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CORONARY, PERIPHERAL, AND STRUCTURAL INTERVENTIONS

CLINICAL CASE SERIES

Prosthetic Heart Valve Interactions and Their Clinical Significance During Transcatheter Left-Sided Double Valve Replacement

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ABSTRACT

A simultaneous transcatheter aortic valve implantation and mitral valve-in-valve procedure has potential for prosthetic valve interactions. Recently, we described preprocedure planning using computerized tomography and bench model simulations in 3 patients to predict various types of interactions. This paper elaborates on the clinical and procedural details of those 3 patients and their clinical outcomes. (JACC Case Rep. 2025;30:103673) © 2025 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/).

In the setting of prohibitive surgical risk, patients with severe native aortic stenosis (AS) and a degenerated bioprosthetic mitral valve (BPMV) may end up with transcatheter aortic valve implantation (TAVI) and mitral valve-in-valve implantation (M-ViV). Transcatheter double valve replacement (DVR) at aortic and mitral positions has potential for prosthetic valve interactions, particularly in the presence of preexisting BPMV.[1,2] Recently, we described preprocedure planning using computed tomography (CT) and bench model simulations in 3 patients to predict various types of interactions. On the basis of the bench tests and the available anecdotal reports, we introduced a new classification system for prosthetic heart valve interactions.[3] This paper elaborates on the clinical and procedural details of those 3 patients and their clinical outcomes.

TAKE-HOME MESSAGES

- Prosthetic heart valve interactions are possible while performing transcatheter left-sided double valve replacement.
- A transcatheter aortic valve implantation first and mitral valve-in-valve second approach minimizes these interactions.

CASE SERIES

In this retrospective case series, we present 3 patients with a degenerated BPMV and severe native AS who underwent simultaneous transfemoral TAVI and transseptal M-ViV using balloon-expandable systems. A waiver of consent was obtained from the institutional ethics committee for publishing anonymized patient data.

CASE 1. A 64-year-old woman with a degenerated Biocor mitral valve with severe valvular regurgitation

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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ABBREVIATIONS AND ACRONYMS

