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CASE REPORT

INTERMEDIATE

CLINICAL CASE

Transcatheter Treatment of Native Idiopathic Multiloculated Aortic Aneurysm Guided by 3D Printing Technology

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ABSTRACT

Pediatric idiopathic aortic aneurysm is rare. Single saccular malformation can complicate native or recurrent aortic coarctation; however, multiloculated dilatations of the descending thoracic aorta, associated with aortic coarctation, have so far never been described in literature. In our case, printed 3D model technology was crucial in planning transcatheter treatment. (**Level of Difficulty: Intermediate.**) (J Am Coll Cardiol Case Rep 2023;8:101662)

HISTORY OF PRESENTATION

A 14-year-old asymptomatic girl was referred to our department after incidental diagnosis of aortic coarctation.

LEARNING OBJECTIVES

- To be able to make a differential diagnosis of aortic malformations.
- To understand the role of 3D imaging technology in the treatment of cardiac and extracardiac pathologies with complex anatomy.
- To understand the role of percutaneous treatment in children with native aortic coarctation.

PAST MEDICAL HISTORY

She had no important comorbidity except for history of precocious puberty treated with triptorelin until the age of 10 years. Genetic analysis was performed to exclude the most common conditions associated with thoracic aortic aneurysms in children, such as Marfan syndrome, Loeys-Dietz syndrome, Turner syndrome, and 22q11.2 deletion syndrome.[1] She had no history of infective or inflammatory disorders. During routine echocardiographic screening after asymptomatic SARS-CoV-2 infection, a high-speed jet spectrum during systole at continuous wave Doppler (3.5 m/s, peak gradient 50 mm Hg) at the level of the aortic isthmus was detected. However, distal to the obstruction, multiple flow abnormalities suggestive

