Percutaneous closure of hypertensive ductus arteriosus

Carlos Zabal, José Antonio García-Montes, Alfonso Buendía-Hernández, et al.

Updated information and services can be found at:

http://heart.bmj.com/content/96/8/625.full.html

These include:

References	This article cites 23 articles, 8 of which can be accessed free at: **http://heart.bmj.com/content/96/8/625.full.html#ref-list-1**
Email alerting service	Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.
Topic collections	Articles on similar topics can be found in the following collections Congenital heart disease (1355 articles) Hypertension (11845 articles)

Notes

To order reprints of this article go to:

http://heart.bmj.com/cgi/reprintform

To subscribe to *Heart* go to:

http://heart.bmj.com/subscriptions

Percutaneous closure of hypertensive ductus arteriosus

Carlos Zabal, José Antonio García-Montes, Alfonso Buendía-Hernández, Juan Calderón-Colmenero, Emilia Patiño-Bahena, Antonio Juanico-Enriquez, Fause Attie

National Institute of Cardiology "Ignacio Chavez", Mexico City, Mexico

Correspondence to
Carlos Zabal, Juan Badiano 1, Col. Sección XVI, Tlalpan, 14080 Mexico City, Mexico; zabal@cardiologia.org.mx

ABSTRACT

Background The Amplatzer duct occluder (ADO) has been used with success to close large patent ductus arteriosus (PDA), but some problems exist especially with hypertensive PDAs, such as incomplete closure, haemolysis, left pulmonary artery stenosis, obstruction of the descending aorta and progressive pulmonary vascular disease.

Methods and results We analysed a group of 168 patients with isolated PDA and pulmonary artery systolic pressure (PSAP) $\geq$50 mm Hg. Mean age was 10.3 $\pm$ 14.3 years (median 3.9), PDA diameter was 6.4 $\pm$ 2.9 mm (median 5.9), PASP was 63.5 $\pm$ 16.2 mm Hg (median 60), Qp/Qs was 2.7 $\pm$ 1.2 (median 2.5), total pulmonary resistance index (PRI) was 3.69 $\pm$ 2.15 (median 3.35) and vascular PRI was 2.73 $\pm$ 1.72 (median 2.37). We used ADOs in 145 (86.3%) cases, Amplatzer muscular ventricular septal defect occluders (AMVSDO) in 18 (10.7%), Amplatzer septal occluders (ASO) in three (1.8%) and the Gianturco-Grifka device in two (1.2%) cases. Device diameter was 106.3% $\pm$ 51% higher than PDA diameter. PASP decreased after occlusion to 42.5 $\pm$ 13.3 mm Hg (p<0.00001). Immediately after closure, no or trivial shunt was present in 123 (74.5%) cases. Immediate complications were device embolisation in five (3%) cases and descending aortic obstruction in one case. The overall success rate was 98.2%. Follow-up in 145 (86.3%) cases for 37.1 $\pm$ 24 months (median 34.1) showed further decrease of the PASP to 30.1 $\pm$ 7.7 mm Hg (p<0.0001).

Conclusions Percutaneous treatment of hypertensive PDA is safe and effective. ADO works well for most cases, but sometimes other devices (MVSDO or ASO) have to be used. When cases are selected adequately, pulmonary pressures decrease immediately and continue to fall with time.

INTRODUCTION

Percutaneous closure of patent ductus arteriosus (PDA) is now considered a first-line alternative to surgery with very good rate of closure and almost no complications with different types of devices.[1-13] However, closure of hypertensive PDA is still a challenge.[13-15] The Amplatzer duct occluder (ADO) has been used with success to close large PDAs, but some problems exist especially with hypertensive PDAs, such as incomplete closure, haemolysis, left pulmonary artery (LPA) stenosis, obstruction of the descending aorta and progressive pulmonary vascular disease.[13 16 17]

We analyse our experience in a group of patients with isolated PDA and pulmonary artery systolic pressure (PSAP) $\geq$50 mm Hg.

METHODS

Patients

From September 1999 to January 2008 we intended to treat 843 patients with PDA. From this group we selected the cases with isolated PDA and PASP $\geq$50 mm Hg. The final study group consisted of 168 cases (19.9% of the whole PDA population).

