Acute and intermediate-term outcome of endovascular stenting of native aortic coarctation in adolescents and adult patients

Ahmed Meawad Alimam[a], Ahmed Azmy[b], Ashraf Abd Alhamid[c]

Departments of [a]Cardiology, [b]Cardiothoracic Surgery, [c]Anesthesia, National Heart Institute, Cairo, Egypt

Correspondence to Ahmed Meawad Alimam, MD, Clinic B, 6th Floor, Tower D, Twin Tower, Almehwar Almarkazy, Alshiekh Zayed City, 6th October, Giza, Egypt.
e-mail: alimam_a@yahoo.com

Received: 14 February 2020
Revised: 22 February 2020
Accepted: 1 March 2020
Published: 28 August 2020

The Egyptian Journal of Surgery 2020, 39:654–661

Introduction
Coarctation of aorta (CoA) is a common form of cardiac lesions requiring intervention. Recently, endovascular management with stent implantation has emerged as the preferred strategy. We aim to report our single-center experience of stenting in a wide range of patients using different types of stents and later on its complications.
Patients and methods
Between January 2012 and December 2017, 56 patients who underwent treatment with stents for CoA were retrospectively studied. All the patients underwent echocardiography and computed tomography scans at 6–12 months follow-up.
Results
There were 18 women and 38 men with a mean age of 23.24±15.75 years (range, 9–55 years). The median sheath size and balloon diameter were 12 mm (10–14 mm) and 14 mm (12–25 mm), respectively. We achieved an immediate success rate of 94.6% with only three cases recording major complications in the form of migration of stent, infective endarteritis, and stent fracture. At 1-year follow-up, no complications were noted in the computed tomography scans.
Conclusion
Stent implantation is a good choice for the treatment of CoA in adolescents and adults. It is associated with a low-residual gradient and a low rate of restenosis, both immediately and at mid-term follow-up. It has a relatively low incidence of complications.

Keywords:
coarctation of aorta, procedural outcome, stenting

Egyptian J Surgery 39:654–661

1110-1121

Introduction

Coarctation of aorta (CoA) is the sixth most common of the congenital heart diseases accounting for 4–8% of all congenital heart disease that require intervention either surgically or catheter based [1].

Due to the cardiovascular consequences of persistently elevated blood pressure and without relief of CoA, many patients die early in their life [2]. About 25% of patients are diagnosed in adolescence and adulthood and even brought to medical attention again due to recoarctation [3].

Surgical correction remained the mainstay management choice for patients with CoA. Yet, from 1980s, the era of balloon angioplasty came to light. Ultimately, in 1996 the first case of CoA managed with stenting was reported [4].

There are many types of stents, namely noncovered and covered stents that are being used nowadays in practice. Although there are many studies reporting the efficacy and safety of aortic stenting, there is still lack of data regarding its outcome due to lack of clinical trials. In addition, there are many concerns regarding the procedural and long-term complications [3,5,6].

In this paper, we report our single-center experience of CoA stenting in a variety of patients using AndraStent, covered and uncovered Cheatham platinum (CP) stents, and the 1-year follow-up of these patients.

Patients and methods

Between January 2012 and December 2017, 56 consecutive patients who underwent stenting for CoA in the National Heart Institute, Cairo, Egypt were included in this study.

All cases were studied by a cardiology team which consisted of an interventional cardiologist, cardiothoracic surgeon, and an anesthesiologist; they

 DOI: 10.4103/ejs.ejs_39_20

postulated the inclusion and exclusion criteria of transcatheter intervention.

The available medical records of the patients were studied retrospectively. The patients were all above 9 years of age and had either arm to leg systolic pressure gradient above 20 mmHg or had lower gradient accompanied with systemic hypertension defined as greater than 95th percentile for age, height, and sex. The main presentation was hypertension. There was no claudication pain, lower limb ischemic symptoms, or other cardiovascular complications apart from left ventricular hypertrophy.

All the patients underwent Doppler echocardiography or computed tomographic (CT) imaging and proceeded to stenting if their anatomies were deemed suitable.

Exclusion criteria were complex anatomy such as transverse arch or long isthmus hypoplasia which was surgically treated. Informed consents were taken from the patients or their caregivers before the procedure.

Stenting technique

All patients underwent cardiac catheterization and biplane aortography under conscious sedation, and in the case of children and adolescents below the age 18 years under deep sedation in the care of an anesthesiologist.

After delineation of the coarctation anatomy and measurement of the coarctation segment in length from distal of the origin of the last arch vessel to the immediate noncoarcted segment in the descending aorta, the diameter of proximal aorta adjacent to the coarctation segment and descending aorta at the level of diaphragm were estimated.

