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Immediate results of percutaneous management of coarctation of the aorta: A 7-year single-centre experience

Irina Steiner [1], Milan Prsa *,[1]

Division of Pediatric Cardiology, Woman-Mother-Child Department, Lausanne University Hospital, Lausanne, Switzerland

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ABSTRACT

Background: Coarctation of the aorta (CoA) is often treated percutaneously. The aim of this study was to describe the immediate results of percutaneous management of native aortic coarctation (NaCoA) and recoarctation of the aorta (ReCoA) at our institution.
Methods: We identified all patients with NaCoA or ReCoA who underwent percutaneous dilatation by either balloon angioplasty (BAP) or endovascular stent implantation (ESI) between 2011 and 2017. Success was defined as a residual peak-to-peak gradient (PPG) <20 mmHg or a ≥50% reduction in the gradient if the pre-intervention PPG was <20 mmHg.
Results: 63 patients (median age 6.8 years, interquartile range [IQR] 0.4–14.2) were identified. Among 11 patients with NaCoA, 7 underwent BAP and 4 had ESI, and among 52 patients with ReCoA, 42 underwent BAP and 10 had ESI. In patients with NaCoA, BAP was successful in 71%, with median PPG decreasing from 32 mmHg (IQR 25–46) to 17 mmHg (IQR 4–23) ($p = .02$), and ESI was successful in 100%, with median PPG decreasing from 20 mmHg (IQR 14.5–40) to 2 mmHg (IQR 0–6) ($p < .01$). In patients with ReCoA, BAP was successful in 69%, with median PPG decreasing from 20 mmHg (IQR 16–31.3) to 9 mmHg (IQR 0–14.3) ($p < .001$), and ESI was successful in 100%, with median PPG decreasing from 18 mmHg (IQR 11.5–22.8) to 0 mmHg (IQR 0–3.5) ($p < .01$). ESI was more successful than BAP ($p = .01$). There was only one complication.
Conclusions: Percutaneous management of CoA is safe and effective in both NaCoA and ReCoA. Stent implantation is more effective than BAP.

1. Introduction

Native aortic coarctation (NaCoA) is a relatively common congenital heart defect, occurring at an incidence of approximately 4 per 10,000 births, and accounting for 4–6% of all congenital heart disease [1,2]. Recoarctation of the aorta (ReCoA) refers to recurrent obstruction after an initially successful percutaneous dilatation or surgical repair, with reported rates ranging from 5% to 50%, depending on patient's age at the time of intervention [3–7]. Percutaneous management with either balloon angioplasty (BAP) or endovascular stent implantation (ESI) is a widely accepted treatment modality for both NaCoA and ReCoA, remaining controversial only in neonates and small infants [8]. The aim of our study was to describe the immediate results of percutaneous management of both NaCoA and ReCoA at the Lausanne University Hospital.

2. Methods

2.1. Patient population

We searched our catheterization database to identify all patients with either NaCoA or ReCoA who underwent percutaneous dilatation by either BAP or ESI between January 2011 and December 2017. Data on age, weight, height, fluoroscopy time, systolic blood pressure, peak-to-peak gradient (PPG) pre- and post-intervention, balloon size, and occurrence of complications was collected for all patients. The study was performed in accordance with the ethical standards as laid down in the 1975 Declaration of Helsinki. The local ethics committee approved the study and written informed consent was waived.

2.2. Definitions

Coarctation of the aorta (CoA) was defined as a systolic upper-to-lower limb blood pressure gradient ≥20 mmHg or evidence of

* Corresponding author at: Division of Pediatric Cardiology, Woman-Mother-Child Department, Lausanne University Hospital, Rue du Bugnon 46, 1011 Lausanne, Switzerland.
E-mail address: milan.prsa@chuv.ch (M. Prsa).

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significant obstruction on echocardiography or magnetic resonance imaging. Successful dilatation was defined as a residual PPG <20 mmHg or a ≥50% reduction in the gradient if the pre-intervention PPG was <20 mmHg. Complications were defined as death, any life-threatening event, any aortic wall injury, any technical complication requiring surgery, and any femoral artery injury requiring intervention.

