Journal Homepage:www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/16545
DOI URL: http://dx.doi.org/10.21474/IJAR01/16545

*RESEARCH ARTICLE*

# ENDOVASCULAR TREATMENT OF AORTIC COARCTATION

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## *Manuscript Info*

***Manuscript History***
Received: 30 January 2023
Final Accepted: 28 February 2023
Published: March 2023

## *Abstract*

**Objectives:** The aim of this study is to present our center's experience with the endovascular treatment inaortic coarctation with a follow-up of 10 years.

**Background:** Stent implantation has been evolved as an important therapeutic strategy for coarctation of the aorta. However, available data is frequently flawed by short follow up, retrospective data and disparity in the approach.

**Methods:** Clinical data, imaging studies and angiographic outcomes of 24 patients treated for CoA were reviewed between january 2007 to december2018. We included native diagnosed aortic coarctation (NCO) and recurrent coarctation.

**Results:** There were 57% male patients and 43% female with a mean age of 26+/- 11 years. 90% of patients had NCO and 10% had re-coarctation after surgical repair in childhood (21+/- 4years after initial repair). Endovascular treatment was performed using BMS (PalmazGenesis peripheral stent, Cordis) in 71% of cases. Covered stent (mounted covered CP stent; Numed) was placed in 2 patients. One patient was treated by balloon angioplasty. Acute procedural success had reached 92% in our series with a technical failure in 2 cases. Mean lesion length and diameter were respectively 15,3+/-11,9 mm and 7,2+/- 2,7mm. Mean systolic pressure gradient decreased from 51,4 +/- 20,4 mm Hg to 7,7±10 mmHg ($P < 0,05$). After a mean follow-up of 60 +/- 38 months, the blood pressure profile was evaluated. the CT scan showed a local aortic wallanevrysms in 1 patient (4.1%). Surgical intervention was needed in 2 patients forrecoarctationand aortic valve replacement.

**Conclusion:** Percutaneous aortic coarctation treatment is effective with an acceptable safety and a good long-termoutcome. Therefore, patients require regular clinical and radiological monitoring tobalance blood pressure, look for local aortic wall complications and assess associated lesions such as aortic bicuspid valve and ascending aorta dimension.



## Introduction:-

Coarctation of the aorta (CoA) is a common congenital heart defect and affects 5% to 8% of live births with congenital heart disease.This anomaly is usually detected in children and it maybe diagnosed or recur in adolescents and adults. CoA occurs as an isolated lesion, very often it's associated with other cardiovascular lesions, such as

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bicuspid aortic valve, aortic arch hypoplasia, sub-aortic stenosis, mitral valve abnormalities, ventricular and atrial septal defects and patent ductus arteriosus (PDA). (1) (2)

More than 50% decrease in lumen diameter at the narrowed site and/or a pressure gradient more than 20 mmHg at restare an indication for repair. (3) Without treatment, half of all patients with CoA can be expected to die before the age of 30. Most deaths resulting from CoA occur during infancy, but patients with mild isthmus narrowing may reach adulthood and the majority of deaths are attributed to cardiac failure (26%), aortic rupture (21%), bacterial endocarditis (18%), and intracranial hemorrhage (12%). (4)

Surgical management of CoA in the adult population has been the gold standard for many years. (5) In recent years, endovascular methods became the treatment of choice. (6)

The aim of this study is to analyze the clinical, echocardiographic parameters before and during the follow up of ten years of patients with aortic coarctation and to describe the endovascular management of these patients.

## Methods:-

We retrospectively reviewed the clinical data of all patients treated for CoA between January 2007 and December 2018 by percutaneous approach.

We have included all patients followed for CoA in its isolated form or associated with other cardiovascular lesion whom underwent endovascular repair, regardless of the age at the interventionor the result.

We excluded all patients whom underwent surgical repair, patients with complex congenital cardiopathy that could not be healed with endovascular intervention and patients who were lost before 3 months of follow up.

Data collection included patient's demographics, cardiovascular risk factors, and radiologic studies. Baseline clinical information at the time of presentation and other comorbidities were also recorded. Angiography and transthoracic echocardiography data were extracted from our institution's medical records.

