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CASE REPORT

INTERMEDIATE

CLINICAL CASE: STRUCTURAL HEART DISEASE

3D Intracardiac Echocardiography in Mitral Transcatheter Edge-to-Edge Repair

When TEE Is Hard to Stomach

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ABSTRACT

Intracardiac echocardiography (ICE) has historically had limited utility in complex structural interventions. Newer 3-dimensional ICE catheters have enhanced imaging and real-time functionality. We present a novel case of mitral valve transcatheter edge-to-edge repair where transesophageal imaging was limited by massive hiatal hernia and where complementary 3D ICE imaging enabled procedural success. (**Level of Difficulty: Intermediate.**) (J Am Coll Cardiol Case Rep 2022;4:780–786) © 2022 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/).

HISTORY OF PRESENTATION

An 81-year-old man was admitted with decompensated left-sided heart failure despite guideline-directed medical therapy.

PAST MEDICAL HISTORY

The patient had a history of ischemic cardiomyopathy with previous percutaneous coronary intervention, stage IV chronic kidney disease, and a large hiatal hernia.

LEARNING OBJECTIVES

- To recognize the strengths and limitations of intraprocedural echocardiographic modalities (TEE and ICE).
- To consider 3D ICE in transcatheter valve interventions, such as mitral valve TEER, where TEE is contraindicated, insufficient, or unavailable.

DIFFERENTIAL DIAGNOSIS

Decompensated heart failure resulting from secondary mitral regurgitation (MR) was suspected. Respiratory causes, including lung compression by the hiatal hernia, were deemed unlikely.

INVESTIGATIONS

The chest radiograph revealed pulmonary congestion and cardiomegaly. Transthoracic echocardiography demonstrated a dilated left ventricle with regional abnormalities (ejection fraction, 35%), as well as a tethered mitral valve with severe MR. Nuclear stress testing demonstrated fixed lateral and apical defects. Right-sided heart catheterization showed elevated filling pressures (pulmonary capillary wedge mean,

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28 mm Hg; v-wave, 40 mm Hg). Outpatient transesophageal echocardiography (TEE) was aborted because of difficulty delivering the probe. A subsequent barium esophagram identified distal esophageal compression secondary to a massive hiatal hernia (Figure 1). After a heart team discussion with the patient, it was agreed to attempt transcatheter edge-to-edge repair (TEER) using MitraClip (Abbott Vascular), preferentially guided by TEE but with 3-dimensional (3D) intracardiac echocardiography (ICE) (VeriSight-Pro, Philips) if necessary.

MANAGEMENT

With the patient under general anesthesia, limited midesophageal TEE views were obtained, confirming severe MR (Video 1) secondary to functional disease and a cleft between P1 and P2 (Figures 2A to 2D and 3). The regurgitant orifice was wide (Figure 2C), and an NTW clip was selected for its width, with a length that would minimize leaflet stress in the setting of functional disease. A 3D TEE-guided transseptal puncture was performed through right femoral vein access, thereby ensuring that the fossa ovalis puncture was at the mitral commissural line with adequate height (Figure 4A). The guide was advanced into the left atrium (LA), followed by a 9-F 3D ICE catheter through left femoral vein access, both positioned by TEE and fluoroscopy (Figure 4B). TEE was used to ensure an appropriate trajectory and clip orientation. Given the acoustic shadowing caused by the hiatal hernia, the leaflets were poorly imaged on TEE when compared with ICE (Video 2). ICE imaging provided an unobstructed view of the clip arms for identification of individual grippers (Video 3) and leaflet grasping (Figure 5). Initial posterior leaflet grasping proved difficult because of the cleft. During continuous 3D ICE imaging, slight counterclockwise rotation allowed adequate leaflet grasping medial to the cleft and successful NTW clip placement. Where TEE lacked tissue resolution for leaflet grasping and tissue bridging, ICE provided detailed 3D assessment (Videos 4 and 5), and after ICE evaluation, the clip was released. Postdevice assessment was performed with both 3D ICE (Figures 6A to 6D) and TEE (Video 6), thus confirming an MR 3D vena contracta area ~10 mm^2 (mild), a 3D mitral valve area ~2.7 cm^2, and a mean gradient of 2 mm Hg. TEE confirmed resumption of systolic dominant pulmonary vein flow, stable ventricular function, and absence of pericardial effusion. The guide and ICE catheters were sequentially withdrawn from the LA with a small left-to-right interatrial shunt documented by TEE. There were no procedural complications; time was 71 minutes from vascular access to closure, with a procedure time (transseptal puncture to guide catheter removal) of 39 minutes.

