Percutaneous Balloon Angioplasty for Severe Native Aortic Coarctation in Young Infants Less Than 6 Months: Medium- to Long-term Follow-up

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Abstract

Background: Although balloon angioplasty (BA) has been performed for more than 20 years, its use as a treatment for native coarctation of the aorta (CoA) during childhood, especially in young infants, remains controversial. This study aimed to assess the effects and potential role of percutaneous transcatheter BA for native CoA as an alternative therapy to surgical repair in young infants.

Methods: The 37 patients aged from 6 days to 6 months with severe CoA in congestive heart failure or circulatory shock were admitted for BA. Patient's weight ranged from 2.4 to 6.1 kg. All 37 patients were experiencing cardiac dysfunction, and eight patients were in cardiac shock with severe metabolic acidosis. Eleven patients had an isolated CoA, whereas the others had a CoA associated with other cardiac malformations. Cardiac catheterization and aortic angiography were performed under general anesthesia with intubation. Transfemoral arterial approaches were used for the BA. The size of the balloon ranged from 3 mm × 20 mm to 8 mm × 20 mm, and a coronary artery balloon catheter was preferred over a regular peripheral vascular balloon catheter.

Results: The femoral artery was successfully punctured in all but one patient, with that patient undergoing a carotid artery puncture**.** The systolic peak pressure gradient (PG) across the coarctation was 41.0 ± 16.0 mmHg (range 13–76 mmHg). The mean diameter of the narrowest coarctation site was 1.7 ± 0.6 mm (range 0.5–2.8 mm). All patients had successful dilation; the PG significantly decreased to 13.0 ± 11.0 mmHg (range 0–40 mmHg), and the diameter of coarctation significantly improved to 3.8 ± 0.9 mm (range 2.5–5.3 mm). No intraoperative complications occurred for any patients. However, in one case that underwent a carotid artery puncture, a giant aneurysm formed at the puncture site and required surgical repair. The following observations were made during the follow-up period from 6-month to 7-year: (1) The PG across the coarctation measured by echocardiography further decreased or remained stable in 31 cases. The remaining six patients, whose PGs gradually increased, required a second dilation. No patient required further surgery because of a CoA; (2) in two cases, an aortic aneurysm was found with an angiogram performed immediately postdilatation and disappeared at 18 and 12 months of age, respectively; (3) tricuspid regurgitation and pulmonary hypertension improved in all patients; (4) all patients were doing well and were asymptomatic.

Conclusions: Percutaneous BA is a relatively safe and effective treatment for severe native CoA in young infants, and should be considered a valid alternative to surgery because of its good outcome and less trauma and fewer complications than surgery.

Key words: Native Aortic Coarctation; Percutaneous Balloon Angioplasty; Young Infants

Introduction

Native coarctation of the aorta (CoA) accounts for 5%–7% of all congenital heart diseases. Open surgical treatment was the only choice until balloon angioplasty (BA) treatment was introduced as an alternative therapy for CoA in the 1980s. In addition to the late complications of restenosis and aneurysm formation, surgical repair has some major immediate complications, such as spinal cord injury, arrhythmia with cardiopulmonary arrest, stroke, and phrenic or laryngeal nerve injury.[1] Although BA is a less invasive procedure and has been performed for more than 20 years, its use as a treatment for native CoA during childhood, especially in young infants, remains controversial. Many studies have reported a high incidence of restenosis and aneurysm formation when performing BA in neonates and young infants (age <3 months).[2-6] This study reported our results when using BA for native coarctation in infants <6 months of age to assess its effects and potential role as an alternative therapy to surgical repair in young infants.

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Methods

Patients

This work was a retrospective study of 37 young infants with discrete native coarctation who underwent BA at Pediatric Heart Center, Children's Hospital of Fudan University, from June 2006 to June 2012. Twenty-eight patients were male and nine were female. The age ranged from 6 days to 6 months (mean 66 ± 45 days) and body weight ranged from 2.4 to 6.1 kg (mean 4.3 ± 1.0 kg). Twenty-eight of these 37 patients were under 3 months of age. All patients were examined clinically and underwent comprehensive transthoracic echocardiography (TTE), a 12-lead electrocardiogram (ECG), and chest radiography. The diagnosis of a discrete CoA with or without mild aortic arch hypoplasia was confirmed by computed tomography angiography (CTA).