AS = aortic stenosis

BPMV = bioprosthetic mitral valve

CT = computed tomography

DVR = double valve replacement

M-ViV = mitral valve-in-valve implantation

TAV = transcatheter aortic valve

TAVI = transcatheter aortic valve implantation

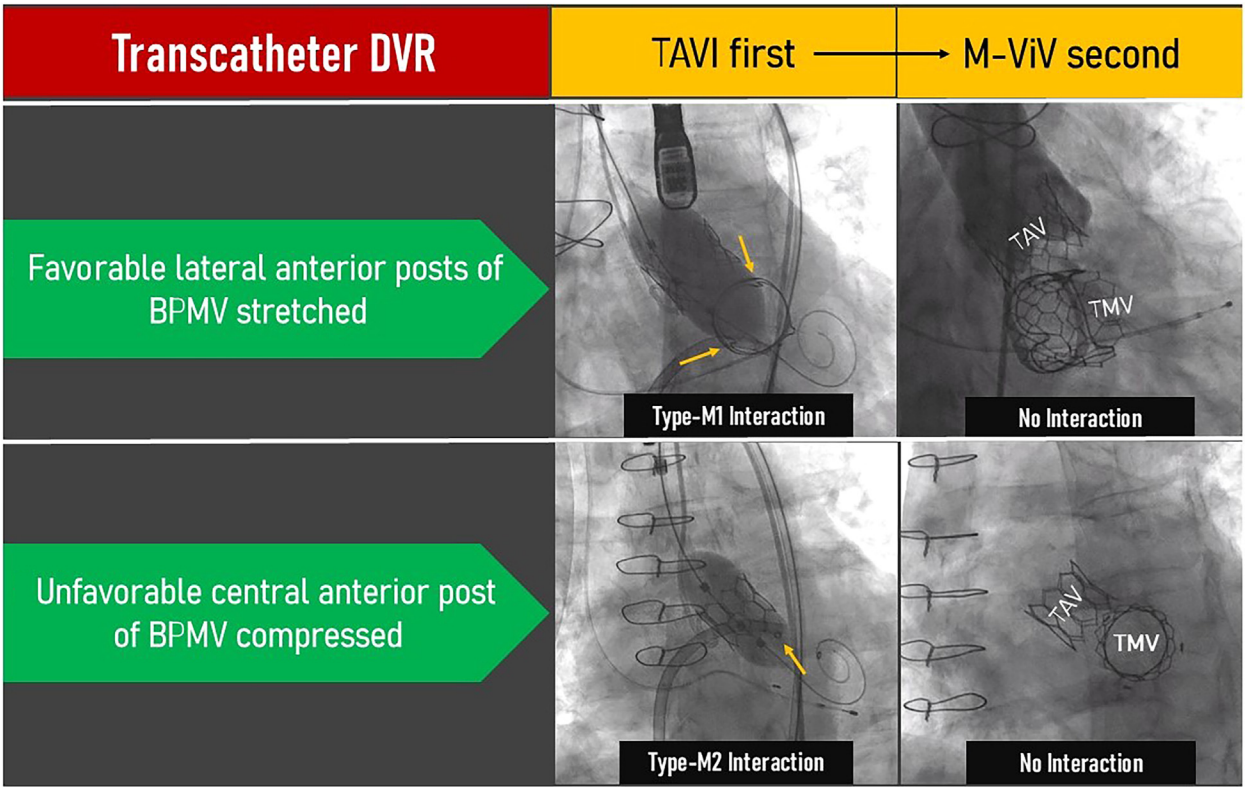
and severe native AS due to rheumatic heart disease presented with community-acquired pneumonia, precipitated congestive cardiac failure, and cardiogenic shock.

Mechanical ventilation and high inotropic support were started, and she could not be weaned off inotropic support or mechanical ventilation. She underwent 3 cardiac surgeries in the past, namely, closed mitral commissurotomy, mitral valve replacement with a tilting disc valve, and redo mitral valve replacement with a Biocor valve (St Jude Medical) at the ages of 21, 46, and 49 years, respectively. The baseline characteristics of this patient are given in Table 1. Considering the predicted surgical mortality of 39.13% by EuroSCORE II, the heart team decided to proceed with transcatheter DVR.

In a patient with combined valvular pathology who is treated sequentially, leaving 1 valve unaddressed may lead to potential hemodynamic consequences in the presence of left or right ventricular dysfunction (Table 2). The operators thus chose simultaneous DVR rather than a sequential approach. The preprocedure CT planning and measurements are elaborated elsewhere.[3] On the basis of the CT parameters, the operators decided to proceed with balloon-expandable platforms for both TAVI and M-ViV. CT and bench model simulations suggested a TAVI first and M-ViV second approach to reduce the interactions.

During the in vivo procedure, while performing TAVI, the interaction was not seen in fluoroscopy, as Biocor (St Jude Medical) posts are not radiopaque. While performing M-ViV, there was no interaction with the transcatheter aortic valve (TAV) frame (Figure 1). The procedural characteristics are listed in Table 3. The postoperative period was uneventful. During follow-up, the patient was hospitalized twice, once for acute pancreatitis and cholecystitis at 26 months post-DVR and again for

VISUAL SUMMARY **Strategy to Minimize the Prosthetic Heart Valve Interactions During Transcatheter Double Valve Replacement**



TAVI first with a preexisting BPMV either ends in type-M1 interaction with favorable lateral anterior BPMV posts position or type-M2 interaction with an unfavorable central anterior BPMV post. M-ViV after TAVI did not create any interactions. Type-M1 reversible stretching of the favorable lateral anterior posts by the TAV balloon. Type-M2 reversible bending of the unfavorable central anterior post by the TAV balloon. BPMV = bioprosthetic mitral valve; DVR = double valve replacement; M-ViV = mitral valve-in-valve; TAV = transcatheter aortic valve; TAVI= transcatheter aortic valve implantation; TMV = transcatheter mitral valve.