The necessary information to plan the stenting was obtained through evaluation of the CTdata.Specific anatomic measurements were performed to determine the diameter and length of the narrowest portion of the aortic segment affected with CoA, the distance from the left subclavian artery to the area of CoA, and the diameters of the normal aorta proximal and distal to the area of CoA.

At our institution, sedation of patients undergoing endovascular stenting for CoA is achieved under local anesthesia and intravenous sedation.

A variety of different brands for stents were used. The premountedCheathamplatinum stent (NuMED®)and the balloon- expandable uncovered stents included the Palmaz stent (Cordis®).

Percutaneous treatment was performed with retrograde access via the right femoral artery using a 5 F sheath.After vascular access was obtained, heparin sulfate (100–150 IU/kg) was administered intravenously.

Aortography is performed to measure the narrowest diameter, the length of CoA, and the diameters above and below the CoA, so as to guide the selection of the appropriate stent.

A long stiff wire with a soft tip, such as Terumo® wire is parked in the ascending aorta or left subclavian artery depending on the straightest wire course and angulation of the lesion.

The 5F sheath was exchanged for another 11F sheath. RC catheter is introduced, then the Terumo® wire is exchangedwith an Amplatz® wire.
On the wire, the balloon catheter is mounted and positioned in the center of the coarctation. The inflation of the balloon at a low pressure allowed us to locate precisely the stenosis.
The balloon is removed. The selected stent is then manually crimped onto a selected high-pressure balloon. The balloon-in-balloon catheter (NuMed ®)was used in some cases. Itgives better control during inflation. Angiography

is performed to check the position of the stent across the CoA prior to inflation of the balloon catheter. Then, the stent is released at the marked site.

The noncompliant balloon used to postdilate the stents was the Maxi LD and Tyshak II balloons.

Upon confirmation of a satisfactory position, the balloon was inflated to expand the stent, broadening the narrowed segment.

Following stent deployment, either a pigtail or multitrack catheter was used to obtain pressure measurements across the stent. LAO projection angiography was performed after stent placement.

Technical success was defined by successful angioplasty with or without stent placement with a post-intervention pressure gradient <20 mmhg.

ReCoa was defined by continuous systolo-diastolic isthmic flow with maximal systolic velocity at 3.5m/s in doppler echocardiography.

Statistical analyses were performed using SPSS 22.0 (USA, Chicago). A P value <0,05 was considered significant.

## Results:-

In all, 24 patients were enrolled between January 2007, and January 2018, 1 month to 46 years old, presenting a coarctation of the aorta (19 cases of native CoA and 2 cases of reCoA) isolated or associated with another non-complex heart disease(CIV, CA, or bicuspid Aortic valve).

Our study included 57% of male and 43% of female patients with a mean age of 26+/- 11 years. The mean age at diagnosis of CoA is 25 ± 11 years.

10 % of our patients who had a surgical repair of CoA during childhood presented with ReCoA after 21 +/- 4 years.

At the time of presentation, hypertension was the main symptom in 62% of cases. A significant difference was observed between systolic blood pressure in men and women (p = 0.024).

Auscultation revealed a systolic ejection murmur in aortic area in 95 % of cases. The femoral pulses were weak or absent in 95% of patients. Demographic and clinical data are summarized in Table1.

Clinical presentation was severe in 5 cases including heartfailure related topostpartumdilated cardiomyopathy(2 patients), acute coronary syndrome (1 patient)and intracranial hemorrhage (2 patients).

The electrocardiography (ECG) showed signs of LV hypertrophy in 43% of cases.

**Table 1:-** Baseline and imaging studies (N=24).

| | N (%) |
|---|---|
| Demographic information | |
| Age (years) | 26+ /- 11 |
| Male (%)<br>Female (%) | 57%<br>43% |
| Resistant hypertension (%) | 62% |
| Blood pressure<br>Systolic blood pressure (mmHg)<br>Diastolicblood pressure (mmHg) | <br>158+ /- 36<br><br>84+ /- 17 |
| Systolicmurmur(%) | 95% |
| Heartfailure (%) | 14% |
| ECG<br>Leftventricularhypertrophy (%) | <br>43% |

