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Review

Endovascular treatment of native aortic coarctation in adults: Two case reports and detailed review of the literature

Erişkinlerde aort koarktasyonunun endovasküler tedavisi: İki olgu sunumu eşliğinde detaylı literatür derlemesi

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Abstract

Coarctation of the aorta (CoA) forms 6-8% of congenital heart diseases (CHD). This narrowing typically occurs in the proximal descending aorta, close to the insertion of the patent ductus arteriosus and can be found with a number of concomitant diseases. CoA is a common cause of secondary arterial hypertension in young adults. Although CoA can be an isolated CHD, it is also commonly found in other congenital syndromes and cardiovascular anomalies. Herein this review paper we reported a brief history of management of aortic coarctation, and current treatment modalities concentrated on stent placement supported with two novel cases.

Keywords: aortic coarctation; stent placement; endovascular

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Öz

Aort koarktasyonu doğuştan kalp hastalıklarının % 6-8'ini oluşturur. Koarktasyon, tipik olarak proksimal inen aortta, patent duktus arteriyozusun başlangıcına yakın bir yerde meydana gelir ve birkaç eşlik eden hastalıkla birlikte bulunabilir. Aort koarktasyonu, genç yetişkinlerde sekonder arteriyel hipertansiyonun yaygın bir nedenidir, izole bir konjenital kalp hastalığı olmasına rağmen, diğer konjenital sendromlarda ve kardiyovasküler anomalilerde de yaygın olarak bulunur. Bu derleme yazısında, aort koarktasyonunun kısa bir yönetim tarihçesini ve iki yeni vaka ile desteklenen stent yerleştirilmesine yoğunlaşan mevcut tedavi yöntemlerini bildirdik.

Anahtar kelimeler: aort koarktasyonu; stent; endovasküler

Introduction

Coarctation of the aorta (CoA) forms 6-8% of congenital heart diseases (CHD). This narrowing typically occurs in the proximal descending aorta, close to the insertion of the patent ductus arteriosus (PDA) [1], and can be found with a number of concomitant diseases. If left untreated in childhood, CoA has a poor prognosis because of arterial hypertension resulting in various complications such as aneurysms, heart failure, dissection, coronary artery disease, and intracranial hemorrhage.[2-4]

Although first described in the 1700s, the first operations for coarctation were performed in 1944.[5,6] Surgical repair remained the only form of intervention from 1945 until the advent of balloon aortic angioplasty reported in 1982 (7), and the use of balloon-expandable endovascular stents became available in the 1990s firstly introduced by Charles Mullins, a congenital interventional cardiologist.[8,9]

In the current era, the repair of the narrowed section has been performed with surgical treatment in infants, and early childhood. Endovascular treatment (EVT) has generally been the procedure of choice for older school-age, adolescent, and adult patients with native coarctation and those with recurrent coarctation. [10,11] As expected, surgical treatment is more invasive. It may cause complications such as bleeding, wound infection, re-coarctation, systemic hypertension, aortic aneurysm formation, endocarditis, premature coronary atherosclerosis, aorto-bronchial or aorto-esophageal fistulas and pain as well as a faulty cosmetic appearance at the incision site. Besides, open repair of CoA entails the cardiovascular and respiratory risks posed by general anesthesia, in addition to procedural and periprocedural complications. Furthermore, open repair often necessitates a median sternotomy or lateral thoracotomy incision, which can result in significant respiratory morbidity, particularly in a patient who has severe asthma with mild airflow obstruction. Moreover, approximately 10% of patients who undergo initial operative repair of coarctation require a subsequent percutaneous intervention for recurrence of aortic obstruction.[12]

Untreated CoA in adolescents and adults represents a different cohort of patients. These patients may have less severe stenosis of the aorta but present with extensive collateral arterials (Like case 1) as well as more comorbidities such as aortic dilation and heart valve disorders (like Case 2), all of which represent additional difficulties for open surgery.[13] Furthermore, paraplegia is a rare but devastating complication after CoA repair. The protection of the collateral arteries or dedicated monitoring of postoperative coagulation are of great importance. That is another reason why EVT has been preferred in adults.