TABLE 1 Baseline Characteristics

	Patient 1	Patient 2	Patient 3
Age, y	64	61	73
Sex	F	M	M
Body surface area, m^2	1.50	1.73	1.75
Body mass index, kg/m^2	25.1	23.6	22.6
EuroSCORE II Prediction of mortality	39.13	15.28	10.85
NYHA functional class	IV	IV	III
Coronary artery disease	No	Yes	No
Prior CABG	No	Yes SVG to LAD and RCA	No
Patency of grafts	NA	Patent	NA
Etiology of first mitral valve replacement	RHD	RHD	MVP, severe MR, infective endocarditis
Prior cardiac surgeries	1. CMC (1979) 2. MVR: Chitra valve (2004) 3. MVR: Biocor valve (2007)	1. CABG, MVR: Mosaic valve (2017)	1. MVR: Perimount valve (2009)
Name of the degenerated BPMV	Biocor	Mosaic	Perimount
Labeled size of the BPMV, mm	27	25	27
Age of the BPMV since implant, mo	179	70	171
Hemoglobin level, g/dL	8.5	12.7	13.8
Packed cell volume	28.1	40.6	43.9
eGFR, $mL/min/1.73\ m^2$	52.8	58.7	75
Baseline electrocardiogram			
Rhythm	AF	Sinus	Sinus
Bundle branch block	LBBB	No	No
AV block	No	First-degree AV block	No
Echocardiogram			
Aortic valve morphology	Tricuspid	Tricuspid	Type 1 bicuspid R/L
Degenerative or rheumatic	Rheumatic	Rheumatic	Degenerative
Aortic valve peak velocity, m/s	3.75	3.04	3.74
Aortic valve mean gradient, mm Hg	32	21	39
AVA, cm^2	0.64	0.90	0.76
Aortic regurgitation severity	Moderate	Mild	Trivial
Mitral valve mean gradient, mm Hg	10	8	18
Mitral bioprosthetic valvular leak grade	Severe	Severe	No
Paravalvular leak	No	No	No
Left ventricular ejection fraction, %	33.3	51.4	41.0
RV TAPSE, mm	9.7	11.2	10.9

AF = atrial fibrillation; AV = atrioventricular; AVA = aortic valve area; BPMV = bioprosthetic mitral valve; CABG = coronary artery bypass surgery; CMC = closed mitral commissurotomy; eGFR = estimated glomerular filtration rate; EuroSCORE II = European System for Cardiac Operative Risk Evaluation II; LAD = left anterior descending coronary artery; LBBB = left bundle branch block; MR = mitral regurgitation; MVP = mitral valve prolapse; MVR = mitral valve replacement; MR = mitral regurgitation; NA = not applicable; RCA = right coronary artery; RHD = rheumatic heart disease; RV TAPSE = right ventricular tricuspid annular plane systolic excursion; SVG = saphenous vein graft.

tachycardiomyopathy due to atrial fibrillation at 31 months post-DVR. During latest follow-up at 33 months, the patient had NYHA functional class II status (Table 4).

CASE 2. A 61-year-old man presented with a degenerated 25 mm Mosaic (Medtronic) mitral bioprosthesis with severe intraprosthetic valvular leak and severe AS. The baseline characteristics are given in Table 1. Given the high-risk EuroSCORE II of 15.28% and patent coronary bypass grafts, the options of surgical DVR vs transcatheter DVR were discussed in a heart team meeting and a decision was made to proceed with simultaneous transcatheter DVR.

