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CASE REPORT
Other

Coronary protection for the small left coronary sinus during transcatheter aortic valve replacement: a case report

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Background Coronary obstruction (CO) is an infrequent but life-threatening complication during transcatheter aortic valve replacement (TAVR).

Case summary We report the case of a patient who accepted TAVR with high anatomical risks of CO due to the small congenital left coronary sinus, which was treated with preliminary coronary protection. This case highlighted the importance of computed tomography angiography (CTA) evaluation, 3D-printing stimulation, predilation as a reference sign, and pre-emptive chimney stenting technology to successfully anticipate and prevent CO during TAVR. At the 3rd month follow-up, CTA evaluation and 3D-printing simulation identified the chimney stenting of the left main coronary arterial patency.

Discussion A 'four-step assessment' method also proposes a new clinical procedure on how to perform TAVR in patients with high risks of CO.

Keywords Aortic valve stenosis • Coronary obstruction • Three-dimensional printing • Chimney stenting • VitaFlow valve • Case report

ESC Curriculum 2.2 Echocardiography • 2.3 Cardiac magnetic resonance • 4.2 Aortic stenosis

Learning points

- The small left coronary sinus is a rare congenital malformation with high risks of coronary occlusion (CO) during transcatheter aortic valve replacement (TAVR).
- Computed tomography angiography evaluation, 3D-printing simulation, and predilation sign could anticipate CO during TAVR by the heart team.
- The pre-emptive chimney stenting technique could prevent CO during TAVR.

Introduction

Transcatheter aortic valve replacement (TAVR) is widely used in the treatment of aortic valve stenosis (AS).[1] However, acute or delayed coronary occlusion (CO) is a rare but devastating complication following TAVR.[2–4] Therefore, it is necessary to assess the risks of CO with the help of preoperative computed tomography (CT) evaluation and intraoperative balloon dilation. Three-dimensional (3D) printed models of aortic root anatomy combined with balloon inflation in-vitro could both help to anticipate the CO.[5] Surgical

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aortic valve replacement (SAVR) should be considered first if patients were identified with high risks of CO. Both TAVR combined with bioprosthetic or native aortic scallop intentional laceration to prevent iatrogenic coronary artery obstruction (BASILICA) procedure or prophylactic coronary protection (CP) by chimney stent could be potential treatment options for high-risk CO patients.[6,7] This case showed a patient with a small left coronary sinus, a rare congenital malformation that had high risks of CO during TAVR. The VitaFlow system (MicroPort, Shanghai, China), a novel self-expanding prosthetic valve,[8] was used to successfully complete the TAVR with the chimney stent technique to protect the left coronary.

Timeline

Day	Hour	Events
0		Computed tomography angiography (CTA) evaluation by 3Mensio Structural Heart software: Evaluation observed high anatomical risks of coronary obstruction (CO) during transcatheter aortic valve replacement (TAVR), because of the patient's small left coronary sinus
3		Three-dimensional printing that modelled the aortic root, and simulation with a balloon dilation, indicated acceptable risks of CO if the patient accepted TAVR
4		The patient refused the surgery and accepted the TAVR after the discussion with the heart team
5	10:00	Aortography demonstrated total occlusion of the left main coronary artery, caused by the left coronary sinus completely compressed by a 22 mm × 40 mm balloon
5	10:15	Placed an undeployed 4.5 mm × 21 mm stent into the left anterior descendent coronary artery
5	10:25	The 24-mm VitaFlow valve was anchored preliminary and maintained as half-released
5	10:26	The undeployed coronary stent was pulled back into the left main coronary artery and protruded to the ascending aorta, then released with high-pressure post-dilation
5	10:30	The VitaFlow valve was completely implanted
8		The patient was discharged 3 days after the operation with dual antiplatelet therapy
100		Follow-up: the CTA evaluation and 3D-printing simulation identified the chimney stenting of the left main coronary arterial patency

