

# Concurrent transcatheter transfemoral tricuspid valve-in-valve and aortic valve implantation using a 3D printed model for pre-OT planning



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## KEYWORDS

- aortic stenosis
- elderly
- prior cardiovascular surgery
- TAVI
- tricuspid disease
- valve-in-valve

## Abstract

Re-operation of a tricuspid bioprosthesis carries high morbidity and mortality, especially when carried out with other concomitant valvular heart surgery. Concurrent transcatheter valve implantation has evolved as an alternative option. Here we report on a 77-year-old lady who suffered from symptomatic severe recurrent stenosis of a tricuspid bioprosthesis (Sorin Pericarbon More, 27) and moderate to severe aortic stenosis (AS) who was declined for redo open heart surgery as it was deemed very high risk. We used a 3D customised printed right heart model for pre-OT rehearsal. Percutaneous V-in-V TVR using a 26 mm Edwards SAPIEN 3 was performed under general anaesthesia via the right femoral vein and showed a satisfactory result in one single attempt. We also evaluated the necessity of aortic valve intervention in detail before and after V-in-V TVR. After confirmation of severe AS, a 26 mm Medtronic CoreValve Evolut R was deployed in the non-calcified rheumatic aortic valve without any predilatation or post-dilatation via the right femoral artery. No significant gradient or leakage was seen. This case shows the feasibility and safety of concurrent transfemoral V-in-V TVR and TAVI. Rehearsal using a 3D printed model helped to increase the accuracy and success rate of the procedure. The transcatheter approach allows detailed haemodynamic assessment after each valvular intervention in the case of multiple valve interventions.

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## Abbreviations

<b>AVA</b>	aortic valve area
<b>IVC</b>	inferior vena cava
<b>PA</b>	pulmonary artery
<b>TAVI</b>	transcatheter aortic valve implantation
<b>TVR</b>	tricuspid valve replacement
<b>V-in-V</b>	valve-in-valve

## Introduction

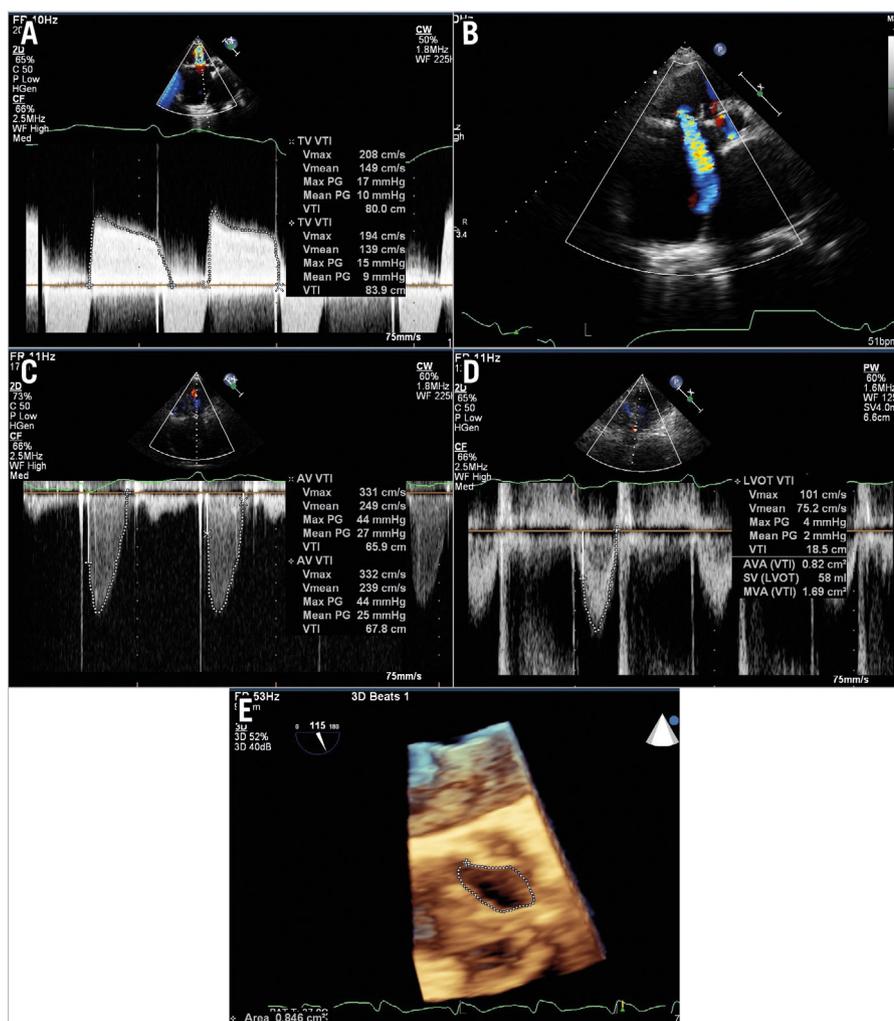
Redo tricuspid valve replacement carries high morbidity and mortality. Transcatheter valve-in-valve (V-in-V) transcatheter valve replacement (TVR) has proved to be an alternative for high-risk patients. With the limited number of cases, a three-dimensional (3D) customised printed model can be used to plan and rehearse the procedure to try to increase its accuracy.