Preprocedure CT and bench model simulations showed reversible bending of one of the BPMV posts by the TAV balloon, but no interactions during M-ViV.[3] The procedural characteristics are given in Table 3. During in vivo DVR, a momentary bending of the central anterior post was documented in fluoroscopy while predilating the aortic valve with an 18 × 40 mm Mammoth balloon (Meril). During TAVI, a significant bending of the same post was noted in fluoroscopy, which returned to its original position immediately after deflating the TAV balloon. During M-ViV, there was no interaction with the TAV frame (Figure 2). The patient had an uneventful

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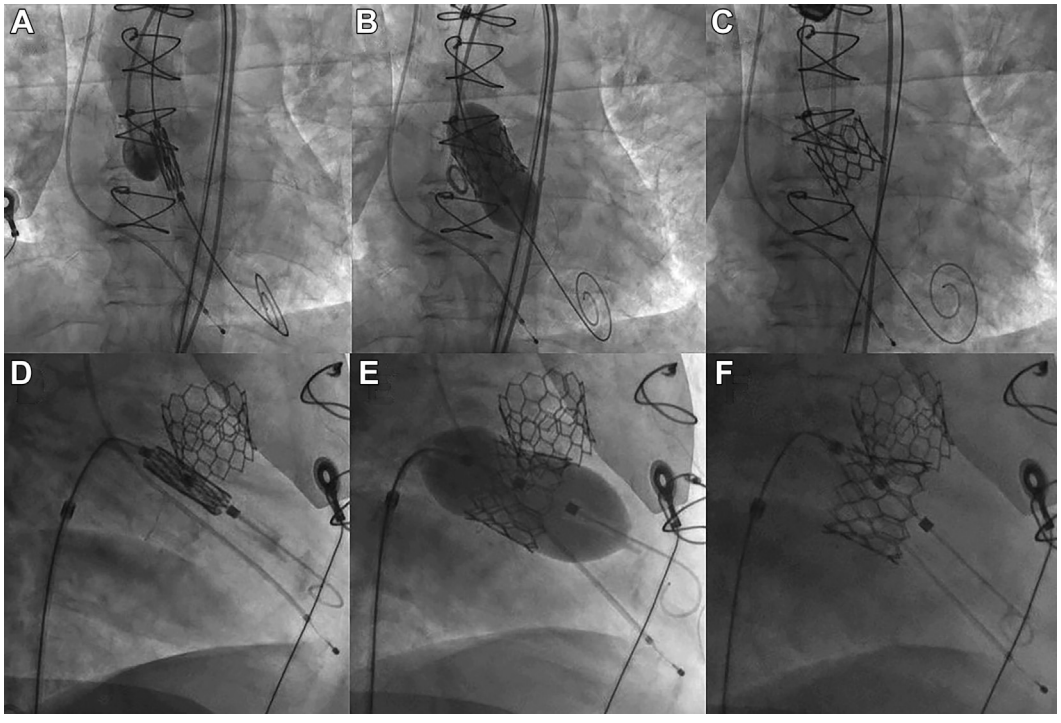
TABLE 2 Hemodynamic Changes of Addressing Combined Aortic and Mitral Valve Pathophysiology Sequentially vs Simultaneously

Pathophysiology	AVR Followed by Sequential MVR	MVR Followed by Sequential AVR	Simultaneous DVR
AS and MS	CO ↑ PVH ⇔ LV afterload ↓↓↓ Suicidal LV	CO ⇔ PVH ⇔ LV afterload ⇔ LV fails because of volume overload	CO ↑↑↑ PVH ↓↓↓ LV afterload ↓↓↓ Afterload mismatch ⇔
AS and MR	CO ↑ PVH ↓ LV afterload ↓↓↓	CO ⇔ PVH ↓↓ LV afterload ↑↑↑ LV fails because of an afterload mismatch	CO ↑↑↑ PVH ↓↓↓ LV afterload ↑ Afterload mismatch ↑
AR and MS	CO ↑ PVH ⇔ LV afterload ↑	CO ⇔ PVH ↓ LV afterload ⇔ LV fails because of volume overload	CO ↑↑↑ PVH ↓↓↓ LV afterload ↑ Afterload mismatch ↑
AR and MR	CO ↑ PVH ↑↑ LV afterload ⇔	CO ↑ PVH ↓↓ LV afterload ⇔	CO ↑↑↑ PVH ↓↓↓ LV afterload ↑↑↑ Afterload mismatch ↑↑↑