CoA is a common cause of secondary arterial hypertension in young adults. Although CoA can be an isolated CHD, it is also commonly found in other congenital syndromes and cardiovascular anomalies. The most common cardiovascular malformation associated with CoA is a bicuspid aortic valve (BAV) with up to 45%-62% prevalence of BAV (both cases). [14] As a result, aortic valve replacement and Bentall/David procedure have been two frequently combined procedures.

A stent's radial strength opposes aortic wall recoil, may improve vessel integrity following the trauma inherent to angioplasty, and avoids the need for balloon overdilation of the adjacent normal aorta, thereby decreasing the risk of

aneurysm formation at the dilation site. Covered stents seem to be particularly useful because of their 'sealing' effect on the stenotic area. Because of this, covered stents are effective in preventing aortic dissection or rupture of the vessel wall. [15] Cheatam- Platinum (CP) stent is one of the most widely used stents in the field of cardiology, which is manufactured from 90% platinum and 10% iridium with an expandable polytetrafluoroethylene covering. While it is available at 8 and 10 rows, it is mostly used in 8-zig configuration, which could be dilated up to 28 mm. This stent has an excellent radial coil strength even at larger diameters and also has brilliant visibility on fluoroscopy.[4]

The BIB balloons provide more controlled inflation because serial angiograms can be obtained after inflating the inner balloon to fine-tune the stent position; they are also associated with less stent shortening.

The European Society of Cardiology guidelines for the management of adult CHD recommended intervention in all patients with a non-invasive pressure difference > 20 mm Hg between the upper and lower limbs accompanied by upper limb hypertension (> 140/90 mm Hg) (Class 1C indication). [16] The AHA guidelines recommend stent implantation in all patients with a gradient >20 mmHg, which are of sufficient size for safe stent placement and in which expansion to adult size is possible.[17]

Herein, we reported two cases: a 20-year-old female with hypertension and suffering from severe asthma with mild airflow obstruction who underwent EVT of simple CoA (without any associated lesions) with a covered stent and followed-up for 26-months; and a 34-year old male who had undergone EVT with a bare-stent 3-years ago and suffering from re-CoA and concomitantly severe aortic stenosis with an ascending aortic aneurysm; providing a detailed review of the literature for management of CoA in the adults.

Case 1

A 20-year-old female patient (small body structure- 150 cm / 38 kg) was evaluated by the nephrology clinic due to systemic hypertension. Past medical history was positive for early-onset atopic asthma with mild airflow limitation requiring treatment with high dose inhaled corticosteroids. After a hypertensive episode, she was admitted to the emergency department, and beta-blocker + enalapril treatment was administered. Following further testing, she was referred to the cardiovascular and endovascular surgery outpatient clinic of Numune Research and Training Hospital Ankara, Turkey, in December 2017. Physical examination revealed weak femoral pulses and brachiofemoral pulsation delay. There was a marked difference in blood pressure between the left arm (161/91 mmHg) and ipsilateral leg (87/63 mmHg). A grade 3/6 systolic murmur was auscultated over the precordial and interscapular areas. Laboratory test results and electrocardiogram were normal. Transthoracic echocardiography (TTE) showed normally functioning BAV with mild aortic regurgitation and a 35mmHg gradient in descending aorta. Subsequently, computed tomography angiography (CTA) reported that the descending aorta narrows in a focal area showed critical stenosis of the proximal descending thoracic aorta compatible with CoA (Figure 1).