Antibiotic prophylaxis and heparin 100 IU/kg body weight were given to every patient. Retrograde crossing of CoA via femoral artery was done in 45 patients and brachial or radial arterial access in 11 patients when the coarcted segment is nearly atretic, or difficult crossing retrogradely. The aortic pressures were recorded in the thoracic aorta before crossing the narrowest segment.

A straight catheter [multipurpose catheter with hydrophilic Terumo glide wire (Terumo Inc., Japan)] was used to cross the lesion with calculation of the peak-to-peak systolic gradient across the coarcted segment (>20 mmHg). By aortography: the anatomy of the aortic arch and coarctation dimensions were calculated. Angiography: left aortic oblique (30–60°), lateral and anteroposterior projections.

Stent diameter is selected based on the diameter of the proximal aorta (mainly transverse or distal arch diameter) or 1–2 mm larger. The stent diameter did not exceed the diameter of the descending aorta at the level of the diaphragm, in order to avoid aneurysm formation or rupture.

Stent implantation technique

Exchange Amplatz Super Stiff guidewire (Meditech) was used as a rigid track, with the tip placed above the coarcted segment in the ascending aorta or the right subclavian artery.

Over that wire, the delivery sheath and its dilator are then advanced to the transverse aorta.

A balloon-expandable stent is hand crimped down onto the balloon.

The balloon–stent complex is advanced within the sheath to the coarctation site and a little bit further. The sheath is then withdrawn, exposing the balloon–stent complex, which is correctly placed across the stenotic lesion.

The position is checked by angiography through the sheath before inflation.

The stent implantation procedure is classically considered successful if the residual gradient is less than 10 mmHg, with an improvement in diameter to more than 90% of the normal adjacent aortic arch vessel.

If the hemodynamic and angiographic results are correct, the sheath is removed. Manual compression was used in all patients to achieve hemostasis.

If the patient is on antihypertensive drug treatment, this is usually continued for 1–4 months.

Restriction for competitive sport or strenuous exercise was achieved.

If the patient is not taking any drug before the procedure, antihypertensive medication (beta blockers) for 1 month was given to avoid barotraumatic lesions and paradoxical hypertension.

Indications for covered stent implantation:

(1) Severe CoA with near atresia in six patients.
(2) Associated PDA in one patient.
(3) Associated aneurysm in two patients.
(4) Severe coarctation with dilated ascending aorta in four patients.
(5) Stent fracture in one patient.

Follow-up

The patients were observed overnight, their blood pressure and femoral pulses were monitored frequently and they were discharged if there were no complications. The patients were all visited in 1, 3, 6, and 12 months interval and yearly thereafter. The patients underwent a control CT scan after 6–12 months and an echocardiography to determine the peak systolic gradients across the aortic arch at each visit using Doppler ultrasound. Although CP stents are MRI compatible, we decided to use CT scan to minimize artifacts, allowing us to better apprehend aortic wall complications. Aspirin was given to patients for at least 6 months and clopidogrel for 1 month.

Repeated catheterization was done in two patients for evaluation of stent stenosis due to elevated PG on echocardiographic assessment.

Statistical analysis

The results are expressed as the mean±SD for numerical data and as counts or percentages for nonnumerical data. χ^2 test was used to examine the relationship between two qualitative variables. All data were analyzed using the Statistical Package for the Social Sciences, version 20 (SPSS Inc., Chicago, Illinois, USA). A P value less than 0.05 was considered significant.

Results

Patient population

A total of 56 patients with a mean age of 23.24±15.75 years (range, 9–55 years) were included in this study. There were 18 (32.2%) women and 38 (67.8%) men. Median (range) of patient's weight was 65 kg (26–102 kg). Bicuspid aortic valve was detected in 26 (46.4%) patients. Upper and lower extremity systolic blood pressure was 150±18 and 110±16 mmHg, respectively (Table 1).

Angiographic data: the median sheath size and balloon diameter were 10 mm (5–14 mm) and 14 mm (12–25 mm), respectively. In 26 (46.4%) patients AndraStent was used, 16 (28.5%) uncovered CP was used while in 14 (25%) patients, covered CP was used. ZMed and crystal balloons were used in 41 (73.2%) and 15 (26.8%) of the studied patients with a median balloon diameter of 14 mm (12–25 mm) (Table 2).

