 (84%) of the 50 cases. In 5 cases, there were trivial intraprosthetic residual shunts. In addition, there was a small residual shunt in one case, left pulmonary artery narrowing in one case, and embolization of the device immediately after the procedure in one case. At 24 hours, color Doppler flow mapping revealed complete closure in all except one case with a small shunt. At 3 months' follow-up, occlusion was complete in all the patients. At a median follow-up of 17 months (range: 3 months to 32 months), all the patients had complete closure.*

Conclusion: *We conclude that although the transcatheter closure of PDA using the ADO is a highly effective and safe treatment for most patients, several complications including embolization and left pulmonary artery narrowing may occur in certain cases.*

J Teh Univ Heart Ctr 3 (2008) 151-156

Keywords: *Patent ductus arteriosus • Child • Infant • Follow-up studies*

Introduction

The reported incidence of persistent ductus arteriosus (PDA) varies because of methodological differences related to the population group studied, age of consideration, and method of detection. Although ductus arteriosus is usually functionally closed within 48 hours of birth, some authors consider the patent ductus to be abnormal only after 3 months of age. In children born at term, the incidence of PDA has been reported to be about 1 in 2000 births.[1] As an isolated lesion, PDA represents 9-12% of all congenital heart diseases.[2] Surgical closure by ligation or division is an effective treatment, but it carries the potential risk of morbidity and rarely, mortality associated with thoracotomy, especially

*Corresponding Author: ***Mostafa Behjati Ardakani,*** *associate professor of pediatric cardiology, Afshar Hospital, Jomhouri Boulevard, Yazd, Iran. Tel: +98 351 5231421. Fax: +98 351 5253335. Email: dr_behjati@yahoo.com.*

in adults.[3,4] Degenerative changes such as calcification, friability, and aneurysm formation with advancing age make the conventional procedure of division and ligation difficult and may mandate the use of a more invasive approach including total cardiopulmonary bypass and trans-aortic patch closure.[4,5] Currently, the benefits of the transcatheter closure of PDA compared to surgical closure seem obvious in terms of shorter in-hospital stay, high success rates, no scar, and insignificant morbidity.[3,4]

The percutaneous closure of PDA using an Ivalon plug device was first described by Porstmann in 1966.[6,7] The Porstmann plug was not widely used because of a large-sized arterial delivery sheath and was, therefore, followed by the Rashkind and Cuaso,[8] later by Sideris,[9] and recently by Amplatzer.[10]

The transcatheter occlusion of PDA using various occluding devices and coils is a widely accepted alternative to surgical closure in most pediatric centers.[11] The Amplatzer ductal occluder (ADO) (AGA medical, Golder Valley, MN, USA) is a new device with easy placement. It is reported to have a higher rate of occlusion than do the other occluders currently available for the transcatheter closure of PDA.[12] Morphologically, there have been a number of different anatomical variants of PDA described. In general, it is simplest to think in terms of three types of lesions. The main type is "the Krichenko Group A" lesion, which is typically saucer-shaped, conical, or funnel-shaped; approximately 80% of all PDAs fall within this category. The next common type is the" Krichenko Group B lesion" which is window shaped, short length and has narrowing at the aortic end. Less common is the tubular lesion (Krichenko Group C), which is long and has no focal narrowing.[13]

The aim of this study was to evaluate the efficacy and safety of the ADO over short and intermediate terms for the closure of PDA.

Methods

Between May 2004 and March 2007, fifty (14 boys and 36 girls) patients underwent the transcatheter occlusion of PDA. Age at intervention ranged from 7 months to 20 years (mean age: 6.11 years). Medium weight was 18.2 kg (range: 6 to 65 kg). All the patients had clinical and echocardiographic findings of PDA. Seventeen patients had symptoms of heart failure and/ or failure to thrive. Associated anomalies observed included mild aortic stenosis (2 patients), small ventricular septal defect (1 patient), medium-sized ventricular septal defect (1 patient), and mild pulmonic stenosis (1 patient). One of the patients had a residual PDA following surgical ligature.

The Amplatzer (AGA®) ductal occluder is a self-expanding nitinol stent that is made up of a flat retention flange that is placed on the aortic wall and a tube (which is placed in the PDA itself) that contains thrombogenic material (a polyester patch sewn to the nitinol stent). The diameter of the retention flange is 4 mm larger than the tube sheath, which is in the form of a cone; the pulmonary end of the cone is 2 mm smaller than the end that is attached to the retention flange. Different ADO models refer to the size in millimeters of the two ends of the tube: 6/4, 8/6, 10/8, 12/10, 14/12, 16/14, and 18/16. The total length of the device is 7 mm in the 6/4 and 8/6 models, and 8 mm in the remaining models.