2.3. Cardiac catheterization

All interventions were performed under general anaesthesia by pediatric cardiologists trained in interventional cardiac catheterization. Access was obtained via the femoral artery and intravenous heparin was administered at 50 IU/kg. The PPG across the CoA was measured pre- and post-intervention with either a pigtail or an end-hole catheter by pullback from the ascending to the descending aorta. Biplane aortic angiography was performed pre- and post-intervention in the PA and lateral projections. The balloon size for both BAP and ESI was chosen so that the inflated diameter was equal to the maximal diameter of the isthmus at the base of the left subclavian artery (LSA). For ESI, a covered Cheatham-platinum stent (NuMED Inc., Hopkinton, New York) was used in 11 patients, an Andrastent (AndraMed GmbH, Reutlingen, Germany) in 2 patients and a Cook Formula 535 stent (Cook Medical, Bloomington, IN, USA) in 1 patient. The length of the stent was chosen so that it covered the distance from the LSA to at least 5 mm beyond the distal end of the coarctation. Stents were implanted in children only if they could be further dilated to adult size. The BAP and the ESI were performed using the previously described techniques [9–11]. Hemostasis was obtained either with manual pressure or a vascular closure device (Prostar XL, Abbott Vascular, Santa Clara, CA, USA).

2.4. Statistical analysis

Continuous variables are presented as median (interquartile range [IQR]) due to non-normal distribution of the data, and categorical variables are presented as percentages (absolute numbers). The Kruskal-Wallis test was used to compare the continuous variables, and the Fisher's exact test to compare the categorical variables. Statistical analysis was performed using IBM/SPSS Statistics (version 26, IBM, Armonk, New York). A p value < .05 was considered statistically significant.

3. Results

3.1. Study subjects

Sixty-three pediatric and adult patients (44 males, 19 females) underwent percutaneous management of CoA between January 2011 and December 2017 at the Lausanne University Hospital. There were 11 patients with NaCoA and 52 patients with ReCoA. Seven patients with NaCoA underwent BAP and 4 had ESI. The mean diameter of the balloons used for BAP was 6 ± 1 mm (range 4–8 mm), and the mean diameter of the balloons used for ESI was 17 ± 2 (range 14–18 mm). Forty-two patients with ReCoA underwent BAP and 10 had ESI. The mean diameter of the balloons used for BAP was 7 ± 3 mm (range 5–16 mm), and the mean diameter of the balloons used for ESI was 14 ± 3 (range 10–20 mm). The baseline characteristics of the patients are presented in Table 1.

Table 2
Immediate results of BAP and ESI in patients with NaCoA and ReCoA.

	PPG pre	PPG post	p	Success rate
	Median (IQR)	Median (IQR)		
NaCoA				
BAP ($n = 7$)	32 (21)	17 (19)	**0.02**	71% (5/7)
ESI ($n = 4$)	20 (25.5)	2 (6)	**0.009**	100% (4/4)
ReCoA				
BAP ($n = 42$)	20 (15.3)	9 (14.3)	**<0.0001**	69% (29/42)
ESI ($n = 10$)	18 (11.3)	0 (3.5)	**0.002**	100% (10/10)

BAP: balloon angioplasty; ESI: endovascular stent implantation; IQR: interquartile range; NaCoA: native aortic coarctation; ReCoA: recoarctation of the aorta; PPG: peak-to-peak gradient; Pre: pre-intervention; Post: post-intervention. p values < .05 are in bold

3.2. Hemodynamic data

In patients with NaCoA, BAP was successful in 71% of cases and achieved a reduction in the PPG from a median of 32 mmHg to a median of 17 mmHg ($p = .02$), whereas ESI was successful in 100% of cases and achieved a reduction in the PPG from a median of 20 mmHg to a median of 2 mmHg ($p = .009$). In patients with ReCoA, BAP was successful in 69% of cases and achieved a reduction in the PPG from a median of 20 mmHg to a median of 9 mmHg ($p < .0001$), whereas ESI was successful in 100% of cases and achieved a reduction in the PPG from a median of 18 mmHg to a median of 0 mmHg ($p = .002$). These results are presented in Table 2, Figs. 1 and 2. The combined success rate of BAP for all patients with CoA was 69%, which was significantly less than the combined success rate of 100% for ESI ($p = .03$).

3.3. Complications

There was only one complication, namely a small aortic aneurysm in a patient with NaCoA who underwent BAP.

4. Discussion

We describe the immediate results of our experience with percutaneous management by either BAP or ESI in 63 consecutive patients with both NaCoA and ReCoA between 2011 and 2017. The majority (83%) of patients had ReCoA and most of them (78%) underwent BAP. Patients undergoing BAP were significantly younger than patient undergoing ESI, reflecting the obvious technical limitations in smaller children of using large sheaths and implanting stents that can be expanded to adult size [12]. Although ESI has been safely performed in children

Table 1
Patient characteristics.