Clinically, all 37 patients presented with heart failure, and eight patients were in cardiac shock with severe metabolic acidosis that required intubation prior to performing the procedure. The left ventricle end-diastolic dimension was enlarged, and the left ventricle ejection fraction was lower than normal measured by TTE [Table 1]. All patients presented with moderate to severe tricuspid regurgitation and pulmonary hypertension. Among these 37 patients, 11 had an isolated CoA, including four patients diagnosed with dilated cardiomyopathy, endocardial fibroelastosis and left ventricular noncompaction, before being referred to our hospital. The other 26 patients presented with other cardiac malformations, including ventricular septal defect (VSD) in 18, atrial septal defect in four, patent ductus arteriosus in four, bicuspid aortic valves with or without mild stenosis in 6, mild mitral stenosis in two, Shone syndrome in one and absent right pulmonary artery with left patent ductus arteriosus in one. Two patients were also associated with noncardiac malformations, one had hypospadias and right inguinal hernia, and another had immune deficiency.

Balloon angioplasty was indicated in infants younger than 6 months of age if the following conditions were met:[8,9] (1) The presence of congestive heart failure or circulatory shock; (2) a lowered or absent femoral pulse with a systolic pressure gradient (PG) across the coarctation that exceeded 20 mmHg as measured by TTE; (3) a discrete CoA with or without mild aortic arch hypoplasia. Patients with a significant hypoplastic aortic arch with a transverse arch or aortic isthmus diameter of <50% of the descending aorta were excluded.[10] For patients with a CoA and a nonrestrictive VSD, balloon dilation was first performed in the cardiac catheterization laboratory, and subsequently transferred to the operating room to surgically repair the VSD. If the VSD appeared restrictive, only balloon dilation was performed. If the patient had a CoA and a large patent ductus arteriosus (PDA) that needed to be closed, surgical repair was recommended in one stage irrespective of other cardiac anomalies.

Angioplasty procedure

After informed consent was obtained from the patients' parents, balloon dilation was performed. Catheterization and angioplasty were performed under general anesthesia using a retrograde femoral arterial approach in all patients except for one who underwent a carotid artery puncture due to a failed femoral puncture. Radial arterial pressure was monitored during the procedure. A 4 French introducer sheath was initially used and changed during the procedure according to balloon size, with the largest sheath being 5 French. A 4 French catheter with end and side holes was placed using a retrograde approach, and the pressures of the ascending and descending aorta were measured. Biplanar angiography was performed before and after the angioplasty in straight frontal and lateral projections. The balloon catheters were inserted and positioned in the narrowest site over a floppy-tip guide wire. The patients were intravenously administered 100 IU/kg of heparin after vascular access was achieved and were given more when necessary based on the activated clotting time (ACT) value. The target ACT value during the procedure exceeded 200 s. Associated cardiac malformations were diagnosed during the procedure if present.

The initial diameter of the balloon for the angioplasty was equal to or 1–2 mm greater than the diameter of the aortic arch at or proximal to the level of the left subclavian artery, and did not exceed the diameter of the aorta at the diaphragm [Figure 1a]. The balloon size ranged from 3 mm to 8 mm, and coronary balloons (3–6 mm) and regular Cordis balloons (6–8 mm) were used. The balloon was inflated 2–3 times under fluoroscopic guidance for each patient under the pressure stated by the manufacturer. If a residual waist was evident at the coarctation site, the next larger balloon by 1–2 mm was selected to dilate the coarctation within the above guidelines. The balloon dilation was considered successful if the peak systolic PG across the coarctation site was <20 mmHg or decreased by more than 50% and the coarcted segment increased in diameter by more than 50%.

Associated procedure

In one case with an absent right pulmonary artery and PDA, the PDA was occluded with an Amplatzer occluder (AGA company, USA) during the BA.

Table 1: The values of LVEDD and LVEF measured by echocardiography before BA (mean ± SD)

Ages	LVEDD (mm)	Reference value (mm)[7]	LVEF (%)	Reference value (%)[7]
0–28 days (n = 10)	21.30 ± 3.23	18.96 ± 1.58	53.00 ± 8.74	69.21 ± 7.13
29 days to 3 months (n = 18)	24.33 ± 3.88	21.18 ± 1.51	61.81 ± 9.34	73.08 ± 4.91
> 3–6 months (n = 9)	27.11 ± 1.59	23.00 ± 1.86	54.00 ± 12.18	74.14 ± 4.72

LVEDD: Left ventricle end-diastolic dimension; LVEF: Left ventricle ejection fraction; BA: Balloon angioplasty.

