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VALVULAR HEART DISEASE

CLINICAL CASE SERIES

Decoding High Post-TAVR Gradients

Insights From 4 Clinical Scenarios

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ABSTRACT

Echocardiography is a well-established tool for evaluating bioprosthetic valve performance after transcatheter aortic valve replacement. The presence of higher-than-expected echocardiographic gradients is not an uncommon finding and can be related to different clinical settings. This case series proposes a practical and multiparametric approach to interpreting high residual gradients after transcatheter aortic valve replacement. We examine 4 common clinical scenarios: 1) pressure recovery; 2) high-flow state; 3) prosthesis–patient mismatch; and 4) suboptimal valve expansion. For each scenario, a comprehensive echocardiographic analysis, along with invasive hemodynamic evaluation, is reported. (JACC Case Rep. 2025;30:102774) © 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/).

The role of echocardiography in evaluating prosthetic aortic valve performance is widely accepted, after both transcatheter aortic valve replacement (TAVR) and surgical aortic valve replacement.[1] Echocardiographic transvalvular gradient assessment is the simplest and most used method in this context, with reference normal values provided for surgical and transcatheter devices according to bioprosthetic model and size.[2]

The presence of postprocedural higher-than-expected echocardiographic gradients is not uncommon, and it should be interpreted case-by-case because different clinical scenarios can potentially be related to this specific finding.[3] Moreover, several studies consistently revealed occasional discrepancies between echocardiographic and invasively measured gradients potentially leading to erroneous conclusions, especially after TAVR with balloon-expandable valves or valve-in-valve (ViV) procedures.[4]

TAKE-HOME MESSAGES

- A higher-than-expected transvalvular gradient is a common finding after TAVR. Case-by-case evaluation, along with a comprehensive multiparametric echocardiographic approach, is recommended when navigating this complex scenario.
- Invasive gradient evaluation remains the gold standard for diagnosing specific clinical scenarios and overcoming noninvasive measurement flaws. Routine invasive gradient measurement after valve implantation might be reasonable to promptly recognize postprocedural echocardiographic discrepancies.
- Predicted gradients and EOA might be useful tools for detecting patients at risk of developing postprocedural PPM. Moreover, comparing measured and predicted postprocedural parameters may guide operators in the decision-making process and valve optimization maneuvers.