Procedural success and complications

The mean diameter of coarctation prestenting and poststenting was 4.6 and 13.8 mm, respectively, with significant difference between them ($P<0.01$). The mean ascending aorta systolic pressure, prestenting, was 136.6±4.04 and poststenting was 126.5±2.34. There was statistical differences between them ($P<0.001$).

The mean descending aorta systolic pressure, prestenting was 88.45±3.36 and poststenting was 116.6±2.82. There was statistical differences between them ($P<0.001$). The mean systolic gradient decreased from 48.95±2.45 to 10.12±1.57, while the mean diastolic gradient decreased from 15.01±1.68 to 3.67±0.99 mmHg from prestenting to poststenting (Table 3). Our data showed that blood pressure was controlled in about 62%, mostly in young women in their 20s and 30s.

Although manual compression of the vascular access was performed in all patients, there were no major vascular complications, or rupture of aorta, or dissection or restenosis. The patients were

Table 1 Demographics and preoperative characteristics of the studied patients

Parameters	Value
Male [*n* (%)]	38 (67.8)
Female [*n* (%)]	18 (32.2)
Age at procedure (year) (mean±SD)	23.24±15.75
Weight (kg) [median (range)]	65 (26–102)
Bicuspid aortic valve [*n* (%)]	26 (46.4)
Upper extremity systolic blood pressure (mmHg) (mean±SD)	150±18
Lower extremity systolic blood pressure (mmHg) (mean±SD)	110±16
Maximal UE-LE systolic blood pressure difference (mmHg) (mean±SD)	36±17

UE-LE, upper extremity–lower extremity.

Table 2 Procedural data

Procedural data	Value
Sheath size (Fr) [median (range)]	10 (5–14)
Stents used [*n* (%)]	
AndraStent	26 (46.4)
Cheatham platinum	16 (28.5)
Covered Cheatham platinum	14 (25)
Balloons used [*n* (%)]	
ZMed	41 (73.2)
Crystal	15 (26.8)
Balloon diameter (mm) [median (range)]	14 (12–25)

Table 3 Hemodynamic and angiographic data at the time of stent implantation and poststenting

	Prestent	Poststent	*P* value
Dimensions			
Transverse arch (mm)	15.4 (7–26)	–	
Aorta at diaphragm (mm)	16.3 (7–31.3)	–	
Coarctation (avg. AP/Lat) (mm)	4.6 (1.0–9.3)	13.8 (11.6–23)	<0.0001
Hemodynamics			
AAo mean pressure (mmHg)	97.85±2.58	93.35±2.49	<0.0001
DAo mean pressure (mmHg)	75.35±2.44	91.22±2.31	<0.0001
AAo systolic pressure (mmHg)	136.6±4.04	126.5±2.34	<0.0001
DAo systolic pressure (mmHg)	88.45±3.36	116.6±2.82	<0.0001
Syst. gradient AAo-Dao (mmHg)	48.95±2.45	10.12±1.57	<0.0001
AAo diastolic pressure (mmHg)	77.3±2.11	75.07±2.21	<0.0001
DAo diastolic pressure (mmHg)	63.22±2.18	73.11±2.12	<0.0001
Diastolic gradient AAo-DAo (mmHg)	15.01±1.68	3.67±0.99	<0.0001

AAo, ascending aorta; Dao, descending aorta.

Table 4 Poststenting complication

Complications	*n* (%)
Major vascular complication	0
Rupture of the aorta, dissection	0
Restenosis	0
Infective endarteritis and aneurysm formation	1 (1.8)
Stent migration and embolization during the procedure	1 (1.8)
Stent fracture	1 (1.8)

discharged without any complications in the next day after the procedure. Three of the 56 (5.3%) studied patients showed major complications: after 2 weeks, one case was presented with infective endarteritis and aneurysm formation and was referred to surgical intervention. One patient had stent migration and embolization during the procedure; the stent was deployed at the descending thoracic aorta safely; the third patient had stent fracture after 1 year. No mortality rate was recorded in our study (Table 4).

Follow-up

On follow up, blood pressure (systolic and diastolic) showed normalization in all young women under 34 year old and the older women showed mild improvement. While normalization of blood pressure was shown in younger men of less than 19 years, partially improved in older patients (66%) and not improved in the rest of older men despite improvement in PG across the coarctation.

The peak echocardiographic aortic arch gradient at 1-year follow-up was 21.73±11.06 mmHg (range, 8–27 mmHg) (Figs 1–4).

