Transesophageal Echocardiographic Planning and Neo–Left Ventricular Outflow Tract Assessment for Transcatheter Mitral Valve Implantation Using Novel Software

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INTRODUCTION

Transcatheter mitral valve (MV) implantation is a viable treatment option for elderly patients with mitral annular calcification (MAC) at prohibitive surgical risk. In cases where contrast-enhanced cardiac computed tomography (CCT) is contraindicated, alternative methods for annular sizing and left ventricular outflow tract (LVOT) obstruction (LVOTO) assessment are necessary. This case report demonstrates the use of a novel echocardiographic software as an alternative to contrast-enhanced CCT for preprocedural valve-in-MAC screening and outlines technical considerations aimed at mitigating the risk of LVOTO.

CASE PRESENTATION

An 85-year-old Caucasian woman presented to the hospital with worsening shortness of breath. The patient was alert and displayed signs of heart failure. The patient's medical history included stage IV chronic kidney disease due to membranous glomerulonephritis, hypertension, a transcatheter aortic valve implantation with a 29 mm self-expandable valve complicated by heart block requiring a permanent pacemaker implantation, degenerative mitral stenosis and mitral regurgitation (MR).

Upon admission, the chest x-ray revealed bilateral lower lung field opacities. The laboratory results showed a creatinine level of 2.39 mg/dL (estimated glomerular filtration rate = 21 mL/min/1.73 m^2), a hemoglobin level of 8.8 g/dL, and a N-terminal prohormone of brain natriuretic peptide of 3, 607 pg/mL. Transthoracic echocardiography confirmed the presence of mixed MV disease with MV area of 1.2 cm^2, transmitral peak/mean gradients of 21 and 9 mm Hg at a heart rate of 66 bpm, and moderate MR (three-dimensional [3D] vena contracta of 0.25 cm^2), establishing these findings as the primary etiology of the cardiac decompensation.

The patient was admitted and initiated on furosemide, which was subsequently placed on hold due to worsening renal function (peak creatinine, 2.8 mg/dL; estimated glomerular filtration rate = 14 mL/min/1.73 m^2). A clinical decision was made to proceed with valve-in-MAC. Due to the significant risk of worsening renal failure following contrast administration, the preprocedural measurements of the mitral annulus (MA) and assessment of MAC were performed on a gated noncontrast CCT. The study revealed a MA area of approximately 5.8 cm^2 and circular MAC, most prominent in the posterolateral aspect (Figure 1A and B). The assessment of the neo-LVOT area was hindered by indistinct LVOT margins in the absence of contrast. To assess the risk of LVOTO, periprocedural 3D transesophageal echocardiography (TEE) with multibeat acquisitions (6 beats, 62 Hz) encompassing the MV, LVOT, and septal wall was performed, which was reconstructed using a new postprocessing software (3D TEE, 3mensio Structural Heart; Pie Medical Imaging). This software allows for a detailed step-by-step reconstruction of the MA, projection of a virtual valve, and assessment of the neo-LVOT area (Video 1). The echocardiographic MA analysis was performed in early diastole (one frame after maximal valve opening), and the neo-LVOT assessment in late systole (one frame before aortic valve closure). The MA area was 5.7 cm^2 with the largest commissure-to-commissure dimension of 29 mm (Figure 1C). The virtual valve was projected in 3 different positions with predicted neo-LVOT areas ranging from 90 to 220 mm^2 (Figure 2), revealing a potential risk of LVOTO, contingent upon the exact placement of the prosthesis within the MA. Considering the limited alternative therapeutic options, a decision was made to implant the valve with the goal of a slightly more atrial positioning with a medial-to-lateral valve trajectory to improve the medial neo-LVOT area. After transseptal puncture, the valve was positioned at the annular level toward the medial commissure and the delivery system was unflexed to promote a slight medial-to-lateral deployment trajectory. The 29 mm Edwards SAPIEN 3 Ultra prosthesis was positioned with a 30% atrial and 70% ventricular orientation and slowly deployed under TEE and fluoroscopic guidance (Video 2). Initial color-flow Doppler assessment revealed a prominent lateral paravalvular regurgitant jet, and a postdilation was performed using the deployment balloon with additional 5 mL volume. Further expansion of the valve was achieved with mild residual lateral paravalvular regurgitation by the end of the procedure (Video 3). Extensive evaluation of the 3D TEE measured a neo-LVOT area of 1.6 cm^2. Following the

