

# Specific Aspects of Percutaneous Closure of Patent Ductus Arteriosus in Adult Patients

Francisco Chamié<sup>1</sup>, Luiz Carlos Simões<sup>2</sup>, Daniel Chamié<sup>3</sup>, Renata Mattos<sup>4</sup>, Pedro de Castro<sup>5</sup>

## ABSTRACT

**Background:** Percutaneous closure of patent ductus arteriosus is a safe, effective and easily reproducible method. Adult patent ductus arteriosus may present degenerative changes that increase surgical risk and favor percutaneous closure. We report a single center experience with percutaneous closure of patent ductus arteriosus in adults and highlight specific technical aspects of this procedure. **Methods:** The records of patients  $\geq 20$  years of age submitted to patent ductus arteriosus closure between March 2001 and December 2012 were evaluated. Cases were selected by transthoracic echocardiography. **Results:** We analyzed 33 patients, most of them females (72.7%), with mean age of  $30.9 \pm 12.8$  years and weight of  $63.9 \pm 12.4$  kg. Only 3 patients had symptoms and 2 had associated congenital defects, treated in the same procedure. Implants were possible in all cases. One Flipper Coil, 19 Amplatzer™ Duct Occluders type I, 3 Amplatzer™ Duct Occluders type II, 8 Cera™ PDA Occluders and 2 Muscular VSD devices were used. Sizing balloons were used in 5 cases. Mean follow-up was  $46.1 \pm 42.9$  months and was obtained in 84.9% of patients. Two cases presented residual shunts immediately after the procedure. There were no major complications or deaths. **Conclusions:** Percutaneous closure of adult patent ductus arteriosus may be performed safely and effectively with the devices used in this study.

**DESCRIPTORS:** Ductus arteriosus, patent. Prostheses and implants. Heart defects, congenital. Adult.

## RESUMO

### Aspectos Particulares da Oclusão Percutânea do Canal Arterial do Adulto

**Introdução:** A oclusão percutânea do canal arterial é um método seguro, eficaz e facilmente reproduzível. O canal arterial do adulto pode apresentar alterações degenerativas, que aumentam o risco da cirurgia e favorecem o procedimento percutâneo. Descrevemos a experiência de um centro único com a oclusão percutânea do canal arterial em adultos e destacamos aspectos técnicos particulares desse procedimento. **Métodos:** Revisamos os registros de todos os pacientes  $> 20$  anos de idade submetidos a oclusão do canal arterial entre março de 2001 e dezembro de 2012. Os casos foram selecionados por ecocardiografia transtorácica. **Resultados:** Analisamos 33 pacientes, a maioria do sexo feminino (72,7%), com médias de idade de  $30,9 \pm 12,8$  anos e de peso de  $63,9 \pm 12,4$  kg. Somente 3 pacientes tinham sintomas e 2 pacientes apresentaram defeitos associados, tratados no mesmo procedimento. Os implantes foram possíveis em todos os casos. Foram utilizadas 1 mola Flipper, 19 próteses Amplatzer™ Duct Occluder tipo I, 3 próteses Amplatzer™ Duct Occluder tipo II, 8 próteses Cera™ PDA Occluder e 2 próteses para comunicação interventricular muscular. O uso de balões medidores foi necessário em 5 casos. O seguimento médio foi de  $46,1 \pm 42,9$  meses e foi obtido em 84,9% dos pacientes. Dois casos apresentaram shunt residual imediatamente após o procedimento. Não ocorreram complicações maiores ou óbitos. **Conclusões:** A oclusão percutânea dos canais dos adultos com os dispositivos empregados pode ser realizada com segurança e eficácia.

**DESCRITORES:** Permeabilidade do canal arterial. Próteses e implantes. Cardiopatias congênitas. Adulto.

<sup>1</sup> Master. Cardiologist. INTERCAT – Interventional Cardiology. Rio de Janeiro, RJ, Brazil.

<sup>2</sup> Master. Cardiologist. INTERCAT – Interventional Cardiology. Rio de Janeiro, RJ, Brazil.

