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ORIGINAL RESEARCH

3-Dimensional Echocardiographic Prediction of Left Ventricular Outflow Tract Area Prior to Transcatheter Mitral Valve Replacement

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ABSTRACT

BACKGROUND New postprocessing software facilitates 3-dimensional (3D) echocardiographic determination of mitral annular (MA) and neo-left ventricular outflow tract (neo-LVOT) dimensions in patients undergoing transcatheter mitral valve replacement (TMVR).

OBJECTIVES This study aims to test the accuracy of 3D echocardiographic analysis as compared to baseline computed tomography (CT).

METHODS A total of 105 consecutive patients who underwent TMVR at 2 tertiary care centers between October 2017 and May 2023 were retrospectively included. A virtual valve was projected in both baseline CT and 3D transesophageal echocardiography (TEE) using dedicated software. MA dimensions were measured in baseline images and neo-LVOT dimensions were measured in baseline and postprocedural images. All measurements were compared to baseline CT as a reference. The predicted neo-LVOT area was correlated with postprocedural peak LVOT gradients.

RESULTS There was no significant bias in baseline neo-LVOT prediction between both imaging modalities. TEE significantly underestimated MA area, perimeter, and medial-lateral dimension compared to CT. Both modalities significantly underestimated the actual neo-LVOT area (mean bias pre/post TEE: 25.6 mm^2, limit of agreement: -92.2 mm^2 to 143.3 mm^2; $P < 0.001$; mean bias pre/post CT: 28.3 mm^2, limit of agreement: -65.8 mm^2 to 122.4 mm^2; $P = 0.046$), driven by neo-LVOT underestimation in the group treated with dedicated mitral valve bioprosthesis. Both CT- and TEE-predicted-neo-LVOT areas exhibited an inverse correlation with postprocedural LVOT gradients ($r^2 = 0.481$; $P < 0.001$ for TEE and $r^2 = 0.401$; $P < 0.001$ for CT).

CONCLUSIONS TEE-derived analysis provides comparable results with CT-derived metrics in predicting the neo-LVOT area and peak gradient after TMVR. (J Am Coll Cardiol Img 2024;■:■–■) © 2024 by the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

3D = 3-dimensional

CT = computed tomography

EF = ejection fraction

LoA = limit of agreement

LV = left ventricle

LVOT = left ventricular outflow tract

LVOTO = left ventricular outflow tract obstruction

MA = mitral annulus

TEE = transesophageal echocardiography

TMVR = Transcatheter mitral valve replacement

ViMAC = valve-in-mitral annular calcification

ViR = valve-in-ring

ViV = valve-in-valve

Anatomic complexity or poor predicted results of transcatheter edge-to-edge therapy have led to a growing number of patients in whom a transcatheter mitral valve replacement (TMVR) device may be preferred. Early experience with dedicated mitral bioprostheses is promising using either a transapical[1] or transseptal approach.[2] TMVR using transcatheter aortic bioprosthetic valves can also treat patients with a dysfunctional surgical valve (valve-in-valve [ViV]), surgical annuloplasty ring (valve-in-ring [ViR]), or native valve in mitral annular calcification (ViMAC).[3] One of the greatest impediments to TMVR design and adoption, however, remains left ventricular outflow tract obstruction (LVOTO)[4] caused by the narrowing of the newly created left ventricular outflow tract (LVOT) (neo-LVOT), which is a predictor of postprocedural LVOT gradient increase and has implications for patient outcomes.[3,5,6] Currently, predicting the risk of this complication requires contrast-enhanced cardiac computed tomography (CT) imaging which entails additional cost and risks of allergic reaction or nephrotoxicity.[6,7]

Transesophageal echocardiography (TEE) is performed in all patients either as a screening tool or to guide TMVR intraprocedurally. To avoid the cost and risks associated with CT, attempts have been made to develop easily available alternative strategies for annular sizing and prediction of LVOTO from TEE images.[8,9] The recent development of a dedicated software package facilitating a semiautomated segmentation of D-shaped mitral annulus (MA) and projection of the virtual valve onto the 3-dimensional (3D) TEE data sets may allow for routine use of TEE for TMVR screening. The aim of our study was to test the accuracy of 3D TEE-derived annular sizing and neo-LVOT area as compared to the baseline CT.

METHODS

STUDY DESIGN AND PATIENT POPULATION. This retrospective study was conducted at New York Presbyterian Columbia University Medical Center, USA, and Bern University Hospital, Switzerland. One hundred sixty-two consecutive patients who underwent TMVR for the treatment of native mitral valve disease or degenerative surgical prosthesis or ring (ViV and ViR) were screened, and 105 were included in the present analysis (Figure 1). Valve prostheses used for the treatment included SAPIEN S3 (Edwards Lifesciences), Tendyne (Abbott Structural), and Intrepid (Medtronic) implanted according to the local standards. Patients were included in the study if there was baseline CT and 3D TEE image of MA and LVOT with sufficient image quality. The study was approved by the local institutional review board or Swiss ethics committee.