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VIDEO HIGHLIGHTS

Video 1: A step-by-step segmentation of the MA is initially displayed, and then a step-by-step assessment of the neo-LVOT area is displayed using echocardiographic datasets in the 3D TEE MV module

Video 2: The fluoroscopic (*left panel*) and echocardiographic (*right panel*) documentation of the bioprosthetic valve deployment (*arrows*) within MAC (valve-in-MAC) demonstrates a well-positioned valve. The *green box* displays the mediolateral dimension; the *red box* displays the anteroposterior dimension; the *blue boxes* demonstrate the MV en face view in a two-dimensional cut plane (*left*) and 3D volume-rendered (*right*) display.

Video 3: Two-dimensional TEE, long-axis (70° and 75°) views without (*left*) and with (*right*) color-flow Doppler, post-implantation (*left 2 images*) and postdilatation (*right 2 images*), demonstrates improvement of the paravalvular regurgitation postdilatation. The central MR in the postimplantation display is due to the wire and is resolved in the postdilatation display after removal of the wire.

Video 4: Two-dimensional TEE, deep transgastric oblique 5-chamber view, without (*left*) and with (*right*) color-flow Doppler after implantation of the valve, demonstrates a turbulent flow pattern through the valve stent (*green arrow*) and neo-LVOT (*red arrow*).

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procedure, the patient's clinical status improved. The postprocedural transthoracic echocardiography showed a well-seated valve with mild central MR. The peak transaortic gradient was 22 mm Hg (mean gradient, 13 mm Hg). The right ventricular stroke volume increased from 75 to 80 mL (accounting for the measured 1.2:1 shunt) and using these values for continuity equation valve area calculations, the MV area increased from 1.1 to 2.0 cm^2 (peak/mean gradients of 13 and 5 mm Hg at a heart rate of 68 bpm, respectively), and aortic valve area decreased from 2.1 to 1.6 cm^2. The patient was discharged home in stable condition on postprocedure day 5.

DISCUSSION

Valve-in-MAC procedures generally carry higher complication rates ranging from 11.2% to 39.7% compared to valve-in-valve or valve-in-ring procedures.[1,2] One of the primary reasons for this increased risk is the unpredictability of the final valve position when adapting to the often asymmetric valve calcification. The Mitral Valve Academic Research Consortium criteria defined LVOTO as a gradient increase of 10 mm Hg,[3] and the expert consensus recommends using the peak gradient as this most accurately reflects the LVOT hemodynamics.[4] According to this definition, this patient experienced LVOTO; however, the mild increase in LVOT gradients was acceptable and did not hinder overall symptomatic and hemodynamic improvement after the procedure.

The following aspects were considered during the procedure to minimize the risk of LVOTO.

Anterior Leaflet Laceration

A transcatheter laceration of the anterior leaflet facilitates the blood flow through the valve stent, increasing the neo-LVOT area (Figure 3A). However, this tactic could reduce valve stability at the anterior aspect of the MA in the absence of circumferential calcium. In this case, the concern for valve embolization was greater than the concern for LVOTO.

Annular Sizing

The MA area was on the lower end for a 29 mm SAPIEN prosthesis. Consideration was given to implanting a smaller valve (26 mm) with added volume, which could potentially shorten the prosthesis and increase the neo-LVOT dimensions (Figure 3B). However, it is important to note that mitral dimensions usually increase during the implantation due to calcium expansion. Furthermore, the largest annular dimension was 29 mm, leading us to be more concerned about the risk of valve embolization and paravalvular regurgitation with a 26 mm valve implantation. Ultimately, the decision was made to implant a larger 29 mm valve, which even then required postdilation with additional volume, confirming the appropriateness of the size choice.

