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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

Implantation of stents for postsurgical recoarctation of the aorta in adolescents and adults

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Abstract

Background: Results of stent implantation (SI) of postsurgical recoarctation of the aorta (ReCoA) are not frequently published.

Aim: This study sought to retrospectively evaluate results of SI in ReCoA in older children and adults.

Methods: Twenty-eight SIs were performed on 26 ReCoA patients with a median age of 23 (10–65) years. Dependent upon availability, the following stents were applied: Palmaz, Cheatham Platinum (CP), Andrastents XL/XXL (AS), Covered CP (CVCP) stents, and self-expanding stents (Smart). Generally, high-pressure balloons were applied to dilate stents.

Results: The procedure was effective in 20/26 patients (77.7%). The mean peak systolic gradient reduced from 40.5 ± 18.7 mm Hg to 13.1 ± 12.1 mm Hg ($p < 0.05$), and the diameter of the stenosed segment increased from 7.5 ± 3.02 mm to 13.1 ± 3.32 mm ($p < 0.05$). In six cases (including a patient treated with a Smart stent) transaortic pressure gradient after SI remained > 20 mm Hg (stiff postsurgical lesion). For one patient (40-year-old male), an acute dissection of the aorta occurred during balloon predilatation. Immediate CVCP implantation resolved this problem. Two more CVCPs were used — one to close a small aortic aneurysm that appeared five years after a Palmaz SI and another to stabilise a broken CP bare metal stent. There were no deaths or aortic dissections during follow-up, and most patients were able to reduce or suspend their medication for systemic hypertension.

Conclusions: Endovascular stenting of ReCoA in adults and adolescents appears to be an acceptable method of treatment in experienced hands. However, for some patients the presence of a stiff lesion can provoke suboptimal results. Considering the serious complications that can occur after SI, all patients should have regular follow-up (including an imaging study). Covered stents should always be available in the cathlab as a rescue device when implanting stents in coarctation of the aorta patients.

Key words: coarctation of aorta, recoarctation, stenting

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INTRODUCTION

Coarctation of the aorta is a common congenital cardiovascular disease and is found in 5–10% of all congenital cardiac defects [1]. Most cases are detected and treated surgically during early childhood. Surgical therapy is associated with the risk of restenosis (recoarctation of the aorta [ReCoA]) during follow-up. Although techniques for surgical repair have progressively evolved over the past 50 years, this problem persists. Cardiovascular teams have generally agreed that transcatheter intervention (for example, balloon angioplasty) is the preferred method for ReCoA treatment [2, 3]. Stent implantation (SI) is an alternative for balloon angioplasty or surgical reintervention.

The aim of this retrospective study is to present our centre's experience with percutaneous stenting of ReCoA in adult and adolescent patients.

METHODS

Between May 1999 and July 2015 stent implantation of ReCoA was performed on 26 patients (18 adults) in our Centre. The clinical characteristics of the patients treated are presented in Table 1. The first procedure was done with Dr. E. Mullins (Houston, USA) as the proctor (patient 1, Table 1). Data were collected retrospectively, analysing details of clinical history, procedure, and follow-up. The study was approved

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Table 1. Clinical characteristics of patients with postsurgical recoarctation of the aorta