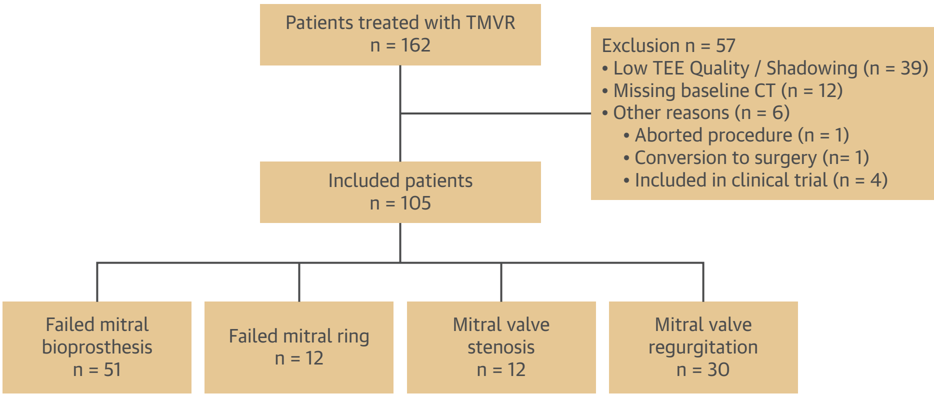
ECHOCARDIOGRAPHIC ANATOMICAL ASSESSMENT. The standard echocardiographic assessment comprised baseline and discharge transthoracic echocardiography (TTE), along with intraprocedural TEE guidance. These examinations were conducted using a commercially available system (Philips Healthcare Epiq CVx with X5-1 [TTE] or X8-2t [TEE] transducers).

LVOT peak velocity was measured at baseline and discharge or during the procedure after valve implantation if TTE was not available. The gradients were determined using pulsed-wave Doppler at baseline, and continuous-wave Doppler was applied after the intervention if the velocities reached the Nyquist limit. The stroke volume was determined by calculating the product of the LVOT area (cm^2) and the pulsed-wave Doppler velocity time integral (cm), both measured 1 to 2 mm ventricular to the aortic valve.[10] In instances of LVOT flow acceleration, the stroke volume was measured in the right ventricular outflow tract.

The 3D TEE images were acquired from the mid-esophageal long-axis view encompassing the whole MA, aortic valve, and LVOT. The intraprocedural 3D data sets were imported to a dedicated postprocessing 3D TEE module (3mensio Structural Heart, version 10.3; Pie Medical Imaging) for the MA and neo-LVOT analyses similar to those performed in the CT-based mitral valve module. For baseline native valve disease, the MA dimensions were measured in early diastole (1 frame after maximal valve opening). The first step involved the identification of the aortic and mitral valves in the multiplanar view and MA tracing by placing 8 points at the mitral valve leaflet hinge point (Figure 2A). Each of the points was assessed separately and manually corrected in the multipoint view (Figure 2B). After creation of a saddle-shaped annulus, D-shape segmentation was performed by identifying the trigones (Figures 2C and 2D).

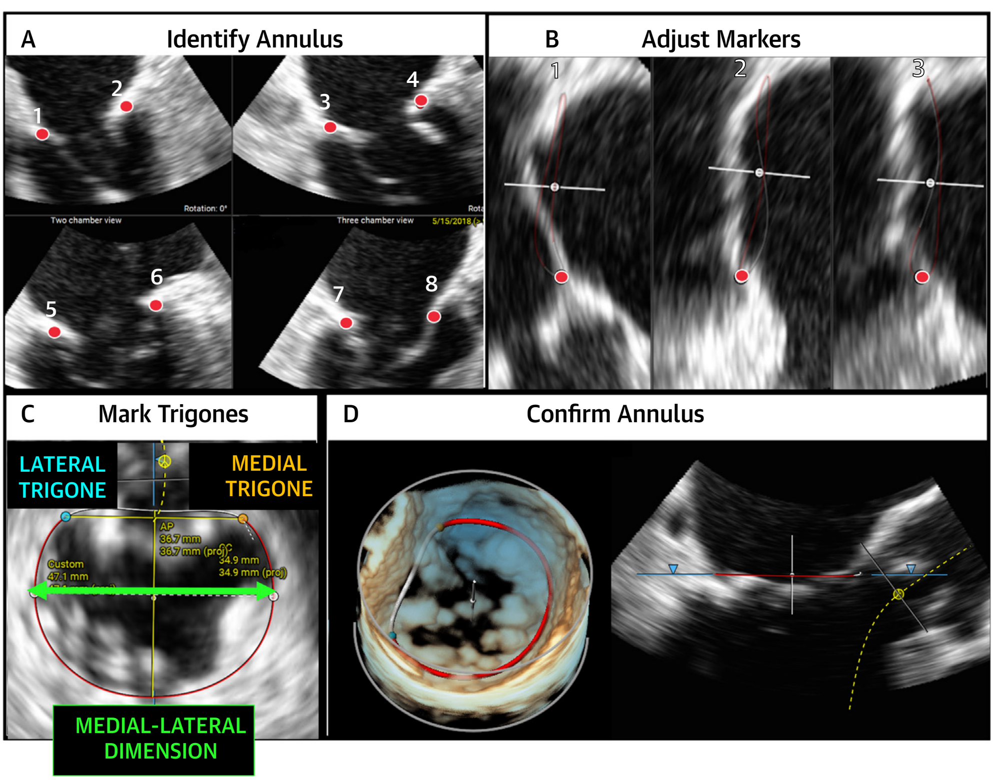
For the measurement of the predicted neo-LVOT, a virtual valve was chosen and projected onto the imaging data set (Figure 3). For both ViR and ViMAC procedures, the virtual valve was positioned in a 20% atrial and 80% ventricular position. In the case of ViV, the virtual valve was aligned with the ventricular end