FOLLOW-UP

Day-1 postprocedure TTE showed a stable clip with mild MR and transmitral peak and mean gradients of 10 and 4 mm Hg, respectively. There was no evidence of any vascular or esophageal complications. The patient was discharged 2 days post-procedure.

DISCUSSION

Management of MR with TEER is reasonable for selected patients with moderate to severe secondary MR[1] and appropriate anatomy.[2,3] To understand mitral valve disease, anatomy, flow dynamics, and severity of regurgitation, comprehensive 2-dimensional (2D) or 3D TEE has become the gold-standard.[4] ICE is a versatile imaging modality with

ABBREVIATIONS AND ACRONYMS

ICE = intracardiac echocardiography
LA = left atrium
MR = mitral regurgitation
TEE = transesophageal echocardiography
TEER = transcatheter edge-to-edge repair
2D = 2-dimensional
3D = 3-dimensional

FIGURE 1 Barium Esophagram

The image demonstrates a massive hiatus hernia above the diaphragm **(white arrow)** compressing the distal esophagus **(yellow arrow).**

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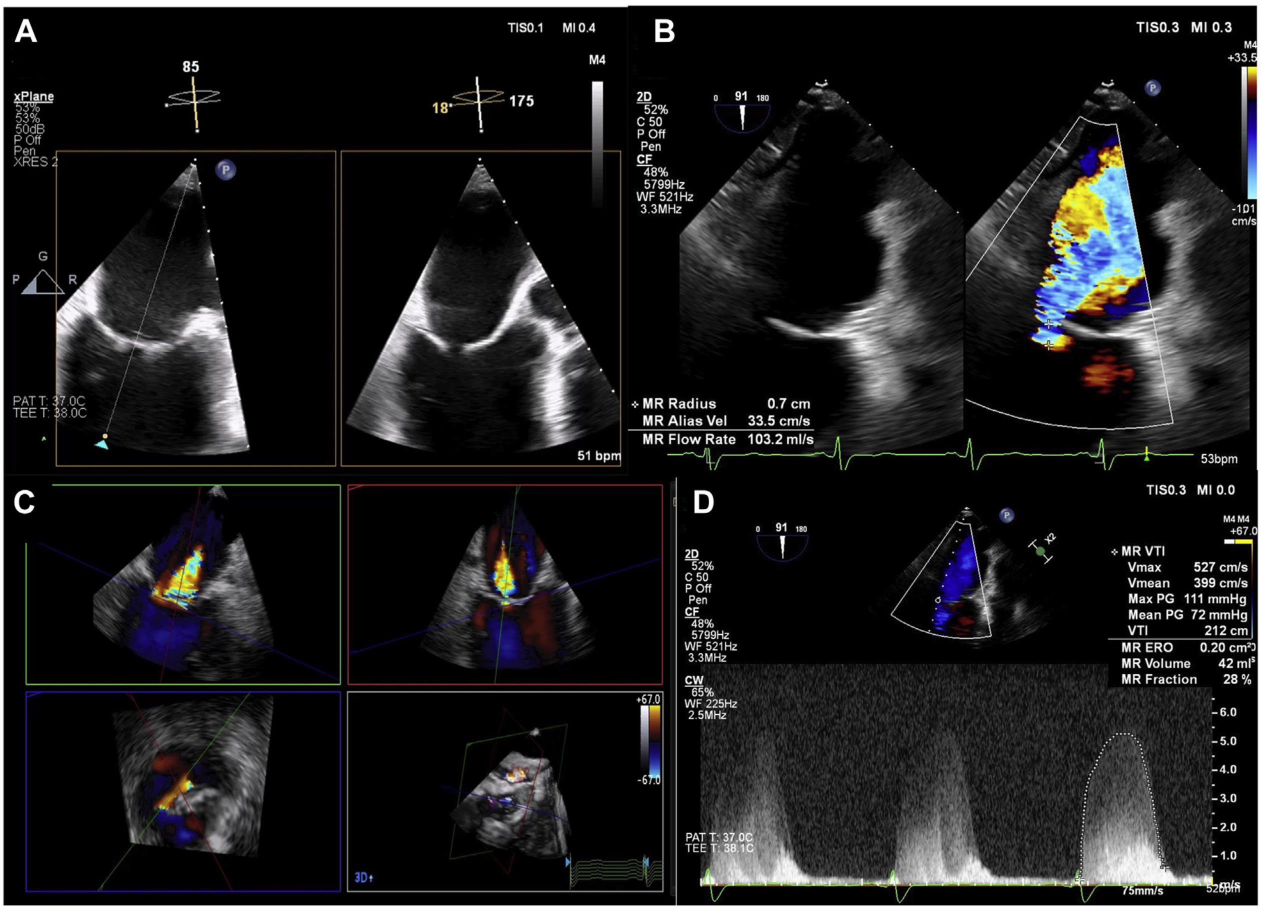
FIGURE 2 Baseline Transesophageal Echocardiography

