Coarctation Stenting in Children 10 Kilograms of Weight or Less Using Non-coronary Stents

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Abstract

Objectives: Showing safety and feasibility of coarctation stenting in small children by peripheral stents.
Background: Surgery and balloon angioplasty of the aortic coarctation are generally the first therapeutic options for small children. However, stenting can be useful when these two options are unsuccessful or carry a high risk. Coronary stents have been used in this situation and extracted surgically after a short time.
Methods: We have used peripheral stents in seven patients 3.2-10 kg of weight.
Results: Technical success was achieved in six patients (86%). One stent was removed surgically. Three stents were redilated. Two patients died of unrelated causes.
Conclusions: We recommend open cell stents, special attention to the femoral arteries, and limitation of x-ray radiation when coarctation stenting is performed in a small child.

Keywords: valeo stent; formula stent; redilation; stent fracture

Conflict of Interest

The authors declare that they have no conflict of interest.

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Introduction

Stenting of the coarctation of the aorta (COA) is an acceptable therapeutic option for adults and older children (1). Absence of an ideal stent implantable in small children and dilatable to the adult size made this intervention inconvenient in small children (2). However, there are patients with COA in whom the other therapeutic options (surgical or balloon angioplasty) either carry a high risk or are unsuccessful in relieving the obstruction. There are occasional reports of COA stenting in small children using coronary stents which have been surgically extracted thereafter (3,4). Although special stents for small children were introduced (5,6), none of them gained widespread use. An ideal stent for small children should be mountable on an 8 mm or smaller balloon catheter, deliverable via a 5 Fr sheath, and redilatable to the adult aortic size without losing its radial force or severe foreshortening (7). However, this ideal stent does not exist in reality. Valeo Vascular stent (Bard peripheral Vascular, USA) and Formula stent (Cook Medical, USA) are newer stents that have some of these features (7). We report our experience of COA stenting by peripheral stents in children with 10 kg of weight or less. All of these patients have not been considered a candidate for surgical repair or balloon angioplasty.

Methods and Methods

From July 2008 to January 2015, we implanted 7 stents in 7 patients weighting 10 kg or less. Patients with symptomatic COA (mostly heart failure), systemic hypertension, or a gradient higher than 20 mmHg were selected for therapeutic intervention. The reasons for avoiding operation were previous surgical repair and parental preference each in two patients; and heart failure, large aortic aneurysm, and complex anatomy each in one. Ballloon angioplasty was unsuccessful in 2 patients. In the remaining 5 patients, balloon angioplasty was not performed due to the presence of a long coarctation segment in 4 patients, and an aortic aneurysm in one.

Informed consent was obtained from all parents. Stenting procedure was carried out as reported previously (1). In 6 patients, the stent was implanted via the femoral artery. In one patient with transposition of the great arteries, we used the femoral vein for stent delivery. In 3 patients we used a long sheath (one through the femoral vein in patient 7, two through the femoral artery in patients 1 and 2). In the remaining four, we delivered the stents via a short radial sheath (Terumo Medical Corporation, Japan). We catheterized carotid artery by a small lumen catheter (Arterial Catheterization Set, Arrow International, USA) to find the best place for stent implantation when a long sheath was not used. Hand injection trough this catheter was used to find the best place for stent implantation (patients 4 and 5). In the patient 6, left ventricular injection through a venous catheter passed from the patent foramen ovale (PFO) played this role. In the patient 3, we found the best place only by comparing the fluoroscopy images with the previous injections.

Results

Median age and weight of the patients were 7 months and 6 kg (ranges 2-30 months and 3.2-10 kg) (Table 1). The procedures were technically successful in six patients. Mean pressure gradient across the stenotic segment was decreased from 30±22 mmHg to 11±12 mmHg after stent implantation.

Two patients died during the follow up period from causes unrelated to the stenting procedure. Patient 3 succumbed into her multiorgan failure after a few days in spite of successful stenting. Patient 5 died of a fatal ventricular tachyarrhythmia two years after stenting.

We have implanted two Palmaz Genesis XD (Cordis, USA; 1910 and 3910), three Formula

414 stents (Cook Medical, USA; two 7x16 and one 6x20), one Valeo Vascular stent (Bard peripheral Vascular, USA; 6x18), and two covered Atrium stent (Maquet Group, Germany; 6x24 and 8x38). Estimated redilation potentials were 18 mm for two, 16 for four, 12 for one, and 8 mm for another one stent (7).