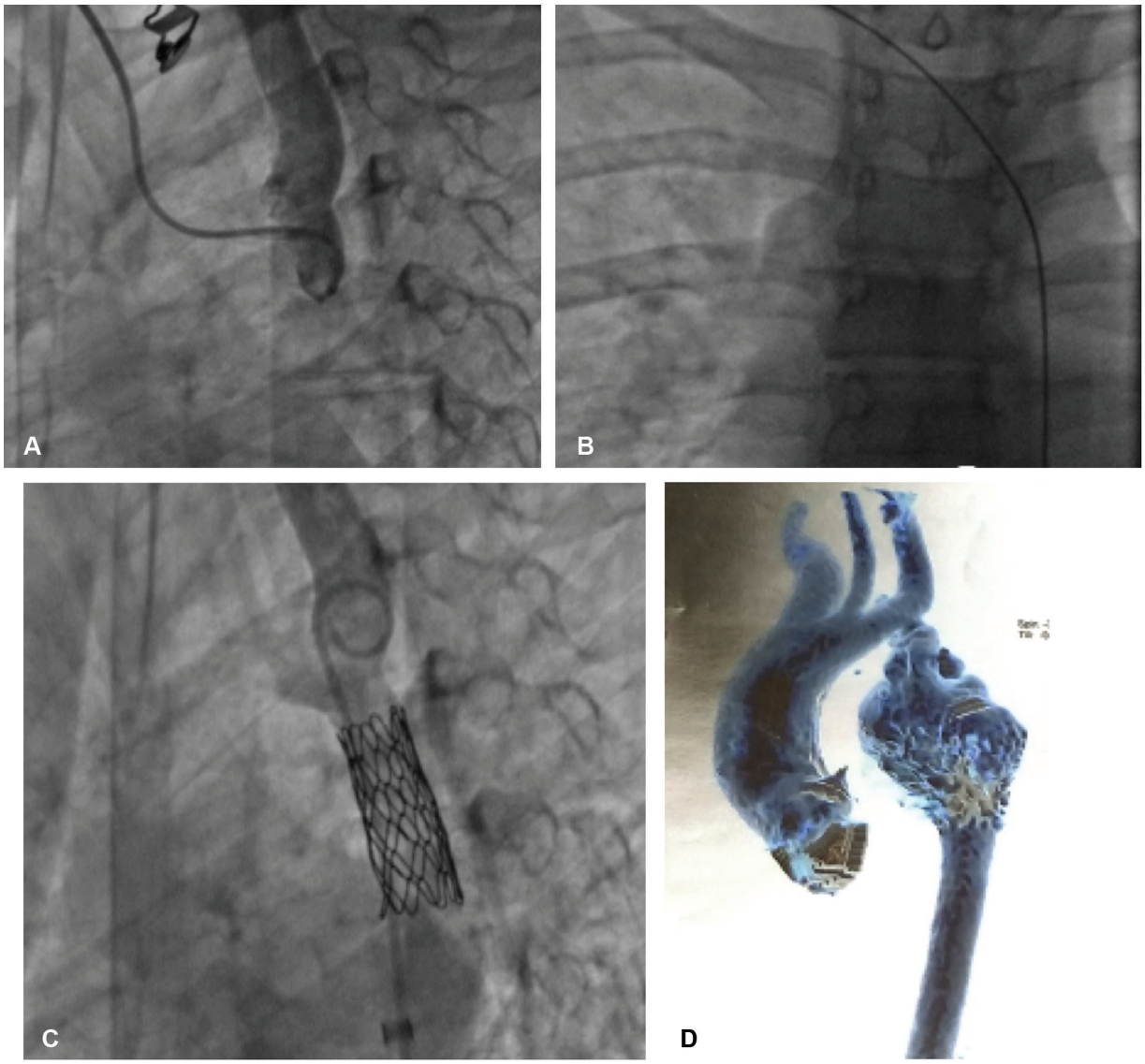
Discussion

Endovascular treatment of CoA includes two transcatheter balloon dilatation and stent implantation. Balloon dilatation is done through positioning the deflated balloon in the stenotic site and through subsequent inflation, stretching the intimal and medial layers of the aorta. This mechanism is accompanied by aortic wall damage and can lead to aneurysm [7]. Implantation of a stent across the coarcted segment as a second method of management of CoA holds a lower risk for aortic wall injuries and more sustained relief of the obstruction compared with balloon dilatation [8].

Reports regarding the safety and outcome of CoA stenting are still being published in the literature. This is the first largest report of procedural outcome and 1-year follow-up of patients undergoing stenting for CoA in Egypt and is unique to include a wide range of patients from adolescents through the late elderly. This report shows the overall efficacy and safety of this procedure in a diverse group of patients. We achieved an immediate success rate of 94.6% with the only complication being in the form of stent migration and embolization, infective endarteritis, and aneurysm and stent fracture.