Patient no.	Date	Age [years]	Sex	Comorbidities	Previous surgery (years before SI)	Indications	Follow-up [years]
1	05.1999	16	Male	PDA	Patch (13)	Elective	17.6
2	02.2003	31	Male	Hypoplasia	Bypass (8)	Elective	13.8
3	06.2003	12	Female	BAV	Waldhausen (2)	Elective	13.5
3a	08.2008	17	Female			Elective	8.3
4	07.2003	15	Male	BAP	Waldhausen (1.3)	Elective	13.4
5	10.2003	41	Male	BAV	Intergraft (21)	Elective	13.2
6	06.2004	10	Female	BAV	Vosschulte (2)	Elective	12.5
7	10.2004	38	Female	BAV	Vosschulte (30)	Elective	12.2
8	05.2005	23	Female		End to end (20)	Elective	11.6
9	06.2006	54	Male	BAV	Bypass (30)	Elective	10.5
10	09.2006	20	Male	FOA	Waldhausen (19)	Elective	10.25
11	12.2007	14	Female	VSD	Waldhausen(13)	Elective	9
12	12.2007	27	Male	LVOT, PS	Vosschulte (19)	Elective	9
13	02.2008	54	Male	BAV	End to end (43)	Elective	8.8
14	03.2008	41	Male	BAV	End to end (35)	Elective	8.75
15	07.2008	31	Female		End to end (20)	Elective	8.4
16	01.2009	17	Male	Hypoplasia	Waldhausen (16)	Elective	7.9
17	11.2009	40	Male	CS	End to end (15)	Rescue	7.1
18	11.2009	34	Female	PDA, aneurysm	Bypass (18)	Elective	7.1
19	12.2011	15	Female	TS, BAV	End to end	Elective	5
20	12.2011	16	Male	BAV	Vosschulte (16)	Elective	5
21	03.2012	65	Female	MI	Vosschulte (53)	Elective	4.75
22	05.2012	21	Female	BAV, AI, VSD	Vosschulte (17)	Elective	4.6
23	01.2013	13	Male	PDA	Vosschulte (13)	Elective	3.9
24	08.2013	12	Female	TS	Waldhausen (12)	Elective	3.3
25	12.2013	29	Female	BAP	Waldhausen (26)	Elective	3
26	06.2015	23	Male	SF	End to end (22.4)	Elective	1.5

AI — aortic insufficiency; BAP — balloon angioplasty; BAV — bicuspid aortic valve; CS — coronary stent; FOA — foramen ovale apertum; LVOT — left ventricular outflow tract; MI — mitral insufficiency; PDA — patent ductus arteriosus; PS — pulmonary stenosis; SF — stent fragmentation; SI — stent implantation; TS — Turner syndrome; VSD — ventricular septal defect

by our Institution Scientific Board, and informed consent was obtained from all patients.

Diagnosis of ReCoA was based on a clinical examination (including systemic hypertension in the upper part of the body and weak pulses in the lower extremities) as well as an echocardiography study and other imaging examinations. According to American College of Cardiology/American Heart Association (ACC/AHA) recommendations [4], indications for SI were a peak-to-peak recoarctation gradient of ≥ 20 mm Hg or patients who have a gradient < 20 mm Hg in the presence of imaging evidence of significant coarctation with significant collateral flow. For one patient, SI was performed as treatment of a previous stent implantation complication (small aortic wall aneurysm formation). Ten patients had a bicuspid aortic valve, one had a left ventricular outflow tract obstruction with multiple pulmonary branches stenosis, and one was diagnosed with an intracranial artery aneurysm. Two patients had Turner syndrome. Other comorbidities are presented in Table 1.

Different stents were applied during this period (depending on availability). These included bare metal stents mounted manually on balloons (Palmaz, Cheatham Platinum [CP], Andrastents XL/XXL [AS]). For three special cases, ePTFE (covered with polytetrafluoroethylene) CP stents (CVCP) were used. In one case of a 10-year-old girl with a body weight of 27 kg, a self-expanding stent (Smart) was applied (patient 6, Table 1). Characteristics of those stents and details of stent implantation are described elsewhere [2, 5, 6]. Palmaz stents are made of steel with sharp ends, while CP, CVCP, and AS are round-ended and composed of gold and platinum as CP/CVCP, or cobalt and chrome alloy as AS.

Table 2. Procedural characteristics of stent implantation for postsurgical recoarctation of the aorta in adolescents and adults