| | |
|---|---|
| Transthoracic echocardiography<br>Peak gradient (mmHg)<br>Peak systolic velocity (m/s)<br>Diastolic extension of flow (%)<br>Ejection fraction (%)<br>LEVD (mm)<br>*Associated intracardiac malformations<br>Bicuspid aortic valve (%)<br>Patent ductus arteriosus (%)<br>Aortic valvestenosis(%)<br>Aortic regurgitation (%)<br>Aortic ascending anevrysm (%)<br>Mitral valve anomaly (%) | <br><br>57+/- 13<br>3,8+/- 0,4<br>95<br>58+/-8<br>50+/-7<br><br><br><br>41<br>12,5<br>16<br>4<br>4<br>4 |
| Computed tomography angiography (%)<br>Hypoplasia of the aortic arch (%) | 100%<br>10% |

**Angiographic outcomes:**
A total of 21 stents have been implanted with an average diameter of 14 ,7 +/- 0,8 mm and a mean length of 40 + /- 1,9 mm.

The diameter of the area of CoA was 7,2+/- 2,7mm, with no differences observed between stent and balloon angioplasty.

The length of the area of CoA was 15,3+/-11,9 mm.

The pretreatment pressure gradient was 51,4 +/- 20,4 mmHg, with no differences observed between men and women and no differences between stent and balloon angioplasty.

There is a negative correlation between the diameter of the CoA area and the gradient ($r=0,58$; $p<<0,05$) and a correlation between the gradient measured by echocardiography and the gradient measured by angiography ($r=0,63$; $p<<0,05$).

Endovascular treatment was performed using stents in 71% of cases, the preferred stent was BMS stent (Palmaz Genesis peripheral stent, Cordis) used in 19 patients and the balloon-expandable covered stent (mounted covered CP stent, Numed) used in 2 patients. One patientwastreated by balloon angioplasty.

The angioplasty balloon diameter and length were 14,2 +/- 2,5 mm and 40 +/- 4,6 mm.

Technical success was achieved in 86% of the patients. There were in total three complications including:
1. Impossibility of crossing the coarctation because of the atretic segment.
2. Stent migration

Mean systolic pressure gradient decreased from 51,4 +/- 20,4 mm Hg to 7,7±10 mmHg after treatment ($p<0,05$).

Mean diameter of the area of CoA increased to 14,3+ /- 1,6 mm ($p=0,034$), which was also significant in the use of stents (14,7 vs 14mm $p=0,026$) as opposed to the balloon angioplasty only.

There was no statistical difference in mean diameters and systolic pressure gradients after treatment among NCO and RCO patients.

One patient developed a femoral hematoma after the procedure. No deaths have been reported.

**Table 2:-** Anatomical Characteristics.

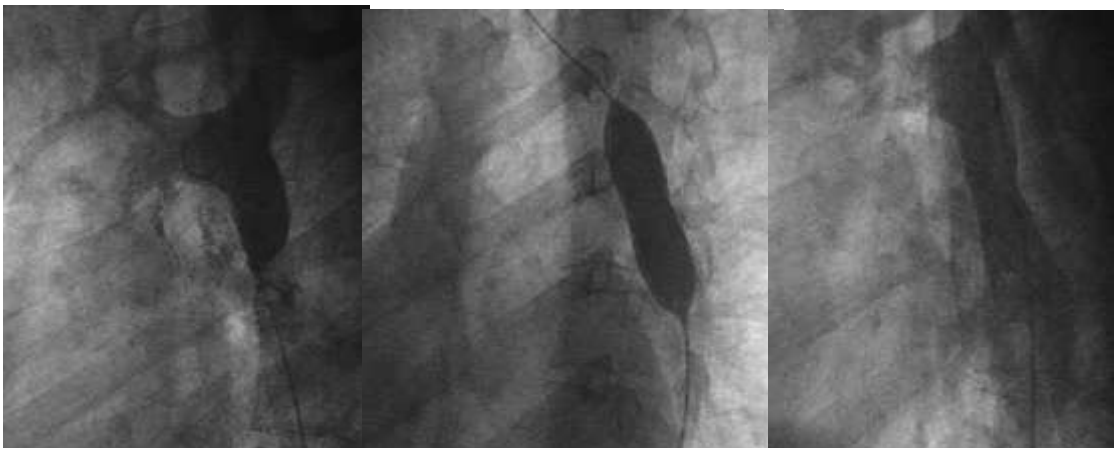
| | |
|---|---|
| TypicalCoA | 10 |
| DiaphragmaticCoA | 1 |
| AtypicalCoA | 9 |
| HypoplasicisthmicCoA | 5 |
| HypoplasicAo transverse | 3 |
| TubularCoA | 1 |
| Left subclavian Artery close to CoA | 4 |