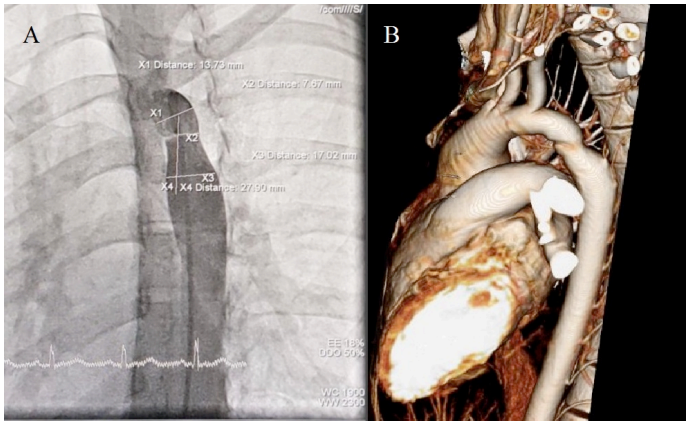

Figure 1. (A)Preoperative angiographic image of case 1. (B) Preoperative 3-D computed-tomography image of case 1

The patient was taken to the angiography suite. Because of severe respiratory status, the procedure was performed under local anesthesia, and mild sedation was provided before and during the deployment of the stent. Under sterile conditions left common femoral artery (CFA) was cannulated following heparin sulfate (100 IU/kg; maximum, 10,000 IU) administration intravenously. The CoA segment was advanced with a 0.035-inch diagnostic guidewire; a marker pigtail catheter was then passed over the wire into the arch of aorta retrogradely. A diagnostic catheterization was performed to determine the exact morphology and the pressure gradient of the stenosis (Figure 1).

We confirmed coarctation in the descending aorta and measured aortic diameter before coarctation (X1=13.73mm), the max-lumen

diameter of the CoA segment (X2=7.67 mm), aortic diameter after the coarctation (X3=17.02 mm) and calculated longitudinal length of the lesion (X4=27.90mm) (Figure 1). The calculated gradient of stenosis was 35 mmHg. Arcus aorta, ascending aorta, and aortic branches were in normal morphology.

The pigtail catheter was changed to a 12F, 75 cm long sheath (Mullins, Cook) over the 0.035-inch exchange guidewire. A manual-mounted eight-zig, with a 22 mm diameter and 3.4 cm long covered CP (NuMED Inc., Hopkinton, NY, USA) stent was loaded on a Balloon-in-Balloon (BIB) delivery catheter with an outer balloon of 14 mm x 3.5 cm (NuMED Inc., Cornwall, Ontario, Canada) was used. All BIBTM catheters have an inner balloon ½ of the balloon diameter of the outer balloon and inner balloon s 1.0 cm shorter than the outer balloon. We delivered the stent using the conventional back-load technique using an Amplatz super-stiff wire that was passed retrograde across the CoA with the help of a JR4 catheter. After ensuring that the stent layout was appropriate, the balloon was manually inflated, according to the manufacturer's recommendations, and the stent was deployed. When the outer balloon was fully expanded (14mm), the stent length shortened to 3.15 cm (a 5.4% shortening), which successfully covered the CoA segment. Angiograms were performed during the stent placement through the sidearm of the sheath to evaluate the results and the presence of any dissection or rupture. Post-treatment angiography showed that the narrowed segment was dilated with no visible gradient (Figure 2)

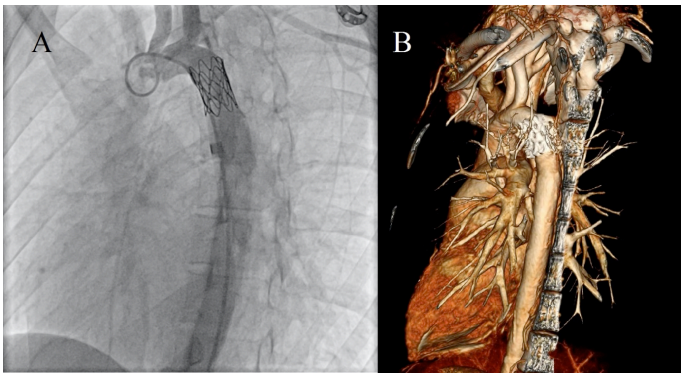

Figure 2. (A)Postoperative angiographic image of case 1. (B) Postoperative 26th month 3-D computed-tomography image of case 1