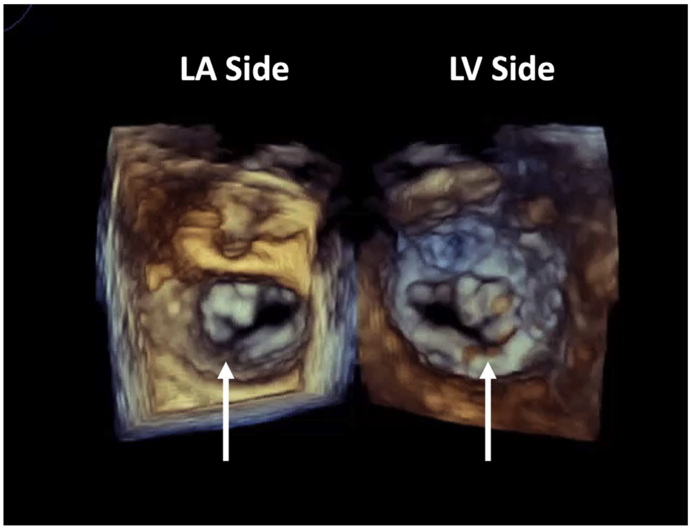


(A) The 2-dimensional X-plane view showing the tethered mitral valve. **(B)** Color Doppler imaging demonstrating central regurgitation. **(C)** Multiplanar reconstruction. **(D)** Mitral regurgitation (MR) velocity time integral (VTI) and effective regurgitant orifice area (EROA) by volumetric methods.

extensive utility across cardiac interventions, including shunt closure, left atrial appendage closure, and electrophysiology.[5] However, until recent advancements, 3D ICE could not replicate TEE, particularly for color Doppler resolution, large field of view, and advanced software that permits biplane imaging and real-time 3D reconstruction. The latest-generation 3D ICE catheter is lower profile (9-F) with an advanced imaging matrix, resulting in improved color Doppler and 3D imaging capabilities. Although 3D ICE has been used as a sole imaging modality in cases where TEE is contraindicated,[6] this is the first report of the complementary role of 3D TEE and 3D ICE for the optimal performance of mitral TEER.