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ABBREVIATIONS AND ACRONYMS

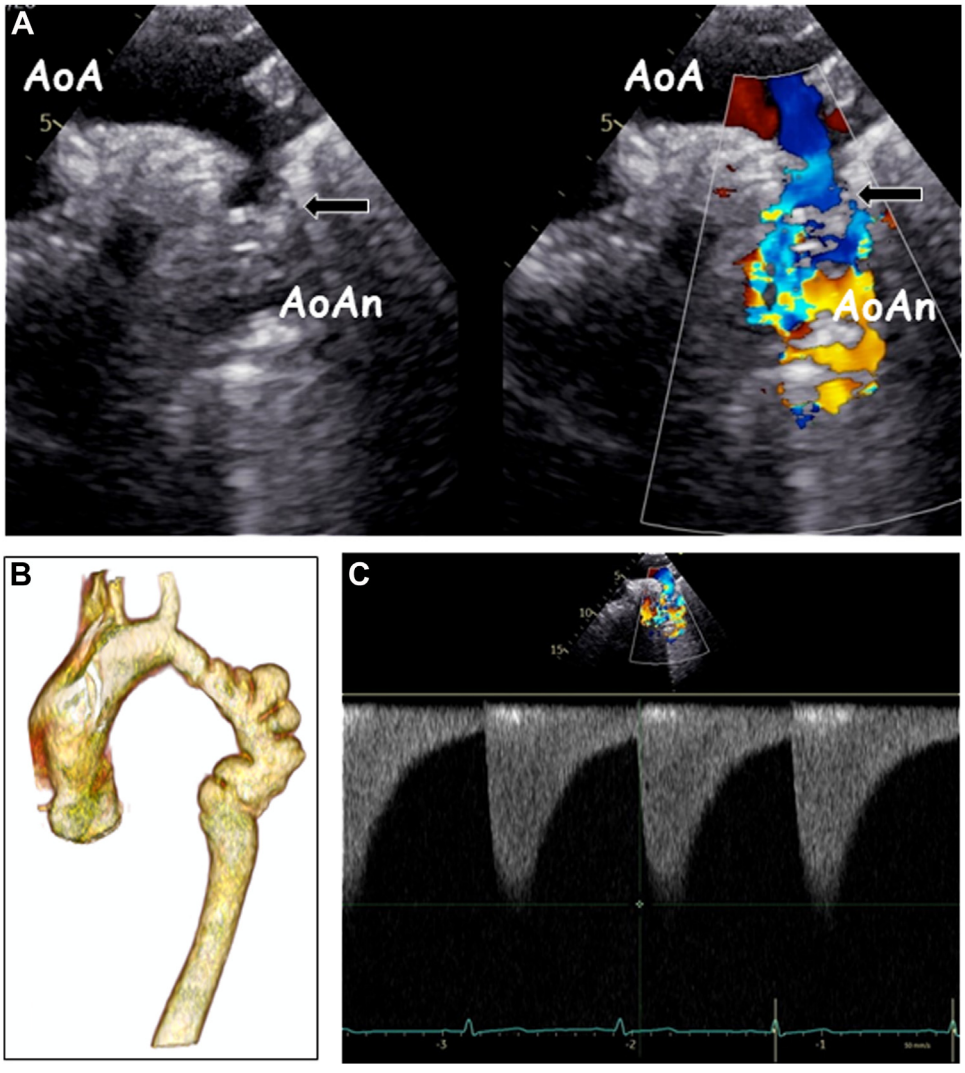
CMR = cardiac magnetic resonance

for aneurysmal dilatation of the descending thoracic aorta were found (Figure 1A). Thus, she underwent thoracic aorta magnetic resonance angiography, which confirmed a complex aortic anatomy, characterized by severe stenosis just distal to the origin of the left subclavian artery and multiple irregular dilatations downstream the aortic isthmus.

INVESTIGATIONS

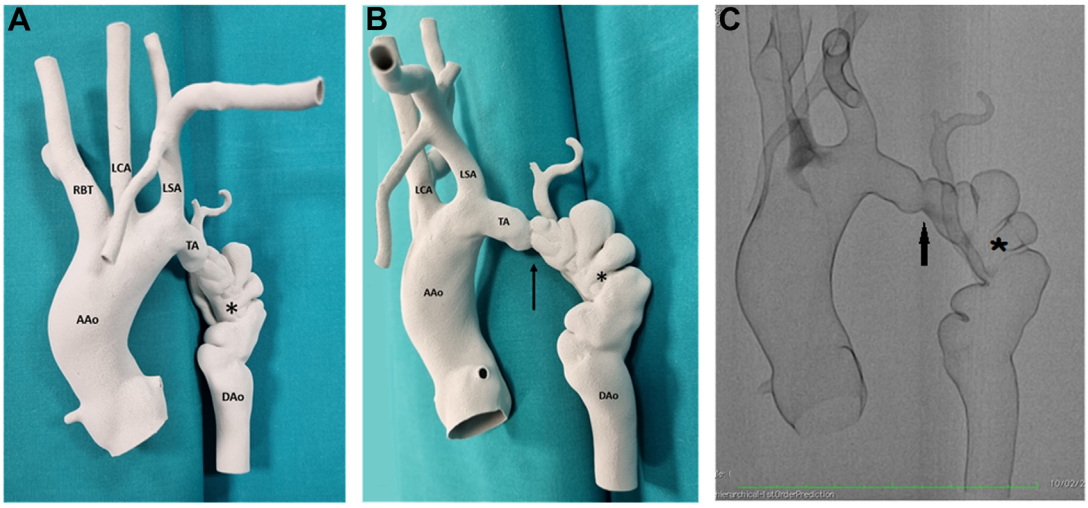
At hospitalization, loud ejection systolic murmur widely spread to the interscapular region was present. In addition, both femoral pulses were weak and delayed with respect to the right and left radial pulse. Systemic arterial pressure was 120/65 mm Hg at the right and left arms and 100/50 mm Hg at the left leg.