Patient no.	Pressure gradient before/after [mm Hg]	Lumen diameter before/after [mm]	Fluoroscopy [min]	Stent	Sheath [F]	Balloon	Others
1	40/4	7/15	15	P5014	11	Maxi 16	
2	44/3	6/16	13	P4014	12	Maxi 16	
3	40/0	7/14	15	P4014	12	BIB 14	
3a	9/5	12/16	8	CVCP34	13	Maxi 18	Anurysm
4	44/36	6/7,5	12	P4014	10	Powerflex 12	Two redilatation
5	111/33	4/14	13.5	P4014	12	Opta 15	Redilatation
6	30/20	6/9	4	Smart 7	7	Cordis 15	Redilatation
7	43/32	7/9	20	P4014	12	Maxi 14	Redilatation
8	30/0	9/13	3	P4014	11	Maxi14	Redilatation
9	54/3	3.5/13.5	6.2	CP39	12	Maxi 16	
10	26/9	10/17	4.9	CP22	12	Tyshak 20	
11	33/0	5/12	8.5	CP22	10	Maxi 14	
12	41/20	7.5/11	4.4	CP39	10	Powerflex 12	Two redilatation
13	44/20	6/12	6	CP39	11	Maxi 14	Redilatation
14	60/37	6/10	6	CP39	12	Maxi 18	
15	40/15	6.6/11	7	CP34	11	Powerflex 12	Redilatation
16	29/9	9.6/14	3.5	CP28	11	BIB 15	
17	41/2	12/20	9	CVCP39	14	Cristal 20	
18	53/17	3/7	14	CP34	11	Powerflex 12	Redilatation
19	20/3	8/12	6.5	ASXXL39	12	Maxi 14	
20	27/1	12/16	5.4	ASXXL39	12	Maxi 18	
21	67/28	4/12	6.7	ASXL35	12	Maxi 14	Redilatation
22	37/7	11/15	5	ASXXL35	12	Maxi 16	
23	26/16	5.5/12	3.7	ASXXL26	10	Maxi 14	
24	18/0	5.8/12	5	ASXL30	10	Maxi 14	
25	25/8	13/18	5	ASXL30	14	Maxi 20	
26	31/17	14/19	7	CVCP45	14	BIB 20	

All stents were implanted retrogradely by the femoral artery. All procedures were performed under general anaesthesia (children) or local anaesthesia (adults). Patients were heparinised 50 U/kg with activated clotting time monitored after the sheath was placed. Antibiotic prophylaxis was also administered by three intravenous cefuroxim doses. Antiplatelet treatment was used during the hospital stay after the procedure (in further follow up till six months). Different balloons were used to expand the stents (depending on availability) such as: Powerflex (by Cordis Comp), Maxi LD (by J & J Comp), and BIB (by Numed Comp). The procedure was considered effective when invasive peak systolic gradient diminished to below 20 mm Hg. All patients were evaluated clinically and by echocardiography the day after the procedure, after one and six months, and yearly thereafter. Angio-computed tomography (CT) or magnetic resonance or angiography were scheduled for all patients between six and 12 months after the procedure.

Statistical analysis

Statistical analysis was performed using Statistica 12. Pre- and post-stent placement data were compared by Wilcoxon test. A p value less than 0.05 was considered statistically significant.

RESULTS

During the study period, 28 stents were implanted in 26 patients with ReCoA. The study included 12 women and 14 men (16 adults and 10 adolescents) with a mean age of 27 ± 15 (range 10–65) years and mean weight 68 ± 21 (range 27–122) kg. Procedural data and some follow-up details regarding redilatation of stents are presented in Table 2. For two patients, two stents were applied (patients 3 and 26, Tables 1 and 2). These patients had their primary surgery of coarctation of the aorta performed for a mean time of 20.6 ± 11.02 years (from 2 to 43 years) before new stent placement. For two patients, before stent implantation, balloon angioplasty was performed.