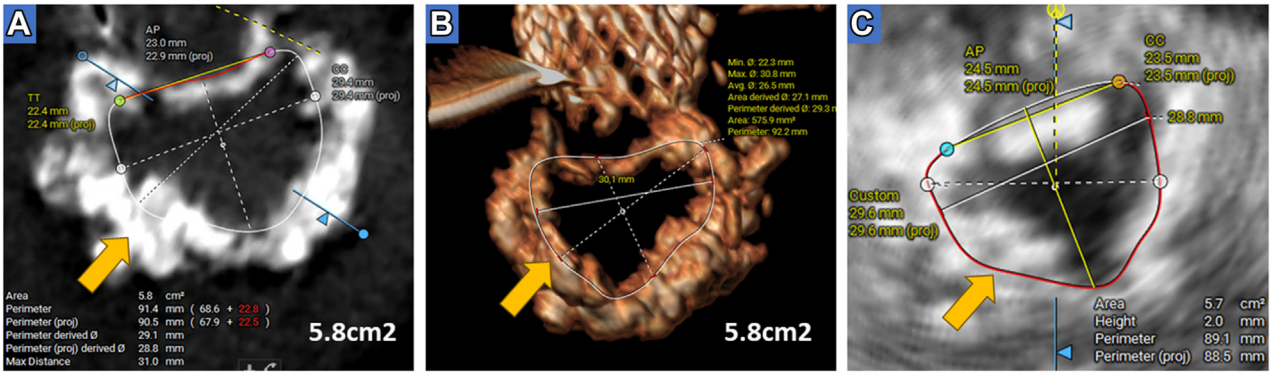

Figure 1 A CCT-derived **(A, B)** and 3D echocardiographic **(C)** en face view of the MV in early diastole demonstrates comparable mitral annular dimensions and annular calcification with protruding spicules in the posterolateral region (*arrows*).