Patient's specific data

Patient 1

A residual coarctation unresponsive to balloon angioplasty was stented by a Palmaz Genesis XD 1910 stent via a 7 Fr long sheath. To avoid using a larger sheath, the stent was implanted on a 5 mm balloon catheter and redilated by a 7 mm balloon catheter at the same procedure. The procedure was successful in relieving the obstruction. However, the integrity of her right femoral artery was lost. Seven years later, the stent was redilated by a balloon catheter to 10 mm. She is continuously under follow up for more than 10 years.

Patient 2

A long-segment was stented primarily using a Palmaz Genesis XD 3910 stent (Cordis, USA) on a 7 mm Opta-pro balloon catheter (Cordis, USA) via a 7 Fr long sheath. During the stent implantation, the stent was displaced proximally to the aortic arch and a 30 mmHg gradient remained in the unstented part of the COA. In addition, we found that the integrity of his right femoral artery was lost. As his blood pressure was under control and there was only the left femoral artery for stent redilation, he was followed up. Four years later, we found that the stent was fractured and made a severe gradient. First, his abdominal coarctation was successfully stented by a Visi-Pro 7x57 stent (Medtronic, USA). Then, the first stent was almost completely removed surgically and the coarctation was repaired. He developed an extensive cerebellar ischemic damage which improved gradually. Finally, he suffered from a primitive neuroectodermal tumor for which chemotherapy has been administered. The tumor disappeared completely after the completion of chemotherapy. He is under follow up and more than 10 years were past from the first stenting procedure.

Patient 3

A patient with ventricular septal defect, patent ductus arteriosus (PDA), and COA developed uncontrollable heart failure with respiratory failure, and increase in blood urea nitrogene and creatinin. As she was a poor surgical candidate, rescue stenting of a long segment COA by a 414 Formula stent 6x20 (Cook Medical, USA) was done successfully. We delivered the stent via a 5 Fr radial sheath and found the best place for implantation only by comparing our fluoroscopic images with the previous injections. Although the procedure was technically successful, she succumbed into her disease after 2 days.

Patient 4

A residual postsurgical COA unresponsive to balloon angioplasty was stented successfully by a 414 Formula stent 7x16 (Cook Medical, USA) via a 5 Fr radial sheath (Fig. 1). We used a small 20 G catheter (Arterial Catheterization Set, Arrow International, USA) in her left carotid artery to find the best place for stent implantation. This patient was lost to follow up.

Patient 5

A patient with single ventricle physiology and pulmonary hypertension was operated at the age of 3 months and his pulmonary artery was banded. At the age of 9 months, we found unsuitable pulmonary artery pressure for a Glenn

shunt and a COA during a diagnostic catheterization. The parents refused COA surgery due to the multiple operations he may need in his life. As the obstruction was long, it was stented by a 414 Formula stent 7x16 (Cook Medical, USA) successfully. The stent was delivered via a radial sheath and left subclavian artery injections via a 20 G catheter (Arterial Catheterization Set, Arrow International, USA) was used for finding the best place for stent implantation. Eighteen months later, he died of a ventricular arrhythmia.

Patient 6

A patient with hydrocephalus and upper thoracic hemangiomas had severe COA and a large aneurysm distal to her coarctation (PHACES syndrome: posterior fossa malformations, hemangioma, arterial anomalies, cardiac defects, eye abnormalities, sternal cleft and supraumbilical raphe). The inherent risk of aneurysm rupture made surgical correction and balloon angioplasty unacceptable for this patient.

We excluded the aneurysm using two long covered stent, Advanta V12 stent 5x24 and 8x 38 (Maquet Group, Germany). The smaller stent was implanted first via a 5 Fr short sheath, and after 2 years it was redilated to 8 mm and the second stent completed the procedure (short 7 Fr sheath) (Fig. 2). The time delay was caused by the absence of a longer or a second small covered stent. The patient is still under follow up after 5 years from the first stent implantation.

Patient 7

A 3-month-old infant with transposition of the great arteries, intact ventricular septum, severe COA, and PDA was presented. As the left ventricle was undertrained for an arterial switch, he was scheduled for an atrial switch operation after six months of age. After a successful balloon atrial septostomy (static technique with double balloons, created defect diameter 7mm, oxygen saturation 80%), his COA was stented by a Valeo Vascular stent 6x18 (Bard peripheral Vascular, USA) via a 6 Fr long sheath from his femoral vein. He was lost to follow up and returned after 2 years with severe cyanosis and right heart failure. Redilation of the Valeo stent to 9 mm and medical therapy controlled his heart failure. He had near-systemic pulmonary hypertension and was added to our heart and lung transplant list. He is still under follow up after 5 years.