FIGURE 1 Preoperative Imaging



(A) Echocardiographic picture of the complex aortic coarctation in 2-dimensional **(left)** and color-Doppler analysis **(right)**, showing the coarctation site **(arrows)**. **(B)** 3-dimensional reconstruction of the aortic arch based on cardiac magnetic resonance data. **(C)** Continuous wave Doppler analysis across the aortic isthmus records a 35-mm Hg peak pressure gradient with diastolic tail across the stenotic segment. AoA = aortic arch; AoAn = aortic aneurysm.

FIGURE 2 **Printed 3D Model**



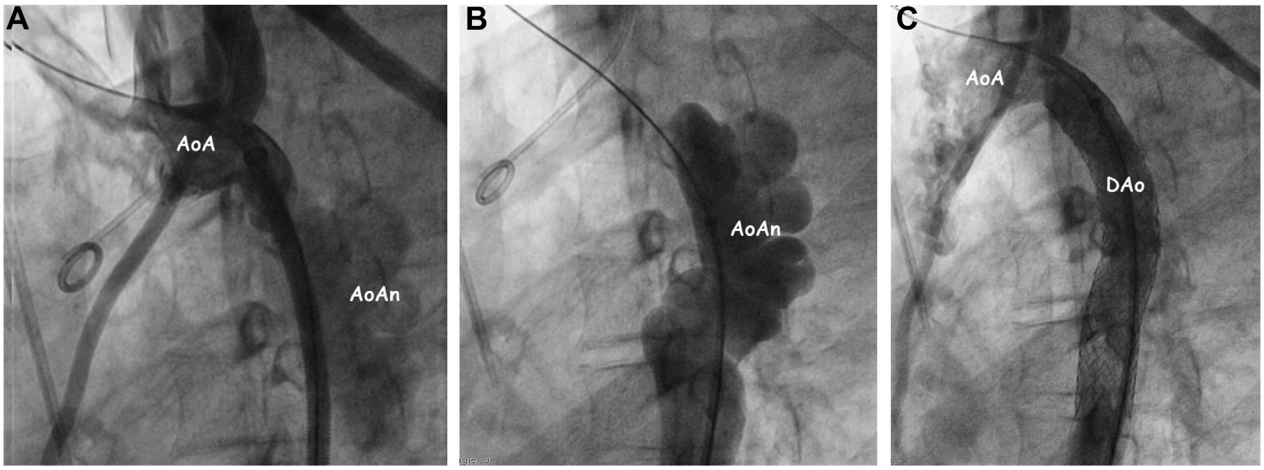
Views from the anterior **(A)** and left oblique **(B)** aspects as well as at fluoroscopy in left anterior oblique view **(C).** The stenotic segment **(arrow)** and the multiple aneurysmal sacs **(asterisk)** are clearly imaged. AAo = ascending aorta; DAo = descending aorta; LCA = left carotid artery; LSA = left subclavian artery; RBT = right brachiocephalic trunk; TA = transverse aortic arch.

At electrocardiogram, incomplete right bundle branch block was detected. At echocardiography, mild left ventricular hypertrophy with preserved ejection fraction was imaged. Aortic arch evaluation showed moderate-to-severe stenosis (40 mm Hg peak-pressure gradient with diastolic tail) localized about 1 cm distal to the left subclavian artery take-off (**Figure 1B**), with the evidence of multiple saccular poststenotic aneurysms. At cardiac magnetic resonance (CMR) scan evaluation, the previously known anatomic data were confirmed (**Figure 1C**, Video 1). Diagnostic laboratory tests resulted normal. She also underwent magnetic resonance angiography of the abdomen, head, and neck without evidence of involvement of other arterial districts, therefore excluding a form of medium and large vessel vasculitis.