In agreement with our study, a landmark study, the Congenital Cardiovascular International Study Consortium published the retrospective survey of 627 stent implants in 565 procedures across 14 centers from 1989 to 2002. In this study, a 98% immediate success rate was reported with a 14.3% complication rate including two deaths. Other complications noted were aneurysm (2.25%), dissection (1.5%), stent migration (4.8%), arterial access injury (2.6%), and stroke (1%) [4,9]. In another prospective trial (COAST), stenting was successfully done in 104 out of 105 patients with stent migration occurring in the remaining case. The overall complication was 34%, much higher than the

Figure 1



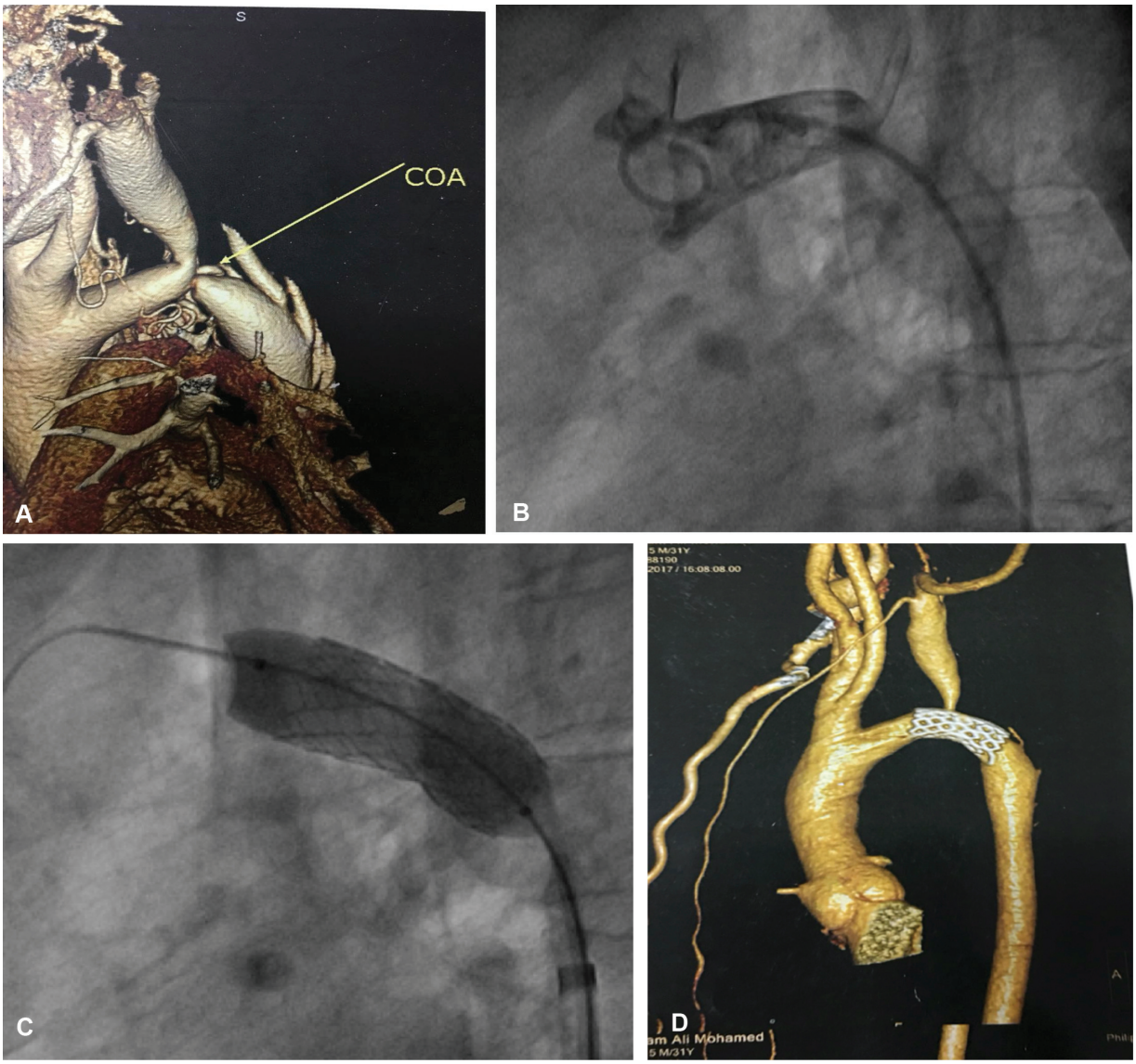
(a) Aortogram through the radial approach showed atretic aorta, (b) arterioarterial loop, (c) poststenting aortogram, follow-up CT, (d) aneurysm formation at the site of stenting. CT, computed tomography.