FIGURE 1 Patient Inclusion Flowchart



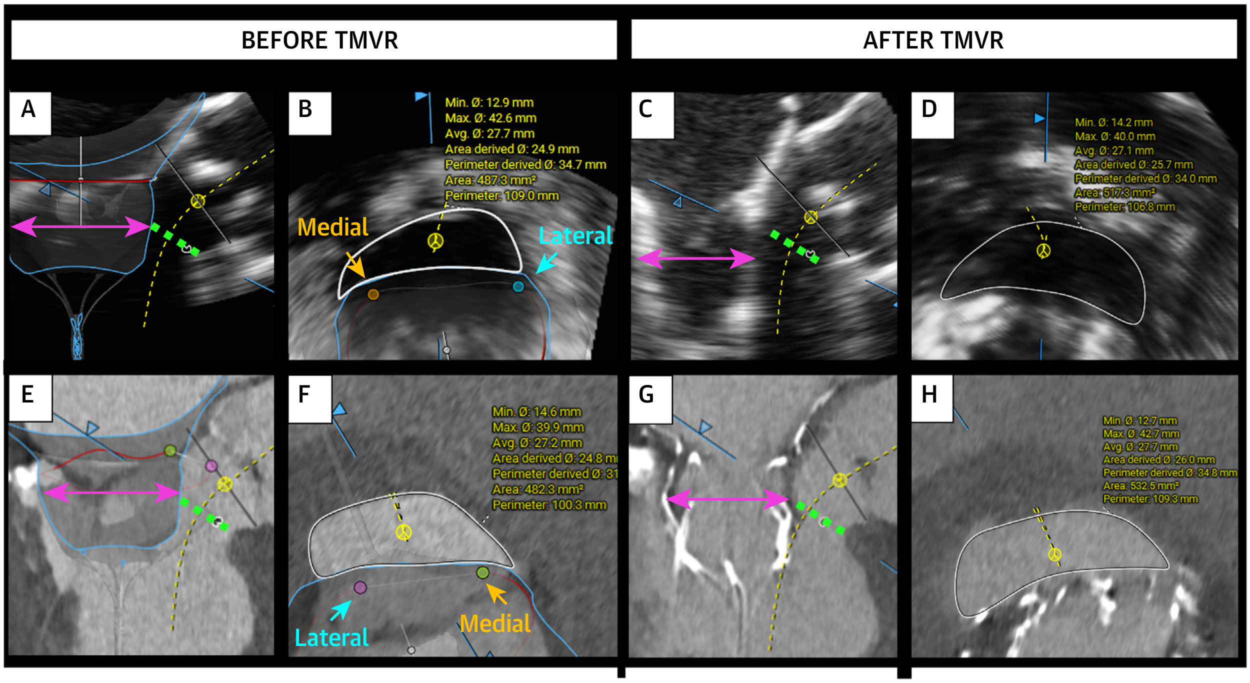
Study flowchart showing the number of patients included in the current analysis. CT = computed tomography; TEE = transesophageal echocardiography; TMVR = transcatheter mitral valve replacement.

FIGURE 2 Echocardiographic Segmentation of D-Shaped Mitral Annulus



(A) Segmenting the D-shaped mitral annulus is performed on a single-beat, 3-dimensional volume acquisition by sequentially positioning a marker on the hinge point of the mitral valve leaflets. The program automatically rotates the image 45 degrees to allow 8 points to be placed. (B) Each point can be individually assessed and manually corrected in the multipoint view. After creating the saddle-shaped annulus, the lateral and medial trigones are visually identified and marked (C) to ultimately achieve the D-shaped annulus (D).

FIGURE 3 **Echocardiography vs CT for Prediction of Newly Created LVOT Area**



(A-D) Newly created left ventricular outflow tract (neo-LVOT) assessment by echocardiography and (E-H) CT, both before and after valve implantation. (A,E) A virtual valve is projected onto the mitral valve annulus to define the centerline for the neo-LVOT (yellow dashed line). (B,F) Tracing of the predicted neo-LVOT (white line) is delineated between the left ventricular septal wall and the valve prosthesis. (C,G) Postprocedural images with implanted transapical TMVR prosthesis and the centerline for the neo-LVOT (yellow dashed line). (D,H) Measurements of actual neo-LVOT. Pink arrows underline the discrepancies between anteroposterior dimension of the projected virtual valve (A,E) and implanted bioprosthesis adapting its shape to the mitral annulus (C,G). Abbreviations as in Figure 1.

of the surgical prosthesis. For dedicated mitral valve prostheses, the projected valve was placed according to valve specifications. Next, a centerline was placed in the neo-LVOT (Figure 3A) and the smallest predicted end-systolic neo-LVOT area was chosen for the measurement in end-systole (1 frame before the closure of aortic valve) (Figure 3B). The predicted neo-LVOT was measured in all patients before the procedure (Figure 3B) and the actual neo-LVOT after the valve implantation (Figures 3C and 3D). The distance between aortic valve plane and narrowest neo-LVOT area as well as angle between aortic valve and prosthesis were measured before and after the implantation to assess the accuracy of virtual valve positioning. Additionally, anterior leaflet length was measured in both TEE and CT at the baseline.

CT ASSESSMENT. The CT scan was performed according to a center-specific mitral protocol. The dedicated postprocessing mitral valve module (3mensio Structural Heart, version 10.3; Pie Medical Imaging) was used for the CT-based assessments of MA and neo-LVOT. The methodology for this assessment has been previously described.[11,12] Briefly, the MA is defined by placing 16 points at the level of mitral valve hinge points and fibrous continuity. The D-shaped annulus is then created by placing lateral and medial trigone points. The virtual valve is projected and LVOT measurements are performed in the same way as described earlier (Figures 3E-3H).