## Methods

Here we report the case of a 77-year-old lady with chronic rheumatic heart disease who had undergone open heart surgery four

times. She had a closed mitral valvotomy in 1973, a mechanical mitral replacement (CM27) in 1988, TVR (Pericarbon More, 27; Sorin Group [now LivaNova], Milan, Italy) in 2007 and surgery the next day for excision of subvalvular chordae of the TVR because of chordal obstruction. A ventricular pacing ventricular sensing inhibition response and rate-adaptive (VVIR) pacemaker was implanted at the coronary sinus in 2007 for her slow atrial fibrillation. A transthoracic echocardiogram in 2011 showed severe stenosis and regurgitation of the tricuspid bioprosthesis. However, redo open heart surgery was declined by the surgeons because of very high surgical risk.

This year, she presented with decreased exercise tolerance and bilateral lower limb oedema with a subsequent transthoracic echocardiogram showing severe stenosis (mean gradient 10 mmHg) and regurgitation of the tricuspid bioprosthetic valve (**Figure 1A, Figure 1B**), moderate to severe aortic stenosis (AS) (mean gradient: 27 mmHg, AVA: 0.82 cm<sup>2</sup>, AVA index: 0.63 cm<sup>2</sup>/m<sup>2</sup>) (**Figure 1C, Figure 1D**) and satisfactory mitral valve replacement (MVR) function without any leakage. Left ventricular



**Figure 1.** Baseline echocardiographic assessments. A) & B) Severe stenosis and regurgitation in tricuspid bioprosthesis. C) & D) Moderate aortic stenosis by Doppler echocardiogram. E) Planimetry of aortic valve area by 3D TEE.

function was satisfactory with an ejection fraction (EF) of 65%, as was right ventricular function. A transoesophageal echocardiogram showed rheumatic AS with doming of leaflets in systole. There was a fused commissure between the non-coronary and right coronary cusps. The planimetry of the aortic area was around 0.7 to 0.85 cm<sup>2</sup> (Figure 1E).

The patient was deemed to be inoperable for redo open heart surgery after discussion in the Heart Team and therefore transcatheter tricuspid V-in-V implantation ±TAVI was planned.

A computed tomography (CT) scan showed a trileaflet aortic valve and the perimeter of the aortic annulus was 64.3 mm, 22.8×17.9 mm in diameter without much calcium. The tricuspid valve bioprosthesis *in situ* had an area of 447 mm<sup>2</sup>. The size of the V-in-V device could be chosen easily using the CT measurement. However, the approach and placement of the supporting wire to obtain the best coaxial plane can be difficult to judge by CT alone. A wire could be placed in the pulmonary artery or in the right ventricle if the right ventricle has enough depth. Therefore, a tailor-made 3D model of the patient's right heart was made in order to

