Progress in Pediatric Cardiology 55 (2019) 101125

Contents lists available at ScienceDirect

Progress in Pediatric Cardiology

journal homepage: www.elsevier.com/locate/ppedcard

Use of covered stent and vascular plug to treat recurrent post-surgical aortic coarctation complicated with aneurysm

Daisuke Kobayashi*, Thomas J. Forbes

Division of Pediatric Cardiology, Children's Hospital of Michigan, Carman and Ann Adams Department of Pediatrics, Wayne State University School of Medicine, Detroit, MI, USA

ARTICLE INFO

Keywords:
Recurrent aortic coarctation
Aortic aneurysm
Covered stent
Vascular plug
Left subclavian artery

ABSTRACT

Recurrent aortic coarctation and/or aneurysm is not an uncommon complication after surgical repair of coarctation of the aorta. When these lesions involve the origin of the left subclavian artery, its management becomes more challenging. We report a 30-year-old female who developed recurrent aortic coarctation complicated with the aneurysm involving the left subclavian artery after the surgical repair. The aortic aneurysm was effectively treated by occlusion of the proximal left subclavian artery by an Amplatzer Vascular Plug Type II and placement of a NuMed Covered Cheatham Platinum stent.

1. Introduction

Recurrent aortic coarctation and/or aneurysm is not an uncommon complication after the surgical and transcatheter therapy of coarctation of the aorta (CoA) [1]. Although the outcome of the open aortic arch repair has significantly improved in the modern era [2,3], endovascular repair is increasingly considered as an effective and less invasive alternative for the complex aortic lesions [4]. Transcatheter therapy utilizing a covered stent has been reported for CoA and/or aortic aneurysm [5–7]. In the United States, the clinical study called "COAST II trial (covered Cheatham Platinum (CP) stents for the prevention or treatment of aortic wall injury associated with CoA Trial)" was conducted to test the safety and efficacy of covered CP stents. The immediate outcome of COAST II trial was reported with a satisfactory result [8]. When recurrent CoA coexists with an aortic aneurysm that anatomically involves the origin of a left subclavian artery (LSCA), the sole use of a covered stent may not suffice. When the circle of Willis is not patent, acute cessation of flow into LSCA by a covered stent potentially leads to brain and left arm ischemia. In contrast, when the Circle of Willis is patent, retrograde blood flow can be established from the left vertebral artery to the left subclavian artery. Aneurysm can be filled from this retrograde flow, even after placement of a covered stent on the aorta. In our report, combination of a covered stent and a vascular plug successfully treated CoA coexisting with the aortic aneurysm involving the LSCA.

2. Case report

A 30-year-old female born with CoA and large ventricular septal defect underwent the surgical CoA repair utilizing end-to-end-anastomosis and pulmonary artery banding at 7 days of life. She underwent removal of the pulmonary artery banding and patch closure of ventricular septal defect at 18 months of life. She was referred to our institution for a concern for recurrent CoA. On presentation, her height was 171 cm and weight was 57.2 kg. Her blood pressure was 105/47 mmHg in the right arm. There was 9 mmHg of gradient between her upper and lower extremities. She had grade 2/6 harsh systolic murmur at the right upper sternal boarder with radiation to the neck and systolic click. Her femoral artery was well palpable with no brachio-femoral pulse delay. Transthoracic echocardiography showed the left aortic arch with a tortuous descending aorta. Doppler evaluation showed flow acceleration (peak gradient 35 mmHg) across the repaired CoA segment. Left ventricular systolic function was normal (ejection fraction 59%) with mild concentric left ventricular hypertrophy. There was no evidence of residual ventricular septal defect. Aortic valve was bicuspid and mildly stenotic (peak gradient 26 mmHg) with no aortic insufficiency. The exercise stress test showed normal aerobic capacity (maximal VO_2 37.5 ml/kg/min, 103% of predicted value) with no evidence of exercise-induced ischemia or abnormal blood pressure response. To delineate her repaired CoA segment, the diagnostic catheterization was performed. The hemodynamic study showed 20 mmHg of a gradient across the repaired CoA segment. Left ventricular end