Case presentation

A 78-year-old woman diagnosed with mild aortic valve stenosis for 6 years had chest tightness on exertion over the past 1 month with cardiac failure New York Heart Association Class III. Comorbidities were hyperlipidaemia, hypertension, and paroxysmal atrial fibrillation. Echocardiography identified symptomatic severe aortic valve stenosis with mean gradient 59 mmHg, peak velocity 4.9 m/s and valve area 0.8 cm^2, left ventricular ejection fraction 65% and left ventricular end-diastolic dimension 38 mm, moderate tricuspid regurgitation, and pulmonary artery pressure 41 mmHg. Computed tomography angiography (CTA) showed no coronary stenosis, and CTA evaluation by 3Mensio Structural Heart software version 10.0 (Pie Medical Imaging, Maastricht, the Netherlands) hinted the high anatomical risks of coronary obstruction (CO) caused by disequilibrium of the tricuspid valve (sinus of the Valsalva dimensions 26.6 mm × 33.5 mm × 32.0 mm), low left coronary ostia (left 6.3 mm, right 13.5 mm), low left sinus height (14.2 mm), and calcium and thickening of leaflets at left coronary ostia (*Figure 1A–D*). 3D-printing model (MA KE MEDICAL, Xian, China) of the aortic root and simulation with a 22-mm balloon dilation showed the acceptable risks of CO if the patient accepted TAVR (*Figure 1E* and *F*).

The patient was first recommended for a surgical aortic valve replacement with the Society of Thoracic Surgeons score of 6.1%, but she refused the surgery and then accepted TAVR. Next, angiography showed a small left coronary sinus (*Video 1*) and a normal left coronary artery (*Video 2*). Aortography demonstrating total occlusion of the left main coronary artery caused by the left coronary sinus completely compressed by a 22 mm × 40 mm balloon (Microport, Shanghai, China) under rapid pacing (*Video 3*). So, our team decided to place an undeployed 4.5 mm × 21 mm GuReater stent (Lepu Medical, Beijing, China) into the left anterior descendent coronary artery through the left radial artery by a 6-Fr guiding catheter and Guidezilla guide extension catheter (Boston Scientific, USA, Supplementary material online, *Video S1*). After the 24-mm VitaFlow valve was anchored preliminary and maintained half-released, the undeployed coronary stent was pulled back into the left main coronary artery and protruded to the ascending aorta, then released with a high-pressure post-dilation. Finally, the VitaFlow valve was completely implanted (*Figure 2*, Supplementary material online, *Video S2*) without hypotension or ST-segment elevation. According to the CHA2DS2-VASc score (4 points) of patients with atrial fibrillation, oral anticoagulation was recommended. The patient was discharged 3 days after the operation, with dual antiplatelet therapy (aspirin 100 mg and clopidogrel 75 mg, once a day) and anticoagulant therapy (rivaroxaban 2.5 mg, twice a day) for the chimney stenting during TAVR. The anticoagulant and antiplatelet therapy (clopidogrel 75 mg and rivaroxaban 10 mg, once a day) were changed a month later for long-term maintenance. The CTA evaluation and 3D-printing simulation identified the chimney stenting of the left main coronary arterial patency after 3 months of follow-up (*Figure 3*).

Discussion

Transcatheter aortic valve replacement is widely used in the treatment of aortic valve stenosis.[1] However, acute or delayed CO is a devastating complication following TAVR.[4] It is difficult to carry out percutaneous coronary intervention or emergency heart surgery after TAVR. So, every operator must consider the risk of CO for every TAVR. Surgical aortic valve replacement should be considered