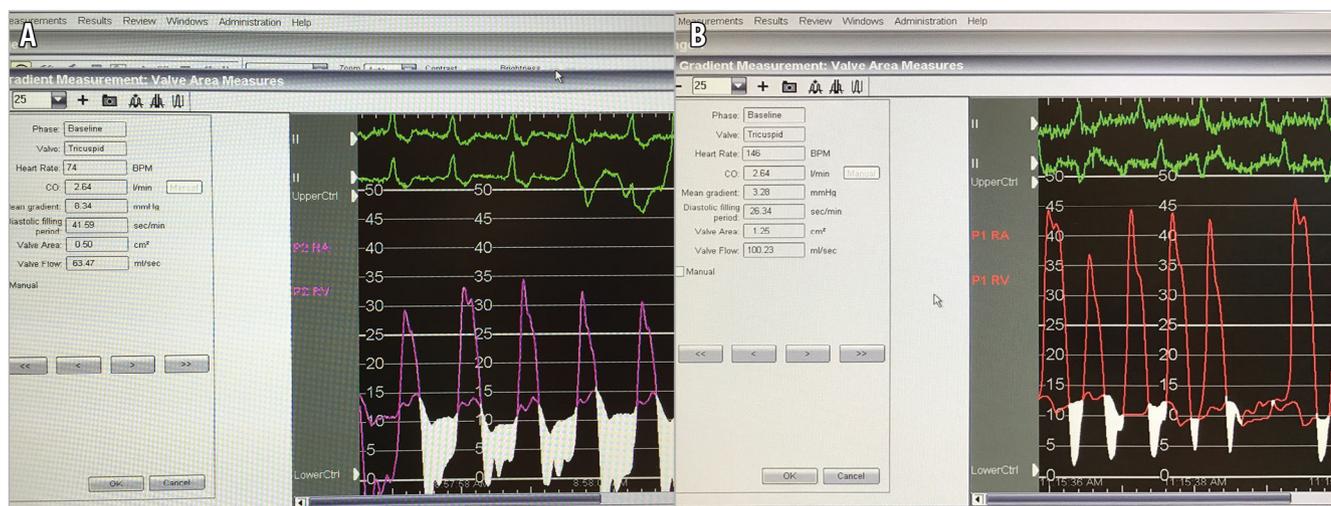
rehearse the V-in-V procedure and to try to find the preferred wire position in order to gain a better coaxial plane between the transcatheter device and the TVR (Figure 2).

A transfemoral venous approach with a supporting wire in the right ventricle instead of the pulmonary artery seemed to be the preferred approach in order to obtain a better coaxial plane for V-in-V TVR implantation, taking into account the dilated right atrium and the angle between the inferior vena cava (IVC) and the right atrium. This might not fully mimic the situation in the real heart as the model was not a beating heart. However, it gave us a rough idea concerning the procedure.

Because severe AS could not be confirmed by the echocardiogram alone and there was uncertainty of change in the aortic gradient after V-in-V TVR, pre-procedure cardiac catheterisation was performed for comparison after V-in-V TVR. Cardiac catheterisation showed a mean gradient across the aortic valve of 31 mmHg, AVA 0.62 cm<sup>2</sup>, AVA index 0.47 cm<sup>2</sup>/m<sup>2</sup>, cardiac output of 3.41 L/min, while the mean diastolic gradient across the TVR was 8.60 mmHg and the TVR area was 0.52 cm<sup>2</sup> (Figure 3A).



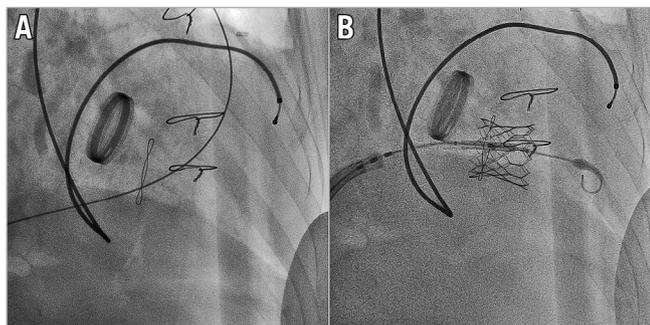
**Figure 2.** Rehearsal with the 3D right heart model. A) Patient's 3D right heart model showing different parts of the right heart including the tricuspid bioprosthesis and pacemaker lead. B) (i) Rehearsal: tilting (not full coaxial) of the SAPIEN 3 device if the wire is placed at the pulmonary artery (PA) and accessed from the inferior vena cava (view from the right atrium). (ii) Orientation of SAPIEN 3 device with wire at PA (view from the right ventricle). (iii) Tilting and a little gap between the SAPIEN 3 device and the bioprosthesis after deployment with wire at PA (view from the right atrium). C) (i) Rehearsal: more coaxial of the SAPIEN 3 device with the wire placed at right ventricle and accessed from inferior vena cava (view from the right atrium). (ii) Orientation of SAPIEN 3 device with the wire in right ventricle (view from the right ventricle). (iii) No tilting or gap between SAPIEN 3 and the bioprosthesis after deployment with wire placed at right ventricle (view from the right atrium).



**Figure 3.** Haemodynamics of tricuspid valve, pre- and post-V-in-V TVR. A) Pre-V-in-V tricuspid valve replacement haemodynamic. B) Post-V-in-V tricuspid valve replacement haemodynamic.

