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ADVANCED

CASE REPORT: DAVINCI CORNER

Transcatheter Treatment of "Complex" Aortic Coarctation Guided by Printed 3D Model

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ABSTRACT

The transcatheter approach is nowadays considered a cost-effective alternative to surgery in adults with "complex" aortic coarctation. The printed 3D model was crucial in planning transcatheter treatment of a complex case of postsurgical aortic re-coarctation, due to coexistence of transverse aortic arch stenosis and pseudoaneurysm as well as aneurysm of the descending aorta. (**Level of Difficulty: Advanced.**) (J Am Coll Cardiol Case Rep 2021;3:900–4) © 2021 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 67-year-old woman was referred for progressive and worsening dyspnea, palpitations, and chest pain at effort, as well as refractory systemic arterial hypertension over the past months.

PAST MEDICAL HISTORY

She had undergone several surgical procedures of aortic coarctation repair: patch angioplasty during adolescence, #12-mm Dacron graft interposition at the aortic isthmus at the age of 20 years, and, finally, extra-anatomic #30-mm Dacron graft interposition between left subclavian artery and descending aorta at the age of 46 years. Several magnetic resonance imaging scans (MRIs), over years, have shown progressive dilation of the descending aorta distal to the bypass graft (55 × 51 mm) associated with severe hypoplasia and stenosis of the distal transverse aortic arch.

INVESTIGATIONS

At hospitalization, loud ejection systolic murmur widely spread to the neck vessels was auscultated. In addition, the left arm and both femoral pulses were weak and delayed with respect to the right radial pulse. Systemic arterial pressure was 145/95 mm Hg at the right arm and 100/50 mm Hg at the left arm. At electrocardiography, signs of left ventricular pressure overload were found. At echocardiographic evaluation, moderate left ventricular hypertrophy without regional functional abnormalities except for reduced diastolic compliance was imaged. Aortic arch evaluation showed moderate

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hypoplasia of the distal transverse arch, proximal to the left subclavian artery take-off, resulting in moderate-to-severe stenosis (50 mm Hg peak pressure gradient with holo-diastolic tail). At computed tomography (CT) scan evaluation, the previously known anatomic data were confirmed and, in addition, a new-onset large pseudoaneurysm (28 × 9 mm) originating from the inferior-posterior surface of the proximal anastomosis of the prosthetic conduit was found (**Figures 1A and 1B,** Video 1). At diagnostic cardiac catheterization, no significant coronary artery stenosis was imaged, and the moderate stenosis at the distal transverse aortic arch (peak-to-peak pressure gradient 30 mm Hg) was confirmed.