MANAGEMENT

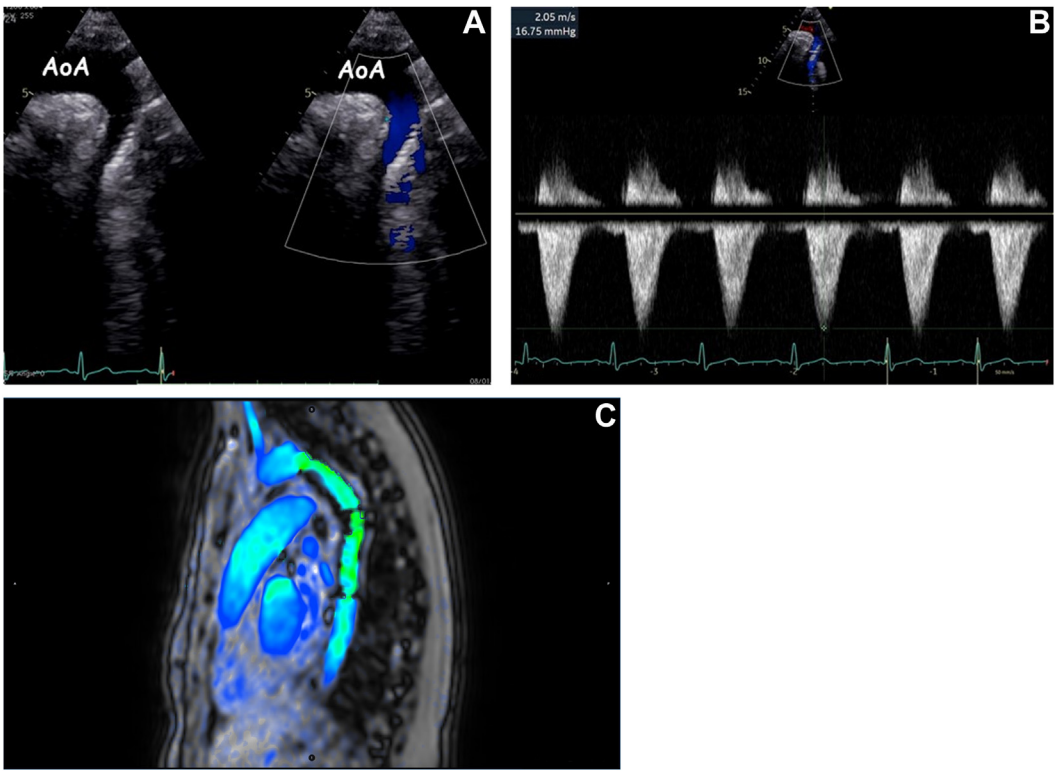
At the heart team discussion, percutaneous treatment of coarctation and multiple aneurysms with covered stents was deemed the best cost-benefit therapeutic option compared with surgical resection and implantation of a prosthetic conduit. Thus, a CMR scan-based 3-dimensional (3D) model of the thoracic aorta, made of thermoplastic polyurethane, was printed to detail this complex anatomy to select the best vascular approach and the most suitable length and diameter of the covered stent (**Figure 2**). Indeed, careful evaluation of the 3D model made us conscious that 2 telescopically implanted long covered stents would be necessary to cover both the stenotic and the aneurysmatic areas, and that the femoral arteries would provide an appropriate vascular access, despite the tortuosity of the postisthmic aortic segment. In addition, the printed 3D model clearly showed the exact distance between the left subclavian artery take-off and the coarctation site. At cardiac catheterization, the moderate stenosis at the level of aortic isthmus (peak-to-peak pressure gradient 25 mm Hg) and the presence of multiple aneurysms extending for about 9 cm from the stenotic segment to the medial portion of the thoracic descending aorta were confirmed (**Figures 3A and 3B**). Thus, the interventional procedure was performed by telescopic implantation of 2 BeGraft 59-mm covered stents (Bentley InnoMed); we chose this stent graft system because it combines high radial force with good flexibility and low foreshortening. It is made of a cobalt-chrome platform covered with a microporous ePTFE membrane. The stents were dilated to 14 mm at the proximal site and 16 mm at the distal site, dilating the stenotic segment and completely excluding the multiple aneurysms with good final angiographic result (**Figure 3C**). Postprocedure

FIGURE 3 **Aortic Angiography Prestent and Poststent Implantation**



(A and B) Angiographic left anterior oblique views of the thoracic aorta showing the discrete coarctation distal to the take-off of the left subclavian artery and the complex geometry of the multiple aneurisms prepercutaneous treatment**. (C)** The poststenting angiography shows relief of the vessel stenosis and complete exclusion of the multiloculated aneurismal sac. Abbreviations as in Figures 1 and 2.