Informed written consent was obtained from the parents of all the patients. In brief, routine right and left heart catheterization was performed usually under local and sedation regimen. Prophylactic antibiotics with 30 mg/ kg cephazoline were administered at the beginning of the procedure and two subsequent doses 8 hours apart, and 100 IU/kg of sodium heparin was administered after catheterizing the artery.

A monoplane left anteroposterior and lateral descending aortogram was performed to outline the ductus and obtain the required measurements that included the length of the PDA, the diameter at the narrowest part, the aortic ampulla, and the center of the PDA (Figure 1).

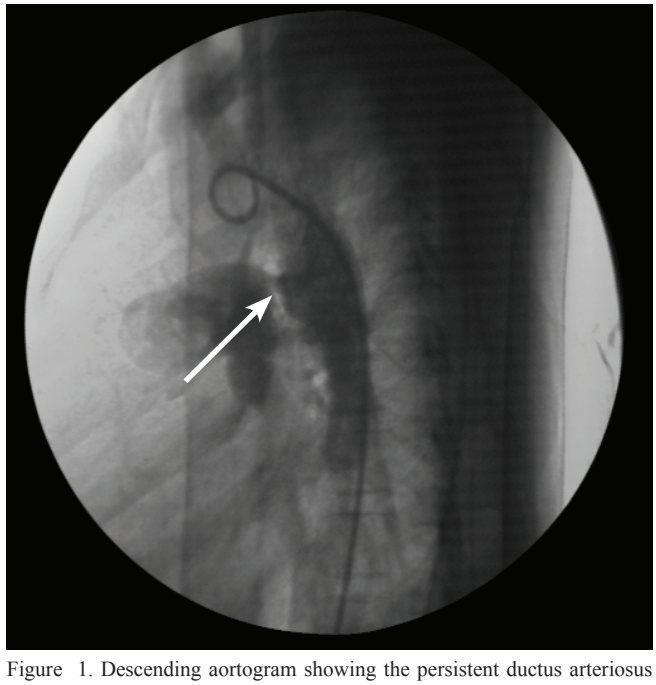

Figure 1. Descending aortogram showing the persistent ductus arteriosus size and shape from a lateral view (arrow)

The device was chosen to be at least 1 to 2 mm larger than the narrowest part of the PDA. Under fluoroscopic guidance, the ADO was advanced via a delivery cable until the retention disk was extruded in the descending aorta across from the ampulla. The disk was opened into the distal thoracic aorta in order to avoid possible damage of the aortic wall by the small metal protrusion of the disk. The device was then pulled gently against the aortic ampulla. An angiogram was performed to assess the position of the device

prior to the deployment of the tubular part of the prosthesis. If the position was satisfactory, then using gentle tension on the delivery cable, the sheath was pulled back to deploy the rest of the device. With the device still attached to the cable, repeat descending aortography (hand injection of contrast medium) was performed to confirm proper device position and exclude left pulmonary or aortic obstruction. Once optimal position was confirmed, the ADO was released by counter- clockwise rotation of the delivery cable. A repeat angiogram was performed 10 minutes after the release to check for residual shunt (Figure 2). Repeat pressure pullback from the ascending aorta and left pulmonary was obtained. All the patients were discharged 24 hours after the procedure and given no medication.

All the patients had complete two-dimensional and color Doppler echocardiographic studies at 24 hours after the procedure and at 1, 6, and 12 months and then serially every 1 year thereafter. Special attention was paid to residual shunts and aortic or left pulmonary obstruction. Endocarditis prophylaxis was discontinued at six months' follow-up if the duct was completely closed.