The strengths and limitations of each imaging modality are listed in Table 1. Avoiding TEE provides an additional benefit of obviating the need for general anesthesia in high-risk patients and the associated risks, including aspiration and gastrointestinal injury. Risk factors for esophageal injury include being underweight, a history of gastrointestinal bleeding, and chronic immunosuppression, as well as longer procedural time.[7] Some disadvantages of ICE include its risk for vascular or intracardiac injury, inferior far-field imaging, and cost of its catheters designed for single-use only. This case exemplifies the concomitant use of TEE and ICE to reduce complication rates and ensure technical success, by relying on the strengths of the individual modality. 2D or 3D TEE was used when a large field of view or multiple imaging planes were required for accuracy: transseptal puncture location, guide positioning or trajectory, device positioning or alignment, and the

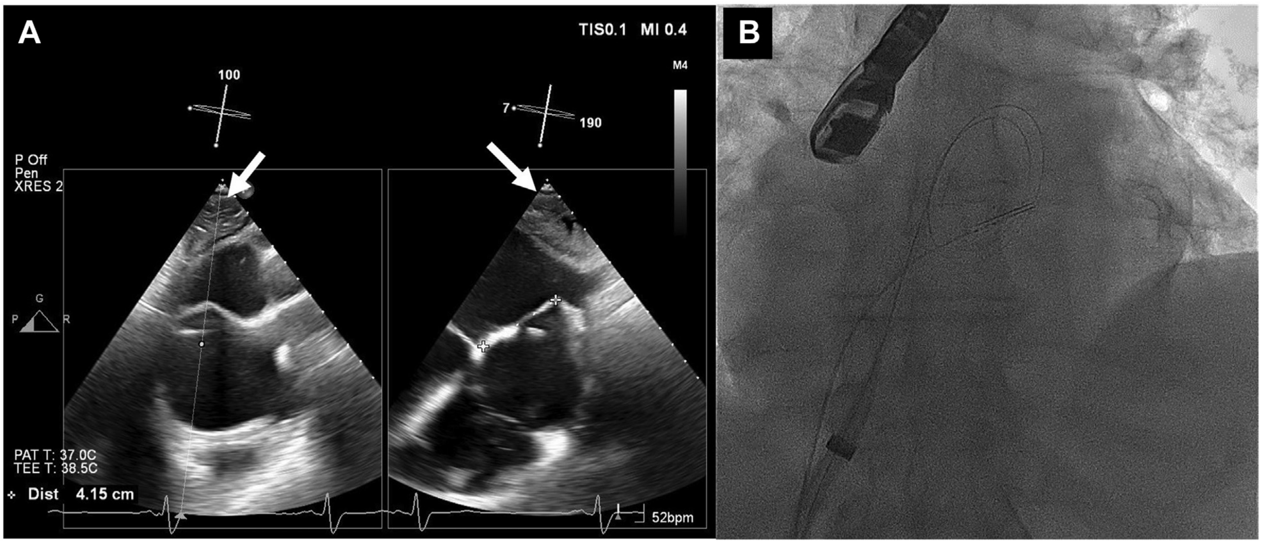
FIGURE 3 Posterior Cleft



The 3-dimensional "en-face" transesophageal echocardiographic view of the mitral valve demonstrates a large posterior cleft **(white arrows)** between P1 and P2. LA = left atrial; LV = left ventricular.

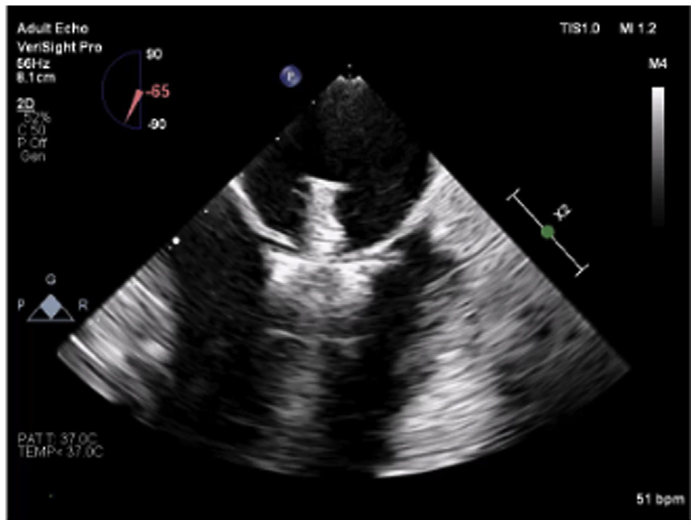
comprehensive post-device assessment. 2D or 3D ICE imaging was used to confirm leaflet grasp and adequacy of MR reduction. The average procedure time in the COAPT Trial (Cardiovascular Outcomes Assessment of the MitraClip Percutaneous Therapy for Heart Failure Patients With Functional Mitral Regurgitation) was 118.9 ± 63.5 minutes for an average of 1.7 ± 0.7 clips.[8] We believe that using both imaging modalities not only optimized procedural success but also shortened procedure time (39