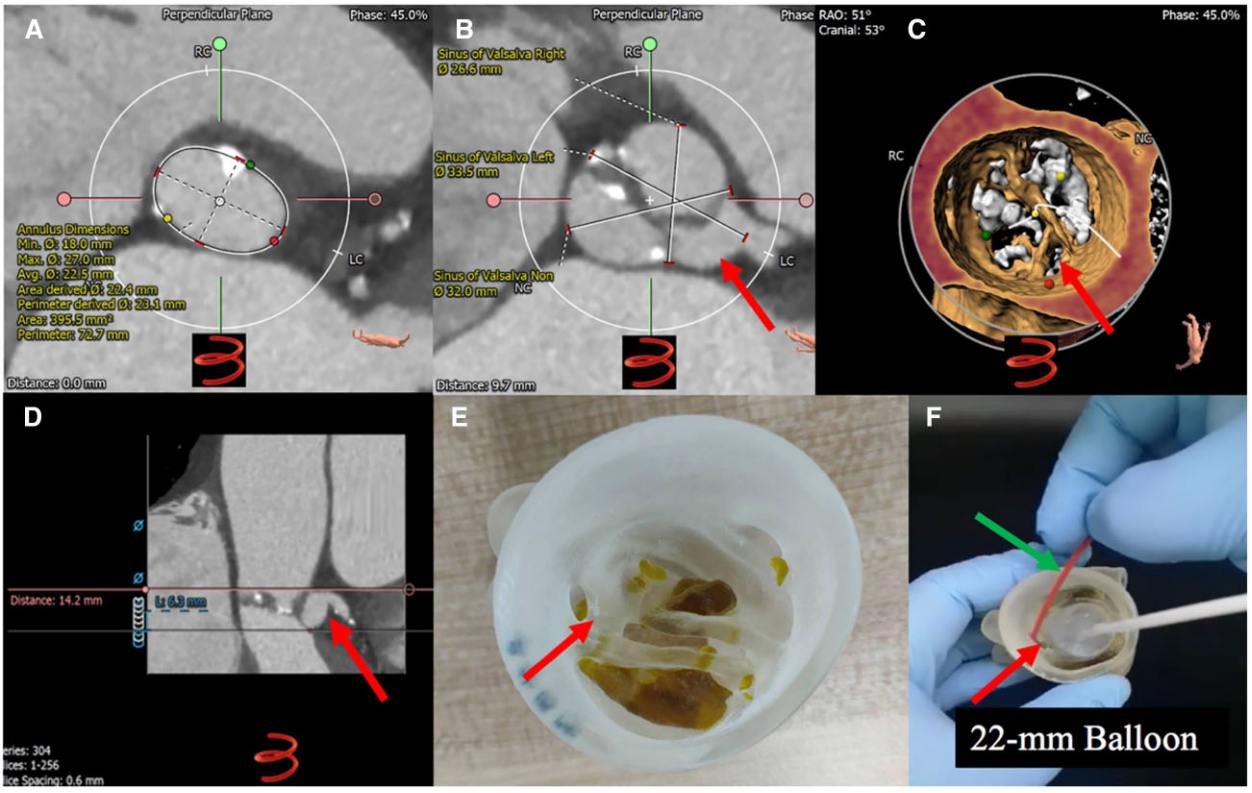
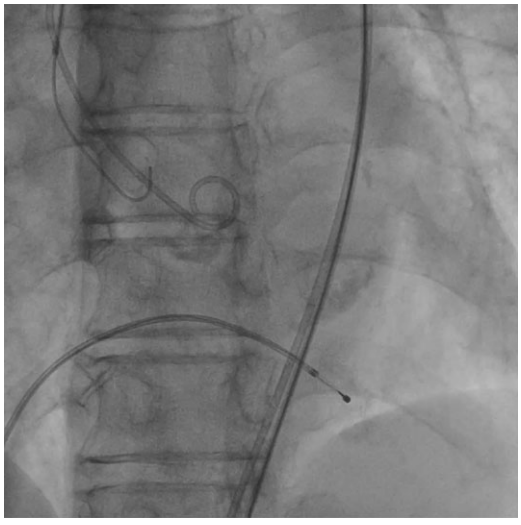
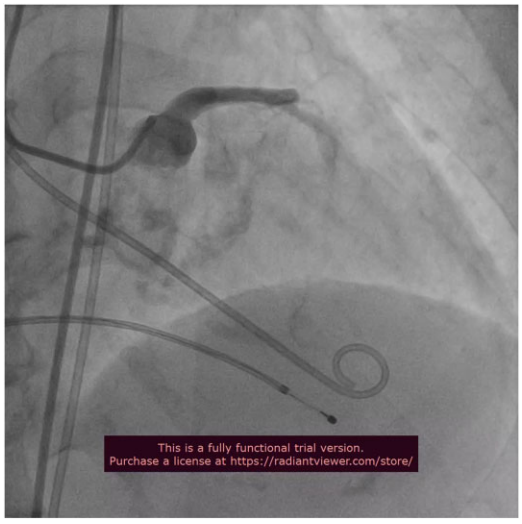


Figure 1 Sizing of aortic valve annulus and sinus of the Valsalva (*A*) and (*B*). Disequilibrium of the tricuspid valve with heavy calcium of leaflets (*C*). Height of left coronary ostium and small coronary sinus (red arrow, *D*). Three-dimensional printing of aortic root, and simulation of 22-mm balloon dilation and probe (green arrow) into left coronary (*E*) and (*F*).