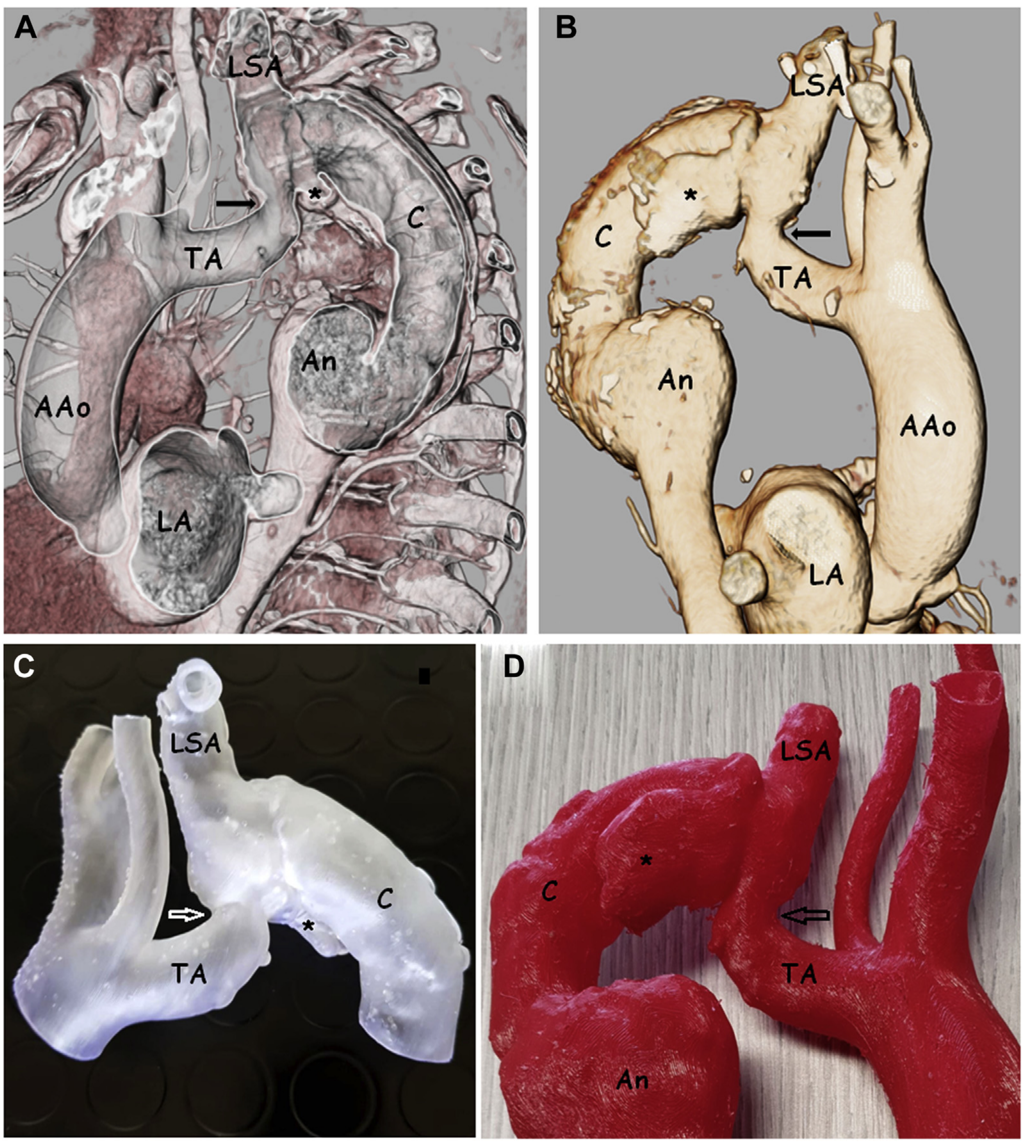
ABBREVIATIONS AND ACRONYMS

3D = 3-dimensional

CT = computed tomography

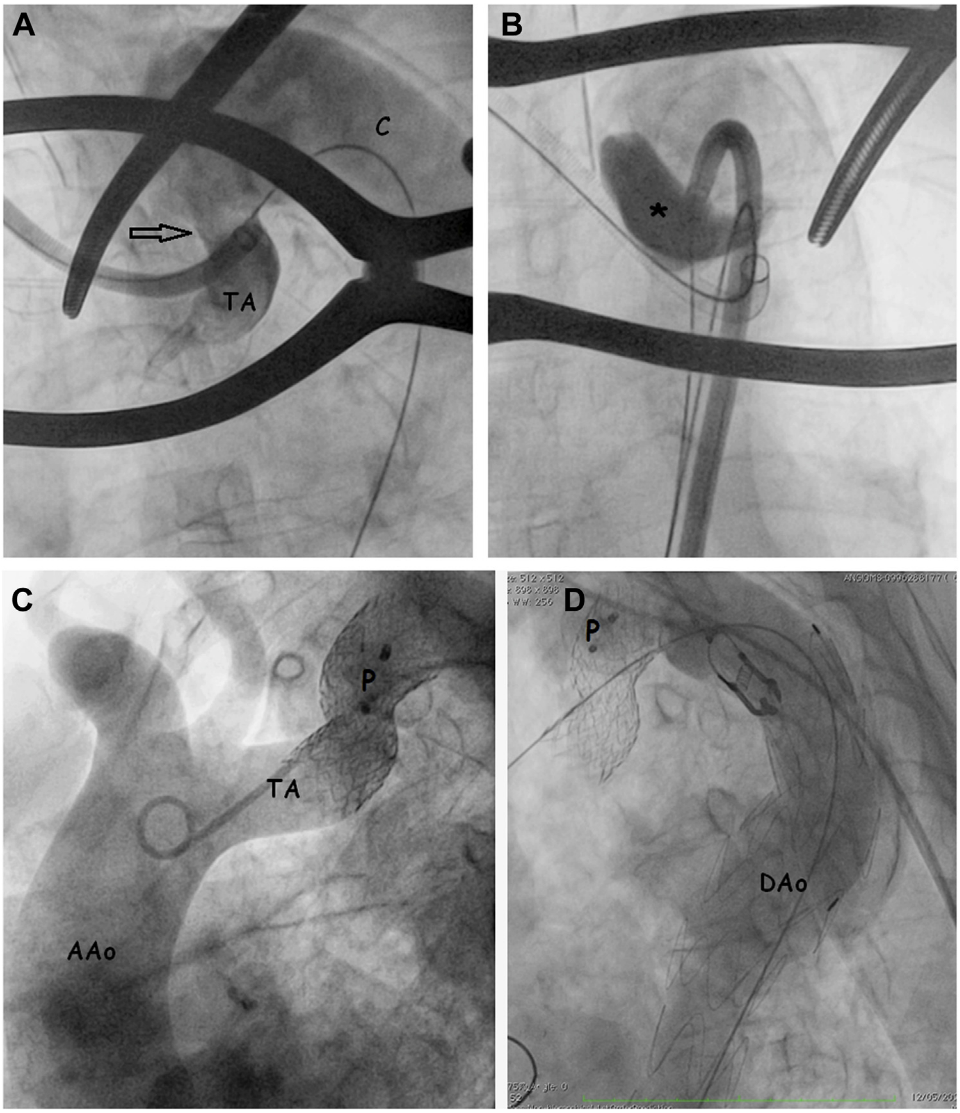
MRI = magnetic resonance imaging

FIGURE 1 **Anatomic Arrangement of the Whole Aorta as Detailed at 3D CT Scan Reconstruction and Printed 3D Model**



CT scan 3D aortic arch reconstruction, as imaged from inside **(A)** (anterior view) and outside **(B)** (posterior view), showing the transverse arch stenosis **(arrow)**, the pseudoaneurysmal sac **(asterisk)**, and the descending aorta aneurysm. Printed 3D model, as viewed from the anterior aspect **(C)** and from behind **(D)**. The complex geometry and tortuous pathway to gain access to the stenotic segment **(arrow)** and the pseudoaneurysmal sac **(asterisk)** at the proximal anastomosis of the prosthetic conduit are clearly imaged. 