Follow-up

In addition to the clinical evaluation, TTE was performed prior to discharge, at 1, 3, 6, and 12 months, and annually thereafter. A CTA was performed if significant restenosis of the aorta or aneurysm formation was evident on the TTE.

Statistical analysis

The data were expressed as the means ± standard deviation (SD). The pre- and post-dilation mean values of the peak-to-peak systolic ascending to descending aorta PG and diameter of coarctation were analyzed with a paired *t*-test. Logistic regression analysis was performed to analyze the risk factors of re-CoA. An odds ratio (*OR*) was used to compare the relative risks. And a standard error was used to compute the statistic data. A Kapaln–Meier curve was used to show the re-intervention free probabilities. All these statistical studies were performed by SPSS 16.0 for Windows (SPSS Inc., Chicago, IL, USA), and a $P < 0.05$ was considered as statistically significant.

Results

Balloon angioplasty

Two sequential balloon dilations were performed in four patients, and one balloon dilation was performed in the other 33 patients. The mean value of the peak-to-peak systolic ascending to descending aorta PG significantly decreased from 41.0 ± 16.0 mmHg (range 13–76 mmHg) to 13.0 ± 11.0 mmHg (range 0–40 mmHg) ($P < 0.001$) after balloon dilation. The mean coarctation diameter significantly increased from 1.7 ± 0.6 mm (0.5–2.8 mm) to 3.8 ± 0.9 mm (2.5–5.3 mm) after balloon dilation ($P < 0.001$). In two neonates with critical coarctation and heart failure that required intubation, the catheterization gradient before BA was < 20 mmHg (13 and 17 mmHg). After BA, the PG decreased to 0, and both patients showed significant sustained clinical improvement. A residual gradient of more than 20 mmHg was considered acceptable in the presence of an increase more than two-fold in the coarctation segment diameter. The procedure was successful in all 37 patients (an example was shown in Figure 1b).

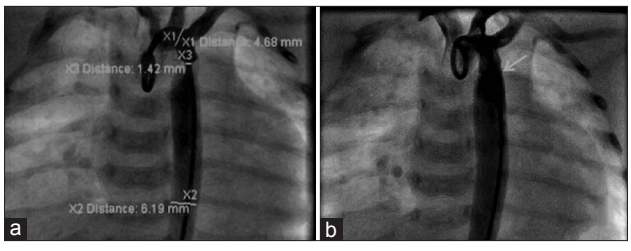

Figure 1: Aortic angiogram and measurements in a 2-month-old baby with severe discrete aortic coarctation before (a) and after (b) balloon dilation. (a) The diameter of the aortic arch (X1), the narrowest site (X3) and the descending aorta at the diaphragm (X2). The diameter of the balloon chosen for angioplasty was equal to or 1–2 mm greater than X1 and not greater than X2; thus, a 6 mm × 2 cm coronary balloon was used for this baby; (b) After balloon dilation, the aortic angiogram showed that the stenosis was completely relieved (arrow) without aneurysm formation.

Procedural complications

Intraoperative complications were absent except for the formation of two small aneurysms seen on a postdilation angiogram. After angioplasty, four patients had decreased femoral pulses, which were resolved by heparin infusion within one to four days. In one patient with a carotid artery puncture, a giant aneurysm formed at the puncture site one week after angioplasty and required surgical repair.

Follow-up

During the 6-month to 7-year follow-up period (mean 74.0 ± 56.0 months), all patients were doing well clinically and did not experience cardiac dysfunction. ECG showed a significant improvement of tricuspid regurgitation, and the seven associated unrepaired VSDs spontaneously closed in two patients and became smaller in the other five patients.

A second percutaneous BA was performed in six cases for re-CoA; the time between the two dilations ranged from 5 to 18 months. After adjustment of age and age-standardized body weight, logistic regression analysis indicated that higher predilation systolic PG across the coarctation site measured by catheter was associated with a higher risk of re-CoA ($P = 0.056$), as shown in Table 2. Re-CoA was absent during the follow-up period of the second dilation, which ranged from 5 to 60 months. Figure 2 showed the actual re-intervention-free probability curves obtained for this group of patients.