Video 1 Aortography showed a small left coronary sinus.



Video 2 Selective coronary angiography identified a normal left coronary artery

first if patients were identified with high risks of CO. Bioprosthetic or native aortic scallop intentional laceration to prevent iatrogenic coronary artery obstruction (BASILICA) procedure could be a good choice for some patients under TAVR with CO.[9] However, the BASILICA procedure was not widely used in clinical practice because of its complexity in China. As a result, as an alternative procedure

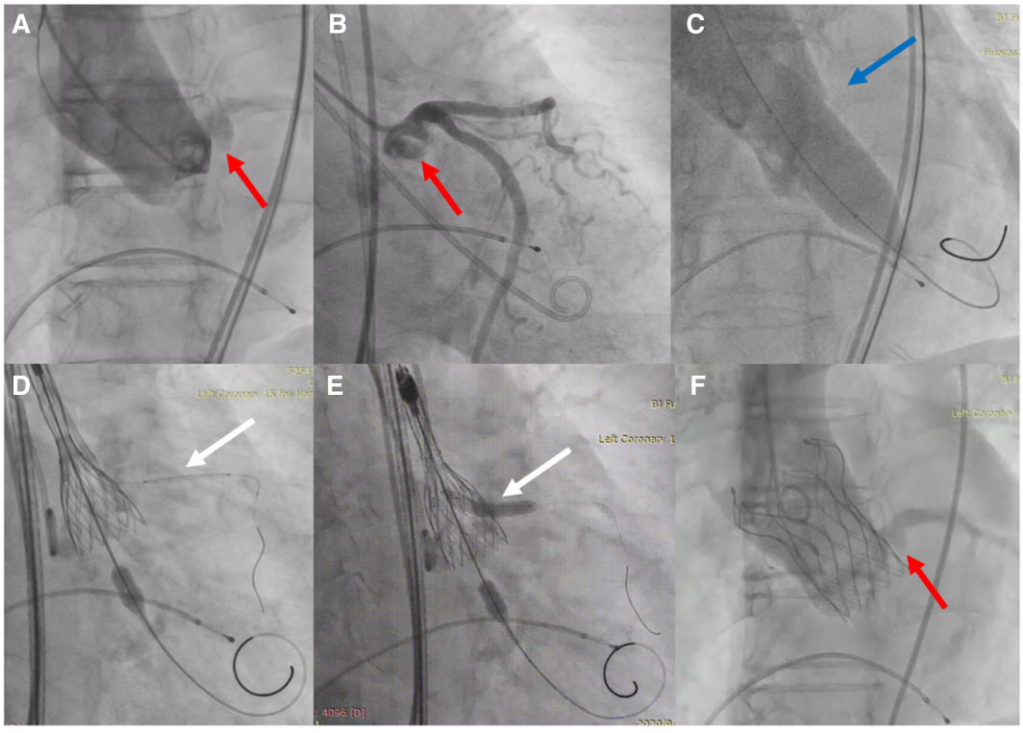
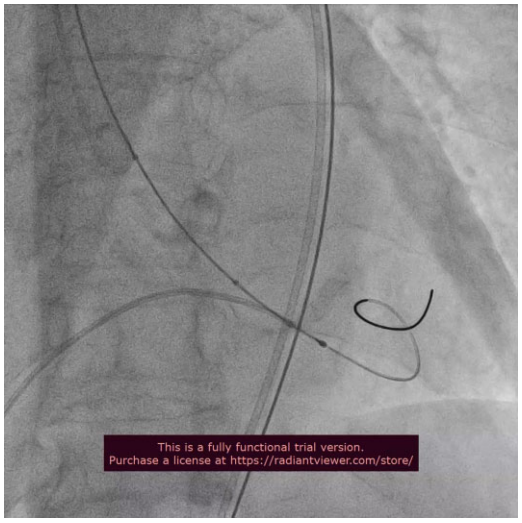


Figure 2 Aortography of aortic root and coronary angiography showed the normal left coronary with the small left coronary sinus (*A*) and (red arrow, *B*). No blood flow in the left coronary (blue arrow) caused by completely compressed left coronary sinus after 22-mm balloon inflation (*C*). Transcatheter aortic valve replacement with a premounted stent (white arrow) in the left coronary (*D*). The pre-mounted stent was released as a chimney stenting (*E*). Aortography showed the chimney stent was patent (*F*).