AR = aortic regurgitation; AS = aortic stenosis; AVR = aortic valve replacement; CO = cardiac output; DVR = double valve replacement; LV = left ventricle/ventricular; MR = mitral regurgitation; MS = mitral stenosis; MVR = mitral valve replacement; PVH = pulmonary venous hypertension.

FIGURE 1 Case 1: Simultaneous TAVI With a 23-mm Myval Valve and M-ViV With a 24.5-mm Myval Valve Inside a 27-mm Biocor Valve With Favorable Lateral Anterior Mitral Posts



(A to C) Positioning and deployment of the 23 mm TAV at the aortic position. The 27 mm Bicor mitral valve sewing ring alone is faintly seen in the enface view below the aortic valve. (D to F) Positioning and deployment of the 24.5 mm TMV inside the 27 mm Biocor mitral valve without interaction with the TAV. M-ViV = mitral valve-in-valve implantation; TAV = transcatheter aortic valve; TAVI = transcatheter aortic valve implantation; TMV = transcatheter mitral valve.

TABLE 3 DVR Procedural Characteristics

	Patient 1	Patient 2	Patient 3
TAVI			
Predilatation balloon size, mm	No	18 × 40 mm Mammoth balloon	20 × 40 mm Mammoth balloon
BPMV interference during predilatation	No	Yes	No
BPMV interference during implantation of a balloon-expandable TAV	No	Yes	No
TAV name	Meril Myval	Meril Octacor	Meril Myval
TAV size, mm	23	21.5	29
TAV % area—oversize	11.3	29.4	-2.7
Postdilatation	No	No	No
M-ViV			
Transcatheter valve name	Meril Myval	Meril Myval	Meril Myval
Transcatheter valve size, mm	24.5	23	27.5
Transcatheter valve, % area—oversize	2.5	23.5	21.0
Postdilatation	No	No	No
BPMV intentional fracture	No	No	No
Interference with TAV	No	No	No

BPMV = bioprosthetic mitral valve; DVR = double valve replacement; M-ViV = mitral valve-in-valve implantation; TAV = transcatheter aortic valve; TAVI = transcatheter aortic valve implantation.

TABLE 4 Outcomes

	Patient 1	Patient 2	Patient 3
Predischarge outcomes			
Technical success	Yes	Yes	Yes
LVOT obstruction	No	No	No
Need for a permanent pacemaker	No	No	No
Index hospital stay, d	27	11	8
Vascular complications	Nil	Nil	Nil
Emergency surgery	No	No	No
All-cause or CV mortality	No	No	No
All stroke	No	No	No
VARC-3 bleeding	No	No	Type 2
Long-term outcomes			
Maximum duration of follow-up, mo	33	16	13
All-cause or CV mortality	Nil	Nil	Nil
All stroke	Nil	Nil	Nil
Any VARC-3 bleeding	Nil	Nil	Nil
Myocardial infarction	Nil	Nil	Nil
CV hospitalization	Yes[a]	Nil	Nil
Non-CV hospitalization	Yes[b]	Nil	Nil
NYHA functional class	II	I	I
Mean TAV gradient, mm Hg	13	15.05	8.23
Mean TMV gradient, mm Hg	4.01	4.35	5.51
LVEF, %	47.9	57.62	53.0

[a]At 31 mo hospitalized for tachycardiomyopathy due to atrial fibrillation and fast ventricular rate. [b]At 26 mo hospitalized for acute biliary pancreatitis and cholecystitis.