In the case with an aneurysm, an angiogram showed that the aneurysm disappeared when the patient was re-dilated for re-CoA at 18 months [Figure 3]. Another aneurysm disappeared on CTA 1 year later. One patient with a bicuspid aortic valve and supramitral valve ring with mild to moderate stenosis (Shone syndrome) underwent surgical repair of

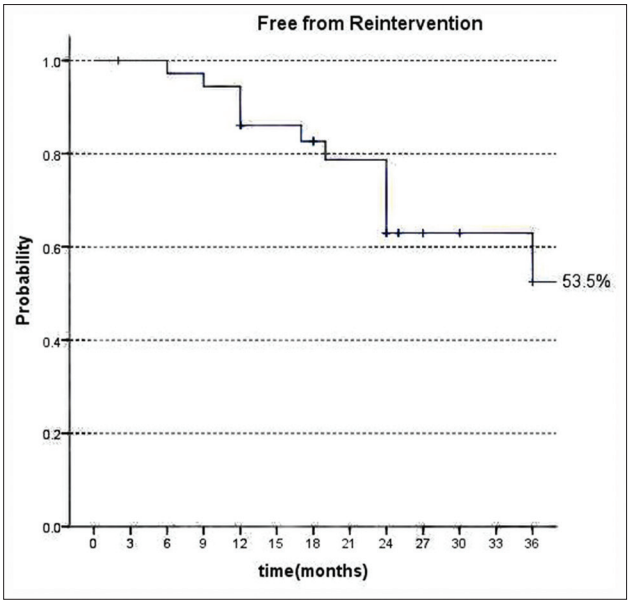

Figure 2: Re-intervention-free probability curves obtained for this group of patients.

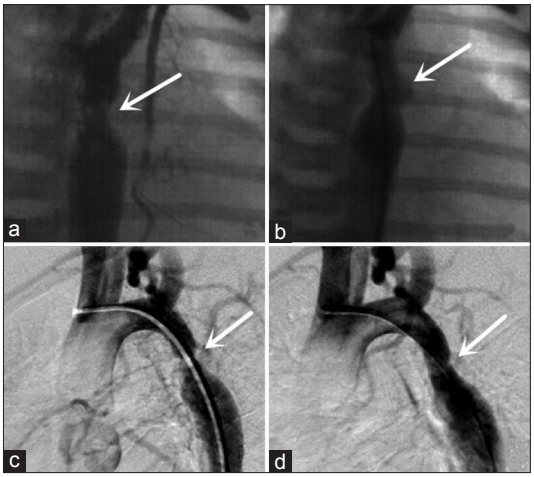

Figure 3: Aneurysm formation and regression shown on the angiogram. (a) Isolated discrete aortic coarctation in a 32-day-old baby (arrow); (b) After a 5-mm balloon dilation, the stenosis resolved, but an aneurysm formed (arrow); (c) Recoarctation of the aorta occurred, and the aneurysm regressed spontaneously over 18 months after the initial procedure (arrow); (d) Successful relief of the recoarctation without aneurysm formation by the repeat balloon angioplasty (arrow).

the mitral valve at 7 years of age. No further surgery was required for CoA in any patients.

Discussion

As reported during the past 30 years, complications such as re-CoA and aneurysm formation have been associated with both surgical repair and BA, making it difficult to draw any meaningful conclusions as to which treatment option is superior. The risk of re-CoA after surgery in young children ranges from 44% in neonates to 11% in older children,[11] and the risk of re-CoA significantly increased if the patient underwent the initial operation at 1 year of age.[12] Aortic aneurysm formation and aortic dissection occurred in about 9% of patients at or near the site of repair late after operation with aortic rupture with a lethal outcome reported in some.[12,13] Wong *et al*.[1] reviewed articles regarding treatment outcomes of patients with native CoA from 1984 to 2005. For the baseline probabilities of successful treatment, complications, re-CoA, and aneurismal formation, they found that BA was preferred over surgery as the initial treatment for native CoA in children after accounting for the preference-weighted probabilities of outcomes. In young infants, it was deemed that more research was necessary to determine which method, BA or surgical repair, yields better long-term results.