Congenital Cardiovascular International Study Consortium study, but no serious complications or deaths were noted, implicating increased experience in this field [3].

In our study, we had a high immediate success rate and faced only three complications which are quite comparable to other studies which almost show an immediate success rate of 100% but with serious complications ranging from 0 to 11% [3,9–14]. No aortic rupture was recorded in our cases; aortic rupture is the most dreaded complication of coarctation stenting and is reported in other studies as well [9,11,13,14]. In CCIS, two patients developed aortic rupture and underwent emergency surgery [9]. In a cohort of 22 patients, one patient developed aortic rupture during stenting with covered stent for whom another covered stent was deployed successfully [11]. In another cohort of 45 patients, one of them developed aortic rupture which was successfully managed with a covered stent [13]. This complication is assumed to occur mostly in the elderly [11]. Risk factors for this complication include performing prestent dilation, location of CoA, and age above 40 years [14].

While some authors advocate the prophylactic use of covered stents to avoid this complication, others have found no evidence to support this notion [5,11,13,14]. The ultimate aim of coarctation treatment has traditionally been the complete relief of a pressure gradient [8]. In this study, 75% of patients had gradients below 10 mmHg at 1 year of follow-up, which is an acceptable gradient [15]. Few studies

Figure 2



(a) Aortogram showed a severe form of coarctation with involvement of the subclavian artery, (b) CT showing severe coarctation, (c) poststenting aortogram, (d) follow-up CT. CT, computed tomography.

have used echocardiographic measurements for follow-up gradients. In one study, the mean gradient was 23.4 ±4.3 mmHg at an average follow-up of 52.6 months [15]. In another cohort, the gradient at 6-month follow-up was 32±19 mmHg [13]. In another study, invasive measurement was done which showed that three out of 22 patients had recoarctation and needed reintervention [11]. In a small cohort of 16 patients, one of them needed reintervention after 14 months due to recoarctation [16]. In some other smaller cohorts using invasive hemodynamic studies, no need for intervention was seen at 1–2 years follow-up [17].

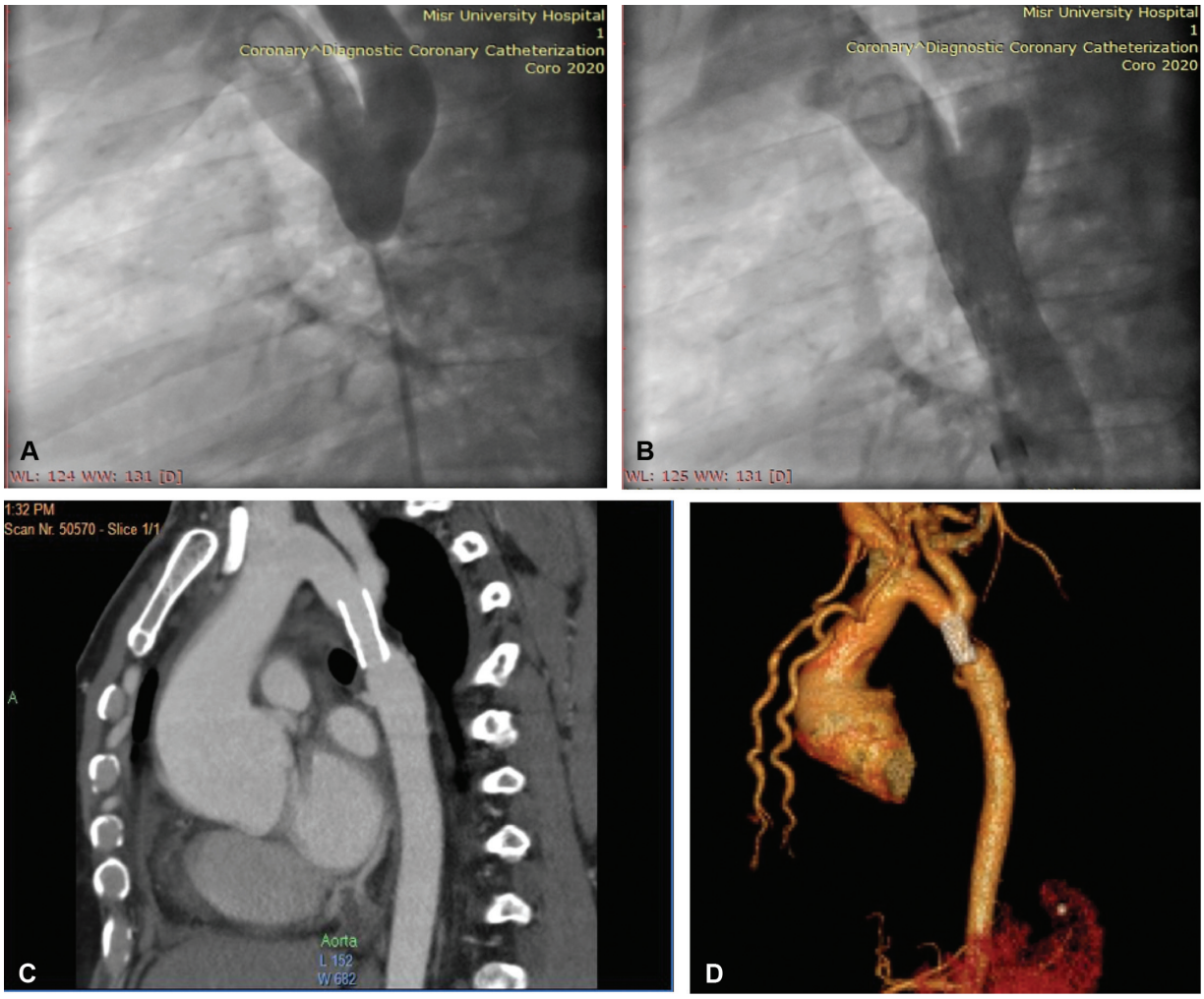
In our follow-up study, one patient had early infective endarteritis and aneurysm formation after 2 weeks; another patient had stent fracture after 1 year. Compared with our results [5], in their study on 235 patients, the late aortic wall complication rate was 16%. Late aortic wall aneurysms seem to occur more frequently in native coarctation than recoarctation.