Catheterisation procedure

The procedure was performed under mild sedation in adults and moderate sedation in children. The first step was to perform an aortic angiography in plain lateral and right anterior oblique views to delineate the PDA. A complete cardiac catheterisation was done and pressures and flows were measured breathing room air and 100% oxygen. Pulmonary vascular resistance was measured estimating oxygen uptake from standardised tables. We also did a pulmonary wedge angiography (PWA) in all cases.

In cases where pulmonary pressure did not decrease at least 20% when breathing 100% oxygen, we performed a test occlusion with a compliant balloon for 10—15 minutes and repeated the measurements. Test occlusion was performed using a 20-mm or 24-mm Amplatzer sizing balloon (AGA Medical Corporation, Golden Valley, MN, USA) hand-inflated with a diluted contrast solution, until a waist could be seen and occlusion of the arterial duct was confirmed by aortic angiography. If response to 100% oxygen and occlusion was non-conclusive, pharmacological challenge with adenosine (10 µg/kg/min for 3 minutes, with increments of 10 µg/kg/min, until significant response or a limit dose of 50 µg/kg/min) or inhaled NO (40 ppm for 10 minutes) was done. Reactivity of pulmonary hypertension (PHT) was established when at least one of the following parameters was achieved: more than 20% decrease in PASP, more than 20% increase in Qp/Qs or a PWA with more than five monopedial arteries and a uniform capillary blush. If reactivity was established, we continued with the selection of the device. In general, if the pulmonary pressure decreased under 60% of the systemic pressure, an ADO (AGA Medical Corporation) at least 50% larger than the smallest PDA diameter was selected (ex: an 8.5-mm PDA with PASP of 42% systemic after oxygen, a 14/12 ADO was used). If pulmonary pressures remained over 60% of the systemic pressure, then an Amplatzer muscular ventricular septal defect occluder (AMVSDO, AGA Medical Corporation) at least 50% larger than the smallest PDA diameter

625

was selected (as in the preceding example if the pulmonary pressure after oxygen was 75% systemic, a 14-mm AMVSDO was used). Complete catheterisation was repeated after closure and a control aortogram was done as the last step. No heparin was used during most of the procedures.

Follow-up

Patients were discharged the following morning on prophylactic antibiotics if a residual shunt was present. Follow-up visits were scheduled 1 month and 6 months after the procedure and yearly thereafter with a clinical examination, x-ray and transthoracic echocardiogram. Pulmonary pressures were measured by echo with a measurable tricuspid regurgitation jet, assuming RA pressure was 5 mm Hg and, when we could not find any measurable regurgitation jet, we calculated it with the Doppler upstroke in the main pulmonary artery. In cases where pulmonary systolic pressure measured by echo was >40 mm Hg, follow-up cardiac catheterisation was performed.

Statistical analysis

Statistical analysis was performed with statistical software (SPSS 13.0 for Windows). Quantitative data are expressed as mean ± SD (median). A paired t test or Wilcoxon test was performed as properly indicated to compare two mean values. Factors associated with acute procedural outcomes were sought with t tests and Kruskal-Wallis analysis of variance. Linear regression was performed to compare some results. A $p < 0.05$ was set as the level of statistical significance.

RESULTS

Demographic data

Mean age of the 168 patients was 10.3 ± 14.3 (3.9) years (limits, 2 months—59 years). There were 137 children (81.5%) and 31 adults (18.5%). From the group of children, 97 (57.7%) were younger than 5 years. There were 117 female (69.6%), and two adults had previous surgical ligation of the PDA in another institution. NYHA class was I in 61 (36.3%) cases, II in 98 (58.3%) and III in nine (5.4%). Some degree of cardiac enlargement was present in all but four cases (CTI ≤ 65 in 148 cases, CTI > 65 in 16).

Procedure data

At angiography, the smallest PDA diameter was 6.4 ± 2.9 (5.9) mm (limits, 1.4—17.9) with 66.7% of cases ≥ 5 mm. The type of PDA was A in 79.8%. Baseline haemodynamic data are summarised in table 1. Test occlusion was performed in 27 cases with a PASP of 72.1 ± 16.8 mm Hg and a PDA with a smallest diameter of 8.7 ± 4 mm that increased to 12.1 ± 4.7 mm for mean 38% increase; therefore we used the stretched diameter to select the device. PASP decreased 36.1 ± 15.4% (median 40%).