* Corresponding author at: Division of Pediatric Cardiology, Children's Hospital of Michigan, Carman and Ann Adams Department of Pediatrics, Wayne State University School of Medicine, 3901 Beaubien Blvd, Detroit, MI 48201-2119, USA.
E-mail address: dkobayas@dmc.org (D. Kobayashi).

https://doi.org/10.1016/j.ppedcard.2019.101125
Received 7 March 2019; Received in revised form 6 June 2019; Accepted 17 June 2019
Available online 19 June 2019
1058-9813/

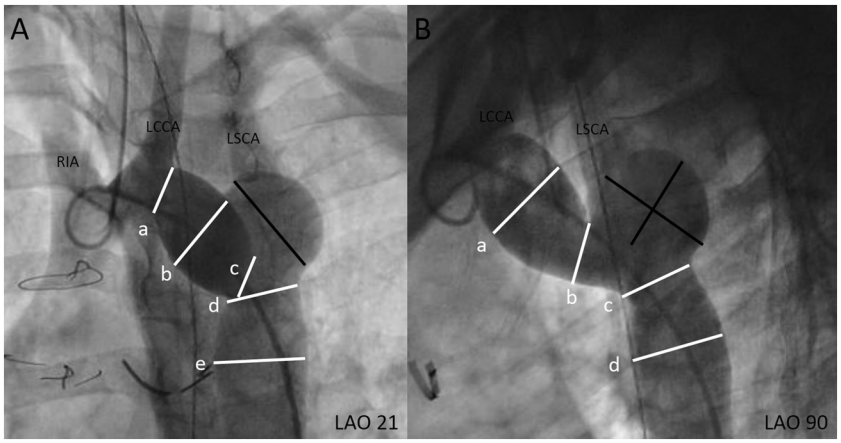

Fig. 1. Aortic angiography. There is an aneurysm at the origin of the left subclavian artery (LSCA). The aortic arch is left sided with a normal branching pattern with the first branch being right innominate artery (RIA) and the second being left common carotid artery (LCCA). There is a recurrent coarctation just proximal to the origin of the aneurysm. (A) Left anterior oblique (LAO) view 21 degree. Measurement: a. 16.4 mm, b. 23.2 mm, c. 10.4 mm, d. 18.6 mm, e. 24.4 mm and aneurysm 29.4 mm. (B) LAO view 90 degree. Measurement: a. 19.4 mm, b. 14.2 mm, c. 14.9 mm, d. 20.5 mm and the aneurysm 22.9 × 24.8 mm.

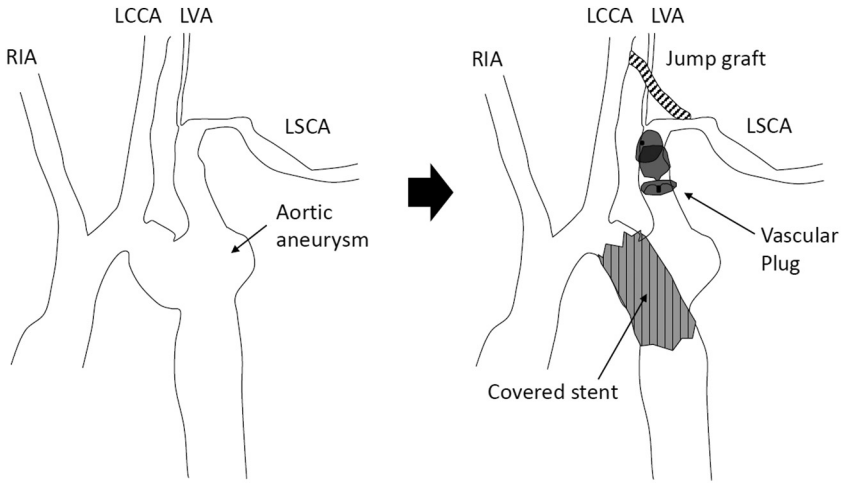

Fig. 2. Schematic figure of aortic anatomy and planned intervention in the antero-posterior view. RIA, right innominate artery; LCCA, left common carotid artery; left vertebral artery; LSCA, left subclavian artery.