STATISTICAL ANALYSIS. Continuous variables are presented as mean (± SD) or median (IQR) according to the distribution. Categorical variables are presented as absolute numbers or as percentages. The Shapiro-Wilk test was used to test for normality of continuous measures. The correlations between TEE-derived measurements and the corresponding CT-derived values as well as between predicted and postprocedural values were quantified using Pearson correlation coefficients. The relationships between the neo-LVOT area and postprocedural LVOT gradients were explored with nonlinear regression with curve estimation regression statistic using inverse model ($y = b0 (b1/x)$). Paired Bland-Altman analyses were performed to assess the bias and limits of agreement (LoA) and the intraclass correlation coefficient was used to assess the accuracy of agreement.

TABLE 1 Baseline Data (N = 105)

Age, y	75.8 ± 10.5
Male	59 (56.2)
Diabetes mellitus	26 (24.8)
Arterial hypertension	89 (84.8)
Chronic obstructive pulmonary disease	20 (19)
Cerebrovascular disease	23 (21.9)
Peripheral arterial disease	11 (10.5)
Atrial fibrillation	77 (73.3)
Coronary artery disease	7 (6.7)
Previous cardiac surgery	88 (83.8)
Renal disease	42 (40)
STS score (MVR)	7.4 (4.4-14.0)
Creatinine, μmol/L	1.6 ± 1.2
GFR, mL/min	48.6 ± 19.1
NT-proBNP, pg/L	2,302 (1,148-4,631)
Hemoglobin, g/L	11.1 ± 1.8
NYHA functional class	
2	25 (24)
3	67 (64)
4	13 (12)
Ejection fraction, %	53.4 ± 11.9
Indication	
Mitral regurgitation	18 (17.1)
Mitral stenosis	12 (11.4)
Mixed mitral disease	12 (11.4)
Ring/prosthesis degeneration	63 (0.6)
Anterior leaflet length (CT), mm	25.6 ± 7.4

Values are median (Q1-Q3), n (%), or mean ± SD.

CT = computed tomography; GFR = glomerular filtrations rate; MVR = mitral valve replacement; NT-proBNP = N-terminal pro-B-type natriuretic peptide; STS = Society of Thoracic Surgeons.

The significance of calculated difference was tested with one sample *t*-test with 0 as the test value. The same tests were performed to compare the predicted neo-LVOT with the actual neo-LVOT in both imaging modalities. The intraobserver and interobserver variability and reliability were evaluated with the intraclass correlation coefficient using 2-way mixed effects model and the coefficient of variation, respectively, with excellent agreement defined as value >0.8. The F-test was used to compare the intraclass correlation estimate to a null distribution. A 2-sided value of $P < 0.05$ was considered to indicate statistical significance. All analyses were conducted with IBM SPSS Statistics V.18 (IBM Corporation).

RESULTS

BASELINE AND PROCEDURAL CHARACTERISTICS. Between October 2017 and February 2024, 105 patients (56% male) were included into the analysis. The mean age was 75.8 ± 10.5 years, and the median Society of Thoracic Surgeons score was 7.4 (STS Score range: 4.4-14.0). Etiologies of mitral valve dysfunction included failed bioprostheses (n = 51), failed mitral annuloplasty (n = 12), native mitral regurgitation (n = 30), and native degenerative mitral stenosis (n = 12) (Figure 1). The most commonly implanted valve prosthesis was the Edwards SAPIEN S3 (n = 74, 70.5%), followed by the Tendyne (n = 25, 23.8%) and Intrepid (n = 6, 5.7%) prostheses. An ejection fraction (EF) of <50% was observed in 26 (24.8%) patients. Patients with lower EF had significantly larger neo-LVOT compared to patients with preserved EF (453.6 ± 200.5 mm^2 vs 341.7 ± 172.5 mm^2; $P = 0.007$). The baseline characteristics are summarized in Table 1. Following valve implantation, stroke volume increased by a mean of 7.1 ± 22.9 mL and LVOT peak gradient increased by a mean of 4.8 ± 14.3 mm Hg (Table 2). There were no significant differences in the distances between the aortic valve and the narrowest neo-LVOT planes, as well as in-valve angulation, in both baseline and post-implantation images, indicating the precision of virtual valve positioning.

COMPARISON OF CT-DERIVED AND TEE-DERIVED BASELINE METRICS. Results of CT and TEE derived analysis are summarized in Table 3. There was moderate-to-high correlation between CT- and TEE-derived parameters. The Bland-Altman analysis did not show any significant bias between the TEE-derived and CT-derived neo-LVOT metrics. In the MA analysis, TEE significantly underestimated the MA area, MA perimeter, and medial-lateral MA distance (Figure 4). There was no significant difference in baseline assessment of leaflet length (mean difference 0.9 mm; $P = 0.059$).

COMPARISON BETWEEN PREDICTED AND POST-TMVR VALUES. A total of 99 patients had available post-procedural 3D TEE volumes and 14 patients had postprocedural CT scans. Supplemental Table 1 shows the indications for postprocedural CT. Bland-Altman analysis revealed that, in comparison to baseline CT, both imaging modalities significantly underestimated the actual neo-LVOT measured after the implantation (Table 4). The mean bias between the predicted and actual CT-neo-LVOT area was 28.3 mm^2 (LoA: −65.8 mm^2 to 122.4 mm^2) whereas the TEE-neo-LVOT bias was 25.6 mm^2 (LoA: −92.2 mm^2 to 143.4 mm^2).