Variable	All ($n = 63$)	NaCoA ($n = 11$)			ReCoA ($n = 52$)		
		BAP ($n = 7$)	ESI ($n = 4$)	p	BAP ($n = 42$)	ESI ($n = 10$)	p
	Median (IQR)	Median (IQR)	Median (IQR)		Median (IQR)	Median (IQR)	
Age (years)	6.8 (13.8)	0.4 (1.5)	23.3 (17.5)	**0.004**	5.2 (13.7)	11.2 (5.7)	**0.02**
Weight (kg)	23.5 (45.8)	7 (7)	79 (13.5)	**0.004**	18 (44)	32 (43.5)	**0.02**
Height (cm)	123 (100)	60 (28)	172 (20)	**0.004**	106 (99.3)	135 (38)	**0.02**
Fluoroscopy time (min)	8.3 (4.6)	8.2 (3.5)	6 (10.3)	0.17	9 (4.8)	7.8 (4.6)	0.35
Systolic BP (mmHg)	93 (20)	95 (15)	104 (39.5)	0.19	87.5 (19)	105 (22)	**0.002**

BAP: balloon angioplasty; BP: blood pressure; ESI: endovascular stent implantation; IQR: interquartile range; NaCoA: native aortic coarctation; ReCoA: recoarctation of the aorta. p values < .05 are in bold.

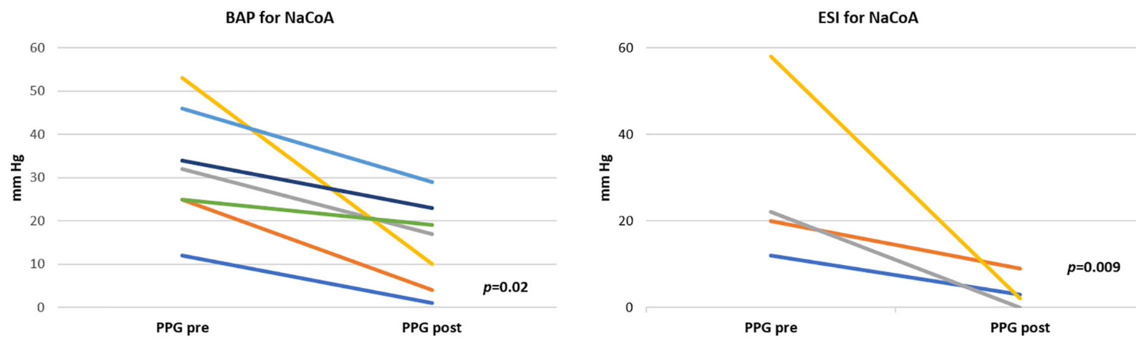

Fig. 1. Pre- and post-intervention peak-to-peak gradient (PPG) in patients with native aortic coarctation (NaCoA) undergoing balloon angioplasty (BAP) and endovascular stent implantation (ESI).

weighing <30 kg [13], only 3 patients (21%) in our study underwent ESI at a weight <30 kg and all had stents that could be further dilated to adult size.

Our study shows a significant reduction in the PPG after both BAP and ESI in patients with both NaCoA and ReCoA. Successful dilatation was defined in our study as a residual PPG <20 mmHg or a ≥50% reduction in the gradient if the pre-intervention PPG was <20 mmHg. The reason for this was the fact that 27 patients (43%) had a pre-intervention PPG <20 mmHg, so that the commonly used definition of only a residual PPG <20 mmHg would have falsely overestimated success [8]. Since all patients met the definition of CoA and therefore had a clear indication for intervention, the most likely explanation for a pre-intervention PPG <20 mmHg in a large proportion of our patients is the hemodynamic effects (i.e. reduction in cardiac output and arterial vascular resistance) of propofol [14], which is routinely used during general anaesthesia in our institution. Another explanation may be significant collateral flow in some patients. Using our modified definition, the combined success rate of BAP for all patients was 69%, which was significantly less than the combined success rate of 100% for ESI. This is hardly surprising, as ESI restores the luminal diameter of the aorta at the CoA site with little residual stenosis [11]. We had a single complication, a small aortic aneurysm developing after BAP in a patient with NaCoA, for a combined complication rate of 2% after BAP and 0% after ESI.