In this study, the immediate success rate was 100%, which was concordant with other studies in which the early success rate in infants aged 3 months or younger ranged from 88% to 100%.[2-4,14,15] During the 6-month to 7-year follow-up period, 6 of 37 cases (16.2%) developed restenosis and needed a second BA. From the exploratory analysis among the limited number of study subjects, we found that higher predilation systolic PG was associated with a higher risk of re-CoA after adjustment of age and body weight [Table 2]. The wider range

Table 2: Logistic regression analysis of pre-PG and re-CoA by adjusting age and body weight

Independent variables	*OR* (95% *CI*)	SE	*Z*	*P*
Age	0.42 (0.14–1.25)	0.23	−1.56	0.119
Weight	1.95 (0.60–6.31)	1.17	1.11	0.267
Pre-PG status*	10.34 (0.93–115.56)	12.74	1.90	0.056

P model = 0.016, R^2 = 0.3147. Pre-PG: Predilation systolic PG across the coarctation site measured by catheter. *Pre-PG status: 1 for pre-PG ≥ mean level, 0 for pre-PG < mean level. *CI*: Confidence interval; PG: Pressure gradient; CoA: Coarctation of the aorta; SE: Standard error; *OR*: Odds ratio.

of OR indicated that this association needs to be supported by future studies with a larger sample size. All six cases with re-CoA resolved via repeated balloon dilation without surgery. Further restenosis was not found in the subsequent 6-month to 5-year follow-up period. According to previous reports, the restenosis rate in infants younger than 12 months ranged from 25% to 71%.[2-4,14-17] In most cases (71–80%) except for a few patients requiring surgery, restenosis was treated with repeated BA with a success rate of 80–100%. BA appears to offer the best results in patients with discrete CoA and a well-developed aortic arch. Further restenosis of the discrete CoA can be successfully managed by repeat BA.

Both immediate and late aneurysm formations have been reported, and the incidence of aneurysms at the dilation site ranges from 0% to 6.5%.[18-21] Once an aneurysm is formed, it is not certain that it will require an immediate intervention because it may not change in size for a long period of time.[22] In this study, 2 of 37 patients (5.4%) developed immediate aneurismal malformations. However, both aneurysms disappeared during the 18- and 12-month follow-up periods. Late aneurysm was not found either by TTE or CTA during a 6-month to 7-year follow-up period.

This group of patients included 11 patients with a CoA associated with a large VSD who underwent surgical repair on the same day or within 1 week. Although one-stage repair of the coarctation with VSD can be performed with low risk at an early age, it is still accompanied by a risk of complications, such as phrenic nerve palsy, delayed sternal closure, and wound infection. In our heart center, repair of VSD and BA of CoA are performed separately. As such, complications that can be associated with coarctation repair, such as spinal cord injury, hemorrhage, phrenic or laryngeal nerve injury, or chylothorax, did not occur. None of the patients died, including the ones with severe heart dysfunction.

For low body weight neonates, we preferred a coronary balloon because of its low profile and small sheath.[10] A smaller balloon was used in our procedure to avoid aneurysm formation and artery complications, and a second dilation at an older age, if necessary, is much safer and more easily accepted by parents. In this group of patients, the angioplasty residual gradient was intentionally left at 32 mmHg and 40 mmHg in two infants (the PG before BA was 71 mmHg and 76 mmHg) with a body weight <5 kg for future repeat BA 6 months and 8 months later.

The successful puncture of the nonpulsating femoral artery is a challenge in young infants. However, puncturing the carotid artery should be avoided because these babies usually have hypertension in the upper limb, making it difficult to compress the puncture site for hemostasis and observation. For this condition in young infants, transfemoral venous anterograde approaches can be attempted if the foramen ovale is patent.[3] Femoral artery occlusion and aneurysm were the most commonly reported artery complications in young infants.[21] However, persistent femoral artery complications did not occur in our group of patients, suggesting that use of a small sheath and administering intensive care after angioplasty might prevent such complications.

In conclusion, percutaneous BA is a safe and effective treatment for native aortic coarctation in young infants <6 months of age. However, long-term close follow-up is essential for infant patients treated with balloon dilation to observe and treat late aneurysms and restenosis.