Discussion

Redilation of the stent after somatic growth is the most important concern after COA stenting in small children. Stents implanted for COA can be redilated safely (1). Stent used for this purpose should have the capability to expand to the adult size. Aortic isthmus sizes in normal males and females are 26.1±4.3 and 21.1±3.2 mm, respectively (2,8). However, adult patients with the diagnosis of COA usually need in average an 18-20 mm balloon catheter for stent implantation (9-11). In occasional patients, even 14-15 mm balloon catheters were used for stent implantation (9,10).

In most of the reported COA stenting in patients 10 kg of weight or less, coronary stents were used and extracted after a relatively short time due to limited redilation capability (4). In some patients, final stent sizes as wide as 14-15 mm can be sufficient even in adult patients. If significant obstruction occurs even with the final stent size, surgical stent removal and stent breaking are the therapeutic options. Surgical stent re-

moval and COA repair carries a high risk of complications like those occurred in our patient and can be reserved as the last solution. Stent breakage (percutaneous by a high pressure balloon) and restenting by a larger and preferably covered stent in later life is a newer solution. Formula and Valeo vascular stents are amenable to breakage when redilated by a high pressure balloon beyond certain diameters (7).

The hazards of x-ray radiation should be considered when COA stenting is performed in a young child. Our patient 2 had 3 angiographies, 3 CT angiographies for his COA, and 4 brain CT scans for his cerebellar accident. The combination of radiations received may contribute to the cancer development. We recommend limiting angiographies and using magnetic resonance or ultrasound techniques to follow the patients. Stent redilation may be required every four years or longer with the patient's growth (1). In addition, limiting the use of the x-ray should be recommended to the other physicians in care of the patient.

Femoral arteries are the preferred route for stent redilation. The risk of arterial injury by a short sheath is lower than that of a long sheath in infants less than 15 kilograms of weight (12). Use of long sheaths in our first two patients led to femoral arterial injury. We have changed our strategy and used short sheaths for stent delivery in the next patients. The most important drawback of a short sheath is the difficulty to find the best place for stent implantation. Different methods were used to solve this problem. Placement of a catheter in the left ventricle through femoral vein and PFO can be the best option when this foramen is patent. Placement of small catheters in the left carotid or subclavian arteries can provide sufficient help. Limiting the frequency of femoral arterial cathete- rizations should be considered as well. Stent implantation on smaller balloon catheters and redilation by a larger balloon catheter at the same procedure may lower the diameter of sheath and hence the risk of vascular injury.

Use of open-cell stents is preferred over close-cell stents due to their lower foreshortening, smaller profile, and the ability to access side branches (13). Formula and Valeo vascular stents are newer stents that can be implanted via small sheaths 5-7 Fr and redilatable up to the twice their initial diameter (7).

Progress in the field of COA stenting in small children is limited due to the long time required to reach adulthood and study the efficacy and safety of a therapeutic method. Another limitation of this report is the consistency of our cohort which involved patients with complex COA, complex congenital heart disease, or fatal comorbidities that led to the early loss of two patients. Third, we suffered unavailability of some stents that we needed. However, we showed that COA stenting in small children is feasible and safe.

Conclusions

The first lines of therapy for COA in small children are surgery and balloon angioplasty. COA stenting in small children can be used as the third option.

Table 1: Characteristics of the patients. PG, pressure gradient; COA, coarctation of the aorta; BA, balloon angioplasty; VSD, ventricular septal defect; PDA, patent ductus arteriosus; SV, single ventricle; PA, pulmonary artery; TGA, transposition of the great arteries; ASD, atrial septal defect.

Patient	Disease	Previous therapy	Weight (kg)	Age (months)	Stent	Balloon (mm)	Change in PG (mmHg)	Complication(s)	Follow up
1	Isolated COA	Surgery, BA	10	30	Palmaz Genesis XD 1910	5-7-10	25->14 23->8	Femoral artery injury	11 years redilated
2	Isolated COA	-	10	18	Palmaz Genesis XD 3910	7	75->33	Femoral artery injury, Stent displacement and fracture	10 years Stent removed
3	VSD-PDA-COA	-	3.2	2	414 Formula 6x20	6	15->4	-	Died of organ failure
4	Isolated COA	Surgery, BA	6	7	414 Formula 7x16	7	30->6	-	Lost
5	SV-PA Band-COA	-	5	9	414 Formula 7x16	7	13->0	-	Died of VF
6	Aneurysm - COA	-	7	4.5	Advanta V12 5x24 and 8x38	5-8	40->20 37->9	-	5 years redilated
7	TGA-ASD PDA-COA	-	4.6	4	Valeo 6x18	6-9	13->3 8->2	-	5 years redilated