3D = 3-dimensional; AAo = ascending aorta; An = aneurysm; C = conduit; CT = computed tomography; LA = left atrium; LSA = left subclavian artery; TA = transverse aortic arch.

FIGURE 2 Angiographic Pictures of the Complex Aortic Arrangement

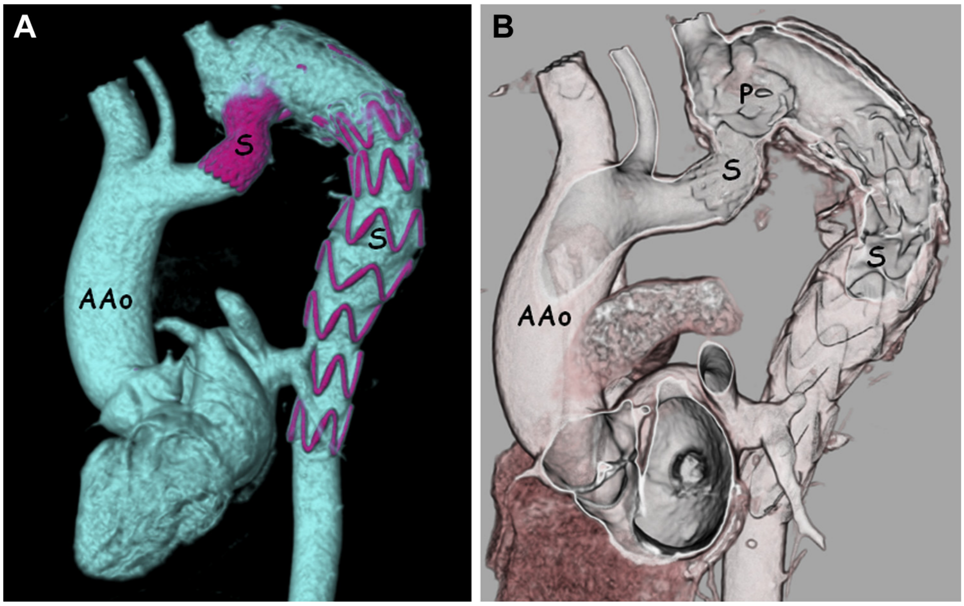


Aortic angiography of the transverse arch stenosis **(arrow, A)** and the pseudoaneurysm **(asterisk, B)**, as imaged antegrade from the right subclavian artery and retrogradely from the femoral artery, respectively. Aortic angiography after plug implantation (P), stenting of the transverse arch and exclusion of the descending aorta aneurysm. Angiography in left oblique view of the ascending aorta **(C)** and thoracic aorta **(D)** after plug implantation (P), stenting of the transverse arch and exclusion of the descending aorta aneurysm. DAo = descending aorta; other abbreviations as in Figure 1.