References

1. Wong D, Benson LN, Van Arsdell GS, Karamlou T, McCrindle BW. Balloon angioplasty is preferred to surgery for aortic coarctation. Cardiol Young 2008;18:79-88.
2. Lee CL, Lin JF, Hsieh KS, Lin CC, Huang TC. Balloon angioplasty of native coarctation and comparison of patients younger and older than 3 months. Circ J 2007;71:1781-4.
3. Rao PS, Jureidini SB, Balfour IC, Singh GK, Chen SC. Severe aortic coarctation in infants less than 3 months: Successful palliation by balloon angioplasty. J Invasive Cardiol 2003;15:202-8.
4. Rao PS, Chopra PS, Koscik R, Smith PA, Wilson AD. Surgical versus balloon therapy for aortic coarctation in infants < or = 3 months old. J Am Coll Cardiol 1994;23:1479-83.
5. Johnson MC, Canter CE, Strauss AW, Spray TL. Repair of coarctation of the aorta in infancy: Comparison of surgical and balloon angioplasty. Am Heart J 1993;125:464-8.
6. Fletcher SE, Nihill MR, Grifka RG, O'Laughlin MP, Mullins CE. Balloon angioplasty of native coarctation of the aorta: Midterm follow-up and prognostic factors. J Am Coll Cardiol 1995;25:730-4.
7. Deng HY, Huang GY, Ma XJ, Liang XC, Lin QS, Sun B, *et al*. Measurements of echocardiography in 1344 healthy children. J Chin Clin Med Imaging 2006;17:301-3.
8. Mullins CE. Dilation of coarctation of the aorta – Native and re/residual coarctation. Cardiac Catheterization in Congenital Heart Disease: Pediatric and Adult. USA: Blackwell Futura; 2006. p. 454-71.
9. Zhou AQ. Coarctation of the aorta. Cardiac Catheterization – Diagnosis and Treatment of Congenital Heart Disease. 2nd ed. Shanghai, China: Shanghai Science and Technology Press; 2009. p. 307-10.
10. Dilawar M, El Said HG, El-Sisi A, Ahmad Z. Safety and efficacy of low-profile balloons in native coarctation and recoarctation balloon angioplasty for infants. Pediatr Cardiol 2009;30:404-8.
11. Vriend JW, Mulder BJ. Late complications in patients after repair of aortic coarctation: Implications for management. Int J Cardiol 2005;101:399-406.
12. Toro-Salazar OH, Steinberger J, Thomas W, Rocchini AP, Carpenter B, Moller JH. Long-term follow-up of patients after coarctation of the aorta repair. Am J Cardiol 2002;89:541-7.
13. Cramer JW, Ginde S, Bartz PJ, Tweddell JS, Litwin SB, Earing MG. Aortic aneurysms remain a significant source of morbidity and mortality after use of Dacron(®) patch aortoplasty to repair coarctation of the aorta: Results from a single center. Pediatr Cardiol 2013;34:296-301.
14. Patel HT, Madani A, Paris YM, Warner KG, Hijazi ZM. Balloon angioplasty of native coarctation of the aorta in infants and neonates: Is it worth the hassle? Pediatr Cardiol 2001;22:53-7.
15. Ammar RI. Balloon angioplasty for native aortic coarctation in children and infants younger than 12 months: Immediate and medium-term follow-up. J Invasive Cardiol 2012;24:662-6.
16. Park Y, Lucas VW, Sklansky MS, Kashani IA, Rothman A. Balloon angioplasty of native aortic coarctation in infants 3 months of age and younger. Am Heart J 1997;134:917-23.
17. Rao PS, Galal O, Smith PA, Wilson AD. Five- to nine-year follow-up results of balloon angioplasty of native aortic coarctation in infants and children. J Am Coll Cardiol 1996;27:462-70.
18. Liang CD, Su WJ, Chung HT, Hwang MS, Huang CF, Lin YJ, *et al*. Balloon angioplasty for native coarctation of the aorta in neonates and infants with congestive heart failure. Pediatr Neonatol 2009;50:152-7.
19. Hu ZP, Wang ZW, Dai XF, Zhan BT, Ren W, Li LC, *et al*. Outcomes of surgical versus balloon angioplasty treatment for native coarctation of the aorta: A meta-analysis. Ann Vasc Surg 2014;28:394-403.
20. Massoud Iel S, Farghly HE, Abdul-Monem A, Botros N, Kassem A, Magraby AE, *et al*. Balloon angioplasty for native aortic coarctation in different anatomic variants. Pediatr Cardiol 2008;29:521-9.
21. Suárez de Lezo J, Pan M, Romero M, Segura J, Pavlovic D, Ojeda S, *et al*. Percutaneous interventions on severe coarctation of the aorta: A 21-year experience. Pediatr Cardiol 2005;26:176-89.
22. Walhout RJ, Lekkerkerker JC, Oron GH, Bennink GB, Meijboom EJ. Comparison of surgical repair with balloon angioplasty for native coarctation in patients from 3 months to 16 years of age. Eur J Cardiothorac Surg 2004;25:722-7.

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