**Table 3:-** Endovascular treatment details.

| | |
|---|---|
| Pretreatment gradient, mmHg | 51,4 +/- 20,4 |
| Post-treatment gradient, mmhg | 7,7±10 |
| Diameter, mm | 7,2+/- 2,7 |
| Lenght, mm | 15,3+/-11,9 |
| Angioplasty balloon<br>Diameter, mm<br>Lenght, mm<br>Inflation<br>Dilatingpressure,atm | <br>14,2 +/- 2,5<br>40 +/- 4,6<br>3,3 +/-0,9<br>4 +/- 0,7 |
| Stentdiameter | 14 ,7 +/- 0,8 |
| Stentlenght | 40 + /- 1,9 |

A B C

**Figure 1:-** Aortograms of a patient undergoing endovascular treatment of CoA using a covered stent A) before stent deployment (C) after stent graft deployment.



A B C

**Figure 2:-** Aortograms of a patient who was admitted for acute coronary syndrome undergoing endovascular treatment of CoA using a BMS A) Coarctation of the aorta , B)The stent is crimped onto the inflating balloon catheter and delivered to the narrowed site, C) after stent graft deployment.

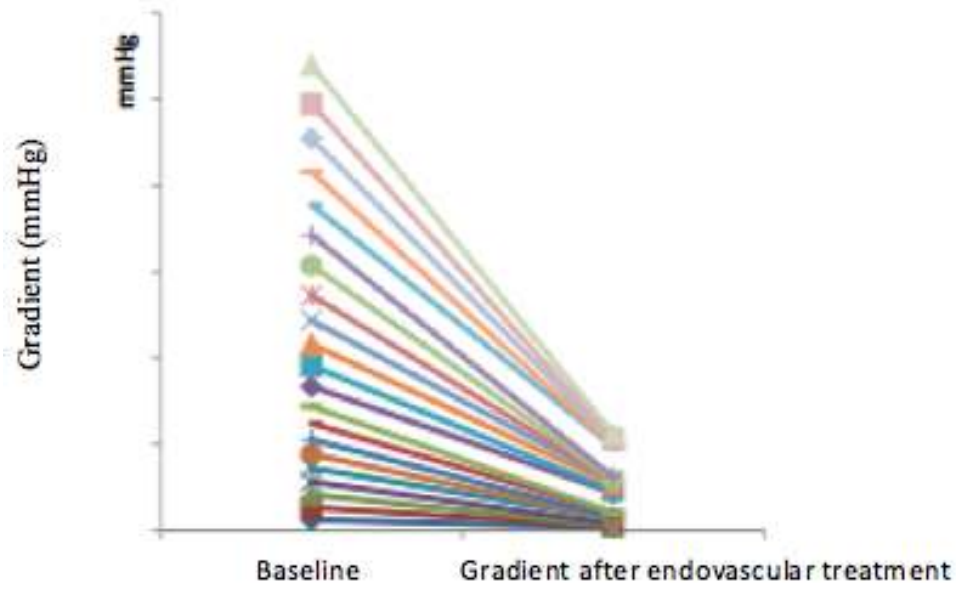



**Figure 3:-** Graphical representation of the early changes in peak gradient before and after endovacular treatment.

**Follow up:**
The mean follow-up was 60 +/- 38 months.

Two patients were operated during the follow up period.

One patient who was admitted for the endovascular treatment of CoA associated with a dilatation of the ascending aortawas complicated by a stent migration.A two stage repair procedure was performed. He underwent aortic valve replacement, the Bentall procedure and an extra anatomic bypass grafts for the repair of coarctation.

One patient followed for aortic regurgitation before angioplasty presented an aggravation of his valvular disease requiring valve replacement.

CT scan didn't show any case of anevrysm or injury of the aortic wall.