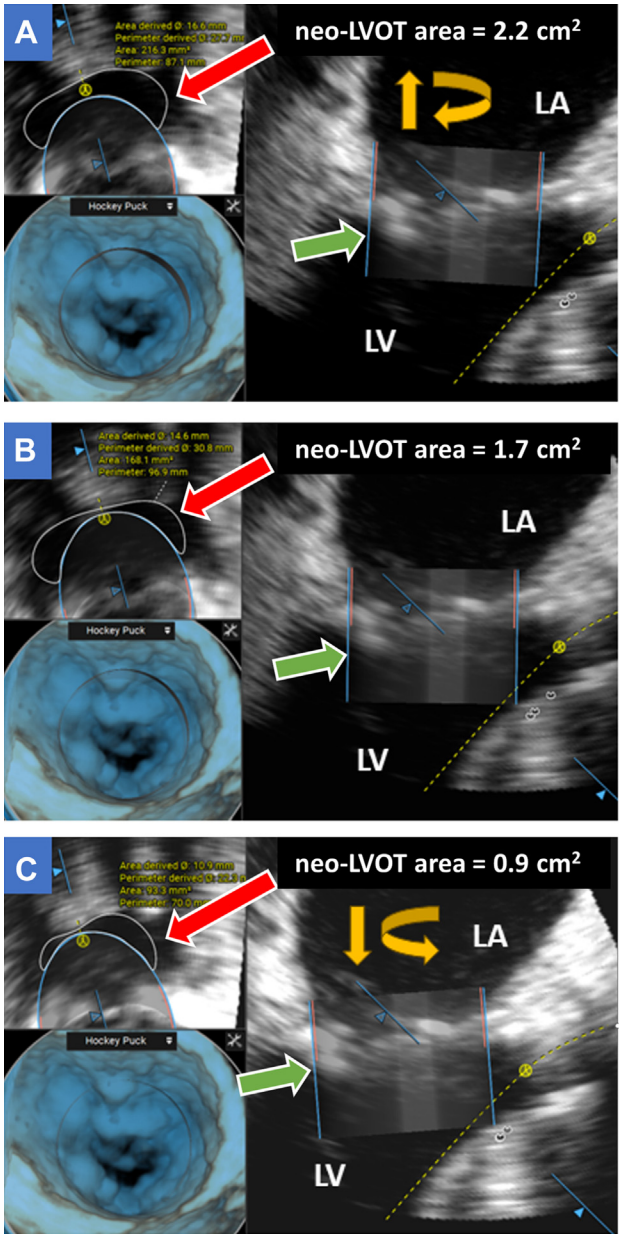

Figure 2 Three-dimensional TEE, zoomed apical long-axis view in end systole (*right panel*) with a multiplanar short-axis reconstruction (*top left*) and volume-rendered en face display (*bottom left*), demonstrates the virtual valve (*green arrows*) projected as a ghost-like overlay positioned in 3 different locations: **(A)** high in the atrium with prosthesis canted away from the LVOT (neo-LVOT area of 2.2 cm^2); **(B)** neutral position aligned with MA (neo-LVOT area of 1.7 cm^2); **(C)** deep in the ventricle and canted toward LVOT (neo-LVOT area of 0.9 cm^2). *Yellow arrows* show the direction of repositioning the virtual valve; *red arrows* indicate the neo-LVOT area. *LA*, left atrium; *LV*, left ventricle.

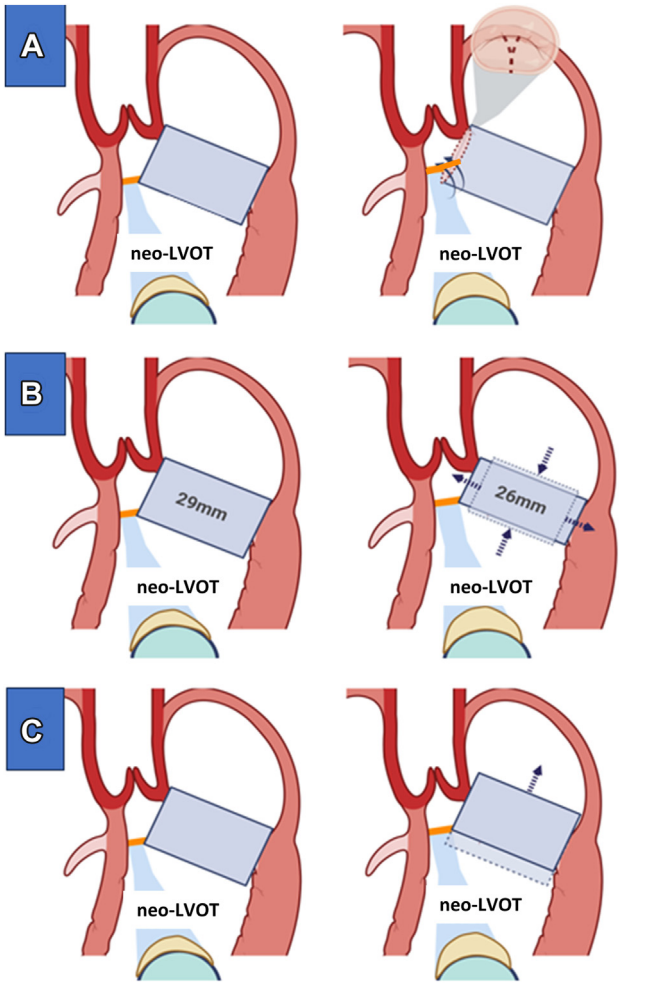

Figure 3 Graphic illustration of the intra-procedural maneuvers considered to minimize the risk of LVOTO. The *left panel* demonstrates the anticipated result without these maneuvers. Shown on the *right panel*: **(A)** transcatheter laceration of anterior leaflet facilitates blood flow through the space created by the laceration; **(B)** implantation of a smaller valve may reduce valve height and limit protrusion into left ventricle; **(C)** a similar effect can be achieved by implanting the valve in a more atrial position.