The stratification based on the type of procedure showed that the observed difference was primarily due to systematic predicted neo-LVOT underestimation in patients who underwent treatment with a dedicated mitral valve bioprostheses. In contrast, patients treated with aortic transcatheter valve

TABLE 2 Changes in Stroke Volume and LVOT Gradients Before and After Implantation

	Before Implantation	After Implantation	Absolute Change	*P* Value
Stroke volume, mL (n = 79)	71.2 ± 26	78.2 ± 27.0	7.1 ± 22.9	0.007
LVOT peak gradient, mm Hg (n = 97)	4.0 ± 2.8	8.9 ± 14.4	4.8 ± 14.3	0.001

Values are mean ± SD.
LVOT = left ventricular outflow tract.

bioprostheses (ViV, ViR, and ViMAC), did not exhibit any significant differences (Supplemental Table 2).

PREDICTION OF LVOT GRADIENTS. Six patients in whom anterior leaflet laceration was performed were excluded from the correlation of predicted neo-LVOT area with gradients. After exclusion, the LVOT gradients before and after TMVR were available in 91 patients with 4 patients experiencing peak gradient of more than 30 mm Hg. There was a moderate, nonlinear, inverse correlation between predicted neo-LVOT area and postprocedural peak LVOT gradient in both modalities ($r^2 = 0.481$; $P < 0.001$ for TEE; $r^2 = 0.401$; $P < 0.001$ for CT) (**Figure 5**). None of the patients with reduced EF demonstrated a peak gradient exceeding 13 mm Hg following the valve implantation.

INTRA- AND INTEROBSERVER VARIABILITY TEST. All CT- and echo-derived parameters showed good or high intraobserver and interobserver reliability (Supplemental Table 3).

DISCUSSION

Whereas TEE is performed in all patients screened for a transcatheter mitral valve intervention, high-quality cardiac CT may not be required in patients with native mitral regurgitation in whom for instance edge-to-edge repair is considered. In such patients, CT may be associated with additional costs and potential risks linked to contrast medium exposure. The ability to predict the risk of LVOTO using TEE images could simplify the screening process for TMVR if this imaging modality could accurately exclude patients at high risk for LVOTO.

The major findings of this study are as follows: 1) 3D TEE-derived analysis of neo-LVOT provides comparable results to CT-derived metrics; 2) both modalities predict postprocedural gradients with similar accuracy; and 3) 3D TEE-derived analysis underestimates the MA dimensions in patients with native valve disease (**Central Illustration**).

COMPARISON OF ECHOCARDIOGRAPHIC VS CT ANATOMICAL ANALYSIS. Numerous investigations have evaluated the diagnostic accuracy of CT scans and TEE for screening before transcatheter valve interventions.[13-16] A study conducted by Mak et al[13] involving the TEE delineation of a D-shaped MA revealed that results akin to those derived from CT-based analyses without substantial bias. This congruence with CT-driven assessments was similarly observed in the findings reported by Piroli et al[14] who showed no statistically significant distinctions in MA and neo-LVOT dimensions when 3D TEE measurements were compared with conventional CT reconstructions.

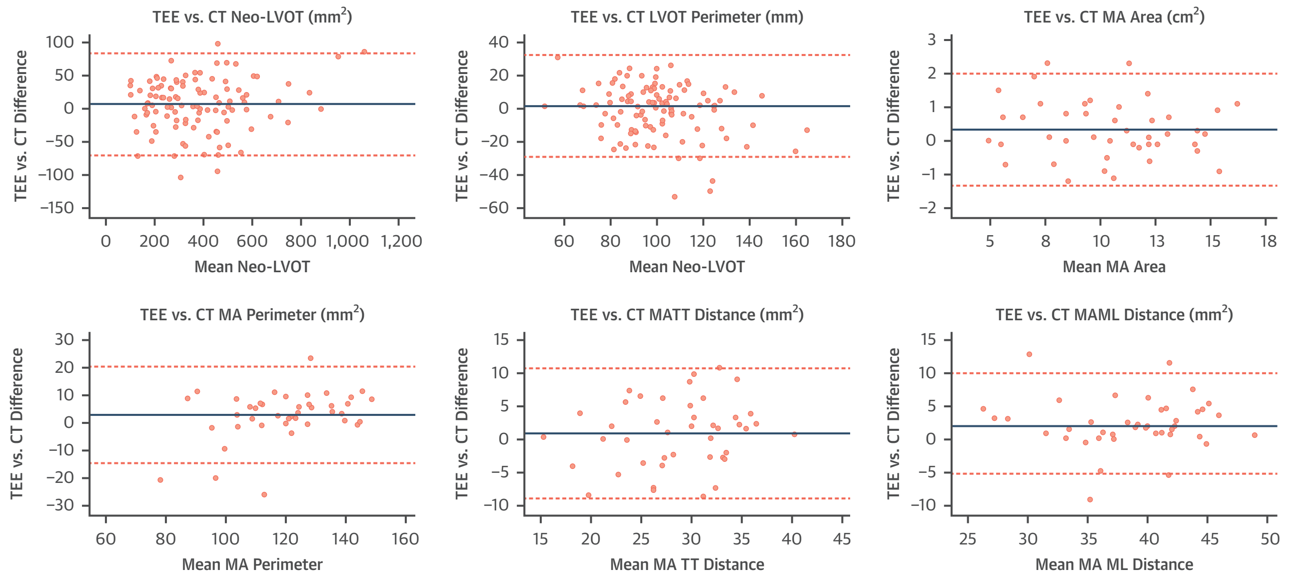
In our study, the 3D TEE measurements significantly underestimated MA dimensions. The underestimation may be related to acoustic "noise" or "blooming artifact" which could be improved by reducing the gain. Although the mean differences may not inherently hold clinical significance, wide LoA for MA area (−1.33 cm^2 to 2.0 cm^2) suggests that TEE and CT assessment could lead to different device sizing. This is less of a concern in ViV and ViR cases because the valve choice is based on the true size of surgical implant and online-application recommendations.[17]