The rather low rate of complications in our study can be ascribed to careful patient selection, avoidance of prestenting dilation and meticulous use of balloons for poststenting dilation of the coarcted segment. The operator should be very cautious in the passage of wires and use of balloons when dealing with CoA to prevent aortic wall injury.

Conclusion

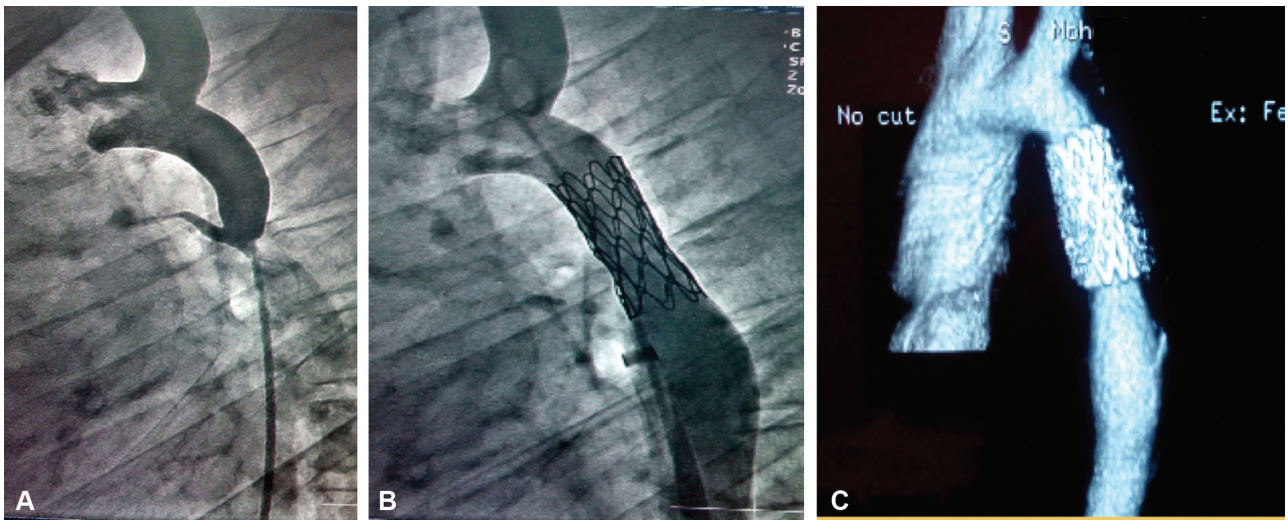
This study is one of the few reports of patients with stenting for CoA in the Egyptian population which comprised a diverse group of patients from adolescents

Figure 3



(a) Prestenting angiogram, LAO projection, (b) poststenting angiogram (follow-up), (c and d) follow-up CT. CT, computed tomography.