Valve Position

Typically, ventricular position of the valve prosthesis is sought to optimize valve hemodynamics. However, given the patient's age, the possibility of slightly less favorable hemodynamics was accepted to increase the neo-LVOT area, and the valve was deployed in a more atrial position (Figure 3C).

The postimplantation images were analyzed, revealing an LVOT area of 1.6 cm^2 (Figure 4). Importantly, the neo-LVOT area estimates assumed that the anterior leaflet would extend to the end of the stent, when in reality there was some flow through the most ventricular part of the prosthesis, resulting in a slightly larger neo-LVOT area than predicted in the baseline analysis (Video 4).

CONCLUSION

The new postprocessing TEE software facilitates the device sizing and assessment of LVOTO risk, which may be particularly helpful in patients with urgent need for transcatheter MV implantation and contraindication for contrast-enhanced CCT.

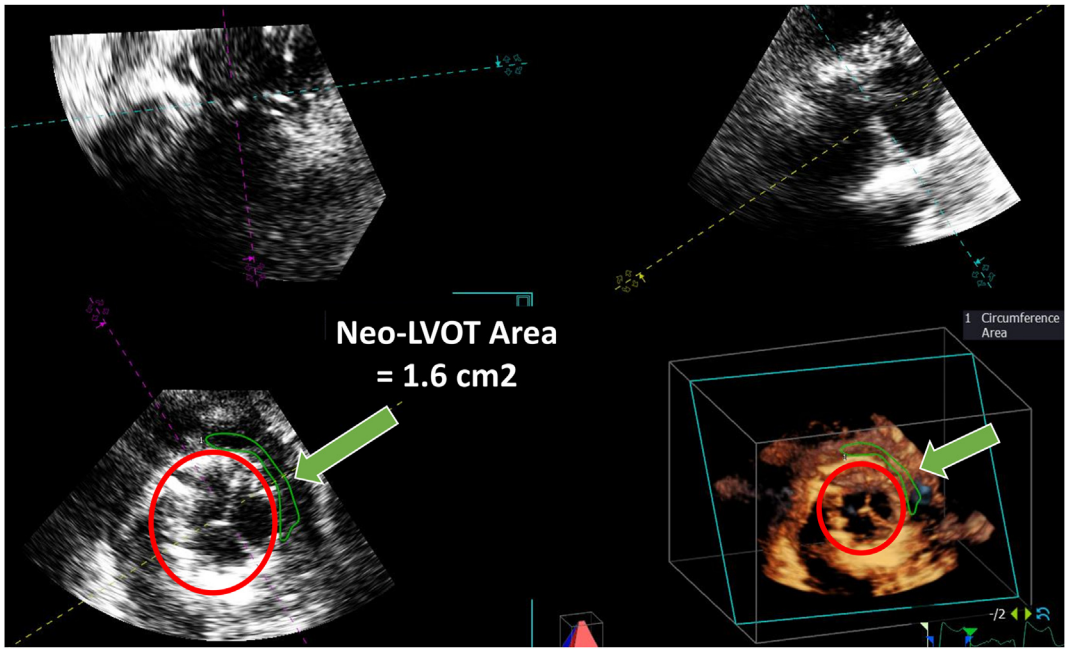

Figure 4 Three-dimensional TEE evaluation using multiplanar reconstruction demonstrates 2 orthogonal cut-plane views (*top*), a cut-plane short-axis view (*bottom left*), and volume-rendered short-axis display (*bottom right*) with the bioprosthesis highlighted (*red circle*). The neo-LVOT area is traced in a *green outline* and measures 1.6 cm^2 (*arrows*).

ETHICS STATEMENT

The authors declare that the work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

CONSENT STATEMENT

Complete written informed consent was obtained from the patient (or appropriate parent, guardian, or power of attorney) for the publication of this study and accompanying images.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.case.2024.02.002.

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