In eight cases pulmonary pressure decreased less than 10% despite test occlusion. The PDA diameter in these cases was 7.5 ± 3 mm, PASP was 65.9 ± 9.2 mm Hg, Qp/Qs was 2.5 ± 1.14 and total PRI was 4.9 ± 2.6. Device occlusion was carried out because of the left to right shunt (all but one Qp/Qs ≥ 1.3), total PRI <6 in six of them and a PWA with more than five monopedial arteries and a uniform capillary blush. In two cases total PRI was 7.4 and 9.4 and decreased after test occlusion to 6.9 in both.

We used ADOs in 145 (86.3%) cases, AMVSDOs in 18 (10.7%), Amplatzer septal occluders (ASO, AGA Medical Corporation) in three (1.8%) and the Gianturco-Grifka device (Cook Inc, Bloomington, IN, USA) in two (1.2%) cases. AMVSDOs used were three of 22 mm, five of 20 mm, two of 18 mm, four of 16 mm, three of 14 mm and one of 12 mm. ASO devices were used in two cases because a 24-mm AMVSDO embolised or passed freely through the ductus and 30-mm and 28-mm devices closed the PDAs safely (figure 1). In the other case, a 16/14 ADO embolised, it was retrieved and changed to a 18-mm AMVSDO that protruded into the LPA causing stenosis; the device was retrieved and changed to a 18-mm ASO that closed the PDA safely with no protrusion to the LPA.

The device diameter was 106.3% ± 51% higher than the smallest diameter of the PDA (PDA diameter 6.4 ± 2.9 mm vs device diameter 12.3 ± 4.1 mm). This oversizing had no difference among age or pulmonary pressure quartile groups.

The device had to be changed in 13 cases because of embolisation, slippage, significant residual shunt or significant stenosis, for a device exchange rate of 7.7%.

The PASP decreased after occlusion from 63.5 ± 16.2 mm Hg to 42.5 ± 13.3 mm Hg ($p < 0.00001$) for a mean decrease of 32.7 ± 13.2%. Immediately after device deployment, PDA was completely occluded in 45 (26.8%) cases, there was trivial (through the device) residual shunt in 78 (46.4%), small (less than 1-mm jet) in 34 (20.2%) and moderate (1—2-mm jet) in 11 (6.5%) cases.
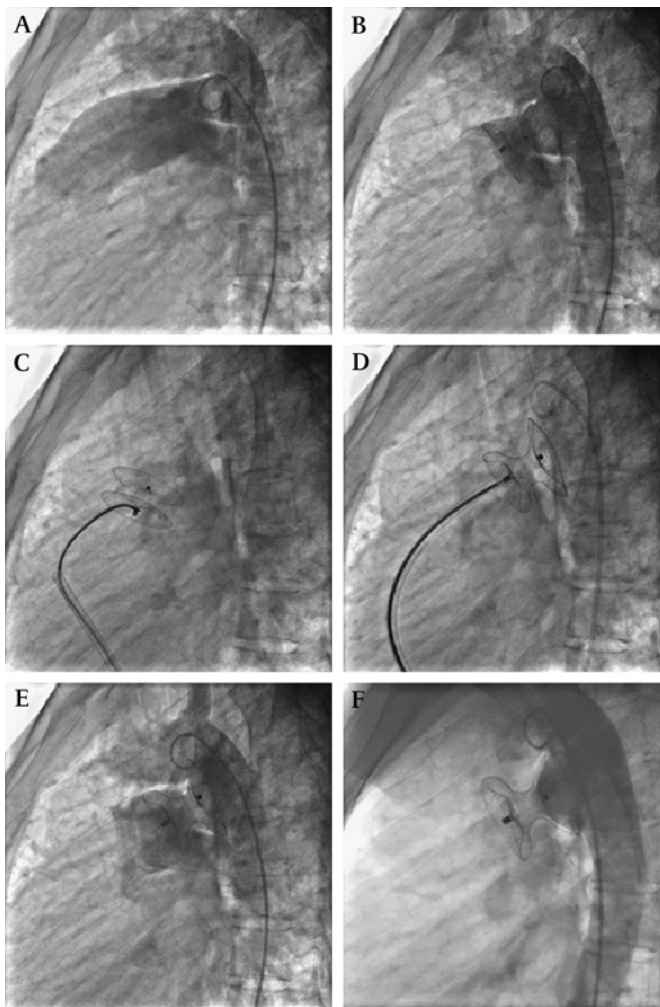
The procedure was completed in 62 ± 20.7 minutes with a fluoroscopy time of 11 ± 6.1 minutes.