FIGURE 4 Transseptal Puncture



(A) Transesophageal view of transseptal puncture, hiatus hernia in view **(arrows)**. **(B)** Fluoroscopy of intracardiac echocardiography catheter traversing the interatrial septum adjacent to the transseptal wire.

FIGURE 5 Leaflet Insertion



Intracardiac echocardiography demonstrating clear visualization of leaflets and clip arms.

minutes for a single clip). Structural heart programs now have several advanced imaging options, including echocardiographic-fluoroscopic fusion imaging, thus providing cumulative effect on procedural safety, efficiency, and precision.

CONCLUSIONS

This is a novel case using concomitant 3D TEE and 3D ICE to achieve mitral valve TEER in a patient with limited TEE imaging related to a massive hiatal hernia. This case exemplifies the important adjunctive role of 3D ICE imaging in structural interventions where TEE is contraindicated, insufficient, or unavailable.

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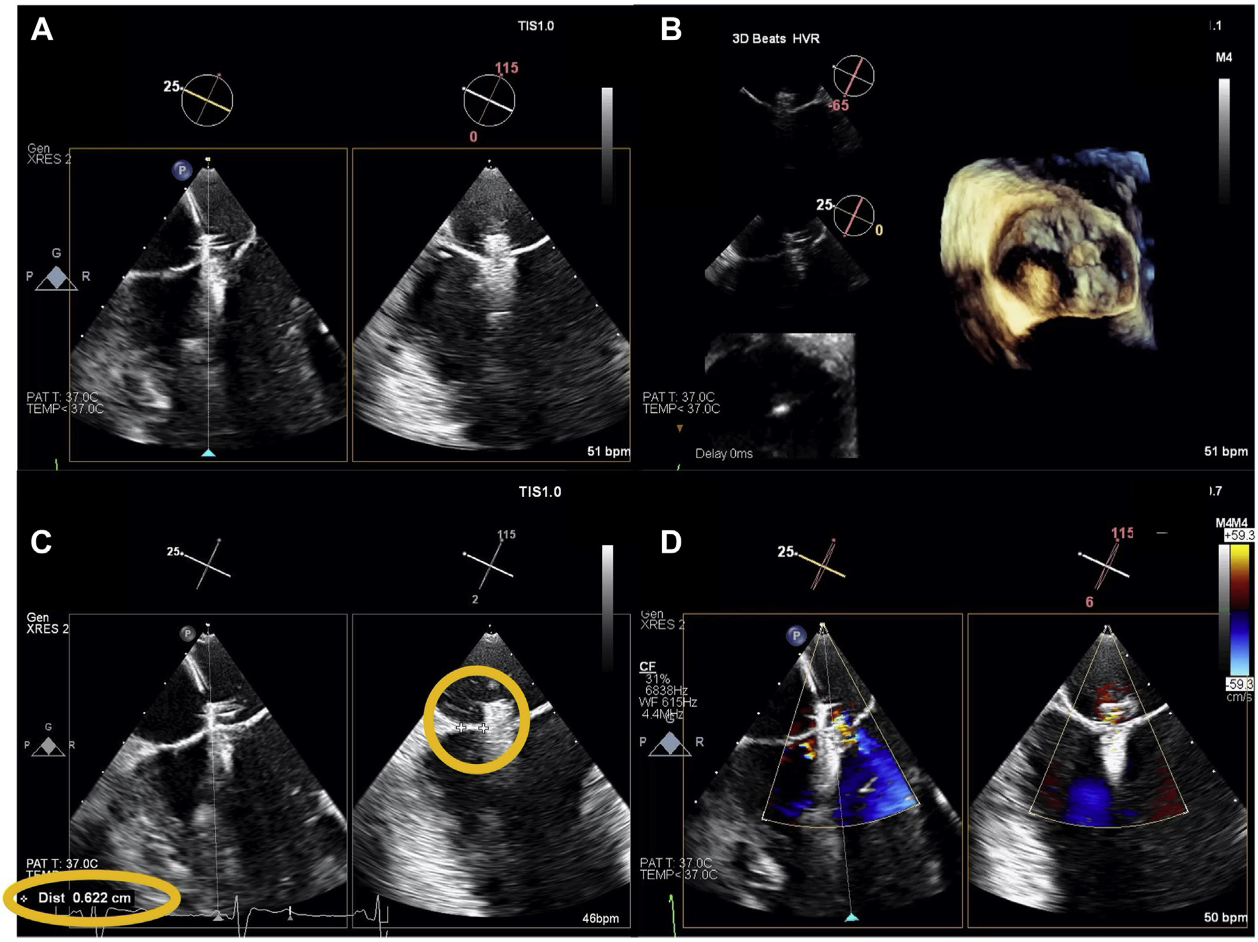
Dr George has consulted for MitreMedical, CardioMech, MITrx, and Vdyne. Dr Kodali has received institutional research support (with no direct financial compensation) from Edwards Lifesciences, Medtronic, and Abbott; has consulted for Abbott, Admedus, and Meril Lifesciences; and has equity options from Biotrace Medical and Thubrikar Aortic Valve. Dr Hahn has received speaker fees from