No complications occurred during and after the procedure. In the immediate postoperative period, strong symmetric pulses were palpable in the lower limbs without pressure gradient between the lower and upper limbs. The postprocedural peak systolic gradient was 0. The diameter of the coarctated segment was increased to 13.67 mm. Postprocedural LMWH and antibiotics were given for 2 days. Aspirin was given 150 mg (5 mg/kg) the night before the procedure and continued for 6 months. Blood pressure was returned to normal limits, as were the discrepancy between upper and lower limbs. The patient was hemodynamically stable and discharged at postoperative 2nd day and has been followed at the outpatient clinic. Follow-up controls were done at 1st, 6th, and 14th and 26th months. CTA was performed at 14th-month control follow-up, which revealed that the stent lumen was open, and there was no re-coarctation re-stenosis or gradient, and no anti-hypertensive treatment was necessary for the follow-up visits. The diameter of the coarctated segment was 13.71 mm.

In 2020, 26th-month CTA control (Figure 2) was revealed no gradient, ascending aorta diameter was 32mm, the coarctated segment was 13.21mm, and aorta and all of the major branches were patent.

Case 2

A 34-year old male was admitted to our clinic because of dyspnea, palpitation, and hypertension. The past medical story included a covered CP stent implantation (12mm x 3.9 cm) to the descending aorta because of CoA 3-years ago in another hospital. He was suffering from intermittent claudication and uncontrolled hypertension despite using three different groups of antihypertensive medications. Physical examination revealed weak femoral pulses and brachio-femoral pulsation delay. There was a marked difference in blood pressure between the left arm (194/112 mmHg) and ipsilateral leg (91/61 mmHg). CTA revealed re-CoA of the previously treated segment and ascending aortic aneurysm with a diameter of 6.8 cm. TTE revealed a BAV with severe stenosis and a gradient of 48mmHg in the coarctated segment. We planned a two-stage procedure. In the first stage, we decided to treat CoA with balloon angioplasty to reduce the afterload. After taking the patient to angio-suite and performing a similar technique with the first case, we measured the length and diameter of stent and aorta, and then we achieved a successful balloon angioplasty for the re-CoA with Z-MED (16x4mm, NuMED Inc., Hopkinton, NY, USA) balloon, which was introduced via 9F catheter and a 0.035-inch guidewire under local anesthesia and sedation. No complications occurred

during and after the procedure. In the immediate postoperative period, strong symmetric pulses were palpable in the lower limbs without pressure gradient between the lower and upper limbs. The postprocedural peak systolic gradient was 3 mmHg. LMWH was administered for 5 days. After ensuring the success of the first stage and the preoperative preparations, a Bentall procedure was performed. The postoperative ICU stay was 2 days, and the hospital stay was 11 days.

Discussion

EVT is now preferred over surgical management in adult patients with discrete coarctation without associated arch hypoplasia.[18] Currently, balloon angioplasty alone is not recommended for the treatment of significant CoA in adults., but it can be preferred for re-CoA.[13] We used balloon angioplasty as a bridge for effective reduction of afterload for a Bentall procedure.

This case also showed that EVT of CoA provides immediate hemodynamic benefit. In both cases, the diameter of the CoA site was increased, and the gradient through the coarctated segment was significantly reduced. Besides, the arm to-leg systolic gradient decreased sufficiently. The results presented in this case confirm the data of other studies that EVT is an effective method of treatment of CoA.[19,20]

Although some operators attempt angioplasty first, balloon-expandable stent implantation is currently regarded as standard-of-care therapy for adolescent and adult patients with primary CoA because stent implantation has proven to reduce the risk of re-CoA as compared with balloon angioplasty by preventing over-dilatation and thereby aortic wall injury and resulting in a lower degree of elastic recoil. [21] The reported risk of aortic aneurysm formation is less than 10% after stent implantation, as compared with 17% in patients after balloon angioplasty alone, and 51% in patients after surgical repair.[22]