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ABBREVIATIONS AND ACRONYMS

DVI = Doppler velocity index

EOA = effective orifice area

EOAi = effective orifice area indexed

ELI = energy loss index

PPM = prosthesis-patient mismatch

TAVR = transcatheter aortic valve replacement

V_{max} = maximum flow velocity

ViV = valve-in-valve

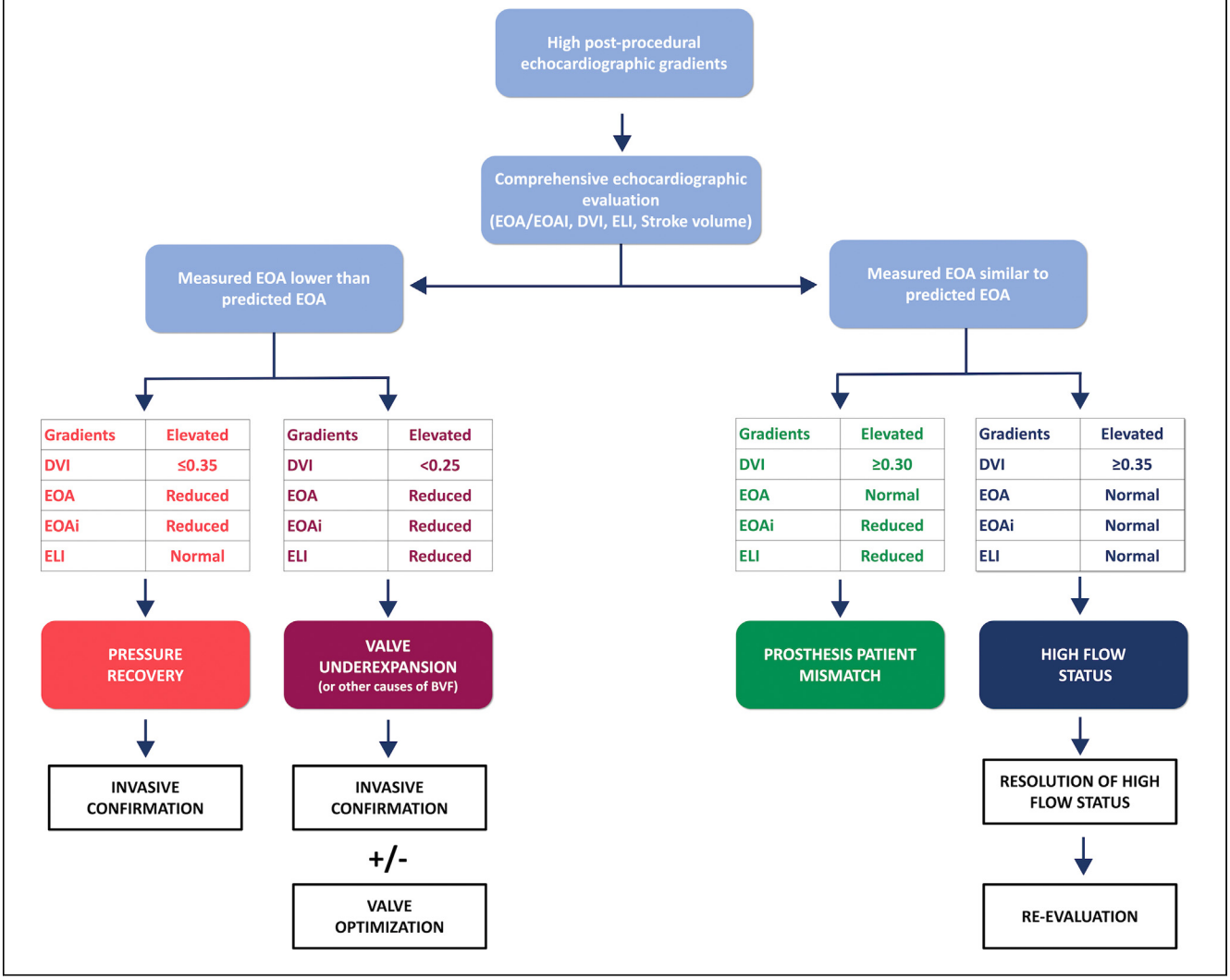
Interpreting postprocedural high gradients is challenging and affects decisions on further valve optimization. With more younger patients being treated, achieving optimal hemodynamic results is mandatory. Accurate interpretation of postprocedural echocardiographic findings is paramount for guiding appropriate treatment strategies.

The current report presents 4 post-TAVR cases characterized by elevated bioprosthetic gradients observed in postprocedural echocardiography (Table 1). Each case includes a thorough echocardiographic evaluation, comparing predicted, noninvasive, and invasive gradient measurements. We provide our analysis of these clinical scenarios using a multiparametric evaluation as a guiding framework.

CASE SERIES

CASE 1: PRESSURE RECOVERY. A 71-year-old woman previously underwent surgical replacement of the ascending aorta (Hemashield 28 mm; Getinge) along with aortic valve replacement with a 23 mm Hancock valve (Medtronic). Thirteen years later, she presented with severe intraprosthetic regurgitation. Because the patient was experiencing a decline in functional capacity, the heart team decided to proceed with ViV TAVR. A 23 mm Evolut R valve (Medtronic) was successfully implanted without complications. Postprocedural echocardiography revealed higher-than-expected gradients (measured mean gradient 26 mm Hg vs predicted mean gradient 15 mm Hg) with a maximum flow velocity (V_{max}) of 3.1 m/s and a reduced Doppler velocity index (DVI) of 0.27 (Figure 1).