<sup>3</sup> Cardiologist. INTERCAT – Interventional Cardiology. Rio de Janeiro, RJ, Brazil.

<sup>4</sup> Cardiologist. INTERCAT – Interventional Cardiology. Rio de Janeiro, RJ, Brazil.

<sup>5</sup> Trainee. INTERCAT – Interventional Cardiology. Rio de Janeiro, RJ, Brazil.

**Correspondence to:** Francisco Chamié. Rua Ministro Armando de Alencar, 16 – ap. 201 – Lagoa – Rio de Janeiro, RJ, Brazil – CEP 22471-080  
E-mail: chamief@gmail.com

Received on: 1/7/2013 • Accepted on: 3/4/2013

**P**ercutaneous closure of ductus arteriosus is, currently, the therapeutic choice in all centers capable of performing procedures in interventional cardiology.<sup>1-7</sup> Although it is a relatively simple procedure when performed in children weighing > 5 kg, some characteristic features are found in adult ductus arteriosus. Anatomical and morphological changes may be present, such as aneurysms, calcifications, diverticula, and friability of the ductal tissue, which increase the surgical risk and favour the option of transcatheter closure.<sup>8-14</sup> Late complications are also reported in the evolution of untreated ductus arteriosus in adults, especially endarteritis, arrhythmias, ventricular dysfunction, and progressive pulmonary arterial hypertension.<sup>15-17</sup>

The transcatheter closure of adult patent ductus arteriosus (PDA) exhibits a few difficulties and requires specific care.<sup>3,8,18</sup> This study reports the group's experience with percutaneous closure of PDA in adults, discussing available options and techniques in detail.

## METHOD

### Study design

This was a retrospective single-arm study, carried out in a single center (Interventional Cardiology – INTERCAT, Rio de Janeiro, RJ, Brazil), which included all adult patients undergoing PDA closure with different devices, between March 2001 and December 2012.

### Patient selection

Records of all patients  $\geq 20$  years of age, with ductus arteriosus and indication for percutaneous closure without associated defects that required surgical correction were reviewed. The cases were selected by means of transthoracic echocardiography with colour flow mapping. The dimensions and morphology of the defects were not used as exclusion criteria.

### Implantation techniques

All patients received general anesthesia and underwent tracheal intubation. Sodium heparin at a dose of 5,000 U plus 2 g of intravenous cefazolin, as antibiotic prophylaxis, were administered. The femoral artery and vein were punctured, and left and right catheterizations were performed with pressure recordings. Oximetry was performed only in cases where it was necessary to study the pulmonary vascular reactivity.

Descending thoracic aorta angiograms were obtained in the right anterior oblique and left lateral view using a 5F pigtail catheter. Angiograms were analyzed regarding shape, according to the classification of Krichenko et al.,<sup>19</sup> and the dimensions of the ductus arteriosus, with special emphasis on its smallest diameter. Some ductae showed significant constriction in the pulmonary end, and it was decided

to attribute the value of 1 mm to its smallest diameter. In this case, when it was impossible to cross them by the antegrade route, they were accessed via arterial route, and the rigid exchange guide wire was captured with a 15 mm or 20 mm catheter loop in the main pulmonary artery and externalized through the venous sheath. Subsequently, the long sheath compatible with the selected device was advanced through the vein to the descending aorta, and the device was implanted in the usual way.<sup>20</sup>

In cases where the angiograms were unable to outline the ductus for morphological analysis and measurement, a partially insufflate sizing balloon, with contrast diluted in saline solution, was introduced intravenously into the descending aorta over the guidewire, to occlude the interatrial septal defect, allowing the contrast to be ejected into the pulmonary artery through the ductus arteriosus. The frames were reviewed in slow motion to verify the exact time of passage through the ductus, making it possible to outline its shape, safely measuring its smaller diameter.<sup>20</sup> The different prostheses used were selected with diameters at least 2 mm larger than the smallest diameter of the ductus arteriosus, according to the protocols of the respective implant manufacturers, as previously reported.<sup>20-23</sup>

Follow-up was performed by transthoracic echocardiography, seeking residual flows<sup>24</sup> and obstructions in the descending aorta and left pulmonary branch on the day following implantation, one month, three months, and six months after the procedure, and annually thereafter. Prophylaxis for infective endocarditis was indicated for six months following the implant.