TABLE 3 Paired Comparison of Baseline TEE and CT Derived Parameters (N = 105)

	Baseline TEE Imaging	Baseline CT Imaging	*P* Correlation	Pearson Correlation	Mean Difference CT-TEE (Limit of Agreement)	*P* Difference	Intraclass Correlation Coefficient
Predicted neo-LVOT area, mm^2	369 ± 185.3	376.4 ± 185.3	<0.001	0.978	6.7 (−70.3 to 83.7)	0.072	0.989
Predicted neo-LVOT perimeter, mm	99.6 ± 22.2	98.2 ± 18.6	<0.001	0.719	1.4 (−29.2 to 32.0)	0.366	0.828
Native valve disease (n = 42)							
MA area, cm^2	10.1 ± 3.1	10.4 ± 2.9	<0.001	0.960	0.33 (−1.33 to 2.0)	0.013	0.977
MA perimeter, mm	116.9 ± 15.9	120.4 ± 18.8	<0.001	0.881	3.0 (−14.4 to 20.4)	0.035	0.923
MA TT distance, mm	28.2 ± 5.7	29.1 ± 6.6	<0.001	0.667	0.9 (−8.9 to 10.7)	0.259	0.793
MA ML distance, mm	37.3 ± 5.7	39.8 ± 5.7	<0.001	0.769	2.1 (−5.2 to 10.0)	<0.001	0.815

Values are mean ± SD.
MA = mitral annulus; ML = medial-lateral; TEE = transesophageal echocardiography; TT = trigone-to-trigone; other abbreviations as in **Tables 1 and 2**.

FIGURE 4 **Bland-Altmann Plots for the Comparison of TEE- and CT-Derived Baseline Neo-LVOT and MA Measurements**



The Bland-Altman analysis did not show any significant bias between the TEE-derived and CT-derived neo-LVOT metrics. In the MA analysis, TEE significantly underestimated the MA area, MA perimeter, and medial-lateral MA distance. ML = medial-lateral; TT = trigone-to-trigone; other abbreviations as in Figures 1 and 3.

The LoA for neo-LVOT also showed variance depending on the choice of imaging modality with potential clinical implication. However, our case-by-case review revealed that the likelihood of divergent clinical decisions was highest in borderline cases and not in instances with the greatest measurement discrepancies, which were often noted with larger neo-LVOT areas.

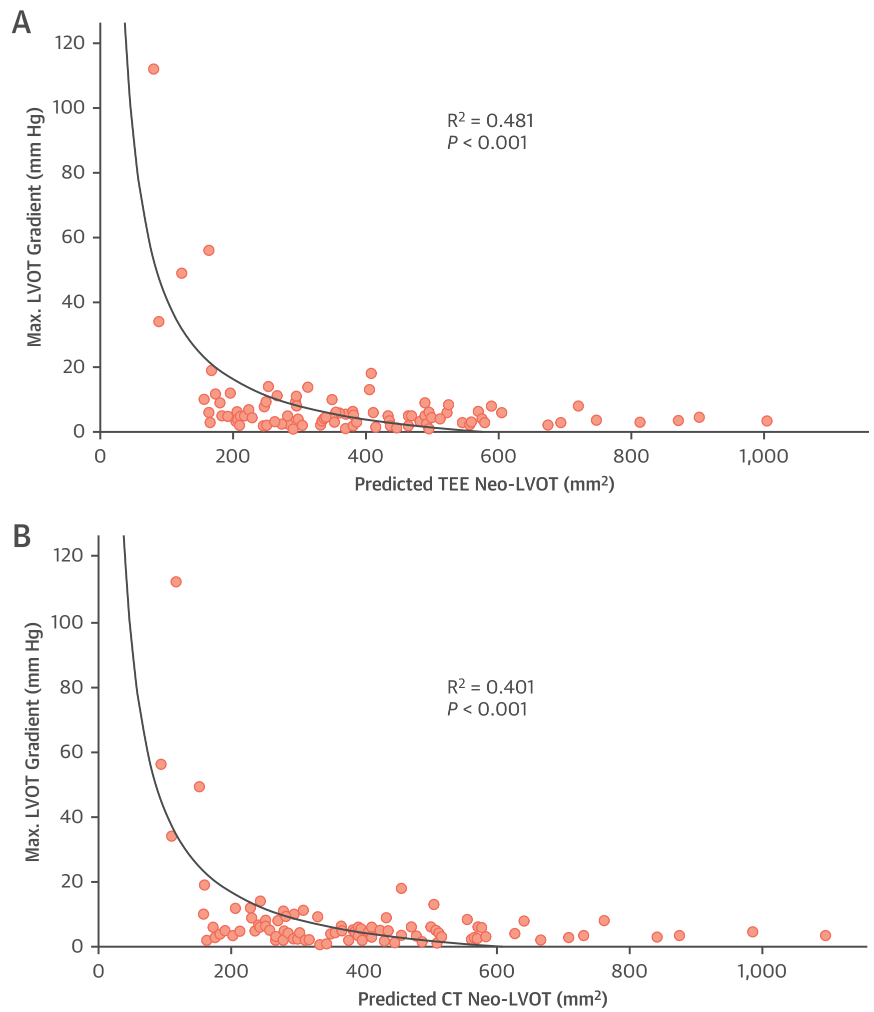
Both imaging modalities underestimated the actual neo-LVOT area in patients treated with dedicated mitral valve bioprostheses in whom also the widest LoA between imaging modalities were observed. The current method of virtual valve implantation onto CT or TEE images cannot anticipate or modify the change in virtual valve characteristics due to tissue constraints, in particular, the intact anterior mitral valve leaflet and chordal attachments. The adaptation of the bioprosthetic valve configuration to the native tissue the final deployment height withing the MA, or the canting of the TMVR device during implantation, could result in a reduction of the anteroposterior dimension and an increase in the actual neo-LVOT area, as shown in Figure 3 (Figures 3A vs 3C and Figures 3E vs 3G). Consequently, the current neo-LVOT cutoffs may prove excessively restrictive for this specific patient group, potentially leading to the unnecessary exclusion of certain high-risk individuals. Computational modeling simulations