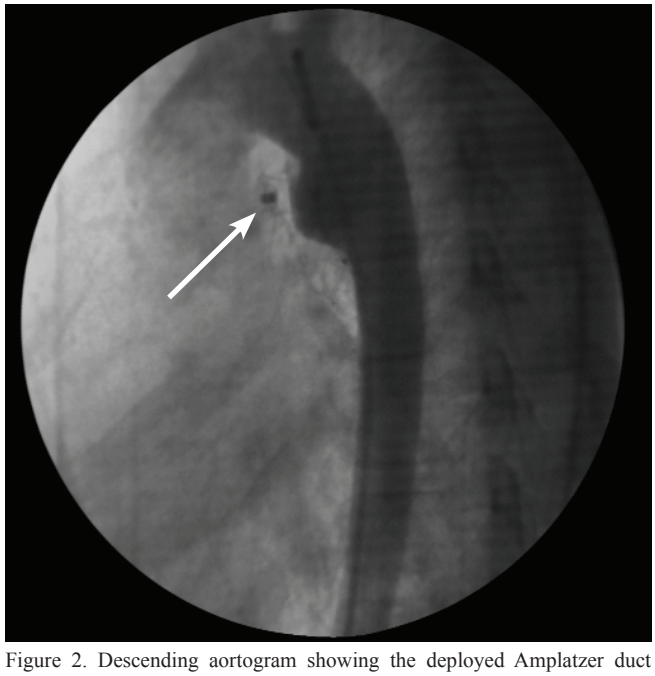

Figure 2. Descending aortogram showing the deployed Amplatzer duct occluder with closed persistent ductus arteriosus (arrow)

The parametric data are expressed as mean±SD, percentage, medium, and range. The data were analyzed with statistical program SPSS 11.0.1.

Results

The device was successfully deployed in all the patients except in one patient, in whom, distal embolization of the device occurred immediately after the procedure. After the device was retrieved percutaneously, the patient underwent surgery. The mean age was 6.11±5.35 years, and the mean weight the time of the procedure was 18.26±14.06 kg. The mean PDA minimal diameter (pulmonary end) was 5.58±2.57 mm (range: 4-16 mm). The pulmonary to systemic flow ratio (Q_P/Q_S) ranged from 1.4-3.3 (mean: 2.3±0.56). All the device sizes were used. Most of the devices employed were moderate sized (8 of the $^{6}/_{4}$ device size, 14 of the $^{8}/_{6}$, 17 of the $^{10}/_{8}$, 7 of the $^{12}/_{10}$, 2 of the $^{14}/_{12}$, 1 of the $^{16}/_{14}$, and 1 of the $^{18}/_{16}$). The procedure time was 54.9±11.96 min (range: 40-90 min). Fluoroscopy time was 12.6±4.4 min (range: 6-25 min) (Table 1).

Table 1. Demographic and catheterization data after using Amplatzer ductal occluder

	Mean	Median	SD	Range
Age (y)	6.11	4.5	5.35	0.58-20
Weight (kg)	18.26	12.5	14.06	6-65
Q_R/Q_S	2.3	2.3	0.56	1.4-3.30
PDA size (mm)	5.58	7.35	2.57	4-16
FT (min)	12.6	12	4.4	6-25
PT (min)	54.9	51	11.97	40-90
F/U (mo)	17.8	16	9.88	3-32

SD, Standard deviation; Q_R/Q_S, Pulmonary to systemic flow ratio; PDA, Persistent ductus arteriosus; FT, Fluoroscopy time; PT, Procedure time; F/U, Follow-up

In 8 patients, the devices were too small to close the defect; consequently, larger ADOs were implanted. Immediate complete occlusion of PDA was achieved in 42 of the 50 cases. In 5 patients, there were trivial intraprosthetic residual shunts immediately after the procedure. In one patient, there was a small residual shunt immediately, 24 hours, and 1 month after the procedure and complete occlusion was achieved two months after the procedure. Three patients required blood transfusion due to significant blood loss. Thrombosis of the right femoral artery occurred in 7 patients, and thrombosis of the left femoral artery occurred in 1 patient. Heparin (continuous intravenous infusion 20 unit/kg/h) was administered unsuccessfully in 4 patients. Streptokinase intravenous infusion (loading does 10000 u/kg over 60 minutes followed by 10000 u/kg for three hours) produced a successful and complete turn of pulses in three patients; another one patient underwent femoral thrombectomy.

Mild inguinal hematoma occurred in two patients. None of the patients had a gradient through the aortic arch on post-implant hemodynamic evaluation. One patient had left pulmonary branches obstruction due to a large-sized Amplatzer ($^{16}/_{14}$). In one patient, distal embolization of the device occurred immediately after the procedure. After the device was retrieved percutaneously, the patient was sent to surgery.

All the patients had echocardiographic evaluations within 24 hours from the procedure.

A small shunt continued to be seen in one infant (age:

9 months). The remaining 48 patients showed complete closure. The patient who had a small shunt had complete closure at 2 months' follow-up. Thus, the closure rate was 100% at 2 months post implant. All the patients underwent echocardiography at 1,3,6, and 12 months and then yearly after the procedure. Echocardiography showed evidence of left pulmonary artery stenosis in one case 1 month after the procedure with 40 mmHg gradient. There was no evidence of aortic obstruction, and nor was there any clinical evidence of hemolytic, bacterial arteritis, and early or late device embolization in any patient.