### Statistical Analysis

Continuous variables were expressed as means and standard deviations, and categorical variables as numbers and percentages. This study aimed to demonstrate the group's experience with the closure of the ductus arteriosus in adult patients, and thus, comparisons between devices were not performed.

## RESULTS

The records of 33 patients submitted to percutaneous closure of patent ductus arteriosus between March 2001 and December 2012 were retrospectively analyzed, of whom 72.7% were females. Ages ranged from 20 to 66 years ( $30.9 \pm 12.8$  years) and weight from 38 kg to 92 kg ( $63.9 \pm 12.4$  kg). Three patients complained of dyspnoea on exertion (patients 5-RSS, 15-LEF, and 25-JOC), and two patients (10-SCFA and 30-LCMM) had severe pulmonary arterial hypertension and were categorized in New York Heart Association (NYHA) functional class III. One patient (33-GOR) also presented an atrial septal defect that was closed with an 18-mm Cera<sup>TM</sup> prosthesis (Lifetech – Shenzhen, China) in the same procedure. Another patient (13-NNFO) had

mesocardia with left pulmonary sequestration, and one patient was deaf-mute (15-LEF).

The smallest ductus diameters varied from 1 mm to 10 mm ( $4.9 \pm 2.8$  mm). Regarding the morphology, the assessed ductae were type A in 76%, type C in

9%, type D in 6%, and type E in 9%. None showed significant tissue degeneration or calcification (Table 1). The implantation was feasible in all cases. One Flipper coil 5PDA5 (Cook Medical Inc., Bloomington, United States), 19 Amplatzer™ Duct Occluders type I (ADO I; AGA – Golden Valley, United States) (three 6-4

**Table**  
**Study population**

Number	Identification	Gender	Age (years)	Morphologic type	Diameter <sup>a</sup> (mm)	PSAP (mmHg)	Prosthesis	Immediate result
1	LER	F	20	E	1	22	Mola Flipper 5PDA5	Closed
2	RRMF	F	38	A	4.5	28	ADO I 8-6	Closed
3	IRC	F	22	A	3.5	32	ADO I 10-8	Closed
4	P8	F	21	A	2.5	21	ADO I 6-4	Closed
5	RSS	F	24	A	2	24	ADO I 8-6	Closed
6	FBS	M	42	A	8	22	ADO I 12-10	Closed
7	MBM	F	22	C	4	22	ADO I 10-8	Closed
8	MGSS	F	42	A	4	32	ADO I 12-10	Closed
9	PEPS	F	30	A	5	33	ADO I 10-8	Closed
10	SCFA	F	50	A	8	85	AMVSD 12	Closed
11	MNM	F	21	A	2	36	ADO I 6-4	Closed
12	AOG	F	20	A	10	31	ADO I 12-10	Closed
13	NNFO	F	21	A	1	28	ADO I 6-4	Closed
14	VPO	M	22	E	3.5	27	ADO I 10-8	Closed
15	LEF	M	30	A	8	30	ADO I 12-10	Minimal shunt
16	FAAE	F	23	A	6	17	ADO I 12-10	Minimal shunt
17	NMO	F	66	D	6	18	ADO I 12-10	Closed
18	JU	F	62	A	6	34	ADO I 12-10	Closed
19	JJMA	M	24	A	6	43	ADO I 12-10	Closed
20	VS	F	32	A	2.5	23	ADO I 8-6	Closed
21	IFP	M	29	A	6	32	ADO I 12-10	Closed
22	AVA	F	21	A	3	24	ADO II 6-4	Closed
23	APNS	F	34	A	4	22	ADO II 5-4	Closed
24	ECAS	F	44	A	3.5	35	ADO II 5-4	Closed
25	JOC	M	27	A	6	42	CPO 12-10	Closed
26	G88	M	20	E	1	39	CPO 6-4	Closed
27	LHL	F	20	A	1	39	CPO 6-4	Closed
28	SLRM	M	33	A	8	20	CPO 12-10	Closed
29	LSG	F	30	C	7	42	CPO 12-10	Closed
30	LCMM	F	35	C	10	95	CMVSD 16	Closed
31	MFP	F	43	A	6	31	CPO 12-10	Closed
32	LPCS	M	23	A	1	23	CPO 8-6	Closed
33	GOR	F	29	D	3	24	CPO 8-6	Closed