VISUAL SUMMARY



The effective orifice area (EOA) and EOA indexed (EOAi) were 0.99 cm^2 and 0.58 cm^2/m^2, respectively, slightly smaller than those predicted according to the bioprosthesis size and model (EOA 1.09 cm^2; EOAi 0.64 cm^2/m^2). Considering the presence of a small noncompliant vascular prosthesis in the ascending aorta, the energy loss index (ELI) was also calculated, showing a normal value (0.90 cm^2/m^2). Invasive catheterization was then performed, showing a transprosthetic mean gradient of 14 mmHg.

Interpretation. As an initial clinical scenario, we reported a case involving a discrepancy between echocardiographic and invasively measured transvalvular gradients. When evaluating a patient presenting with higher-than-expected post-TAVR gradients at echocardiography, it is essential to conduct a thorough assessment of valve performance before determining the necessity of additional valve optimization and interventional maneuvers. In this case, a significant amount of pressure recovery was evident, possibly exacerbated by the patient's small and fixed ascending tubular aorta.[5] A multiparametric echocardiographic assessment (including, for example, ELI and DVI) could aid in initially distinguishing this scenario from others with higher post-TAVR gradients.[3] Nevertheless, in cases in which significant pressure recovery is suspected, a comprehensive evaluation involving invasive gradient measurement is mandatory to confirm the diagnosis.[1,5] Indeed, as documented in previous studies, disparities between noninvasive and invasive bioprosthetic gradients are not uncommon.[4] Factors contributing to this inconsistency include inaccuracies of the Bernoulli equation in nonrestrictive orifices, small and noncompliant ascending aortas, and turbulent flow across different valve-frame designs, among others.[1,5] These factors, however, are not yet fully understood, and case-by-case evaluation is strongly recommended.

CASE 2: HIGH-FLOW STATE. A 78-year-old woman presented with symptomatic severe structural valve degeneration (maximum/mean gradient 63/40 mm Hg; DVI 0.25). Four years prior, she had undergone TAVR with an ACURATE neo size S valve (Boston Scientific). The heart team decided to proceed with a redo-TAVR procedure using a 23-mm Sapien 3 valve (Edwards Lifesciences). Postprocedural echocardiography revealed higher-than-expected gradients (measured mean gradient 28 mm Hg vs predicted mean gradient 13 mm Hg). V_{max} was increased (3.5 m/s) with a normal DVI (0.38) (**Figure 2**). The measured and predicted EOAs were concordant (1.55 cm^2 and 1.45 cm^2, respectively). The EOAi was 0.90 cm^2/m^2. An increased indexed stroke volume was also reported (61 mL/m^2). After careful patient evaluation, severe postprocedural anemia (hemoglobin 6.8 g/dL) was deemed responsible for the high-flow status. Following multiple blood transfusions, the echocardiographic trans-prosthetic mean gradient decreased to 12 mm Hg. Invasive gradient evaluation was also performed to confirm good valve performance (mean gradient 8 mm Hg).