Immediate complications were device embolisation in five (3%) cases, three were retrieved and changed and two were sent to surgery, and in one case a 10 mm Hg immediate gradient across the aorta increased to 30 mm Hg in the following days and the patient was sent to surgery. An LPA peak gradient <12 mm Hg was present in three (1.8%) cases. The overall success rate was 165/168 (98.2%).

Follow-up data

Follow-up was possible in 145 (86.3%) cases for a mean of 37.1 ± 24 (34.1) months (limits, 1—108). The 20 cases that were lost to follow-up had a post-procedure PASP of 41.5 ± 11.9 mm Hg and 17 had no or trivial residual leak.

On transthoracic echocardiography (echo), only two (1.4%) cases had trivial residual leak, the rest had complete closure of the PDA. Pulmonary pressures measured by echo at the first month of follow-up were very similar to those obtained by catheterisation at the end of the procedure. At their last visit (133 cases > 12 months), pulmonary pressure measured by echo (in 132 (91%) cases by tricuspid regurgitation jet and in 13 (9%) by Doppler upstroke) or cardiac catheterisation (14 patients) decreased further to 30.1 ± 7.7 mm Hg ($p < 0.0001$). In the eight cases where the immediate PASP decreased less than 10%, follow-up at least for 1 year showed further decrease of the PASP from 64 ± 10.5 mm Hg (limits, 50—75) to 38.9 ± 7.9 mm Hg (limits, 25—48, $p < 0.0001$) (figure 2). There were 14 cases with

Table 1 Baseline haemodynamic data

	Mean±SD (median)
Pulmonary artery pressure	
Systolic	63.5±16.2 (60)
Diastolic	31.8±11 (30)
Mean	42.4±12.2 (40)
Pulmonary to systemic flow ratio	2.73±1.2 (2.5)
Total pulmonary resistance index	3.69±2.15 (3.3)
Vascular pulmonary resistance index	2.73±1.7 (2.37)

Figure 1 Angiographic images of a 25-year-old woman with hypertensive patent ductus arteriosus (PDA). Pulmonary pressures were 90/50 (63) and Qp/Qs 1.3. (A) Aortogram in left lateral projection showing a type C large PDA that measured 17.9 mm. Test occlusion showed a decrease of pulmonary pressures to 45/30 (35) and a PDA stretched diameter of 22 mm. (B) A 24-mm Amplatzer muscular ventricular septal defect occluder (AMVSDO) was used and the control aortogram shows moderate residual shunt and not good apposition of the central waist of the device to the PDA walls. (C) After 10 minutes, the device embolised to the PA and was retrieved. (D) A 28-mm Amplatzer septal occluder (ASO) was then positioned and released. (E) Aortogram shows a better apposition of this device to the PDA walls with slight protrusion to the left pulmonary artery (LPA) and the aortic arch. (F) Control aortogram 8 months after closure showing complete closure with a good conformation of the aortic disc to the PDA ampulla. Pulmonary pressures were 40/18 (23) with no gradient in the LPA.

a PASP >40 mm Hg measured by echo (all with TR jet) that were catheterised. Of these, a PASP >40 mm Hg at follow-up was confirmed in 12 (8.3%) cases (figure 3). These cases had significantly bigger PDAs (6.4 ± 2.8 mm vs 8.5 ± 3.7 mm, p=0.01), higher PASPs (61.6 ± 14.8 mm Hg vs 90.8 ± 17.7 mm Hg, p<0.00001) and their immediate PASP decreased significantly less (34% ± 12.2% vs 22.7% ± 16.9%, p=0.002). All these cases showed a continuous decrease of the pulmonary pressure through follow-up to 47 ± 4.9 mm Hg, five of them, that had a post-occlussion PSAP above 70 mm Hg, are taking sildenafil.