diastolic pressure was 8 mmHg with normal right ventricular systolic pressure (24 mmHg). Angiography showed the aortic aneurysm (23 × 25 × 29 mm in diameter) at the base of LSCA (Fig. 1). The narrowest diameter of the descending aorta just proximal to the aneurysm measured 10.4 × 14.2 mm. The transverse arch measured 19.4 mm. The diameter of the descending aorta at the diaphragm measured 15.6 mm. The left vertebral artery (LVA) arose off the LSCA. After extensive discussion, the decision was made to treat her recurrent CoA and aneurysm with a covered stent and a vascular plug (Fig. 2). Although the magnetic resonance angiography of brain and neck showed patency of the Circle of Willis and the bilateral carotid and vertebral arterial system, a surgical jump graft bypass between left common carotid artery (LCCA) and LSCA was considered as a more secure approach to preserve a blood flow to the LSCA and the LVA.

Four months later, a jump graft bypass surgery between the LCCA and the LSCA was performed utilizing a 6 mm ring-reinforced Gore-Tex tube graft. The next day, the cardiac catheterization intervention was performed under general anesthesia. The gradient across the repaired CoA segment was 30 mmHg. The aortic and selective angiography showed the patent jump graft bypass and the proximal LSCA measures 8.3 mm (Fig. 3A and B). Firstly, a 12 mm Amplatzer Vascular Plug Type II (St. Jude Medical, Inc., St. Paul, MN) was deployed to block off the communication with the distal LSCA and the aortic aneurysm (Fig. 3C). Stent placement was assisted by right ventricular pacing to decrease a cardiac output. A 45 mm length NuMed Covered CP stent (NuMed, Inc. Hopkinton, NY) was mounted on a 20 mm BIB angioplasty catheter though a 14-Fr Mullins sheath. The stent was positioned to cover both the stenotic lesions proximal and distal to the aneurysm. The covered stent was successfully delivered on 2 inflations (8 atm). Post-stent angiography showed a satisfactory position of the stent, the widely patent descending aorta and exclusion of the aneurysm (Fig. 4A, B and Video 1). The jump graft effectively bypassed blood flow between the LCCA and the LSCA, providing blood flow to the distal LSCA and the LVA (Fig. 4C). Post-stent, the CoA gradient improved to 6 mmHg. There were no complications. She was discharged the next morning and placed on aspirin 81 mg.

At the 17-month follow-up visit, she was doing well from a cardiovascular standpoint. Her blood pressure was 113/57 mmHg in the right arm with no blood pressure gradient between her upper and lower extremities. Transthoracic echocardiography showed normal left ventricular systolic function and the widely patent stent at the aortic isthmus. On Doppler evaluation, the peak gradient across the stented descending aorta was 20 mmHg. Computed tomography of chest with contrast showed excellent contour of the stented descending aorta with no evidence of an aortic aneurysm or contrast leak (Fig. 5). However, the jump graft between the LCCA and the LSCA was occluded. There was retrograde flow from the LVA to the LSCA through the Circle of Willis. The artery photoplethysmography study showed a normal upstroke and pulsatility with retention of the dicrotic notch at the digit of the left hand, indicating preservation of the arterial flow in the left arm.

3. Discussion

Aortic arch aneurysm is a serious complication of surgical repair of

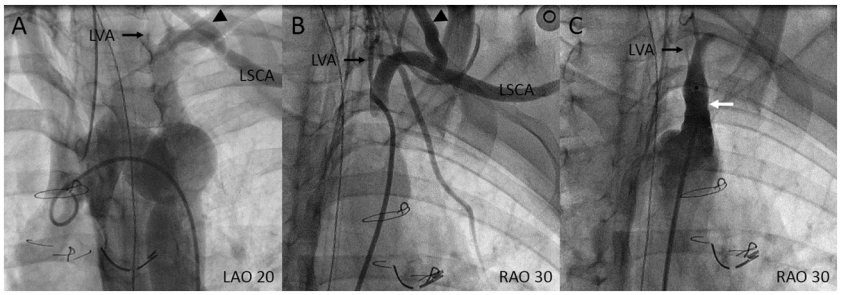

Fig. 3. (A) Aortic angiography after placement of the jump graft bypass between the left common carotid artery and the left subclavian artery (LSCA). The jump graft bypass (black arrow head) is shown with the left vertebral artery (LVA) and the LSCA in the left anterior oblique (LAO) view 20 degree. (B) Selective angiography in the proximal LSCA in the right anterior oblique (RAO) view 30 degree. The origin of the LVA arises from the proximal portion of the LSCA (8.3 mm in diameter). (C) Selective angiography in the proximal LSCA shows that a 12 mm Amplatzer Vascular Plug Type II (white arrow) is positioned proximal to the origin of the LVA.