CV = cardiovascular; LVEF = left ventricular ejection fraction; LVOT = left ventricular outflow tract; TAV = transcatheter aortic valve; TMV = transcatheter mitral valve; VARC = Valve Academic Research Consortium; VARC-3 bleeding = Valve Academic Research Consortium-3 classification of bleeding.

postoperative period. During latest follow-up at 16 months, the patient had NYHA functional class I status (Table 4).

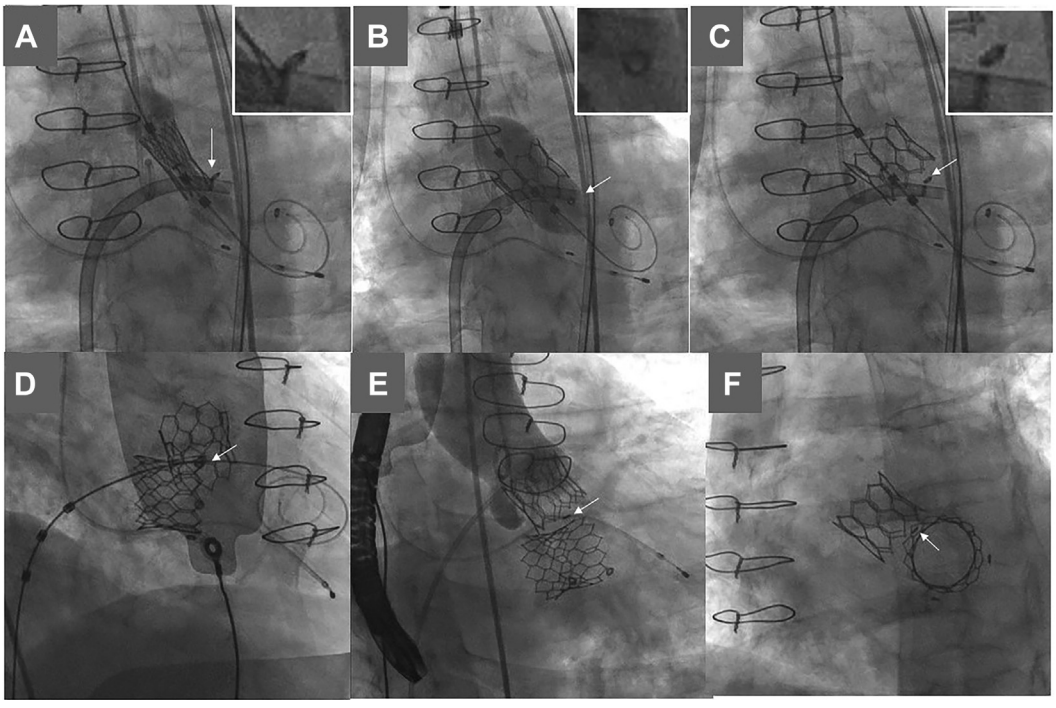
CASE 3. A 73-year-old man presented with a degenerated 27 mm Perimount (Edwards Lifesciences) BPMV with severe stenosis and severe native type 1 bicuspid AS. Given the predicted high-risk EuroSCORE II of 10.85%, the decision to perform simultaneous transcatheter DVR was made in the heart team meeting. The baseline characteristics are provided in Table 1. Preprocedure CT and bench model simulations showed reversible stretching of 2 anterior BPMV posts by the TAV balloon, but no interactions during M-ViV.[3]

While performing in vivo DVR, momentary stretching of the BPMV anterior posts was noted in fluoroscopy during the final quarter of TAV balloon inflation. The procedural characteristics are given in Table 3. This bicuspid aortic valve was predilated with a 20 × 40 mm Mammoth balloon without interacting with the BPMV, as the balloon was fitting between the posts with the interpost distance of 21.30 mm. A 29 mm Myval (Meril) valve (2.7% undersized) was deployed at the aortic position to reduce the stretching of the posts instead of the 30.5 mm valve (Figure 3). A 27.5 mm Myval (Meril) valve was deployed inside the 27 mm Perimount (Edwards Lifesciences) valve without interacting with the TAV. The postoperative period was uneventful, and during latest follow-up at 13 months, the patient had NYHA functional class I status (Table 4).