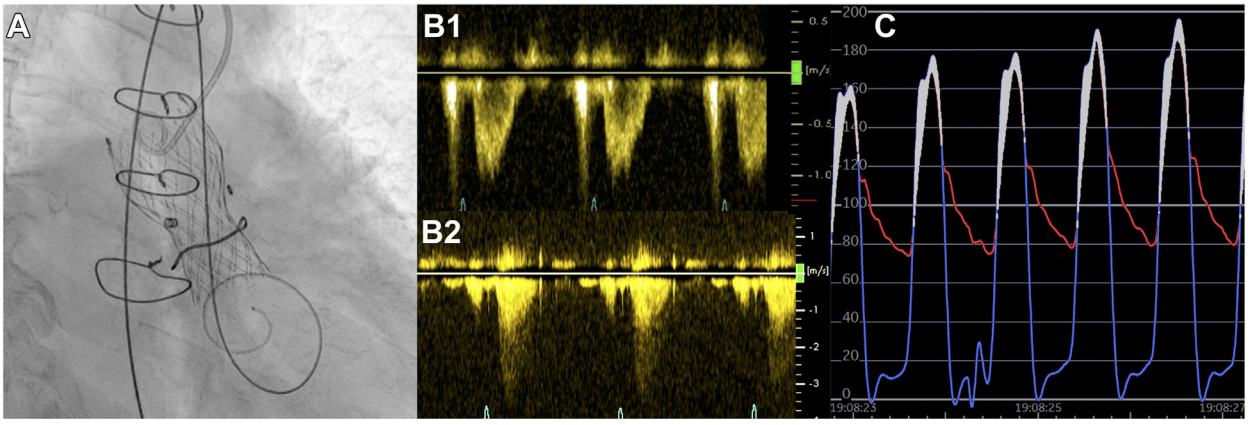
Interpretation. Our second scenario involved a case of higher postprocedural gradients attributed to an external factor unrelated to valve performance. Collateral findings such as anemia and new-onset infections, both common among patients undergoing TAVR procedures, can influence valve hemodynamics by increasing blood velocity (and gradients) through the left ventricular outflow tract and the bioprosthetic orifice.[5] As illustrated in our case, a comprehensive echocardiographic assessment proves to be more sensitive than isolated gradient measurements, resulting in a more accurate evaluation and interpretation of flow status and valve performance. Invasive gradient verification is generally not strictly necessary. Stroke volume, as measured in echocardiography, along with the discrepancy between predicted and measured transvalvular gradients, can be useful in monitoring patient conditions and assessing the restoration of normal flow status. In cases of high-flow dependent gradients, careful attention should be given in evaluating the presence of significant aortic valve regurgitation. Indeed, severe peri-valvular leaks may contribute to high-flow status. In such specific situation, valve optimization is generally advisable.[6]

TABLE 1 Comprehensive Echocardiographic and Invasive Evaluation for Each Clinical Scenario

	Case 1	Case 2	Case 3	Case 4
Diagnosis	Pressure recovery	High-flow state	PPM	Valve sub-expansion
Valve type/size	Evolut R 23 mm	Sapien 3 23 mm	Sapien 3 20 mm	Evolut R 26 mm
Predicted EOA by valve size/type, cm^2	1.09	1.45	1.22	1.69
Predicted mean gradient by valve size/type, mm Hg	15	13	16	7.5
Echocardiographic mean gradient, mm Hg	26	28	24	22
V_{max}, m/s	3.1	3.5	2.7	2.8
DVI	0.27	0.38	0.34	0.24
EOA, cm^2	0.99	1.55	1.15	1.28
EOAi, cm^2/m^2	0.58	0.90	0.63	0.78
Invasive mean gradient, mm Hg	14	8	22	20

DVI = Doppler velocity index; EOA = effective orifice area; EOAi = effective orifice area indexed; PPM = prosthesis-patient mismatch; V_{max} = maximum flow velocity.