There were four (2.7%) complications at follow-up; two vascular (femoral artery pseudoaneurysm and AV fistula) that required surgical treatment, one stroke 5 months after PDA occlusion in a child with protein S deficiency, and an LPA gradient of 20 mm Hg in a 3-year-old girl with an 8.6 mm type A PDA that was completely closed with a 16/14 ADO.

DISCUSSION

Percutaneous closure of PDA has been widely available since 1990 and is now considered a first-line alternative to surgery with very good rate of closure and almost no complications using different types of devices.[1-13] Devices such as coils and the Nit-Occlud work very well for small PDAs, but have major disadvantages when used for large and specially hypertensive ducts.[14 15] The ADO has been used with success to close large PDAs, but some problems exist especially with large and hypertensive PDAs, such as embolisation, incomplete closure, haemolysis, left pulmonary artery stenosis, obstruction of the descending aorta and progressive pulmonary vascular disease.[13 16 17]

Masura et al reported the first human experience with ADO where only one patient had significant PHT (mean 46 mm Hg) with immediate reduction of the pulmonary artery mean pressure to 24 mm Hg.[18] Thanopoulus et al reported the first use of AMVSDO in seven patients with severe PHT with 100% occlusion rate and decrease of pulmonary pressures.[19] More recently, Yan et al published their experience with 29 adults, all with PHT using ADO and AMVSDO, and they achieved closure in 20 cases with clinical improvement at a maximum 6-month follow-up, but with no pulmonary pressure measurements.[20] Szkutnik et al reported their experience in a high altitude environment with 13 patients, children and adults, 38% with PHT, all but one closed successfully with the ADO.[21]

In this paper we report our experience, we believe one of the largest published to date, in a group of patients with isolated PDA and PASP ≥50 mm Hg.

The most important dilemma in these patients is whether to close or not to close the PDA, because of the risk of progressive pulmonary vascular disease. Patients with a pulmonary resistance >6 Wood units when breathing 100% oxygen have been considered unsuitable candidates for repair of congenital heart defects. As others do, we believe that temporary occlusion of the duct is a very good tool to assess the consequences of PDA closure and thereby evaluate the reactivity of severe pulmonary arterial hypertension. If we also perform a pulmonary wedge angiography, a reflection of the anatomical condition of the pulmonary vascular bed, and, in cases that have a non-conclusive response to 100% oxygen, a pharmacological challenge with adenosine or inhaled NO, we can enhance the possibility of ascertaining that pulmonary pressure will decrease after PDA closure, as we did in our cases where, even in the eight patients with an immediate very mild decrease in PASP, we achieved a very good result at follow-up with more than 90% of our cases normalising pulmonary pressures.[19 20 22]

Although calculation of pulmonary vascular resistance is also important in assessing the reactivity of pulmonary arterial hypertension, it is just one of the multiple parameters that we have to measure in these patients. Also, we have available today a good number of pulmonary vasodilators that can be used before or after PDA closure.[23]

We think that using all the tools to evaluate each patient as described, we are expanding the number of patients in whom the PDA can be closed with good results. The two patients in whom the PDA was closed with PRI >6 Wood units and PASP

Congenital heart disease
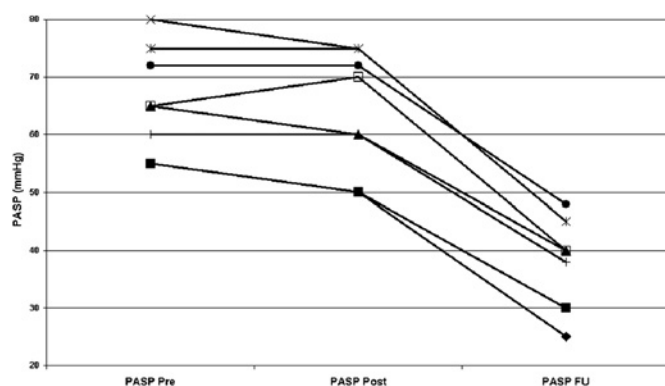
Figure 2 Graphic showing evolution of the pulmonary artery systolic pressure (PASP) in the eight patients with a <10% decrease in pressure with test occlusion.