During the follow up period, we didn't notice any problems for the patient who was treated by balloon angioplasty only. A patient who was treated during the neonatal period becomea thirteen years old healthy boy. We did not find any cases of ReCoA on clinical, echocardiographic and CT criteria during the follow-up periodof ten years.

All patients have normalized blood pressure. The reduction in the number and doses of antihypertensive medication is observed in all patients. They are treated by beta blockers.

Two patients who were admitted for heartfailure related to dilated cardiomyopathy have normalized their LV function during the follow up.

There were no deaths during our follow-up period.

## Discussion:-

CoA of the aorta is a common congenital heart defect and affects 5% to 8% of live births with congenital heart disease (7)(8).Coarctations are associated with other cardiac malformation in almost 50% of cases (9).In our series, 45% of the patients had a CoA associated with a bicuspid aortic valve .

Native coarctation has historically been treated by surgery. Recently, transcatheter approaches have been increasingly refined, in part because of increased operator experience, and also because of improved balloon and stent technology, which has translated to improved safety and success of these procedures. As a result, numerous institutions have reported success with transcatheter treatment of native coarctation. (10)

In review of other series for the treatment of coarctation including both adults and children, such as the ones by Forbes et al (11) and Roselli et al (12). It has been reported that intravascular stent placement, although a technically demanding procedure, has an acceptable rate of complications and reinterventions. Furthermore, it has been successful at reducing the aortic gradient and relieving symptoms in these patients. Our data suggests that there is significant improvement in both CoA gradient and diameter after endovascular treatment.

Most studies, such as our series, have defined success as 20 mm Hg systolic gradient across coarctation segment. However, recorded gradients immediately after repair, measured in the catheterization laboratory while under anesthesia can lead to underestimating the true gradient. All the effort must be made in order to obtain a post treatment gradient <10 mmhg(12). In our study, the mean systolic pressure gradient was 7,7±10 mmHg after treatment.

Stenting is considered advantageous when compared to BA alone. It improves luminal diameter, results in minimal residual peak pressure gradient, and sustained hemodynamic benefit. It reduces the risk of dissection and aneurysm formation. Furthermore, stent implantation does prevent vascular recoil resulting in re-CoA. (13)

The intermediate outcomes from the Coarctation of the Aorta Stent Trial (COAST) published by Meadows et al (14) seem encouraging for the treatment of CoA in all patients (adults and children), with excellent technical success (99%) and good midterm outcomes at 2 years. Their preferred method of treatment was the use of balloon-expandable covered stents, which provided excellent results in this population of patients. We were able to observe in our study thatthe preferred stent was BMS stent and the balloon-expandable covered stent with good longterm outcomes of 10 years.

Stent implantation in young children remains controversial due to the need for frequent re-dilation to accommodate the growing aorta. For Alkashiri et al, stent placement is considered only in patients who are large enough (usually over 15 kg in weight) to receive a stent that can be expanded to an adult size. (15)

Aorticcoarctation is a chronic disease that requires a clinical, biological and radiological long-life follow-up (16) (17). Persistent hypertension can be observed in as many as 50% of patients even with a “perfect” repair, particularly if initial repair is performed after 1 year of age (18)(19). In our study,all our patients have normalized blood pressure.

For both the BA group and the stent group, acute complications were due almost exclusively to aortic wall injury. Acute dissections and aortic ruptures have been described in both procedures, with the majority occurring in older patients (20). Hassan et al. (21) noted an anevrysm rate of 7.5%, all observed at 1-year angiographic evaluation, which is significantly more than what we have observed.

In contrast to surgical patients, anevrysm formation in BA patients and stent patients typically occurs within the first year after the transcatheter procedure (6), with rare situations observed where progression of the anevrysm required covered stent or surgical treatment. (22)

In Erben et al. (23), the freedom from reintervention at 5 years was calculated to be 85%, which is reassuring regarding the endovascular treatment of CoA,which has also been demonstrated in our study.

## Conclusion:-

Percutaneous aortic coarctation treatment is effective with an acceptable safety and a good long-term outcome. Therefore,patients require regular clinical and radiological monitoring tobalance blood pressure, look for local aortic wall complications and assess associated lesions such as aortic bicuspid valve and ascending aorta dimension.

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