TABLE 1 Strengths and Limitations of TEE and ICE for Mitral TEER

	2D or 3D Transesophageal Echocardiography	2D or 3D Intracardiac Echocardiography
Strengths	• Wide field of view (both 2D and 3D) and depth of imaging • Multiple imaging levels of the same structure • No interference with intravascular catheters	• Unobstructed views of intracardiac devices • Does not require additional anesthetic considerations
Limitations	• Longer procedures typically require general anesthesia • Probe positioning limited by esophageal path • Acoustic shadowing by intracardiac devices • Esophageal injury in high-risk populations	• Transvenous vascular access required • Limited imaging windows, dependent on catheter stability and position • Smaller field of view (both 2D and 3D) and depth of imaging • Lower 3D temporal and spatial resolution • Cost for single-use catheters
Utility during mitral TEER	• Transseptal location by 2D or 3D MPR (ie, within the fossa ovalis, at the commissural line, with adequate height above annular plane) • Trajectory of guide using 2D or 3D MPR • Location and orientation of device arms • Leaflet grasp with reduction of TR • Comprehensive postdevice assessment including valve area and mean gradients, MR severity, pulmonary vein flow, LVOT stroke volume, residual IAS, pericardial effusion	• Leaflet grasp with reduction of TR • Limited 3D for clip orientation (TEE preferred) • Limited postdevice assessment including valve area and mean gradients, MR severity, residual IAS (TEE preferred for other assessments)

IAS = interatrial shunt; ICE = intracardiac echocardiography; LVOT = left ventricular outflow tract; MPR = multiplanar reconstruction; MR = mitral regurgitation; TEE = transesophageal echocardiography; TEER = transcatheter edge-to-edge repair; TR = tricuspid regurgitation; 2D = 2-dimensional; 3D = 3-dimensional.

FIGURE 6 **Postdeployment Intracardiac Echocardiography**



(A) Scanning across clip device. **(B)** 3D view to assess the tissue bridge of the clip. **(C)** Adequate leaflet length within device confirmed **(yellow circles)** **(D)** Color Doppler imaging showing mild mitral regurgitation. HVR = high volume rate.

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KEY WORDS intracardiac echocardiography, mitral regurgitation, transesophageal echocardiography

APPENDIX For supplemental videos, please see the online version of this article.