of 75 mm Hg and 80 mm Hg are doing well, with PASP measured by echo at 45 mm Hg and one has been recatheterised with a PASP of 42 mm Hg with sildenafil treatment. We have had three patients with PAH (>70), low Qp/Qs (<1.3), PRI over 6 Wood units, no reactivity even on test occlusion and a poor anatomy on the PWA that did not undergo closure. They are being treated with bosentan and are waiting to be recatheterised.

Oversizing of Amplatzer devices has been reported to have an important role in achieving a virtually 100% occlusion rate and decreasing the likelihood of embolisation. Oversizing has been reported from 22% to 83%.[19—21] In our institution from previous experience, we select at least a 50% larger device than the smallest angiographically estimated duct diameter. With this policy, we had a device exchange rate of 7.7% and a 3% incidence of embolisation. At the end, to achieve a 98% success rate the mean oversizing was 106%. We believe that this could be a consequence of our working environment at an altitude of 2240 metres above sea level with more compliant PDAs as were Szkutnik et al in La Paz, Bolivia.[21]

ADO worked very well in most of our patients (86.3%) and, in selected cases where PASP remained over 60% of the aortic pressure, we used the AMVSDO or the ASO. Despite using large devices, our incidence of LPA stenosis or descending aortic stenosis was low (overall, 2.4%). In cases where the long
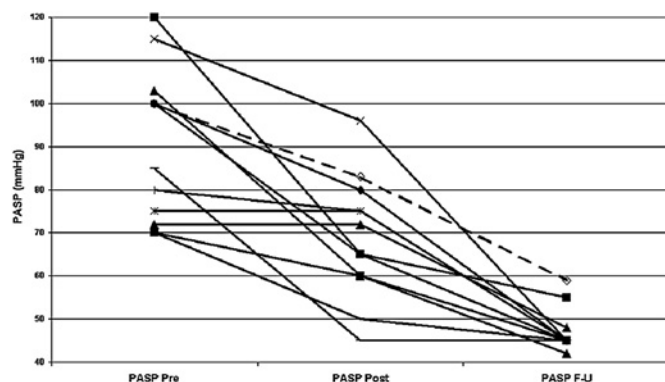
AMVSDO causes LPA stenosis, this can be resolved by changing the device to a shorter ASO, as we did in one case.

Although the use of an isolated measure of PASP could be unreliable and echo measurements of PASP are indirect, we think that when you use the same method of measurement in a series of evaluations in the same patient, it gives you a very good perspective on how this variable evolves with time.

Study limitations
Pulmonary pressures at follow-up in most cases were measured by echocardiography. Although a very good tool, it is still an indirect measure. Three years of follow-up may not be enough time to ascertain that PHT will not recur.

CONCLUSIONS
Percutaneous treatment of hypertensive PDA is safe and effective. Cases should be evaluated individually for reactive PHT with all tools we have available. ADO works well for most cases, but sometimes other devices (MVSDO or ASO) have to be used. When cases are selected adequately, pulmonary pressures decrease immediately in most of them and continue to fall with time.