## Results

A V-in-V TVR was performed under general anaesthesia and transoesophageal echocardiographic guidance immediately after cardiac catheterisation. The TVR was crossed with a multipurpose catheter and exchanged for an extra-stiff wire in the main pulmonary artery via the right femoral vein. Predilatation with an Edwards 20 mm×4 cm balloon was carried out. Based on the area of 447 mm<sup>2</sup> on CT and the Pericarbon More 27 having an inner diameter of 23 mm, a 26 mm SAPIEN 3 device (Edwards Lifesciences, Irvine, CA, USA) was chosen. The SAPIEN 3 finally passed through the stenotic TVR but with a poor coaxial plane. Based on the result in the 3D model, the best alignment parallel to the axis of the TVR could be obtained immediately after pulling the wire to the right ventricle. The 26 mm SAPIEN 3 device was deployed uneventfully without rapid pacing (**Figure 4**) and no immediate regurgitation was seen after the deployment. Catheterisation showed that the mean diastolic gradient across the transcatheter valve (TV) was 2.41 mmHg with a TV area of 1.20 cm<sup>2</sup> (**Figure 3B**).

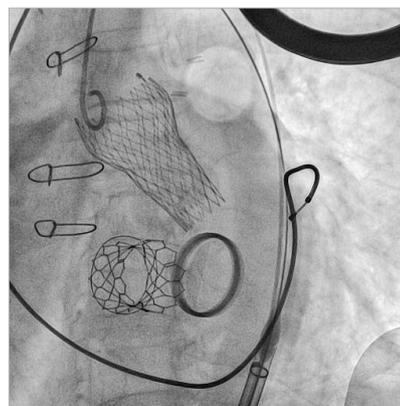


**Figure 4.** V-in-V TVR. A) & B) Cine images showing pre- and post-V-in-V tricuspid valve replacement using a 26 mm SAPIEN 3 device.

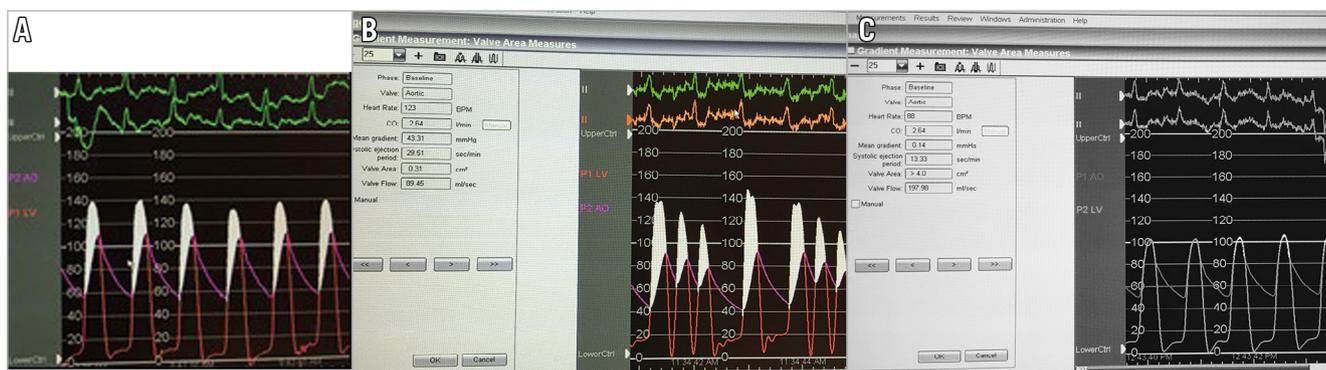
Re-evaluation of the aortic stenosis showed that the mean gradient had increased from 31 mmHg to 46.36 mmHg, with an AVA of 0.54 cm<sup>2</sup>, and an AVA index of 0.41 cm<sup>2</sup>/m<sup>2</sup>.

Concurrent TAVI was performed via the right femoral artery with confirmation of severe AS. A 3D model was not developed for TAVI even with the presence of MVR in this case, as in the CT double oblique multiplanar reconstruction (MPR) view the distance from the aortic annulus to the MVR was 11.3 mm. It was much longer than 7 mm, which has been shown to be an independent risk factor for embolisation<sup>1</sup>. A 26 mm CoreValve® Evolut™ R (Medtronic, Minneapolis, MN, USA) was deployed directly at the aortic annulus as usual (**Figure 5**) without any pre or post balloon dilatation. There was no significant gradient or leakage across the TAVI device (**Figure 6**). The patient was discharged on post-procedure day five.