Video 3 Aortography demonstrated total obstruction of the left main coronary artery caused by the left coronary sinus completely compressed by the aortic valve balloon inflation.

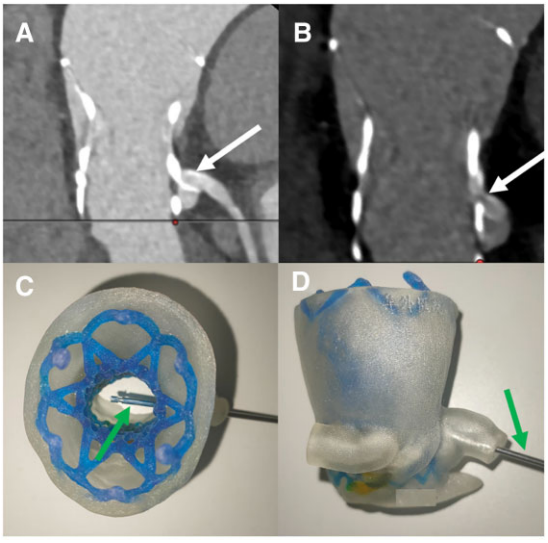


Figure 3 Computed tomography angiography identified the chimney stenting (white arrow) patency at follow-up (*A*) and (*B*). Three-dimensional printing model and probe (green arrow) into left coronary (*C*) and (*D*).

that could also avoid CO,[6,10] TAVR combined with preliminary coronary protection (CP) by chimney stenting are more commonly carried out.

For a patient with high risks of CO during TAVR, a 'four-step assessment' is necessary to prevent CO. First, a detailed CTA assessment checking for risks of CO including the coronary artery height (<10 mm), size (diameter <30 mm) and height of sinus and sinotubular junction (especially valve cusp length > sinotubular junction height), leaflets at the level of the ostium of the coronary artery (especially valve cusp length > coronary ostium height), leaflets characteristics (length, thickening, or bulky calcification), and contralateral or adjacent structure of coronary artery such as raphe or calcium on the non-coronary cusp[4] (*Table 1*). Second, 3D-printing is used to enhance the visual understanding of the interaction between the transcatheter valve and patient-specific aortic platform and further evaluate the risks of CO by simulating with balloon inflation *in vitro*.[5] Third, the risks of CO can be indicated directly by simultaneously carrying out balloon predilation and aortography. Fourth, based on the results of the third step, whether to use the pre-emptive guide wire and coronary stent for CP can be determined.

Table 1 Comprehensive assessment of coronary occlusion risk by CT analysis

Parameter	Numerical value and notes
Coronary artery height	<10 mm
Sinus height	Valve cusp length > sinotubular junction height
Sinus size	<30 mm, shallow sinus
The valve at coronary opening level	Valve cusp length > coronary artery height
The thickening and calcification of Valve	The tissue of the valve leaflet fills the sinus and directly compresses the coronary opening
Contralateral structure of coronary artery	The raphe or calcium on the non-coronary cusp squeeze the prosthetic valve close to the coronary artery
Adjacent structure of coronary artery	The raphe or calcium on the coronary cusp squeeze the prosthetic valve away from the coronary artery

The chimney stenting technique has some disadvantages. Late stent thrombosis and stent failure have been reported with potential mechanisms such as persistent turbulent flow across the transcatheter heart valve and the coronary stent, local inflammatory processes, and galvanic corrosion between both metallic frames. The optimal post-procedural antiplatelet or antithrombotic strategy is unclear. Although the short- and mid-term outcomes were satisfied, data for long-term outcomes are still pending.[10] In addition, current data that examine the association between valve type and CO are contradictory. However, there have been reports of a higher incidence of CO with self-expandable devices, possibly due to the persistent expansion pressure.[4]