Discussion

The percutaneous closure of PDA is a well- established technique that has a low incidence of complication.[14] Percutaneous closure with the new ADO has significantly improved the results of the transcatheter closure of moderate-sized and large ducts.[15]

The major advantages of the ADO over previous devices (such as double umbrella, controlled removable coils, etc.) are the smaller delivery sheaths (6-8 French), the ability to reposition the device before release, and a significantly lower rate of complications and residual shunts.[10,12,16]

The device has the advantage of closing a large PDA that otherwise may require long or multiple coils or special additional techniques that can render the procedure more difficult with potential coil embolization or protrusion causing pulmonary artery or aortic narrowing.[17]

Technically, the placement of the ADO is easy without complicating mechanisms. This significantly reduces the fluoroscopy time and shortens the learning curve for each operator. Indeed, the fluoroscopy time in this study was much lower than that reported for other PDA occluders, including coils.[11,18,19]

Faella et al.[16] reported the immediate and short-term results of the international registry of the transcatheter closure with the ADO. Three hundred and sixty patients were treated at a median age of 2.1 years. The occlusion rate was up to 100% at one year's follow-up. Seven patients experienced significant complications including death, hemolysis, transient asystole, device embolization, device misplacement, St depression, and blood loss.

Bikis et al.[20] reported on a long series of 205 patients with PDA occluded with the ADO. Closure was successful in all the patients. Complications occurred in 6 patients: embolization in 3, mild aortic narrowing due to large device in 1, and blood loss that required transfusion in 2.

Butera G et al.[21] reported on a large series of 197 infants and young children with PDA occluded with the ADO. The occlusion rate was 100% at 24 months' follow-up. Complications occurred in 3 patients: right femoral thrombosis in 1 patient and mild left inguinal hematoma in 2 patients.

In our study, the thrombosis rate in the femoral artery was as high as 16%. The main cause was the long time for the placement of the large artery sheath in the femoral artery. Femoral artery thrombosis can be successfully cured with urokinase or streptokinase intravenous infusion.[21,22]

In another study, the ADO was used in large ducts and coils were employed in patients with small to moderate-sized ducts. In group I (coil ductal occluder), PDA occlusion was successful in 207 (96.7%) patients. In group II (ADO), ductus closure was successful in 134 (98.5%) patients. There was no significant difference in the success rates between groups II and I. Distal embolization occurred in 19 patients of group I and in 2 of group II, respectively. Left pulmonary artery stenosis was found exclusively in 9 patients of group I at 6 months' follow-up ($P<0.05$). Nine patients in group I required second intervention to achieve complete occlusion.[23]

Santoro G et al.[24] reported on 34 patients with large PDA occluded with the ADO. Closure was successful in 97.1% patients over a mid-term follow-up. They concluded that percutaneous closure might be considered effective and safe also in large clinically significant PDA.

Li JJ et al.[25] reported the successful use of the ADO to occlude PDA over a long-term follow-up (five years). According to the report of Li JJ et al.,[25] late complications occurred in 5 patients, including hemolysis in 3 patients and loss of the femoral artery in 2 patients. The incidence of residual shunts at follow-up periods of 24 hours and 1, 2, 36, 48, and 60 months after device occlusion was reported to be 9.2%, 2.8%, 1.2% 0.8% 0, 0, 0, and 0, respectively. The previous reported incidence of residual shunts was 0% to 38%.[10,12] In the present study, the incidence of residual shunts was 12%. Wang JK et al.[26] reported that the transcatheter closure of moderate to large-sized ducts with the ADO was effective and safe. Several studies have reported hemolysis, device embolization, infection, and significant narrowing of the left pulmonary artery or descending aorta as major complications.[20,27-29]