DISCUSSION

A degenerated BPMV and native AS are traditionally treated by combined aortic and mitral valve replacement surgery. In high-surgical risk patients, well-planned simultaneous transcatheter DVR reduces the probability of mortality and morbidity. If severe AS or regurgitation is not addressed after MVR, cardiac output will not improve, and the left ventricle may fail because of volume overload. If severe mitral stenosis or regurgitation is not addressed after AVR, then neither cardiac output nor pulmonary venous hypertension improves. Simultaneous DVR provides favorable hemodynamics in all types of combined aortic and mitral valve pathophysiologies except in aortic and mitral regurgitation. There will be a significant afterload mismatch, particularly in the presence of left ventricular dysfunction (Table 2). Whether it is a sequential or simultaneous approach, TAVI should be performed first, as the M-ViV first approach will lead to significant interaction of the TAV balloon with the TMV stent frame.

FIGURE 2 Case 2: Simultaneous TAVI With a 21.5-mm Octacor Valve and M-ViV With a 23-mm Myval Valve Inside a 25-mm Mosaic Valve With an Unfavorable Central Anterior Post



(A) A 21.5-mm Meril Myval valve at the aortic position. At the beginning of inflation, the eye of the central anterior post is seen in the coplanar view (arrow and inset). (B) During full inflation of the balloon, the eye of the anterior post is seen in the enface view, suggesting significant bending of the post. (C) After deflation of the balloon, the aortic Octacor valve was deployed and the recovery of the Mosaic anterior post is shown (back to coplanar). (D) A 23-mm Myval valve was deployed inside the Mosaic mitral valve and did not show any interaction with the aortic Octacor valve. (E and F) The relation of the 2 transcatheter valves in the cusp overlap view and the mitral enface view. M-ViV = mitral valve-in-valve implantation; TAVI = transcatheter aortic valve implantation.

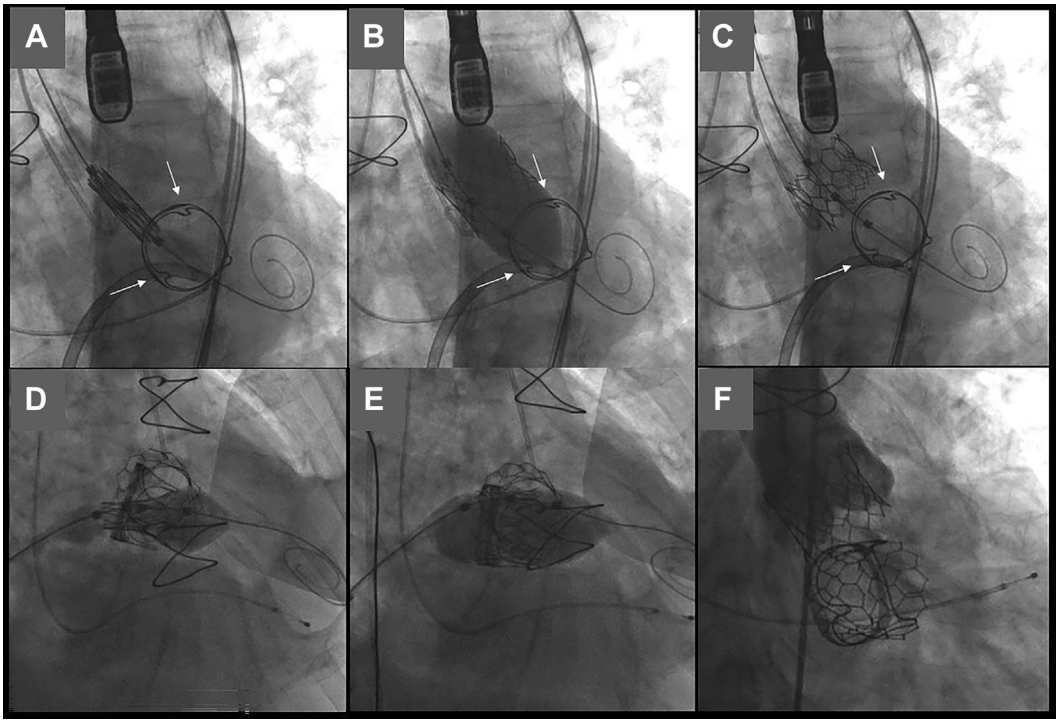
In cases 1 and 3, we observed reversible stretching of the lateral anterior posts of the degenerated BPMV (type-M1 interaction) during TAVI. In case 2, we noticed a reversible bending of the central anterior BPMV post by the TAV balloon (type-M2 interaction). While performing M-ViV, no interaction was noted with the TAV.