The reported patient has been assessed the high risks of CO according to the pre-operative CTA, such as a small left coronary sinus, a rare congenital malformation. So, a VitaFlow system, a novel self-expanding prosthetic valve that features low density and large cells at the superior end, (the end which protrudes to the ascending aorta)[8] (*Figure 4*), was selected and used to complete TAVR successfully with chimney stent technique to protect the left coronary. This

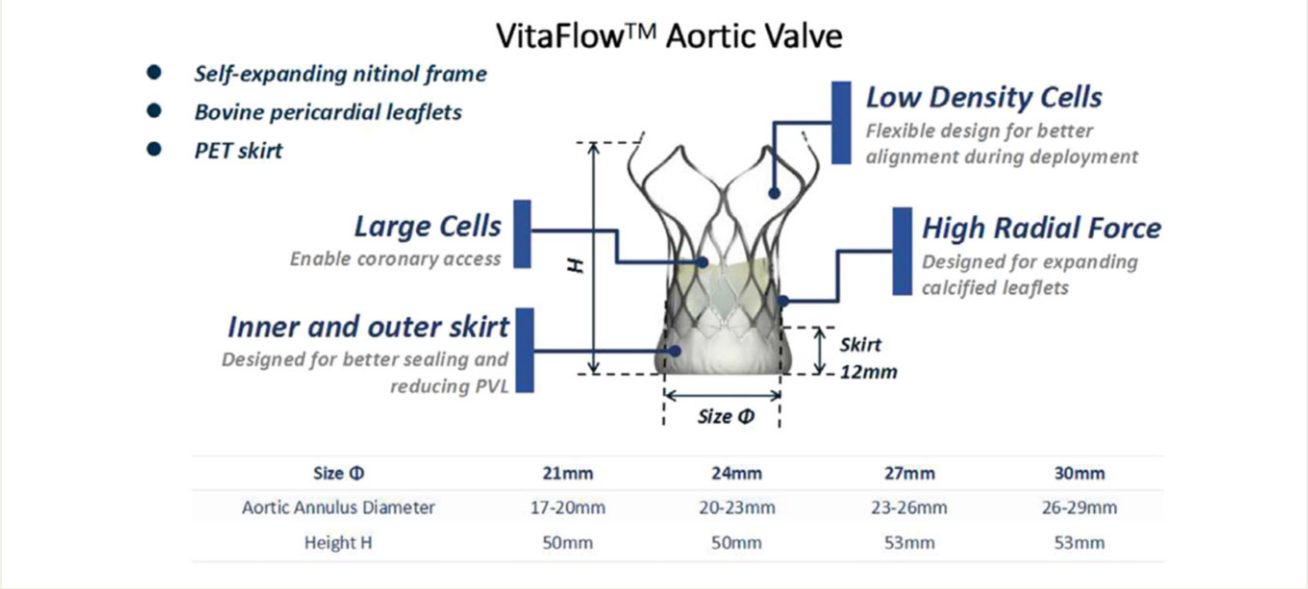


Figure 4 The VitaFlowTM transcatheter aortic valve. VitaFlowTM transcatheter aortic valve is made of a self-expanding nitinol frame and tri-leaflet bovine pericardial valve. It is characterized by low density and large cells at the ascending aorta part, and outer polyethylene terephthalate skirt at the left ventricular outflow tract part.[8]

was the first case of a patient with a congenital small left coronary sinus, which presents a high-anatomical risk of CO that has been successfully treated with preliminary CP and TAVR.

This case highlighted the importance of CTA evaluation, 3D-printing simulation, predilation as reference sign, and pre-emptive chimney stenting technique by heart team to anticipate and prevent the CO during TAVR successfully. A 'four-step assessment' method also proposes a new clinical procedure on how to perform TAVR in patients with high risks of CO.

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Supplementary material

Supplementary material is available at *European Heart Journal—Case Reports online*.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written consent for submission and publication of this case report including image(s) and associated text has been obtained from the patient in line with COPE guidance.

Conflict of interest: None declared.

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