A follow-up transthoracic echocardiogram at one month showed no significant leakage or gradient across both TAVI and V-in-V TVR. The patient's functional class improved from New York Heart Association functional Class III to II.



**Figure 5.** Deployment of a 26 mm Evolut R at the aortic valve.



**Figure 6.** Pre- and post-TAVI haemodynamics. A) Before valve-in-valve tricuspid valve replacement. B) Post V-in-V tricuspid valve replacement. C) Post TAVI.

## Discussion

Transcatheter valve implantation does provide a new option to patients who have had no surgical options in the past, such as our patient. This case showed the safety and feasibility of concurrent transfemoral tricuspid V-in-V implantation and TAVI. We used both the latest-generation balloon-expandable and self-expanding TAVI devices to treat different pathologies. We used the SAPIEN 3 for V-in-V TVR because the balloon-expandable devices (SAPIEN or Melody™ valve [Medtronic]) have the most evidence in the setting of V-in-V TVR<sup>2</sup>. With relatively little calcium at the aortic annulus in our case, we used a self-expanding TAVI device, the Evolut R, to decrease the chance of device embolisation<sup>3</sup>.

The transcatheter approach in our patient had several advantages. Firstly, the procedure is feasible and relatively safe. Data from a valve-in-valve registry showed an ~99% success rate and few serious complications for V-in-V TVR<sup>2</sup>. Secondly, we had the chance to assess the aortic valve after V-in-V TVR implantation in order to decide on the necessity of TAVI. Thirdly, recovery time was short in our patient even with two valves being treated concurrently. Detailed and accurate preprocedural planning and imaging by using a multislice CT scan with 3D reconstruction and a 3D printed model for pre-OT rehearsal are suggested to be beneficial in order to achieve good results with few complications.

## Limitations

The 3D printed model was not a beating heart and the nature of the material was not exactly the same as heart tissue. However, it gave us a rough idea and the possibility of practising before the real procedure.

## Conclusion

Concurrent transcatheter multiple valve implantation is possible with good outcome and allows faster recovery and a shorter hospitalisation time. Different devices fit different anatomies according to different factors such as the valve involved, bioprosthesis,

size and calcification. A 3D printed model seems to be useful to increase the accuracy of the procedure.

## Impact on daily practice

Multiple transcatheter valve implantations are safe and have good outcome.

## Conflict of interest statement

A. Yeung has received research grant support from Edwards and Medtronic, and is also a scientific advisor for Medtronic. The other authors have no conflicts of interest to declare.

## References

1. Amat-Santos IJ, Cortés C, Nombela Franco L, Muñoz-García AJ, Suárez De Lezo J, Gutiérrez-Ibañes E, Serra V, Larman M, Moreno R, De La Torre Hernandez JM, Puri R, Jimenez-Quevedo P, Hernández García JM, Alonso-Briales JH, García B, Lee DH, Rojas P, Sevilla T, Goncalves R, Vera S, Gómez I, Rodés-Cabau J, San Román JA. Prosthetic Mitral Surgical Valve in Transcatheter Aortic Valve Replacement Recipients: A Multicenter Analysis. *JACC Cardiovasc Interv.* 2017;10:1973-81.
2. McElhinney DB, Cabalka AK, Aboulhosn JA, Eicken A, Boudjemline Y, Schubert S, Himbert D, Asnes JD, Salizzoni S, Bocks ML, Cheatham JP, Momenah TS, Kim DW, Schranz D, Meadows J, Thomson JD, Goldstein BH, Crittendon I 3rd, Fagan TE, Webb JG, Horlick E, Delaney JW, Jones TK, Shahanavaz S, Moretti C, Hainstock MR, Kenny DP, Berger F, Rihal CS, Dvir D; Valve-in-Valve International Database (VIVID) Registry. Transcatheter Tricuspid Valve-In-Valve Implantation for the Treatment of Dysfunctional Surgical Bioprosthetic Valves: An International, Multicenter Registry Study. *Circulation.* 2016;133:1582-93.
3. Bilge M, Saatçı Yaşar A, Alemdar R, Ali S. Transcatheter aortic valve implantation with the CoreValve for the treatment of rheumatic aortic stenosis. *Anadolu Kardiyol Derg.* 2014;14:296-7.