<sup>a</sup> Smallest diameter observed.

PASP, pulmonary artery systolic pressure; F, Female; ADO, Amplatzer™ Duct Occluder; M, Male; AMVSD; CPO, Cera™ PDA Occluder; CMVSD, Cera™ Muscular VSD Occluder.

prostheses, three 8-6 prostheses, five 10-8 prostheses, and eight 12-10 prostheses), three ADO II prostheses (two 5-4 prostheses and one 6-4 prosthesis), eight Cera™ PDA Occluders (CPO; two 6-4 prostheses, two 8-6 prostheses, and four 12-10 prostheses), one 12-mm Amplatzer™ Muscular VSD prosthesis Occluder (AMVSD) and one 16-mm Cera™ Muscular VSD prosthesis Occluder (CMVSD). Angiography was not capable of clearly delineating the shape and size of the ductus arteriosus in five cases: four type A, measuring 3.3 mm, 6 mm, 6 mm, and 8 mm, and one type C, which measured 10 mm. In these cases, 24-mm AGA sizing balloons were used in ductus type A and a 30-40 mm PTS sizing balloon (Numed, Hopkinton, USA) was used in type C ductus, which is larger (Figure 1).

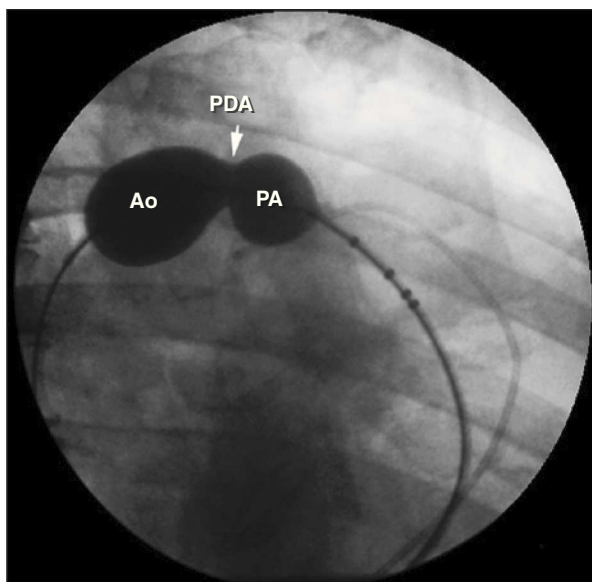
The prevalence of large calibre ductus arteriosus was a frequent finding in adults, but the smaller diameter of the ductus arteriosus showed no correlation with systolic pressure in the pulmonary artery. Pulmonary systolic pressure ranged from 17 mmHg to 95 mmHg ( $33.8 \pm 17.6$  mmHg) and was  $> 30$  mmHg in 51.5% of patients. One patient (30-LCMM) with severe pulmonary arterial hypertension and pulmonary vascular resistance of 4.1 Wood U had multiple VSD, also known as “Swiss cheese” ventricular septum, associated with a 10-mm type C ductus arteriosus, which was closed using a 16-mm CMVSD prosthesis (Figure 2). Two other muscular VSDs were closed in the same procedure. In a second session, three more sizeable muscular VSDs were closed, with a single

restrictive VSD remaining open. After a complicated evolution, immediately after the second procedure, the patient is in NYHA functional class II, undergoing treatment protocol for pulmonary arterial hypertension with sildenafil and bosentan. Another patient (10-SCFA) with pulmonary arterial hypertension showed significant atrial fibrillation with low ventricular response. The PDA was successfully closed with a 12-mm AMVSD prosthesis, and she presented severe hemodynamic instability immediately after the procedure, requiring temporary pacemaker implantation, followed by a permanent pacemaker. The patient was discharged in good condition with a fully closed PDA, and is in good clinical condition seven years later.