A direct comparison between the three main treatment strategies (surgical, balloon, or stent) in CoA is challenging. The initial treatment effect is usually evaluated by the gradient reduction after a repair, but data with regard to residual gradients after surgical repair are lacking. In 2011, Forbes et al. published data of a multicenter, observational, nonrandomized study involving 350 patients from 36 institutions. Compared with surgery, stent placement appeared to produce hemodynamically equivalent results during follow-up observation. Moreover, stenting was associated with significantly fewer complications [2.3% versus 8.1% for surgery and 9.8% for balloon angioplasty ($p < 0.001$)] and shorter hospital stays [2.4 days versus 6.4 days for surgery]. The reintervention rate was higher in the stent group; however, this finding was attributed to staged procedures or patient somatic growth, and all reinterventions carried a similar low risk of morbidity and mortality aortic wall complications of any type occurred significantly more often in the balloon angioplasty group as compared with the surgery or stent repair group.[23] On the other hand, in the Quebec Native Coarctation of the Aorta Study, investigators retrospectively compared surgical repair to angioplasty in 80 patients (mean age, 12 years) treated between 1998 and 2004. Procedure-related complications were far more common in the surgical group (50%) than in the angioplasty group (18%) ($p = 0.005$). The median hospital stay was 7 days for the surgical group and 1 day for the angioplasty group ($p < 0.001$). At 38 ± 21 months, however, the rate of follow-up repeat intervention was higher in the angioplasty group (32%) than in the surgical group (0%) ($p < 0.0001$) (24). The main reason for which surgery favors stent repair is the increased risk for complications after stent repair in children that are not outgrown, which are usually below the age of 8–10 years. The use of bioabsorbable stents may be a promising technique in the setting of coarctation stenting.

The direct end-to-end sutured anastomosis, which had been initially described by Crafoord and Nylin [5] in 1945, has mostly been abandoned due to high rates of re-CoA. Patch aortoplasty, have long been associated with high rates of aneurysmal formation (20–40%) .[25] The addition of polytetrafluoroethylene (PTFE) for aortoplasty lowered rates of aneurysmal disease but, unfortunately, raised the rates of recoarctation to 25%.[26] Surgical repair of CoA can be performed by resection with end-to-end anastomosis, extended end-to-end anastomosis, subclavian flap aortoplasty, graft conduit interposition, bypass graft, or prosthetic patch aortoplasty.[27] Aortic aneurysm formation within the surgical repair group was exclusively found in the subclavian flap and patch angioplasty group.[23] The rate of aneurysm formation has been reported to be between 3% and 20% in long-term

studies of patients who have undergone coarctation repair. Patients repaired with synthetic patch technique are at higher risk of late-term aneurysm development.[14]

Spinal cord ischemia (due to prolonged clamping of the aorta) may cause severe complications, such as paraplegia (0.3% to 2.6%).[22,23] It is especially feared when there is limited collateral flow. In order to avoid spinal cord injury, distal aorta perfusion techniques may be used (i.e., Gott shunt, left heart bypass, femoro-femoral bypass, or cerebrospinal fluid drainage.[13]

The risk of acute complications was lowest after stent repair as compared with after surgery or balloon angioplasty. The overall mortality rates have significantly been more than the stents, such as 30 years after surgery is reported to be 23.7% reintervention 20% as described by Toro-Salazar et al. [28] Longest follow-up balloon angioplasty was performed by Reich et al. with 20 years, and they reported a rate of mortality of 8.1% and reintervention 28.3%.[29] The difference in secondary outcomes partially is attributed to the difference in follow-up durations, as with approximately 10 years after stent repair, 20 years after balloon angioplasty, and up to 50 years after surgery. [30]. However, there are also studies reporting low mortality rates despite extended follow-up as Brown and associates, of the Mayo Clinic, reported an overall 2.4% mortality rate for 819 patients with isolated CoA who underwent primary operative repair between 1946 and 2005 by means of extended end-to-end anastomosis, patch angioplasty, interposition grafting, bypass grafting, or subclavian flap or "other" repair, but they concluded that comparison to age- and sex-matched populations, patients who underwent open repair had reduced long-term survival. Repair at an early age was an independent risk factor for reintervention. At 30 years' follow-up, patients who underwent an initial repair before 1 year of age had an average reintervention rate of 31.1%, and patients who underwent an initial repair before 5 years of age had an average reintervention rate of 73.3% .[31]. A Cochrane review demonstrated that no randomized trials were available to compare surgery and stent repair, which emphasize the need for randomized data to compare different treatment strategies.[32]