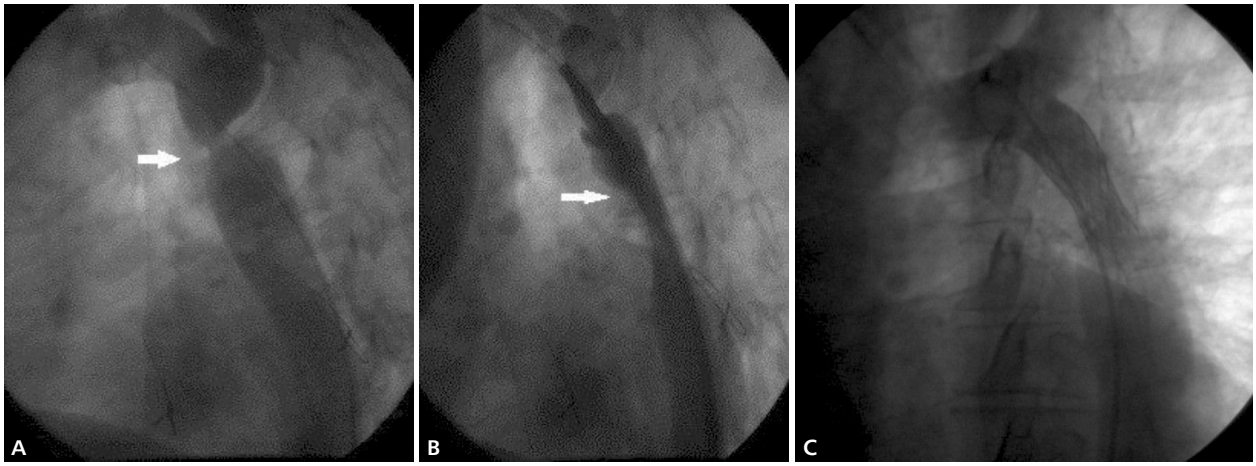

Figure 1. Aortography of recoarctation of the aorta (ReCoA) (LAO 90); **A.** Tight stenosis of postsurgical ReCoA (white arrow) before "testing" balloon angioplasty; **B.** Acute dissection of aorta after balloon angioplasty. White arrow indicates dissection and a narrow true aortic lumen caused by haematoma. Undeployed covered stent in position; **C.** Properly deployed stent dilating ReCoA and covering dissection gate

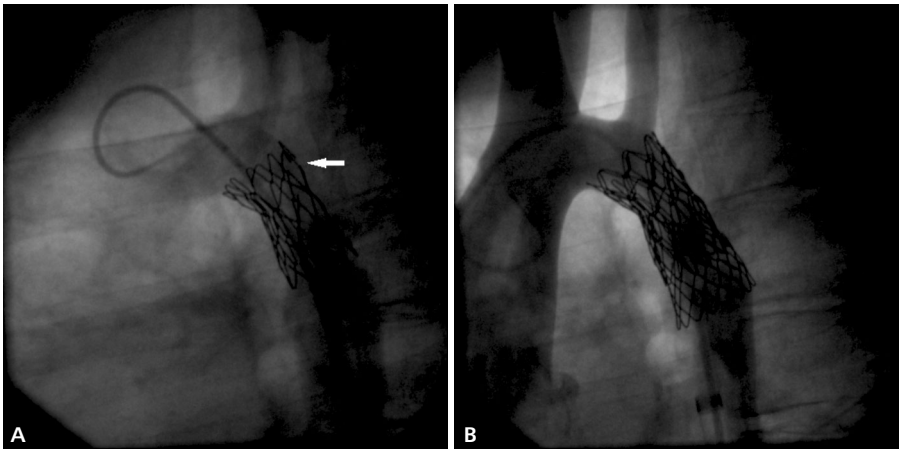

Figure 2. Aortography of recoarctation of the aorta previously treated by CP stent implantation and redilatation of this stent with a balloon; **A.** Before covered stent implantation (white arrow indicates fractures of CP stent); **B.** Stent fractures secured by CVCP stent

Twenty-five procedures were performed as elective and one as a rescue intervention (urgent). For 23 patients, different types of bare metal stents were used, such as: Palmaz P4014 or P5014 (seven patients), Cheatham Platinum (10 patients), or Andrastents XL or XXL (seven patients). For one patient, a covered stent was used as primary treatment (patient 17, Tables 1 and 2). For this patient (40-year-old male) acute dissection of the aorta occurred during predilatation with the balloon, which led to a sudden drop in blood pressure. A covered stent was immediately used to close the initial tear of the dissection with successful dilatation of the coarctation (Fig. 1A–C). In our opinion, the immediate CVCP stent implantation saved his life. This relatively young patient additionally had coronary artery disease, which required coronary stent implantation. Most likely he also manifested some form of praecox atherosclerosis, which could explain the need for this unusual clinical course.