Bauernschmitt et al[2] reported compression of the TMV stent frame by the TAV balloon during simultaneous transcatheter transapical DVR using Sapien 3 (Edwards Lifesciences) valves in a 67-year-old woman with degenerative AS and MR (type-M3 interaction). In this case, they followed the TMV first and TAVI second protocol. This interaction resulted in the migration of the TMV into the left ventricular outflow tract 5 months later.[2]

Amat-Santos et al[1] reported self-expandable TAV embolization and paravalvular leak due to the interaction of the self-expandable TAV with the prosthetic mitral valve sewing ring (type-A1 interaction). Lutter et al[4] reported simultaneous transapical DVR in a 59-year-old woman with a degenerated BPMV and native AS using Sapien 3 valves. Although the investigators did not provide CT measurements, they did mention that TAVI was performed first to avoid interaction with the mitral valve stent. The investigators did not notice any interaction of the TAV balloon with the BPMV during TAVI. Bashir et al[5] reported transfemoral and transseptal DVR for native aortic and mitral valves in an 87-year-old woman. Transfemoral TAVI first followed by transseptal valve-in-mitral annular calcium was performed using Sapien 3 valves. No interaction was documented in their report.

Although anecdotal transcatheter DVR reports are available, to our knowledge, this is the first case series of simultaneous transfemoral and transseptal DVR in a preexisting degenerated BPMV, which described the various valve interactions peculiar to the aortomitral continuity and its clinical significance. In-depth CT analysis with newer parameters is necessary to predict these valve interactions.

FIGURE 3 **Case 3: Simultaneous TAVI With a 29-mm Myval Valve and M-ViV With a 27.5-mm Myval Valve Inside a 27-mm Perimount Mitral Valve With Favorable Posts**



(A) A 29-mm Meril Myval valve at the aortic position. At the beginning of inflation, the TAVI system fits between the lateral anterior posts without interaction. (B) During full inflation of the balloon, mild stretching of the anterior posts was seen. (C) After deflation of the balloon, the aortic Myval valve was deployed and the normal anterior mitral posts are shown. The two arrows in A to C indicate the favourable lateral anterior posts of bioprosthetic mitral valve on either side of the left ventricular outflow tract. (D and E) A 27.5-mm Myval valve was deployed inside the 27-mm Perimount mitral valve and did not show any interaction with the aortic Myval valve. (F) The relation of the 2 transcatheter valves. M-ViV = mitral valve-in-valve implantation; TAVI = transcatheter aortic valve implantation.

LIMITATIONS. This case series is small. Larger data with these novel CT parameters and cutoffs for these distances need to be understood to predict the valve interactions and their clinical significance.

CONCLUSIONS

Simultaneous transfemoral TAVI and transseptal M-ViV potentially carry a higher probability of prosthetic heart valve interactions. Meticulous preprocedure CT planning helps in understanding these interactions and predicting the outcome.

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KEY WORDS aortic valve, complication, computed tomography, double valve replacement, interaction, mitral valve, valve replacement