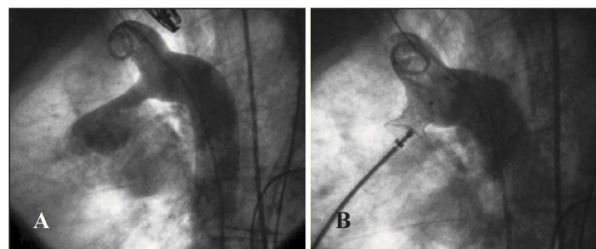
Immediately after the procedure, only two patients had minimal residual shunt, with no gushing inside the devices (ADO I 12-10 prostheses in both cases), which were completely closed in the transthoracic echocardiography performed in the first postoperative month. Follow-up was achieved in 84.9% of patients, and ranged from three to 132 months ( $46.1 \pm 42.9$  months). No case had a gradient in the descending aorta or in the left branch of the pulmonary artery. The only complication was a right femoral pseudoaneurysm in a 62-year-old patient (18-JU), resolved by local compression through the ultrasound transducer; the hematoma was reabsorbed by applying local heat and anti-inflammatory drug use. There were no deaths in the present series.

## DISCUSSION

The percutaneous closure of adult PDA has some aspects that differentiate it from procedures in children. The correct viewing of the ductus through conventional angiography is sometimes extremely difficult. The high flow through the defect, associated to the large diameter of the adult aorta, may prevent its measurement by conventional angiography. In such cases, the solution is to use sizing balloons, which, similar to the evaluation of the stretched diameter of septal defects, slightly distend the ductus, and during the passage from the descending aorta through the ductus to the pulmonary



**Figure 1** – Ductus arteriosus type A, of large calibre (8 mm), outlined with the help of a 24-mm AGA sizing balloon. The mark in the balloon corresponds to the smallest diameter in the ductus arteriosus, in the pulmonary end. Ao, aorta; PA, pulmonary artery; PDA, patent ductus arteriosus.

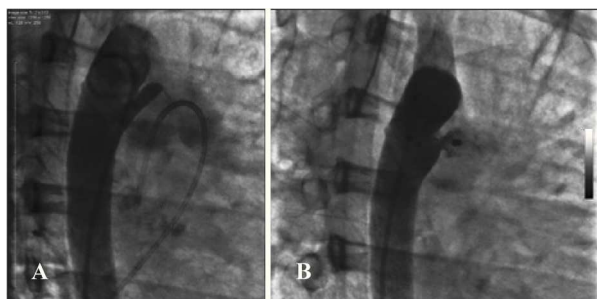


**Figure 2** – In **A**, descending aortography in lateral view showing tubular ductus arteriosus type C, measuring 10 mm. In **B**, occlusion with 16-mm Cera™ Muscular VSD Occluder prosthesis still connected to the delivery catheter. The aortography shows no residual shunt.

trunk, accurately outline the defect diameter, allowing the morphological analysis and accurate measurement so that the appropriate device can be chosen. In the present study, this technique was necessary in five cases, and was successful in all.

Another problem to be addressed is that the natural elasticity of the ductus arteriosus is underestimated by angiography, which draws its outline only at the moment of contrast injection, of but is not capable of assessing its distended diameter. In some cases, the ductus arteriosus appeared too small or to have a severe narrowing at its pulmonary end, but it was crossed by a diagnostic catheter, without any difficulty, allowing for the use of larger-calibre prostheses than initially estimated (Figure 3). The stringent oversizing of devices increases procedural safety, preventing embolization. It is of utmost importance that the ADO I and CPO devices are positioned so that they are compressed in their middle portion by the smallest diameter of the ductus arteriosus, leaving the pulmonary end slightly dilated, preventing slippage of the prosthesis into the descending aorta.