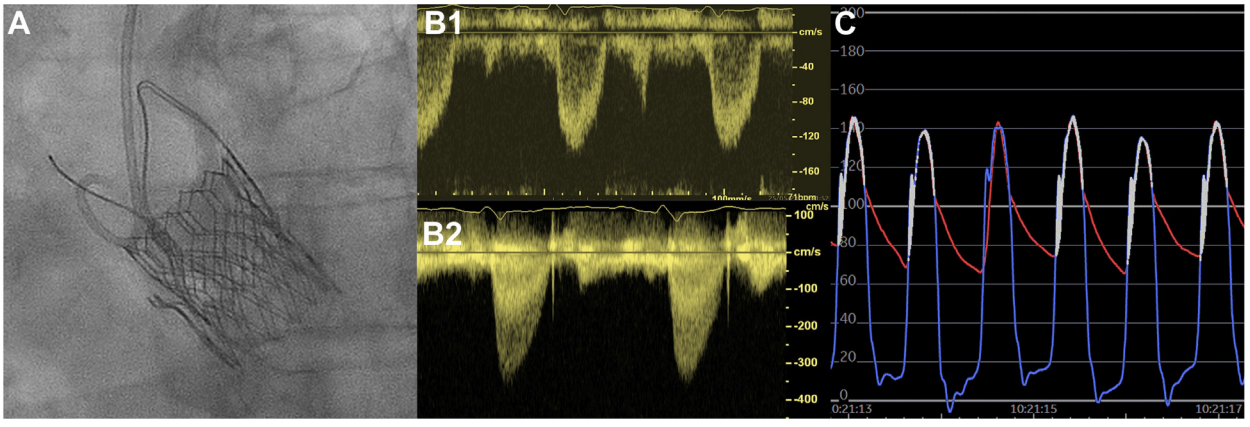
FIGURE 1 Case 1 Overview



(A) Final fluoroscopic result. (B) Echocardiographic evaluation (B1: left ventricular outflow tract pulsed wave Doppler signal; B2: aortic valve continuous Doppler signal). (C) Invasive gradient evaluation.

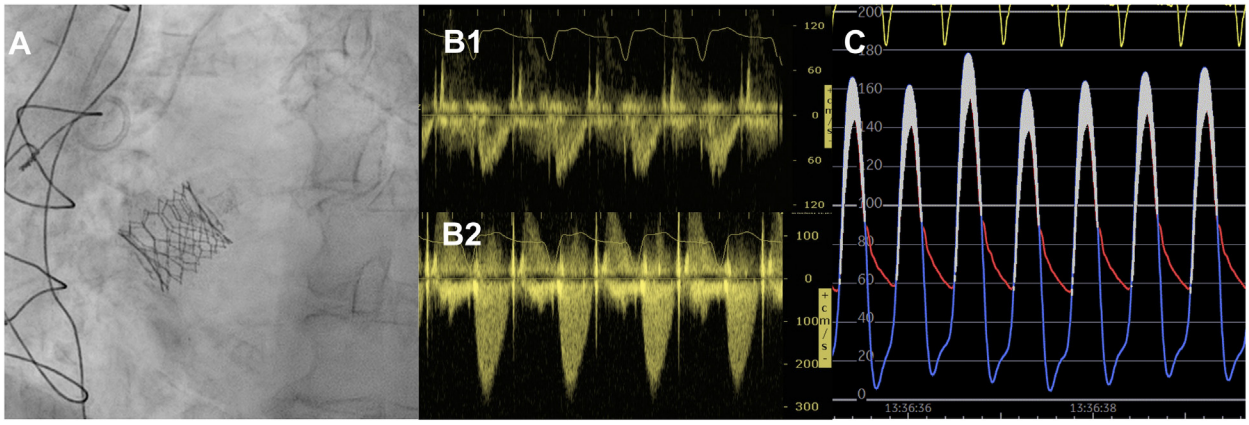
CASE 3: PROSTHESIS-PATIENT MISMATCH. A 79-year-old woman had previously undergone surgical aortic valve replacement with a Trifecta 21 mm valve. Eight years later, she presented with congestive heart failure due to severe structural valve degeneration (maximum/mean gradient 59/30 mm Hg; V_{max} 3.9 m/s; EOA 0.67 cm^2) in the presence of a low-flow state (indexed stroke volume 35 mL/m^2) and reduced left ventricular ejection fraction (38%). After discussion with the heart team, a ViV TAVR procedure using a 20 mm Sapien 3 valve was performed. The chimney technique was also used to reduce the risk of coronary flow obstruction after valve implantation. Post-procedural echocardiography showed higher residual gradients than predicted (measured mean gradient 24 mm Hg vs predicted mean gradient 16 mm Hg). V_{max} was 2.7 m/s, and the DVI was 0.34 (Figure 3). The measured EOA was 1.15 cm^2, comparable to the predicted value (1.22 cm^2). Both the EOAi and the ELI were reduced (0.63 cm^2/m^2 and 0.70 cm^2/m^2, respectively). Invasive hemodynamic evaluation confirmed the presence of a high transvalvular gradient (mean

FIGURE 2 Case 2 Overview



(A) Final fluoroscopic result. (B) Echocardiographic evaluation (B1: left ventricular outflow tract pulsed wave Doppler signal; B2: aortic valve continuous Doppler signal). (C) Invasive gradient evaluation.