We used the ADO for very large PDA (≥12mm); nonetheless, unfortunately left pulmonary artery stenosis occurred in one patient with a PDA size of 14 mm and the ADO size of $^{16}/_{14}$. Our study showed that the immediate, short, and intermediate term results of PDA closure using the ADO were excellent, although two significant complications occurred: left pulmonary artery stenosis in 1 patient and distal embolization of the device in another patient. The previous reported Amplatzer embolization rates ranged from 0% to 3%.[12,29,30] In the present study, the embolization rate was 2%. It is worthy of note that left pulmonary artery narrowing is an infrequent complication.[30] In our study, a single patient had a gradient 20 mmHg from left pulmonary artery to main pulmonary artery. At 18 months' follow-up, this patient had a gradient on echocardiogram over 40 mmHg. Because of the small number of significant left pulmonary artery obstruction observed, conclusion as to the etiology or means of preventing this complication is not obvious from these data. However, in general, it seems likely that the use of a

large or oversized device in small patients might be a risk factor for this complication. Transcatheter occlusion has become the treatment of choice for most patent ducts in children and adults. In cases of calcified ductus arteriosus with increased pulmonary vascular resistance, transcatheter closure offers considerable advantages over surgical closure, which frequently involves cardiopulmonary bypass with an anterior approach through a median sternotomy.[1] The surgical repair of the ductus is considered safe and carries a low morbidity and mortality. Repair does not require the use of cardiopulmonary bypass, but it does require general anesthesia and endotracheal intubation. Cases of recanalization or incomplete initial ligation have occurred after the use of surgical ligation only. With the more detailed and sophisticated techniques of evaluating these patients using color Doppler, the incidence of residual ductal patency following ligation seems to be higher.

Serious complications of surgical repair include inadvertent ligation of the left pulmonary artery or the descending aorta with catastrophic results. Morbidity after classical surgical repair is mainly due to lateral thoracotomy.[31]

Conclusion

Percutaneous PDA closure with the ADO is an effective method for the treatment of PDA.

The low incidence of complications and residual shunts makes this device ideal for the percutaneous closure of PDA. The immediate, short, and intermediate term results are very encouraging. Achieving complete closure in the catheterization laboratory is desirable but unnecessary, since most residual trace flows seen immediately after device placement will cease at follow-up. The transcatheter closure of moderate to large-sized ducts with the ADO is effective and safe; however, in very large PDA, it can cause left pulmonary artery stenosis. Further studies are required to document its efficacy, safety, and long-term results in a larger number of patients.

Acknowledgement

The authors wish to thank Dr. M. Dehghani for teaching us the technique of the PDA closure using the new ADO. This study was approved and supported by the Cardiovascular Research Center of Afshar Hospital.

Reference

1. Schneider DJ, Moore JW. Congenital heart disease for the adult cardiologist, patent ductus arteriosus. Circulation 2006;114:1873-1882.
2. Al-Motarreb A, Al-Hammadi M, Shamsan M, Kherbash H, AL-Hakeem F. Percutaneous transcatheter closure of patent ductus arteriosus using amplatzer duct occluder: first Yemeni experience. Heart views 2006;7:101-104.
3. Schrader R, Kadel C. Persistent ductus arteriosus: is closure indicated also in asymptomatic adult with small ductus and minor shunt. Z Kordiol 1993;82:563-567.
4. Black LL, Goldman BS. Surgical treatment of patent ductus arteriosus in the adult. Ann surg 1972;175:290-293.
5. Wright JS, Newman DC. Ligation of a patent ductus: technical considerations at different ages. J Thorac cardiovasc surg 1978;75:695-698.
6. Porstmann W, Wierny L, Warnke H. Closure of persistent ductus arteriosus without thoracotomy. Ger Med Mon 1967;12:259-261.
7. Porstmann W, Wierny L, Warnke H, Gerstberger G, Rumaniuk PA. Catheter closure of patent ductus arteriosus: 62 cases treated without thoracotomy. Radiol clin North Am 1971;9:203-212.
8. Raskind WJ, Cuaso CC, Transcatheter closure of a patent ductus arteriosus: successful use in a 3.4 kg infant. Pediatr cardiol 1979;1:3-7.
9. Rao PS, Kim SH, Choi JY, Rey C, Haddad J, Marcon F, Walsh K, Sideris EB. Follow up results of tranvenous occlusion of patent ductus arteriosus with buttoned device. J Am coll cardiol 1999;33:820-826.
10. Masura J, Walsh KP, Thanopoulous B, Chan C, Bass J, Goussous Y, Gavora P, Hijazi ZM. Catheter closure of moderate-to large-sized patent ductus arteriosus using the new Amplatzer duct occluder. Immediate and short term results. J Am coll cardiol 1998;31:878-882.
11. Galal O, de Moor M, Fadly F, Qureshi S, Naffa S, Oufi S, Suhl M, Abbag F, Schmaltz AA. Problems encountered during introduction of the patent arterial duct. Eur Heart J 1997;18:625-630.
12. Thanopoulos BD, Hakim FA, Hiari A, Basta E, Zarayelyan AA, Tsaousis GS. Further experience with transcatheter closure of the patent ductus arteriosus using the Amplatzer duct occluder. J Am coll cardiol 2000;35:1016-1021.
13. Krasuski RA. Patent ductus arteriosus closure. J interv cardiol 2006;19:S60-66.
14. Ruiz AF, Cero Marin MJ, Rubio Vidal D, Gussoni MCC, Granados FM. Transcatheter closure of patent ductus arteriosus using the Amplatzer duct occluder: initial results and mid-term follow up. Rev ESP cardiol 2002;55:1057-1062.
15. Al-Hakim F, Eleftherakis NG, Simeunovic SD. Transcatheter closure of high pulmonary artery pressure persistent ductus arteriosus with the Amplatzer muscular ventricular septal defect occluder. Heart 2002;87:260-263.
16. Faella HJ, Hijazi ZM. Closure of the patent ductus arteriosus with the Amplatzer PDA device: immediate results of the interventional clinical trial. Cathet cardiovasc Interv 2000;51:50-54.
17. Ebeid MR, Masura J, Hijazi ZM. Early experience with Amplatzer ductal occluder for closure of persistently patent ductus arteriosus. J Interv Cardiol 2001;14:33-39.
18. Hijazi ZM, Geggel RL. Transcatheter closure of large patent ductus arteriosus (>4mm) with multiple Gianturco coils: immediate and midterm results. Heart 1996;76:536-540.
19. Podnar T, Masura J. Percutaneous closure of patent ductus arteriosus using special screwing detechable coil. Cath cardiovasc Diagn 1997;41:386-391.
20. Bilkis AA, Alwi M, Hasri S, Haifa AL, Geetha K, Rehman MA, Hasanah I. Amplatzer duct occluder experience in 209 patients. J Am Coll Cardiol 2001;37:258-261.
21. Butera G, Rosa GD, Chessa M. Transcatheter closure of