Vanagt et al. reported a 9-year experience with CP stents and pointed out

CP as a valuable tool in the management of patients with simple and complex congenital heart disease including CoA, and claimed that the addition of a covering around a stent allows adequate sealing of existing or expected tears, thereby increasing the safety margin with complete dilation of stenotic lesions, with a better expected long-term outcome. [33] Sohrabi et al., evaluated 120 patients with a mean age of 23.60<10.99 years with post-ductal, short-segment, severe native CoA and compared the results of bare CP stent with covered CP stent and concluded that implanting both stents have very high success rates with remarkable hemodynamic effects in severe native CoA patients.[19]

Also, there are several reports in the literature with different uncovered stents such as Kische et al. who treated 52 patients with the Sinus-XL stent concluded that adult coarctation of the aorta treatment utilizing a self-expandable uncovered stent is safe and durable and reported an event-free survival of 82.2±6.3% for 5 years.[34] Tzifa et al. presented the situations where covered stents were chosen: 1) as a rescue treatment in patients with CoA aneurysms or previous stent-relatedd complications 2) in patients at risk of complications because of complex CoA anatomy or advanced age (21) as later confirmed by 2018, AHA/ACC Guideline for the management of adults with congenital heart disease.[35]

Although overall anatomical and hemodynamic results of stent implantation are satisfactory, CoA stenting is not without risk. Frequent complications after stent repair involve difficulties with sheath delivery, vascular complications, restenosis, and aortic aneurysm formation and failure to adapt to the growing child for which dilatation is necessary. One of the most catastrophic complications of CoA stenting is aortic disruption. Stent migration is also one of the most frequently encountered technical complications. The incidence is declared (28/588) 4.8% in multicenter retrospective series. [11] The incidence of peripheral vascular complications after stenting is 2-5% in the literature.[36]

Careful evaluation before the procedure is crucial to prevent vascular complications since covered stent implantation requires an extensive delivery system. After our preoperative evaluation, we decided to cannulate the left CFA instead of the right CFA because of the smaller diameter of the right common iliac artery. BP reduction is a primary goal in the treatment of CoA.[37]

We achieved strict control of blood pressure without medical therapy in approximately 3 years. However, HT may persist after

CoA stenting in adult life, probably due to structural and functional abnormalities of the arterial wall, which can result in diminished arterial wall compliance and increased rigidity.[38] Baykan A et al., after evaluating 20 patients with CP stents because of CoA reported that carotid intima-media thickness, pulse wave velocity (an indirect marker of arterial stiffness), and cardiac output index were found to be significantly higher in CoA patients.[39]

CP stents have also been successfully used for postsurgical recoarctation of the aorta.[40]

In 2018, the AHA/ACC Guideline for the management of adults with congenital heart disease [35] is published. In this guideline, they claimed that multiple factors help to determine whether surgery or stenting is optimal, including anatomic features such as proximity of native coarctation to head and neck vessels or concomitant aneurysm and concluded that, if stenting is the planned strategy for treatment, then a covered stent is needed. Furthermore, they reported that balloon angioplasty alone is associated with a higher rate of intimal tears and aneurysm formation compared with stent placement.

Surgical repair is recommended for most patients with duct-dependent neonatal coarctation, while stent implantation for older children and adults has been shown to have excellent short-term results. Balloon angioplasty for (native) coarctation and re-CoA is effective in leading to an acute gradient reduction [30], as we preferred to perform EVT of CoA with covered stents in Case 1, because of adult age, respiratory problems increase the risk of general anesthesia, extensive collateral development. We preferred to perform balloon angioplasty in Case 2 for re-CoA to provide an immediate hemodynamic reduction of gradient and afterload to be a successful bridge for following the Bentall procedure.