The results of our study are overall comparable to the previously published results, although with a lower success rate of BAP for both NaCoA and ReCoA, but also with a lower rate of aortic wall complications. Del Cerro et al. reported on immediate results of BAP for NaCoA in 53 children during 2 different time periods, and found a success rate of 69% and 82%, respectively [15]. In another study on the results of BAP for NaCoA in 57 adolescents and adults, Fawzy et al. reported a significant immediate reduction in the PPG from a mean of 60 ± 22 mmHg to 8.5 ± 8 mmHg ($p < .0001$), with a success rate of 90%, but a 7% rate of aneurysm formation [5]. Adjagba et al. looked at the immediate results of BAP to manage NaCoA and ReCoA in 25 infants [7]. They reported a significant immediate reduction in the PPG from a mean of 28.7 ± 12 mmHg to 9.3 ± 7.9 mmHg ($p < .001$) and a success rate of 83.4% in patients with NaCoA, as well as a significant immediate reduction in the PPG from a mean of 30.7 ± 14.5 mmHg to 9.2 ± 7.8 mmHg ($p < .001$) and a success rate of 92.3% in patients with ReCoA. However, they had a 7.7% rate of aneurysm formation. In studies of ESI, Hamdan et al. examined the initial results in 34 patients with both NaCoA and ReCoA, and found an overall reduction in the PPG from a mean of 32 ± 12 mmHg to 4 ± 11 mmHg ($p < .001$), with a success rate of 100% and a 6% incidence of major complications [16]. Chessa et al. reported on the results of ESI for NaCoA and ReCoA in 71 consecutive patients, demonstrating a reduction in the PPG from a mean of 39.3 ± 15.3 mmHg to 3.6 ± 5.5 mmHg ($p = .004$), with a 100% success rate and a 5.6% complications rate [17]. In a multi-institutional study of results and acute complications in 565 ESIs for both NaCoA and ReCoA in patients over 4 years of age, Forbes et al. found a combined success rate of 97.9% with a reduction in the PPG from a mean of 31.6 ± 16 mmHg to 2.7 ± 4.2 mmHg ($p < .001$) among successful procedures [18]. The rate of aortic wall complications was 3.9%. Finally, in a more recent study, Thanopoulos et al. reported on the initial results of ESI in 74 children with both NaCoA and ReCoA, showing a reduction in the PPG from a mean of 68 ± 16 mmHg to 8 ± 5 mmHg ($p < .05$), with a success rate of 100% and a complication rate of 2.7% [19].

5. Limitations

The main limitations of our study are its retrospective design and the small number of both patients with NaCoA and those undergoing ESI, underpowering the study for subgroup comparison. Additional limitations include the modified definition of a successful dilatation as

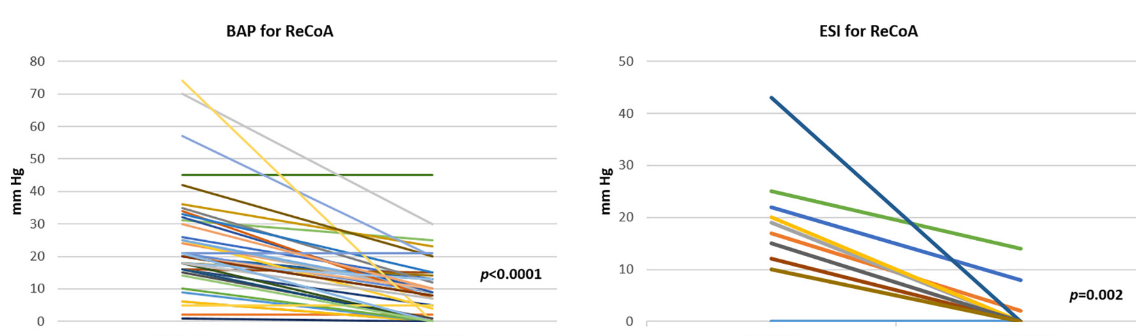

Fig. 2. Pre- and post-intervention peak-to-peak gradient (PPG) in patients with recoarctation of the aorta (ReCoA) undergoing balloon angioplasty (BAP) and endovascular stent implantation (ESI).

explained above, and the fact that we only analyzed the immediate results of percutaneous management of CoA.

6. Conclusions

BAP and ESI can be successfully performed in both NaCoA and ReCoA, with a very low complication rate. ESI is more effective than BAP, which still remains the only percutaneous management option for smaller children. Long-term follow-up of patients is required.

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Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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