Although some patients had large-calibre ductus arteriosus, pulmonary arterial pressure was not comparatively high in most cases. This might have been due to the length of the ductus, which attenuates the transmission of systemic pressure to the pulmonary artery. In cases with pulmonary hypertension, increase in the systolic pulmonary pressure was considered mild ( $< 1/3$  of the systemic pressure); it was  $> 40$  mm Hg in five cases, of which only two had pressure  $> 75\%$  of systemic levels. In both cases in which the pulmonary arterial pressure was very high, prostheses were used to occlude the muscular VSD (12 mm AMVSD and 16-mm CMVSD) for safety reasons. Sizing balloons were also used in both cases (24 mm AGA and 30-40 mm PTS).<sup>25-27</sup>



**Figure 3** – In **A**, descending aortography in right anterior oblique view, showing ductus arteriosus type E with significant constriction in the pulmonary end. Note the gush of contrast material opacifying the pulmonary trunk and branches. Although the stenosis at the pulmonary end appeared extremely constricted, the ductus was crossed without difficulty with the multipurpose catheter (at the right of the image, positioned in the pulmonary artery), demonstrating the high elasticity of the defect, underestimated by the angiographic image. In **B**, the fully closed ductus with a Cera™ PDA Occluder prosthesis.

## CONCLUSIONS

The percutaneous closure of the ductus arteriosus in adults can be performed quite safely and effectively using traditional techniques and available devices. When the analysis of the ductus arteriosus shape and size cannot be performed satisfactorily by conventional angiography, the use of a sizing balloon is a strategy that can be used to overcome this limitation.

## CONFLICT OF INTEREST

Chamié Francisco is a consultant and proctor of Boynton (Porto Alegre, RS, Brazil). The other authors declare no conflicts of interest.

## REFERENCES

1. Arora R, Sengupta PP, Thakur AK, Mehta V, Trehan V. Pediatric Interventional Cardiac Symposium (PICS-VI). Device closure of patent ductus arteriosus. *J Intervent Cardiol*. 2003;16(5):385-91.
2. Brunetti MA, Ringel RN, Owada C, Coulson J, Jennings JM, Hoyer MH, et al. Percutaneous closure of patent ductus arteriosus: a multiinstitutional registry comparing multiple devices. *Catheter Cardiovasc Interv*. 2010;76(5):696-702.
3. Meadows J, Landzberg M. Advances in transcatheter interventions in adults with congenital heart disease. *Progr Cardiovasc Dis*. 2011;53(4):265-73.
4. Pass RH, Hijazi ZM, Hsu DT, Lewis V, Hellenbrand WE. Multicenter USA Amplatzer patent ductus arteriosus occlusion device trial. *J Am Coll Cardiol*. 2004;44(3):513-9.
5. Pedra CAC, Esteves CA, Braga SLN, Kambara A, Fontes VF. Oclusão percutânea do canal arterial: estado da arte. *Rev Bras Cardiol Invasiva*. 1997;5(1):22-35.
6. Simoes LC, Pedra CAC, Esteves CA, Camargo R, Braga SLN, Loureiro P, et al. Fechamento percutâneo do canal arterial com a prótese Amplatzer: experiência no Brasil. *Arq Bras Cardiol*. 2001;77(7):520-31.
7. Sun WF, Dong ZF, Gong K, Zhang GP, Cui T, Xia YD, et al. Transcatheter closure with use of the SHSMA occluder. *Tex Heart Inst*. 2010;37(5):531-7.
8. Gamboa R, Rios-Mendez RE, Mollon FP, Arroyo GM. Percutaneous closure of patent ductus arteriosus in adults using different devices. *Rev Esp Cardiol*. 2010;63(6):726-9.
9. Kataoka G, Nakamura Y, Tagusari O, Nagashima M. Adult patent ductus arteriosus closure with a pedicled pulmonary arterial patch. *Ann Thorac Surg*. 2010;90(3):346-e48.
10. Li FQ, Sun L, Hu J, Pan H. A safe technique for closure of patent ductus arteriosus in adult patients. *Surg Innov*. 2010;17(3):195-7.
11. Omari BO, Shapiro S, Ginzton L, Milliken JC, Baumgartner FJ. Closure of short, wide patent ductus arteriosus with cardiopulmonary by-pass and balloon occlusion. *Ann Thorac Surg*. 1998;66(1):277-8.
12. Sasaki B, Shimizu S, Ohno N, Tsukuda K, Fujiwara K. Open stent grafting for adult patent ductus arteriosus with a distal aortic arch aneurysm. *Gen Thorac Cardiovasc Surg*. 2011;59(12):806-8.
13. Toda R, Moriyama Y, Yamashita M, Iguro Y, Matsumoto H, Yotsumoto G. Operation for adult patent ductus arteriosus using cardiopulmonary by-pass. *Ann Thorac Surg*. 2000;70(6):1935-8.
14. Yamabe K, Shimizu H, Nemoto A, Yozu R. Endovascular aortic repair of patent ductus arteriosus in an adult patient. *Interact Cardiovasc Thorac Surg*. 2012;14(2):217-9.