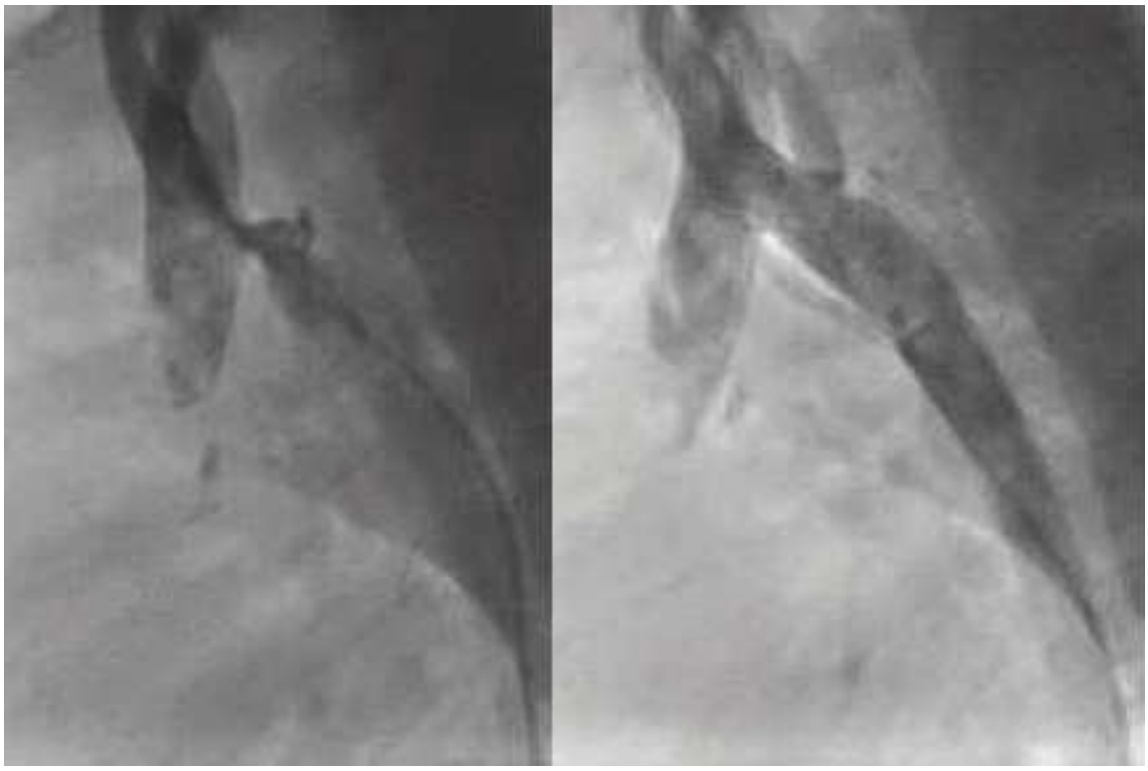

Fig. 1: Angiogram of the aortic coarctation in patient 4 before (left) and after (right) stenting.

Fig. 2: Angiogram of the aortic coarctation in patient 6 before (left), after the first stent (middle), and after the second stent (right).

Resumo

Celoj: *Montri sekurecon kaj fareblecon de koarktacia stentado en malsanuletoj per periferiaj stentoj*

Fono: *Kirurgio kaj balon-angioplastio de aorta koarktacio estas unuaj kurac-metodoj por malsanuletoj. Tamen, oni povas konsideri stentadon kiam ili estas fiaskaj aŭ tro riskaj. Koronariaj stentoj devas kirurgie eltiriĝi se oni uzas ilin por tiu malsano.*

Metodoj: *Ni uzis periferiajn stentojn en sep malsanuletoj 3.2-10 kilogramojn pezaj.*

Rezultoj: *Teknika sukceso okazis en ses malsanuletoj (86%). Unu stento eltiriĝis kirurgie. Tri stentoj redilatiĝis. Du malsanuloj mortis pro ne-rilataj kialoj.*

Konkludo: Ni rekomendas malfermit-ĉelajn stentojn, specialan atenton al femuraj arterioj, kaj limigon de iks-radiado kiam koaktacia stentado estas farata en malsanuleto.

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