TABLE 4 **Paired Comparison Between Predicted and Actual Parameters With Baseline CT Metrics as Reference Value (N = 99 for TEE; N = 14 for CT)**

	Predicted	Actual	P Correlation	Pearson Correlation	Mean Difference CT-TEE (Limit of Agreement)	P Difference	Intraclass Correlation Coefficient
TEE neo-LVOT area, mm^2	370.8 ± 188.3	402.3 ± 188.7	<0.001	0.950	25.6 (−92.2 to 143.4)	<0.001	0.969
CT neo-LVOT area, mm^2	355.7 ± 253.8	384.0 ± 255.3	<0.001	0.723	28.3 (−65.8 to 122.4)	0.046	0.989
TEE neo-LVOT perimeter, mm	100.1 ± 22.5	100.3 ± 23.7	<0.001	0.982	2.2 (−30.4 to 34)	0.184	0.820
CT neo-LVOT perimeter, mm	96.7 ± 25.5	97.2 ± 33.2	<0.002	0.895	0.5 (−29.7 to 30.7)	0.901	0.932

Values are mean ± SD.
Abbreviations as in Tables 1-3.

FIGURE 5 **Inverse Correlation Between Predicted Neo-LVOT Area and Post-Implantation LVOT Gradients**



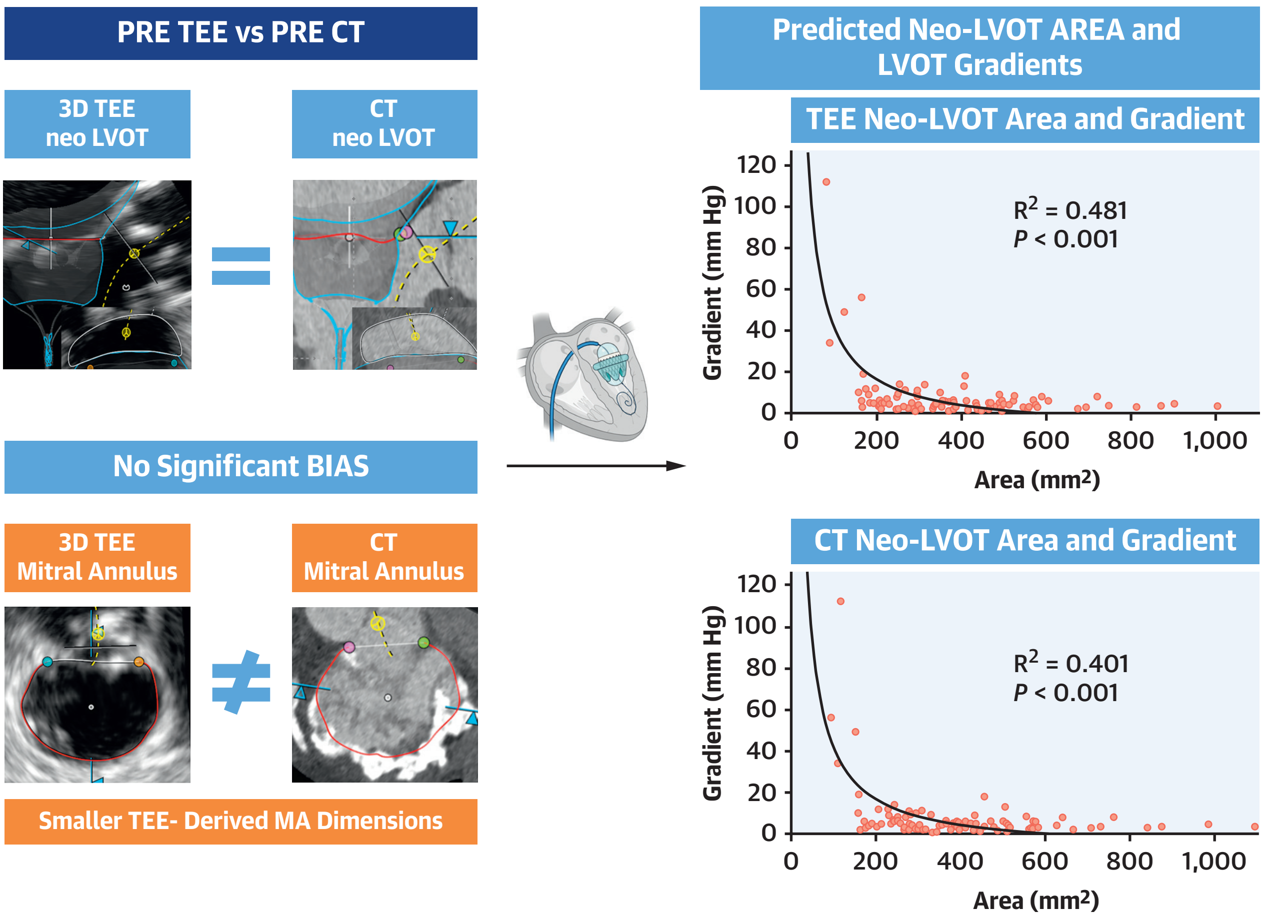
There was a moderate, nonlinear, inverse correlation between predicted neo-LVOT area and post-procedural peak LVOT gradient using TEE (A) and CT (B). Max = maximum; other abbreviations as in Figures 1 and 3.