CoA. Conservative approach for post-surgical aortic aneurysm is not favored, because of its high incidence of rupture in the previous reports [9]. Open aortic arch repair has been the traditional approach for these complex lesions. The early operative mortality has improved significantly but remains 5–14% with the incidence of neurologic dysfunction of 5% even in the modern era [2,3]. Endovascular repair is a valid and less invasive alternative which has comparable mortality and morbidity [4]. Forbes et al. reported the outcome to compare surgical and stent treatment of the native CoA [1]. Endovascular stent placement for CoA was as effective as surgery but had fewer complications acutely. The incidence of re-obstruction and unplanned re-intervention was comparable between the surgery and stent groups at the intermediate follow-up. Treatment of complex aortic arch pathology can be achieved with a multimodality approach. In a single center study of 110 patients with CoA and/or aneurysm, either open, hybrid or endovascular repair was chosen based on the surgical indication and anatomy [10].

Covered stent can effectively and safely treat an aortic CoA and/or aneurysm. Kenny et al. reported 38 covered stents in 37 patients for the aortic CoA with or without aneurysm formation [5]. There were no procedural deaths. One patient had aortic rupture requiring an emergent surgery. Most patients (89%) had no significant post-stent residual arch gradient. Butera et al. reported the use of covered stents in 11 patients for the coarctation associated with aneurysm [11]. There were no procedural deaths or complications. The aneurysms were completely sealed with successful relief of obstruction in all patients. Taggart et al. reported the immediate outcome of COAST II Trials [8]. Among 83 patients with the pre-existing aortic wall injury, complete coverage was achieved in 76 patients (92%); 7 patients had minor endoleaks. The most common complication was an access site arterial injury. In our patient, the aortic aneurysm was completely covered with a single covered CP stent. There was no vascular injury.

The origin of a LSCA can be in close proximity to an aortic CoA complicated with an aneurysm. Pre-procedural brain and neck magnetic resonance angiography plays an important role to show patency of the Circle of the Willis and a carotid-vertebral arterial system. Rehders et al. reported intentional occlusion of the LSCA during the stent-graft implantation in the thoracic aorta in 171 patients [6]. Seven patients (4%) developed mild subclavian steal syndrome, whereas the majority showed no chronic functional deficit. Marcheix et al. reported stent-grafting of the post-surgical aortic aneurysm in 4 patients [7]. Among 3 patients in whom the origin of LSCA was covered, 1 showed left arm ischemia requiring a carotid-subclavian bypass. In our case, pre-procedural imaging study showed the patency of the Circle of Willis and the carotid-vertebral arterial system. However, the decision was made to perform placement of a jump graft bypass between the LCCA and the LSCA, to secure a more reliable flow into the distal LSCA and the LVA. Unfortunately, the follow-up computed tomography showed complete occlusion of the jump graft. The LSCA received blood flow in a retrograde fashion from the LVA through the Circle of Willis. Because our patient did not have symptoms of subclavian steal syndrome and the artery photoplethysmography showed preservation of the arterial flow in the left arm, no further intervention was pursued for the occluded jump graft in our case.

The use of a vascular plug has been reported to prevent Type II Endoleak before an endovascular aneurysm repair [12,13]. Patel et al. reported a 68-year-old man who underwent the thoracic endovascular aneurysm repair of a type B thoracic aortic dissection [14]. In this reported case, an Amplatzer vascular plug was placed to occlude the origin of LSCA after a carotid subclavian bypass. Two years later, emboli originating from the occluded LSCA stamp caused a stroke. This phenomenon is so called subclavian stump syndrome. Although a jump graft bypass was chosen based on the discretion of our vascular surgeon, we acknowledge that a left subclavian-carotid transposition could be a better approach with a long-term patency and no associated risk of subclavian stump syndrome. Because the origin of LSCA would be ligated with a left subclavian-carotid transposition, aortic aneurysm would be excluded without the need of vascular plug in the LSCA. The mechanism of the jump graft failure was speculated elsewhere [15]. Blood flow is retrograde from the subclavian anastomosis to the vertebral artery, possibly causing turbulent flow in carotid subclavian jump graft. In contrast, blood flow is prograde in subclavian-carotid transposition.