15. Berko NS, Haramati L. Simple cardiac shunts in adults. *Semin Roentgenol.* 2012;47(3):277-88.
16. Gatzoulis MA. Patent arterial duct. In: Gatzoulis MA, Swan L, Therrien J, Pantely GA, editors. *Adult congenital heart disease: a practical guide.* London (UK): Blackwell; 2005. p. 145-52.
17. Schneider DJ. The patent ductus arteriosus in term infants, children and adults. *Semin Perinatol.* 2012;36(2):146-53.
18. Akagi T. Catheter intervention for adult patients with congenital heart disease. *J Cardiol.* 2012;60(3):151-9.
19. Krichenko A, Benson LN, Burrows P, Möes CAF, McLaughlin P, Freedom RM. Angiographic classification of the isolated persistent ductus arteriosus and implications for percutaneous catheter occlusion. *Am J Cardiol.* 1989;63(12):877-80.
20. Chamié F, Chamié D, Ramos S. Oclusão percutânea dos canais arteriais com prótese Amplatzer. *Rev Bras Cardiol Invasiva.* 2007;15(1):15-24.
21. Chamie F, Simoes LC, Chamie D, Mattos R. Fechamento de canais arteriais com dispositivo CERA PDA Occluder: mais uma boa opção na caixa de ferramentas. *Rev Bras Cardiol Invasiva.* 2012;20(1):77-81.
22. Chamié F, Pereira SJ, Sbaffi F, Serra Junior A, Athayde JG. Fechamento de canal arterial com molas de Gianturco. *Arq Bras Cardiol.* 1996;67(1):23-7.
23. Queiroz FJAC, Simoes LC, Queiroz DSC, Ramos S, Silva JFA, Mattos R. Tratamento percutâneo do canal arterial com a prótese Amplatzer Duct Occluder II (ADO II): nova opção para um antigo defeito. *Rev Bras Cardiol Invasiva.* 2010;18(2):204-11.
24. Celiker A, Aypar EL, Karagoz T, Dilber E, Ceviz N. Transcatheter closure of patent ductus arteriosus with Nit-Occlud coils. *Catheter Cardiovasc Interv.* 2005;65(4):569-76.
25. Bialkowski J, Glowacki J, Zabal C, Garcia-Montes A, Bermudez-Canete R, Flores-Arizmendi R, et al. Patent ductus arteriosus at low and high altitudes: anatomical and haemodynamic features and their implications for transcatheter closure. *J Kardiol Pol.* 2011;69(5):431-6.
26. Thanopoulos BD, Tsaousis GS, Djukic M, 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(3):260-3.
27. Zabal C, Garcia-Montes A, Buendia-Hernandez A, Calderon-Colmenero J, Patino-Bahena E, Juanico-Henriquez A, et al. Percutaneous closure of hypertensive ductus arteriosus. *Heart.* 2010;96(8):625-9.