derived from patient-specific clinical imaging could provide a detailed understanding of the biomechanics of the valve and subvalvular apparatus, as well as the interaction of the tissue with the specific TVMR mechanical properties.[18]

PREDICTION OF LVOT GRADIENT INCREASE. Both CT and TEE-derived neo-LVOT areas exhibited significant but moderate correlation with post-procedural peak LVOT gradients. Other determinants of gradients besides neo-LVOT area are LV contractility and loading conditions.[19] Additionally, in the whole population, only 7 patients had a gradient increase of more than 30 mm Hg and 3 were excluded from the correlation analysis because of the anterior leaflet laceration performed before the implantation. Nevertheless, the predicted neo-LVOT area continues to be the most reliable predictor of LVOTO[6] and the correlation of this parameter with gradients remained consistent across both imaging modalities.

PRACTICAL CONSIDERATIONS. The 3mensio 3D-TEE module is commercially available for clinical use; however, its application necessitates additional training and generates additional costs. It adheres to the same conceptual framework as a conventional CT-based mitral valve module and can be seamlessly executed by any clinician experienced in CT or echocardiographic assessment, introducing minimal additional workload in the context of TMVR

CENTRAL ILLUSTRATION Computed Tomography- and Transesophageal Echocardiography-Derived Screening Method for Assessing Annular Dimensions and Left Ventricular Outflow Tract Obstruction Risk Before Transcatheter Mitral Valve Replacement



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When compared to the standard computed tomography (CT)-derived method, the echocardiographic parameters showed no significant differences in assessment of neo-left ventricular outflow tract (LVOT) area but tended to underestimate mitral annular dimensions. Both CT- and transesophageal echocardiography (TEE)-derived neo-LVOT areas show a similar but moderate inverse correlation with postprocedural LVOT gradients. 3D = 3-dimensional; CT = Computed Tomography; LVOT = Left Ventricular Outflow Tract; MA = Mitral Annulus; TEE = Transesophageal Echocardiography.

screening. The echocardiographic module is integrated into the standard 3mensio software and linked to the local imaging server. This integration allows for nearly instant import and analysis of 3D images, facilitating real-time assessment during the TMVR procedure.

Dedicated software for echocardiographic valve implantation simulation may emerge as a valuable tool for TMVR prescreening primarily to rule out or confirm eligibility. However, for borderline neo-LVOT cases and in cases where device sizing depends solely on native MA dimensions, a comprehensive approach incorporating detailed CT analysis is preferred. Although proven effective in isolated high-risk cases,[20] 3D echocardiographic virtual valve simulation method requires validation through a prospective, multicentric study to ensure generalizability before widespread implementation in standard practice.

STUDY LIMITATIONS. Firstly, a high proportion of patients were excluded from the study due to suboptimal imaging quality, potentially introducing a selection bias. A prospective data collection with

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dedicated images acquisition for virtual valve simulation could certainly mitigate the number of unsuitable cases. Secondly, TEE is not electrocardiogram-triggered, potentially leading to slight differences in the timing of measurements between the 2 modalities. Systematic measurements 1 frame prior to aortic valve closure were performed to minimize the temporal disparities between both modalities. Moreover, the observed plot trends of peak gradient and neo-LVOT are heavily affected by the small number of patients with elevated neo-LVOT gradients. Although it indicates a significant association between neo-LVOT dimensions and peak gradients, a more precise quantitative correlation warrants validation in larger cohort for comprehensive insights. Finally, in some cases, changes in stroke volume could be impeded by LVOT flow acceleration. In such cases, the stroke volumes in the right ventricular outflow tract before and after the intervention were used for our analysis, which could be impacted by the left to right shunt from atrial septal defect. However, the significance of this phenomenon is rather small given the limited number of patients with LVOT flow acceleration and the small mean increase in stroke volume.

CONCLUSIONS

TEE- derived neo-LVOT analysis provides comparable results with CT-derived metrics. Both modalities underestimate the actual neo-LVOT dimensions and predict postprocedural LVOT gradients with similar accuracy.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: CT- and TEE-derived neo-LVOT analysis predict post-procedural LVOT gradients with similar accuracy. The use of the new 3D TEE software can simplify the screening process for TMVR.

TRANSLATIONAL OUTLOOK: A prospective, multicentric study is needed to confirm the accuracy of 3D echocardiographic analysis.

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APPENDIX For additional tables, please see the online version of this paper.