4. Conclusion

Aortic aneurysm involving LSCA was successfully treated with the combined use of covered stent and vascular plug. Pre-procedural planning was crucial to perform this complex intervention.

Supplementary data to this article can be found online at https://

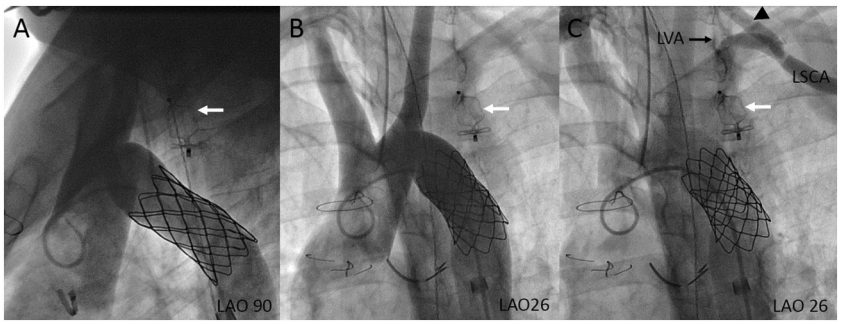

Fig. 4. Post-stent aortic angiography. (A) A 45 mm Numed Cheatham-Platinum covered stent is well positioned in the widely patent descending aorta in the left anterior oblique (LAO) view 90 degree. No contrast is noted in the previously seen aortic aneurysm. A 12 mm Amplatzer Vascular Plug Type II is shown as white arrow. (B and C) LAO view 26 degree in the earlier and later phases of angiography, respectively. In the later phase, blood flow courses from the jump graft bypass (black arrow head) to the distal left subclavian artery (LSCA) and the left vertebral artery (LVA). The proximal LSCA is completed occluded by the Vascular Plug. No contrast is noted in the previously seen aortic aneurysm.

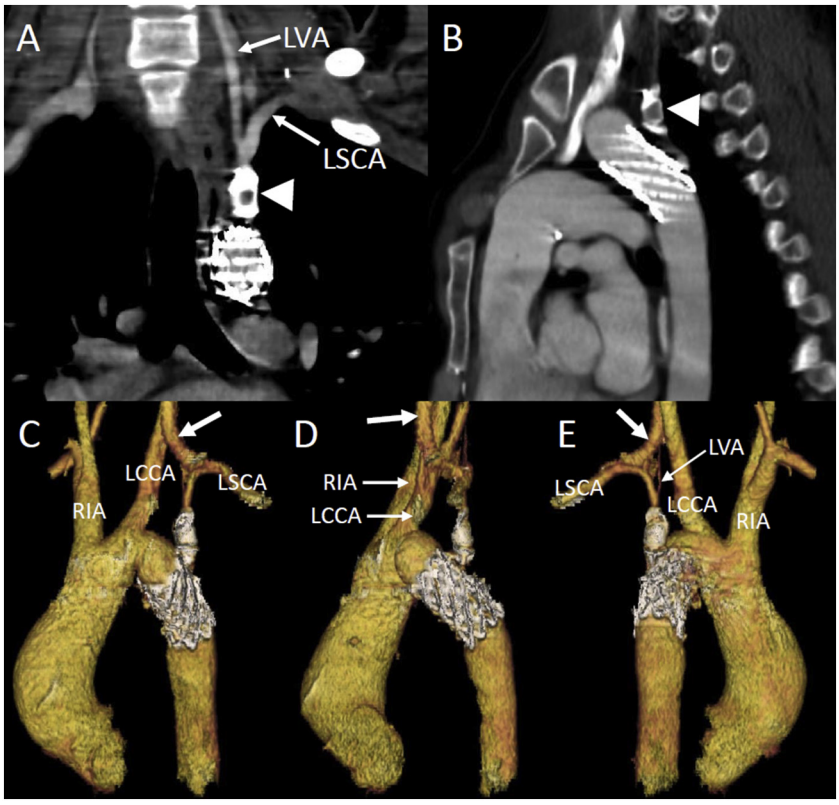

Fig. 5. Follow-up computed tomography of chest 17 months after stent placement. The vascular plug and the covered stent (arrow head) effectively excludes communication with the aortic aneurysm in the coronal (A) and sagittal (B) views. The left vertebral artery (LVA) is patent and arises from the proximal left subclavian artery (LSCA). (C-E) The 3D reconstructed images from the different angle views. RIA, right innominate artery; LCCA, left common carotid artery. Jump graft bypass is shown by white arrow.

doi.org/10.1016/j.ppedcard.2019.101125.