For two patients, two more covered stents were used as secondary treatment (patients 3 and 26, Tables 1 and 2). For the first patient (12-year-old female) an "old fashion" long Palmaz stent was applied to dilate her ReCoA. Five years later, during a control CT study, a small aneurysm was detected on the upper ridge of the stent. This was successfully treated by application of CVCP. The second patient had their primary surgical treatment at the age of two months. At the age of 13 years a CP stent was implanted because of

recoarctation, and seven years later redilatation of this stent was carried out (both procedures took place in another hospital). Subsequently, fractures of the CP stent were observed, producing important restenosis (gradient in catheterisation study — 31 mm Hg). A covered stent implantation resolved this problem (Fig. 2A, B).

The procedures were effective in 20/26 patients (77.7%). Mean peak systolic gradient in the entire group diminished from 40.5 ± 18.7 mm Hg to 13.1 ± 12.1 mm Hg ($p < 0.05$) and the diameter of stenosed segment increased from 7.5 ± 3.02 mm to 13.1 ± 3.32 mm ($p < 0.05$). In six cases the procedure was ineffective (transaortic pressure gradient after SI remained > 20 mm Hg) despite application of high-pressure balloons (patients 4, 5, 6, 7, 13, 21, Table 2). Planned redilatation of these patients was effective in two of them (patients 7 and 21, Table 2), including a child, in whom a self-expanding stent was applied (patient 6, Table 2). Surgical removal of the stent and surgical correction of ReCoA was carried out half a year after SI. Mean fluoroscopy time for the group was 7.8 (3–20) min. Planned redilatation with a balloon was performed in 10 patients because of restenosis or intima proliferation (patients 4, 5, 6, 7, 8, 12, 13, 15, 18, 21, Table 2). For one patient, in whom a Palmaz P4014 was implanted as a primary treatment, five years later a covered CP stent was successfully applied (patient 3, Table 2) to repair an aneurysm formation in the upper region of the stent.

Clinical, Doppler echocardiography and other imaging studies (angio-CT, nuclear magnetic resonance) were analysed during a mean period of 8.7 (1.5–17) years. All patients experienced a good clinical outcome. No deaths nor new aortic dissection aneurysms were observed in any patients. For most, medication for their systemic hypertension was reduced or suspended. Contact was lost with five of the patients during follow-up (Table 2).

DISCUSSION

For our patients, all procedures of SI in ReCoA were performed successfully without any stent migration. The result of this study is in contrast with the results presented by Chessa et al. [7] and Alcibar et al. [8]. In our group of patients, similarly to others [6, 9–11], no deaths were observed during or after SI. Data of surgical treatment of aortic coarctation are confounded because of heterogeneous subject population, incomplete follow-up, and frequently unclear distinctions between planned and unplanned intervention.

Unfortunately, six (23.3%) our cases of SI had suboptimal results. This is a highly important point, which indicates stiffness in some ReCoA, probably caused by scar tissue. Similar results (suboptimal outcome) were presented by Hamdan et al. [9] in one of 21 patients with recoarctation treated by stent implantation. Unfortunately, it was difficult to predict or distinguish such cases by an imaging study (CT, magnetic resonance, or even angiography). For some patients, subsequent balloon redilatation of the stent can be useful. Generally, our experience indicates that a bare metal stent was a good choice for ReCoA.

The discussion of which type of stents are better in the treatment of coarctation of the aorta is still open [8, 10]. Aneurysm formation was observed in only one patient, five years after the primary procedure. This was probably caused by the sharp ends of the Palmaz P4014 stent applied (this stent is no longer used in clinical practice). The aneurysm was treated successfully with a covered CP stent implantation.

Another example of application of a covered stent was the rescue procedure performed on a patient with acute dissection. This was the only patient in whom balloon predilatation was performed. We diagnosed this clinical complication immediately, as shortly after balloon angioplasty the patient lost conscious and became hypovolaemic. In our opinion, rapid implantation of a covered stent saved his life. We took this experience as a warning that balloon predilatation of ReCoA before SI is not recommended. This was also an indication that it should be mandatory to have covered stents in the operating room as a rescue device during SI in coarctation of the aorta. From our experience, a bare metal SI was also effective in the treatment of native coarctation of the aorta in an adult patient who experienced extremely critical heart failure [12]. One of our patients (patient 26, Table 1) had serious complications after implantation of a CP stent. In this case fragmentation of this stent occurred, which caused an obstruction in the region of the coarctation of the aorta. Implantation of another covered CP stent resolved this problem.