FIGURE 4 **Postoperative imaging**



(A and B) Control echocardiographic evaluation after stent implantation showing complete relief of the aortic isthmus obstruction and exclusion of the aneurysmal sac. **(C)** 4-dimensional flow cardiac magnetic resonance showing the complete exclusion of the thoracic aorta aneurysm. Abbreviations as in Figures 1 and 2.

echocardiographic evaluation showed complete relief of the aortic obstruction and coverage of the aneurysmal sacs (**Figure 4**).

DISCUSSION

Aortic aneurysms and pseudoaneurysms complicating either native or postsurgical coarctation carry an important risk of rupture or fistulization with high mortality rate.[2,3] In this scenario, surgical repair has significant drawbacks in pediatric patients because it involves replacement of the entire aortic segment with a prosthetic conduit, which should be changed as the patient's growth ensues. In recent years, endovascular treatment of aortic pathology with endoluminal stent graft has emerged as a minimally invasive alternative to surgical repair.[4] In addition, using balloon-expandable covered stents has a further advantage in young patients because they can be safely redilated to fit the physiological growth and flow of the aortic arch.[5,6] However, percutaneous treatment requires long-term follow-up because it may be burdened by mid- and long-term complications, including stent fracture, which may need reinterventions, such as stent-in-stent implantation.[7] Moreover, stent implantation remains technically challenging in some cases with complex, unpredictable geometry, because of a short landing zone, which can result in neck and/or thoracic artery compromise. In this setting, preoperative planning with accurate diagnostic tools is particularly important.[5,6,8,9] Recently, 3D modelling technologies are making amazing progress in helping patient-tailored surgical and interventional procedures.[10-12] The 3D printing is a technique consisting in the conversion of digital images, mostly obtained by computed tomography or CMR scan, into a 3D physical model by depositing material in successive layers based on a specific digital design. As usual in complex anatomic settings,[6,13] we therefore decided to build a 3D model of the whole thoracic aorta, which reproduced in detail the aneurysm geometry and size and its spatial relationship with the surrounding structures. This model was crucial in selecting the best vascular approach to the target lesion as well as the most appropriate size and length of the covered stents that would properly dilate the coarcted segment and exclude the aneurysmal sacs. Finally, by enabling better knowledge of the patient's anatomy and procedure's possible pitfalls, accurate preoperative planning allows for preventing possible complications and decreasing the procedure time and, therefore, the amount of contrast media and patient exposure to ionizing radiation.

FOLLOW-UP

The patient was uneventfully discharged home 2 days after the procedure in good clinical status. Computed tomography angiography scan, performed 3 months after hospital discharge, showed effective dilatation of the coarctation site, as well as compete sealing of the multiloculated aneurysmal sac (**Figure 4C**, Video 2).

CONCLUSIONS

Percutaneous treatment of aortic coarctation, with the use of covered and redilatable stent, might be considered a good option in children with complex, challenging anatomy, whenever surgery carries an important risk of complication and reoperation with patient's growth. Preoperative planning based on interactive 3D models can significantly simplify complex transcatheter interventions, by precisely detailing the local geometry and simulating the planned procedure ex vivo.

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Dr Santoro has served as a proctor of Abbott, WL Gore, and Occlutech. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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KEY WORDS 3D printing, aortic coarctation, aortic aneurysm, cardiac MRI, stent

APPENDIX For supplemental videos, please see the online version of this paper.