Declaration of Competing Interest

The authors declare that we have no conflict of interest.

References

[1] Forbes TJ, Kim DW, Du W, et al. Comparison of surgical, stent, and balloon angioplasty treatment of native coarctation of the aorta: an observational study by the CCISC (Congenital Cardiovascular Interventional Study Consortium). J Am Coll Cardiol 2011;58:2664–74.
[2] Quintana E, Bajona P, Schaff HV, et al. Open aortic arch reconstruction after previous cardiac surgery: outcomes of 168 consecutive operations. J Thorac Cardiovasc Surg 2014;148:2944–50.
[3] Iba Y, Minatoya K, Matsuda H, et al. Contemporary open aortic arch repair with selective cerebral perfusion in the era of endovascular aortic repair. J Thorac Cardiovasc Surg 2013;145(3 Suppl):S72–7.
[4] De Rango P, Ferrer C, Coscarella C, et al. Contemporary comparison of aortic arch repair by endovascular and open surgical reconstructions. J Vasc Surg 2015;61:339–46.
[5] Kenny D, Margey R, Turner MS, Tometzki AJ, Walsh KP, Martin RP. Self-expanding and balloon expandable covered stents in the treatment of aortic coarctation with or without aneurysm formation. Catheter Cardiovasc Interv 2008;72:65–71.
[6] Rehders TC, Petzsch M, Ince H, et al. Intentional occlusion of the left subclavian artery during stent-graft implantation in the thoracic aorta: risk and relevance. J Endovasc Ther 2004;11:659–66.
[7] Marcheix B, Lamarche Y, Perrault P, et al. Endovascular management of pseudoaneurysms after previous surgical repair of congenital aortic coarctation. Eur J Cardiothorac Surg 2007;31:1004–7.
[8] Taggart NW, Minahan M, Cabalka AK, et al. Immediate outcomes of covered stent placement for treatment or prevention of aortic wall injury associated with coarctation of the aorta (COAST II). JACC Cardiovasc Interv 2016;9:484–93.
[9] Knyshov GV, Sitar LL, Glagola MD, Atamanyuk MY. Aortic aneurysms at the site of the repair of coarctation of the aorta: a review of 48 patients. Ann Thorac Surg 1996;61:935–9.
[10] Roselli EE, Qureshi A, Idrees J, et al. Open, hybrid, and endovascular treatment for aortic coarctation and postrepair aneurysm in adolescents and adults. Ann Thorac Surg 2012;94:751–6.
[11] Butera G, Heles M, MacDonald ST, Carminati M. Aortic coarctation complicated by wall aneurysm: the role of covered stents. Catheter Cardiovasc Interv 2011;78:926–32.
[12] Burbelko M, Kalinowski M, Heverhagen JT, et al. Prevention of type II endoleak using the AMPLATZER vascular plug before endovascular aneurysm repair. Eur J Vasc Endovasc Surg 2014;47:28–36.
[13] Knepper J, Criado E. Surgical treatment of Kommerell's diverticulum and other saccular arch aneurysms. J Vasc Surg 2013;57:951–4.
[14] Patel R, Muthu C, Goh KH. Subclavian stump syndrome causing a posterior circulation stroke after thoracic endovascular aneurysm repair (TEVAR) with adjunctive carotid to subclavian bypass and endovascular embolization of the left subclavian artery. Ann Vasc Surg 2014;28. 1318.e13–6.
[15] Cinà CS, Safar HA, Laganà A, Arena G, Clase CM. Subclavian carotid transposition and bypass grafting: consecutive cohort study and systematic review. J Vasc Surg 2002;35:422–9.