FIGURE 3 Case 3 Overview

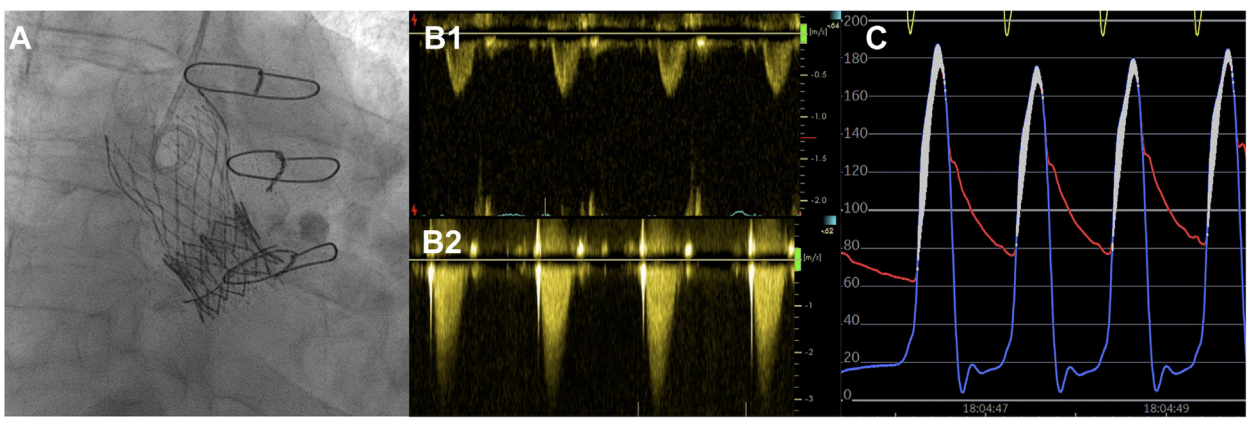


(A) Final fluoroscopic result. (B) Echocardiographic evaluation (B1: left ventricular outflow tract pulsed wave Doppler signal; B2: aortic valve continuous Doppler signal). (C) invasive gradient evaluation.

22 mm Hg). After careful patient evaluation, no additional post-dilatation was performed due to the high perceived risk of coronary flow obstruction.

Interpretation. In the third clinical scenario, we presented a case involving significant patient-prosthesis mismatch (PPM). Postprocedural PPM is by far the most widely studied and well-known circumstance among the 4 different scenarios presented in this series.[7] It is more commonly observed in patients undergoing implantation of smaller devices and ViV procedures. Echocardiographic assessment has generally been accepted as a reliable and standardized means of confirming the diagnosis.[1] However, more recently, some authors have questioned this approach in TAVR patients, highlighting potentially significant differences between the predicted valve area (calculated according to device model and size and/or pre-TAVR left ventricular outflow tract area) and the measured one. Although the exact explanation for these findings remains unclear, we cannot exclude the possibility that significant discrepancies between invasive and noninvasive

FIGURE 4 Case 4 Overview



(A) Final fluoroscopic result. (B) Echocardiographic evaluation (B1: left ventricular outflow tract pulsed wave Doppler signal; B2: aortic valve continuous Doppler signal). (C) Invasive gradient evaluation.

gradient measurements among the patients included in these studies might contribute to these results. When encountering a patient with suspected PPM after TAVR, we believe that comparing measured and predicted EOA could be useful in identifying those patients for whom invasive confirmation of the gradients is preferable. Moreover, a careful evaluation of anterograde flow is recommended to differentiate true PPM cases from "pseudo-PPM," in which insufficient anterograde flow fails to adequately open the valve, resulting in a smaller EOAi.[7] In our case example, this mechanism might have contributed to postprocedural PPM. However, at least moderate PPM had already been anticipated preprocedurally due to the small valve size used (predicted EOAi 0.67 cm^2/m^2). Generally, during ViV procedures, it is advisable to intra-operatively test postimplantation gradients to assess the need for further valve manipulation and optimization.[8] Unfortunately, the tight valve-to-coronary space in our patient did not allow for bioprosthesis post-dilatation.