According to the published data of Meadows et al. [11], CP stent fractures were noted in two patients after one year, and in 11 patients after two years (among 104 treated), with evidence of fracture progression. From our experience (presented elsewhere [6]) we observed no fractures in any of the 48 Andrastents XL and XXL that we used to dilate native coarctation of the aorta and ReCoA.

CONCLUSIONS

Endovascular stenting of ReCoA in adults and adolescents appears to be an acceptable method of treatment. However, in some patients the presence of a stiff lesion can provoke suboptimal results. Taking into consideration the serious complications that may occur after SI, all patients should have regular follow-up to assess the long-term results of stent implantation after surgery.

Conflict of interest: *none declared*

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Implantacja stentów w poszerzaniu pooperacyjnej rekoarktacji aorty u osób dorosłych i nastolatków

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Streszczenie

Wstęp: Wyniki implantacji stentów w pooperacyjnej rekoarktacji aorty są rzadko publikowane.

Cel: Celem niniejszej pracy była retrospektywna ocena wyników implantacji stentów w pooperacyjnej rekoarktacji aorty u starszych dzieci oraz u osób dorosłych,

Metody: Dwadzieścia osiem implantacji stentów zostało przeprowadzonych u 26 pacjentów z rekoarktacją aorty, których średni wiek wynosił 23 (10–65) lata. Zależnie od dostępności stosowano następujące stenty: Palmaz, Cheatham Platinum (CP), Andrastenty XL/XXL (AS), Covered CP (CVCP) oraz u jednego dziecka stent samorozprężalny (Smart). U większości stenty były rozprężane przy użyciu balonów wysokociśnieniowych.

Wyniki: Zabieg był skuteczny u 20/26 pacjentów (77,7%). Średni gradient obniżył się z 40,5 ± 18,7 mm Hg do 13,1 ± ± 12,1 mm Hg ($p < 0,05$), a średnica aorty na poziomie zwężenia zwiększyła się z 7,5 ± 3,02 mm do 13,1 ± 3,32 mm ($p < 0,05$). U 6 osób (w tym u 1 pacjenta, u którego zastosowano stent Smart) gradient w pomiarze bezpośrednim po implantacji stentu utrzymywał się > 20 mm Hg (niepodatne zwężenie pooperacyjne). U 1 chorego (40-letni mężczyzna) wystąpiło ostre rozwarstwienie aorty w trakcie balonowej predylatacji. Natychmiastowa implantacja stentu CVCP rozwiązała problem. Ponadto zastosowano 2 stenty CVCP — jeden do zamknięcia małego tętniaka aorty, który pojawił się 5 lat po implantacji stentu Palmaz, oraz jeden do stabilizacji złamanego metalowego stentu CP. W okresie obserwacji nie odnotowano żadnego zgonu czy rozwarstwienia aorty, a u większości pacjentów możliwa była redukcja dawek lub całkowite zaprzestanie stosowania leków hipotensyjnych.

Wnioski: Wewnątrznaczyniowa implantacja stentu w rekoarktacji aorty u osób dorosłych oraz nastolatków wydaje się dobrą metodą terapii stosowaną przez doświadczonych lekarzy. Jednak u pacjentów, u których występuje niepodatne zwężenie, wyniki mogą być tylko częściowo zadowalające. Stenty pokryte powinny być zawsze dostępne w pracowniach hemodynamiki, w których poszerzana jest koarktacja aorty, jako urządzenie mogące zabezpieczyć potencjalne komplikacje, a nawet uratować życie pacjenta. Uwzględniając poważne powikłania, które mogą wystąpić po implantacji stentu w okresie pozabiegowym, wszyscy chorzy powinni zostać objęci obserwacją (uwzględniając kontrolne badania obrazowe).

Słowa kluczowe: koarktacja aorty, rekoarktacja, stenty

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