MANAGEMENT

At the heart-team discussion, the percutaneous approach was deemed as the therapeutic option with the best risk-benefit profile. To effectively plan the transcatheter intervention in terms of vascular access and procedure steps, a CT scan-based 3-dimensional (3D) model of the aortic arch was printed (Figures 1C and 1D). After careful evaluation of the 3D model, due to tortuosity and different cross-sectional areas of transverse aortic arch segments, we had some concerns about complete sealing of the pseudoaneurysm using just a covered stent. In addition, the printed 3D model made clear that, for the particular spatial relationship between the site of re-coarctation and the descending aorta, the use of the right subclavian artery provided a straighter vascular course to the coarctation site than the femoral artery did. Based

FIGURE 3 **Final Post-Intervention Result as Imaged at 3D CT Scan Reconstruction**



CT scan 3D reconstruction as viewed from outside **(A)** and inside **(B)** at 3 months from the procedure. Noteworthy, no residual leak into the pseudoaneurysm and true aneurysm sacs can be imaged. P = vascular plug; S = stent; other abbreviations as in Figure 1.

on this, we planned a sequential treatment of this complex lesion by retrograde occlusion of the pseudoaneurysmal sac from the femoral artery, antegrade stenting of the transverse aortic arch from the subclavian artery, and retrograde exclusion of the descending aorta aneurysm from the femoral artery and were able to fully mimic it ex vivo. A hybrid approach consisting in surgical cut-down of the right subclavian artery and percutaneous entry of the right femoral artery was performed. Aortic angiography confirmed the remarkable tortuosity of the transverse aortic arch, which tapered up to a severe stenosis just proximal to the left subclavian artery take-off and imaged the large pseudoaneurysm at the proximal anastomosis of the prosthetic conduit (Figures 2A and 2B). As mimicked ex vivo, closure of the pseudoaneurysm was achieved retrogradely using a steerable catheter (Agilis NXT, Abbott) with an Amplatzer Vascular Plug II 20 mm (Abbott). Then, stenting of the transverse aortic arch stenosis was performed antegradely with a BeGraft 48-mm covered stent (Bentley InnoMed) dilated to 20 mm that completely sealed off the pseudoaneurysmal sac. Last, exclusion of the aortic aneurysm distal to the prosthetic conduit was achieved by a custom-made Terumo Aortic prosthesis 32/20 × 140 mm (Terumo Aortic, Vascutek Ltd) implanted through the femoral artery, with good final angiographic result (Figures 2C and 2D).

DISCUSSION

Late complications of aortic coarctation treatment, either surgical or percutaneous, are mainly recurrent stenosis and aortic pseudoaneurysms. If left untreated, the latter can rupture, fistulize, or compress surrounding structures (1) with resulting high morbidity and mortality of rescue surgical repair (2). In recent years, endovascular treatment of aortic coarctation has been increasingly considered as the choice option in adults, even in "complex" anatomic settings (1,3,4). However, this approach still remains technically challenging in the case of coexistence of stenosis and nearby pseudoaneurysm or true aneurismal dilatation, mainly in postsurgical settings in which unpredictable fibrosis and anatomic distortion could be found. In this case, pre-operative planning with more accurate diagnostic tools could be particularly important, to decrease overall complexity and risk of either surgical or percutaneous repair.

Three-dimensional printing is a fabrication technique that transforms digital objects into physical models by depositing material in successive layers based on a specific digital design, in most cases by CT or MRI source datasets (5-8). Although this is a recently developing technology, it can reproduce highly detailed complex cardiac and extracardiac anatomic malformations, so providing important additional perspectives, either in percutaneous or surgical treatment of cardiac malformations (9,10).

In our case, building a 3D model of the whole aorta was helpful to choose the best vascular approach to every lesion, by accurately showing the spatial relationship among the irregular and tortuous post-surgical aortic segments. In addition, it finely detailed the pseudoaneurysm geometry and its spatial relationship with the surrounding structures. Finally, mimicking ex vivo the entire procedure made it possible to select the most suitable occluding device, the length and size of the covered stents used to dilate the re-coarctation, and exclude the aortic aneurysm. Overall, this approach was useful to decrease the length and complexity of the procedure and, thereby, the amount of contrast media and patient exposure to ionizing radiation.

FOLLOW-UP

The patient was uneventfully discharged home after 10 days in fairly good clinical condition, except for moderate hypo-chromic anemia. Over mid-term follow-up, her clinical conditions steadily improved, as did the pharmacologic control of the systemic pressure. CT scan performed 3 months after the procedure confirmed the effective dilatation of the re-coarctation site, as well as compete sealing of both the transverse arch pseudoaneurysm and descending aorta aneurysm (**Figure 3**, Video 2).

CONCLUSIONS

Percutaneous treatment of postsurgical aortic re-coarctation in adult patients should be considered feasible and cost-effective even in complex, challenging anatomic settings. Pre-operative planning based on interactive 3D models could be a valuable tool to significantly improve and simplify complex transcatheter or hybrid procedures by enhancing the knowledge of the patient's specific anatomy, choosing in advance or fabricating the most appropriate devices as well as helping to anticipate and prevent potential procedural complications.

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KEY WORDS 3D printing, stent

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