CASE 4: SUBOPTIMAL VALVE EXPANSION. A 70-year-old man had previously undergone a Bentall procedure with implantation of a Pericarbon More 27 mm aortic valve (Sorin) and a 32 mm Valsalva vascular prosthesis, followed after 8 years by a ViV TAVR procedure with a Sapien XT 26 mm valve (Edwards Lifesciences). He was admitted for congestive heart failure due to severe structural valve degeneration (maximum/mean gradient 81/48 mm Hg; V_{max} 4.5 m/s; EOA 0.65 cm^2). After evaluation by the heart team, the patient underwent a new ViV procedure with an Evolut R 26 mm device. Postprocedural echocardiographic gradients were significantly higher than expected (measured mean gradient 22 mm Hg vs predicted mean gradient 7.5 mm Hg) with increased V_{max} (2.8 m/s) and a reduced DVI (0.24) (**Figure 4**). The measured EOA/EOAi was smaller than the predicted one (measured EOA 1.28 cm^2 vs predicted EOA 1.69 cm^2; measured EOAi 0.78 vs predicted EOAi 1.03 cm^2/m^2). Invasive evaluation confirmed increased trans-prosthetic gradients (mean gradient 20 mm Hg) with no significant pressure recovery phenomena. In addition, fluoroscopic views highlighted suboptimal valve expansion with evident constriction of the valve stent in its mid-portion. In this case, no ring fracture was attempted due to the presence of a vascular prosthesis in the ascending aorta.

Interpretation. In this last scenario, we present a case of suboptimal valve expansion. Severe calcifications, bicuspid aortic anatomy, and the presence of previous bioprosthetic devices may prevent complete valve expansion.[8] In such cases, hemodynamic valve performance is compromised, leading to residual high gradients. An echocardiographic multiparametric evaluation is generally accurate in distinguishing this scenario from others.[1,5] A multimodality imaging approach, utilizing transesophageal echocardiography, fluoroscopy, and computed tomography imaging, can help identify stent subexpansion and rule out leaflet thrombosis or endocarditis.[1] However, invasive confirmation of residual high gradients is generally recommended, and, when possible, valve post-dilatation should be attempted.

LIMITATIONS

This case series involved only 4 patients, serving as practical examples of different clinical scenarios rather than offering definitive conclusions. Many patients may not fit into the 4 categories described or may present nuanced clinical and echocardiographic findings. The currently proposed cutoff values for DVI, as indicated in available references,[1] should be considered provisional. It is important to acknowledge that values closer to 0.5 may still be associated with pressure gradients, as suggested by Van Mieghem et al.[9] Moreover, the rate at which pressure gradients increase across a broader range of DVI values remains uncertain and warrants further investigation. Nonetheless, the proposed diagnostic algorithms could be useful for the initial patient assessment. Our case series exclusively includes patients treated with Evolut or Sapien devices. Predictive gradient values for other commercially available transcatheter heart valves are documented in separate studies.[10] Finally, the concepts of predicted gradients and EOA, applied here to ViV procedures, are generally intended for TAVR in native annuli.

CONCLUSIONS

Higher-than-expected postprocedural transvalvular gradients are frequently observed after TAVR and can result from different clinical scenarios. Because TAVR procedures are increasingly performed on younger patients, a standardized multiparametric evaluation of postprocedural outcomes, incorporating both noninvasive and invasive tests, is essential to identify cases that may benefit from additional valve interventions. Until larger studies are available, our proposed algorithm can serve as a practical guide in managing this complex situation.

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