Figure 4



(a) Aortogram in the lateral view showed severe coarctation with small PDA, (b) aortogram after deployment of graft stent showed dilated coarctation segment and obliteration of the PDA, (c) follow-up CT. CT, computed tomography.

to the elderly. Although we faced no mortality in this study which is rarely reported in other series, very few late complications were noted. As a result, it was demonstrated that stenting is a safe and effective procedure if done carefully and performed in selected patients in well-equipped centers.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 Alkashkari W, Albugami S, Hijazi ZM. Management of coarctation of the aorta in adult patients: state of the art. Korean Circ J 2019; 49:298–313.

2 Jurcut R, Daraban AM, Lorber A, Deleanu D, Amzulescu MS, Zara C, *et al.* Coarctation of the aorta in adults: what is the best treatment? Case report and literature review. J Med Life 2011; 4:189–195.

3 Ringel RE, Vincent J, Jenkins KJ, Gauvreau K, Moses H, Lofgren K, *et al.* Acute outcome of stent therapy for coarctation of the aorta: results of the coarctation of the aorta stent trial. Catheter Cardiovasc Interv 2013; 82:503–510.

4 Ringel RE, Gauvreau K, Moses H, Jenkins KJ. Coarctation of the Aorta Stent Trial (COAST): study design and rationale. Am Heart J 2012; 164:7–13.

5 Gewillig M, Budts W, Boshoff D, Maleux G. Percutaneous interventions of the aorta. Future Cardiol 2012; 8:251–269.

6 Moltzer E, Roos-Hesselink JW, Yap SC, Cuypers JA, Bogers AJ, de Jaegere PP, *et al.* Endovascular stenting for aortic (re)coarctation in adults. Neth Heart J 2010; 18:430–436.

7 Vergales JE, Gangemi JJ, Rhueban KS, Lim DS. Coarctation of the aorta – the current state of surgical and transcatheter therapies. Curr Cardiol Rev 2013; 9:211–219.

8 Salcher M, Naci H, Law TJ, Kuehne T, Schubert S, Kelm M. Balloon dilatation and stenting for aortic coarctation a systematic review and meta-analysis. Circ Cardiovasc Interv 2016; 9:e003153.

9 Bozzani A, Odero A. Stent implantation in the native and recurrent aortic coarctation in children. Am J Cardiol 2012; 109:1822.

10 Shennib H, Rodriguez-Lopez J, Ramaiah V, Wheatley G, Kpodonu J, Williams J, *et al.* Endovascular management of adult coarctation and its complications: intermediate results in a cohort of 22 patients. Eur J Cardiothorac Surg 2010; 37:322–327.

11 Tanous D, Collins N, Dehghani P, Benson LN, Horlick EM. Covered stents in the management of coarctation of the aorta in the adult: initial results and 1-year angiographic and hemodynamic follow-up. Int J Cardiol 2010; 140:287–295.

12 Baykan A, Karagöz T, Celiker A. Endovascular stent implantation for coarctation of the aorta in children and young adults: intermediate follow-up results from Turkey. Turk J Pediatr 2009; 51:116–119.

13 Erdem A, Akdeniz C, Sarıtaş T, Erol N, Demir F, Karaci AR, *et al.* Cheatham-Platinum stent for native and recurrent aortic coarctation in children and adults: immediate and early follow-up results. Anadolu Kardiyol Erg 2011; 11:441–449.

14 Godart F. Intravascular stenting for the treatment of coarctation of the aorta in adolescent and adult patients. Arch Cardiovasc Dis 2011; 104:627–635.

15 San Norberto García EM, González-Fajardo JA, Gutiérrez V, Fernández B, San Román A, Vaquero C. Open surgical repair and endovascular treatment in adult coarctation of the aorta. Ann Vasc Surg 2010; 24:1068–1074.

16 Wheatley GHIII, Koullias GJ, Rodriguez-Lopez JA, Ramaiah VG, Diethrich EB. Is endovascular repair the new gold standard for primary adult coarctation? Eur J Cardiothorac Surg 2010; 38:305–310.

17 Thanopoulos BD, Giannakoulas G, Giannopoulos A, Galdo F, Tsaoussis GS. Initial and six-year results of stent implantation for aortic coarctation in children. Am J Cardiol 2012; 109:1499–1503.