persistent ductus arteriosus with the Amplatzer duct occluder in very young symptomatic children. Heart 2004;90:1467-1470.
22. Zhiwei Z, Mingyang Q, Huishen W, Yufen L. Transcatheter closure in 354 pediatric cases of patent ductus arteriosus using five different devices. CMJ 2001;114:456-458.
23. Wang JK, Hwang JJ, Chiang FT, Wu MH, Lin MT, Tee WL, Lue HC. A strategic approach to transcatheter closure of patent ductus: Gianturco coil for small-to-moderate ductus and Amplatzer duct occluder for large ductus. Int J cardiol 2006;106:10-15.
24. Santoro G, Bigazzi MC, Carrozza M, Palladino MT, Sarubbi B, Scorpati C, Dalto M, Russo MG, Calabro R. Percutaneous treatment of moderate-to-large patent ductus arteriosus with different devices: early and mid term result. Ital Heart J 2005;6:396-400.
25. Li JJ, Li YF, Zhang ZW, Qian MY, Wang HS. A follow up study on transcatheter closure of patent ductus arteriosus with Amplatzer duct occluder in children. Zhonghua Er Ke Za Zhi 2005;43:608-611.
26. Wang JK, WU MH, Hwang JJ, Chiang FT, Lin MT, Lue HC. Transcatheter closure of moderate to large patent ductus arteriosus with the Amplatzer duct occluder. Catheter Cardiovasc Interv 2007;69:572-578.
27. Al-Ata J, Arfi AM, Hussain A, Kouatli AA, Jalal MO. The efficacy and safety of the Amplatzer ductal occluder in young children and infants. Cardiol Young 2005;15:279-285.
28. Ali Khan MA, al Yousef S, Mullins CE, Sawyer W. Experience with 205 procedures of transcatheter closure of ductus arteriosus in 182 patients, with special reference to residual shunts and long-term follow-up. J Thorac Cardiovasc Surg 1992;104:1721-1727.
29. Jang GY, Son CS, Lee JW, Lee JY, Kim SJ. Complications after transcatheter closure of patent artriosus. J Korean Med Sci 2007;22:484-490.
30. Pass RH, Hijazi Z, Hsu DT, Lewis V, Hellenbrand WE. Multicenter USA Amplatzer patent ductus arteriosus occlusion device trial: initial and one-year results. JACC 2004;44:513-519.
31. Robida A. Nonsurgical transcatheter closure of ductus arteriosus. Heart Views 1999;1:64-69.