Resection and interposition of a graft conduit is the technique of choice in many centers for adult patients (who have reached their growth potential). It can be surgically tricky due to extensive arterial collaterals -as in our cases- or calcification of the aortic wall (ubiquitous in adult CoA). Furthermore, after EVT, patients often have shorter hospital stays, avoiding many common postsurgical complications such as urinary tract infections, pneumonia- as our patient was vulnerable because of asthma-, and deep venous thrombosis. The role of infections, particularly viral infections, in asthma exacerbations is well-established, and their contribution to asthma development and progression increasingly recognized There is an association between Staphylococcal superantigen-specific IgE antibodies and asthma severity and sinusitis, while fixed airflow limitation has been associated with positive serology for intracellular pathogens, such as Chlamydia pneumonia.[41] Several studies suggest that oxidative and nitrative stress is also increased in severe asthma, deteriorating the postsurgical recovery.

Surgical techniques are mainly reserved for patients with complex aortic arch anatomy such as extended arch hypoplasia or stenosis or para-CoA aneurysm formation. Extended aneurysms can be covered by conformable stents, but stent implantation may require preparative vascular surgery.[42]

Here comes another question. What should we do in the case of post-CoA aneurysmal formation? Theoretically, covered stents have the advantages of reducing the extent of the intimal tear, creating a framework for neointimal growth, and allowing control of the integrity of the aortic wall. For these reasons, they should be the standard of care for managing the coexistent aneurysmal disease.

Here comes another grey-area. The use of a covered stent may be complicated by the occlusion of aortic side branch arteries, and the left subclavian artery is more commonly involved due to the anatomical position. Although it has been suggested that it may be tolerated well, in some cases, it causes claudication of the left arm that requires a carotid to subclavian graft. As a solution, Tufaro et al. dealt with this issue by creating a handmade pinhole in the covered stent before the implantation procedure. By using the stiffer wire in the ascending aorta, they helped the stent to be directed in the standard position. After stent implantation, the pinhole fenestration was adapted to the left subclavian artery size by performing a balloon angioplasty that increased the artery flow. Their technique does not require stent perforation after its deployment, and the most considerable advantage is a significant reduction in the risk of vessel damage.[43]

The ideal patient for stenting has achieved full body growth and has an average transverse aortic arch dimension with a coarctation located at the isthmus, far from the carotid and subclavian arteries. Patients with a gothic geometry of the aortic arch are probably poor candidates for stenting and best treated with an extra-anatomic conduit, which can bypass the aortic arch and the coarctation area. Stenting may be

less successful in patients with suboptimal anatomy, vessel tortuosity, and transverse arch hypoplasia. For these patients, the decision to perform stent placement versus surgical correction must be made case-by-case by the clinical team. [44] A stent provides a more sustainable relief of gradient, with less vascular injury and a more even distribution of forces providing radial support to the vessel wall. Overdistension of the arterial wall, which can cause dissection, is avoided. A stent can seal intimal flaps to the aortic wall, preventing intimal dissection, promoting healing and reinforcing a weakened area [45], but here are also studies in patients with localized native CoA, without isthmic hypoplasia, confirming excellent long-term results with balloon dilatation, as well as a low rate of recurrence and no aneurysm formation.[42]

Conclusion

The endovascular treatment of CoA, as described in this case, is a safe and effective therapeutic option in the selected cases with a low rate of complications and less invasive for adult patients. As an algorithm, native CoA in infants and children should be treated with surgery, Baloon dilatation can be preferred in re-CoA of infants and small children, and as an emergent procedure for bridging the patient to a concomitant procedure. Nevertheless, as a standard, CoA, and reCoA in adults and reCoA in outgrown children should be treated with stents. All patients are prone to aneurysm formation, and recurrent coarctation, so lifelong follow-up is recommended.

Ethical Approval: The study was conducted in compliance with the Declaration of Helsinki with ethics approval provided by our hospital's ethics committees.

Declaration of conflict of interest

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