REFERENCES
1. **Cambier PA,** Kirby WC, Wortham DC, et al. Percutaneous closure of the small (less than 2.5 mm) patent ductus arteriosus using coil embolization. Am J Cardiol 1992;**69**:815—16.
2. **Moore JW,** George L, Kirkpatrick SE, et al. Percutaneous closure of the small patent ductus arteriosus using occluding spring coils. J Am Coll Cardiol 1994;**23**:759—65.
3. **Hays MD,** Hoyer MH, Glasow PF. New forceps delivery technique for coil occlusion of patent ductus arteriosus. Am J Cardiol 1996;**77**:209—11.
4. **Grifka RG,** Miller MW, Frischmeyer KJ, et al. Transcatheter occlusion of patent ductus arteriosus in a Newfoundland puppy using the Gianturco-Grifka vascular occlusion device. J Vet Intern Med 1996;**10**:42—4.
5. **Berdjis F,** Moore JW. Balloon occlusion delivery technique of closure of patent ductus arteriosus. Am Heart J 1997;**133**:601—4.
6. **Ing FF,** Sommer RJ. The snare-assisted technique for transcatheter coil occlusion of moderate to large patent ductus arteriosus: immediate and intermediate results. J Am Coll Cardiol 1999;**33**:1710—18.
7. **Le TP,** Freudenthal F, Hofstetter R. Transcatheter occlusion of PDA using detachable nitinol coil (Abstract). In: Abstracts. The fourth Paediatric Interventional Cardiac Symposium (PICS-IV). Illinois, USA: Catheter Cardiovasc Interv 2000;**51**:121—9.
8. **Faella HJ,** Hijazi ZM. Closure of the patent ductus arteriosus with the Amplatzer PDA device: immediate results of the international clinical trial. Catheter Cardiovasc Interv 2000;**51**:50—4.
9. **Kumar RK,** Krishnan MN, Venugopal K, et al. Bioptome assisted simultaneous delivery of multiple coils for occlusion of the large patent ductus arteriosus. Catheter Cardiovasc Interv 2001;**54**:95—100.
10. **Ebeid MR,** Gaymes CH, Smith JC, et al. Gianturco Grifka vascular occlusion device for closure of patent ductus arteriosus. Am J Cardiol 2001;**87**:657—60, A11.
11. **Moore JH,** Schneider DJ, Dimeglio D. The Duct-Occlud Device: Design, Clinical Results, and Future Directions. J Interv Cardiol 2001;**14**:231—8.
12. **Pass RH,** Hijazi Z, Hsu DT, et al. Amplatzer patent ductus arteriosus occlusion device trial: initial and one-year results. J Am Coll Cardiol 2004;**44**:513—19.
13. **Arora R.** Transcatheter closure of patent ductus arteriosus. Expert Rev Cardiovasc Ther 2005;**3**:865—74.
14. **Kumar RK,** Anil SR, Kannan BRJ, et al. Bioptome assisted coil occlusion of moderate-large patent arterial ducts in infants and small children. Catheter Cardiovasc Interv 2004;**62**:266—71.
15. **Wang JK,** Liau CS, Huang JJ, et al. Transcatheter closure of patent ductus arteriosus using Gianturco coils in adolescents and adults. Catheter Cardiovasc Interv 2002;**55**:513—18.
16. **Arora R.** Transcatheter devices for large patent ductus arteriosus. Cardiology Today 2004;**8**:121—3.
17. **Rigby ML.** Closure of a large patent ductus arteriosus in adults: first do no harm. Heart 2007;**93**:417—18.

Figure 3 Graphic showing evolution of the pulmonary artery systolic pressure (PASP) in the 12 patients with a PASP >40 mm Hg at follow-up.

18. **Masura J,** Walsh KP, Thanopoulous B, *et al*. 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—82.

19. **Thanopoulos BD,** Tsaousis GS, Djukic M, *et al*. Transcatheter closure of high pulmonary artery pressure persistent ductus arteriosus with the Amplatzer muscular ventricular septal occluder. *Heart* 2002;**87**:260—3.

20. **Yan C,** Zhao S, Jiang S, *et al*. Transcatheter closure of patent ductus arteriosus with severe pulmonary arterial hypertension in adults. *Heart* 2007;**93**:514—18.

21. **Szkutnik M,** Menacho-Delgadillo R, Palmero-Zilveti E, *et al*. Transcatheter closure of patent ductus arteriosus among native high-altitude habitants. *Pediatr Cardiol* 2008;**29**:624—7.

22. **Nihill MR,** McNamara DG. Magnification Pulmonary Wedge Angiography in the Evaluation of Children with Congenital Heart Disease and Pulmonary Hypertension. *Circulation* 1978;**58**:1094—106.

23. **Ussia GP,** Mulè M, Caruso E, *et al*. Combined endothelin receptor antagonist and transcatheter interventional therapy of patent ductus arteriosus with severe pulmonary artery hypertension. *Int J Cardiol* 2007;**116**:427—9.