Intracardiac Echocardiography-Guided Transcatheter Edge-to-Edge Repair for Mitral Regurgitation

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INTRODUCTION

Transcatheter mitral valve (MV) edge-to-edge repair (M-TEER) is a widely accepted treatment option for patients with severe mitral regurgitation (MR) with high surgical risk.[1,2] Although the most commonly used modality of imaging guidance for transcatheter edge-to-edge repair (TEER) has been transesophageal echocardiography (TEE),[3-5] we occasionally encounter situations in daily practice in which TEE is contraindicated. Although transthoracic echocardiography (TTE) can be used in such situations,[6] its imaging quality is far inferior to that of TEE.

Intracardiac echocardiography (ICE) is widely used for various electrophysiological and structural heart disease interventions, such as transcatheter ablation, left atrial appendage occlusion, and atrial septal defect closure.[7] Because it also has the potential to visualize MV leaflets with high resolution, it can be a useful alternative in intraprocedural imaging of TEER. However, evidence regarding the utility of ICE for TEER is limited.

Here we report a successful case of TEER guided by ICE with difficulty in inserting the TEE probe into the esophagus owing to laryngeal stenosis.

CASE PRESENTATION

An 80-year-old woman was admitted for acute heart failure. The patient had a medical history of thyroid cancer resection and postoperative radiation therapy. Physical examination showed a Levine 3/6 pansystolic murmur at apex. Blood testing showed an elevated brain natriuretic peptide level (402 pg/mL). A TTE revealed preserved left ventricular ejection fraction (72%) with severe functional MR (regurgitant volume 50 mL; regurgitant fraction 47%) originating from the central portion of the A2/P2 (Figure 1A and B, Videos 1 and 2). The etiology of MR was considered as atrial functional MR based on the flat coaptation and dilated left atrium (LA; left atrial volume index, 67 mL/m^2). The MV anatomy showed sufficient leaflet length (Figure 1C; A2: 26.4 mm; P2: 10.5 mm) without obvious degeneration, indicating suitability for a simple A2/P2 grasping procedure with a 1-clip for M-TEER.

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VIDEO HIGHLIGHTS

Video 1: Preprocedural TTE with color-flow Doppler, apical 3-chamber view, demonstrates severe concentric functional MR originating from the central portion of A2/P2.
Video 2: Preprocedural 2D TTE with color-flow Doppler, apical 2-chamber (bicommissure) view, demonstrates severe functional MR originating from the central portion of A2/P2.
Video 3: Two-dimensional ICE image, right ventricular perspective obtained just before leaflet grasping, demonstrates that both leaflets are well stabilized on the device arms through the entire cardiac cycle.
Video 4: Two-dimensional ICE image obtained during leaflet grasping demonstrates the device was gradually closed under observation of the ICE image.
Video 5: Two-dimensional ICE image obtained after leaflet grasping demonstrates good leaflet insertion after full device closure.
Video 6: Postprocedural 3D TTE, apical 3-chamber, 4-beat (breath-held) acquisition view, multiplanar reconstruction display, demonstrates well-stabilized leaflets in 3 orthogonal 2D displays (*left panel*). The volume-rendered 3D image demonstrates the residual double-orifice MV (*right panel*).

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Based on TTE confirmation of these preferable anatomical conditions, our heart team decided to perform M-TEER, considering high age, frailty, and medical history of chronic kidney disease. Although preoperative TEE evaluation was attempted, strong resistance at the larynx inhibited TEE probe insertion despite multiple attempts. Therefore, we decided that intraoperative TEE probe insertion should be attempted under laryngoscopic observation of the larynx by an experienced anesthesiologist under muscle flaccidity.

After the induction of anesthesia, an experienced anesthesiologist carefully tried to insert an X8-2t TEE probe (Royal Phillips Electronics), with observation of the larynx achieved using the laryngoscope. Nevertheless, insertion into the esophagus proved impossible due to strong resistance even with laryngoscope guidance, despite observation of successful insertion of the nasogastric tube into the esophagus. We attributed this resistance to stenosis of the esophageal inlet due to postoperative radiation therapy after thyroid surgery. Thus, we finally decided to perform ICE-guided M-TEER complemented with TTE.

Two-dimensional ICE catheter was inserted from the left femoral vein. Transthoracic echocardiography was also used to complement the ICE guidance. The MitraClip G4 system (Abbott) was inserted

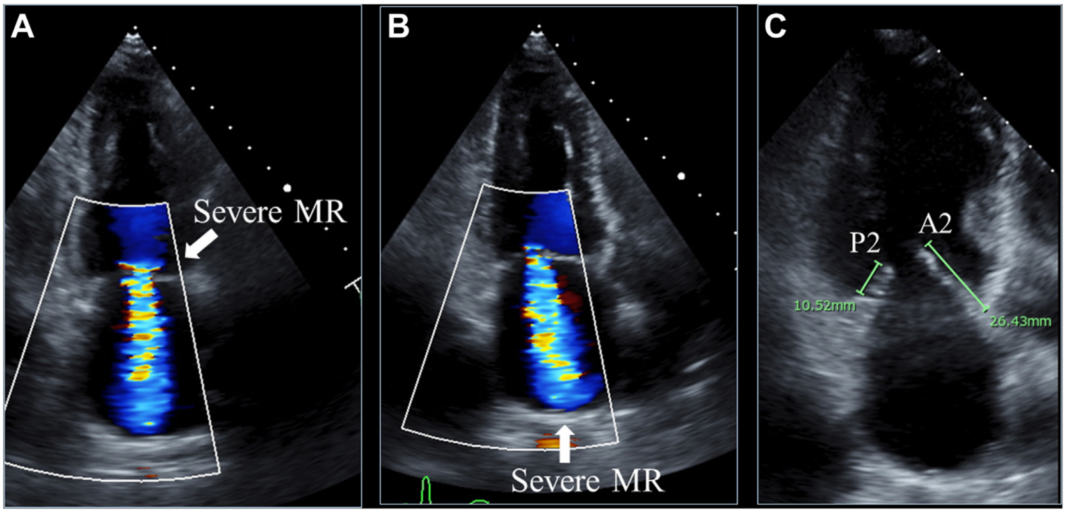

Figure 1 Preprocedural 2D TTE with color-flow Doppler, apical 2- **(A)** and 3- **(B)** chamber views, systolic phase, demonstrates severe functional MR originating from the central portion of A2/P2. Apical 3-chamber view without color-flow Doppler **(C)** demonstrates nonprolapsing, nondegenerative leaflets with sufficient leaflet length (A2: 26.4 mm; P2: 10.5 mm).

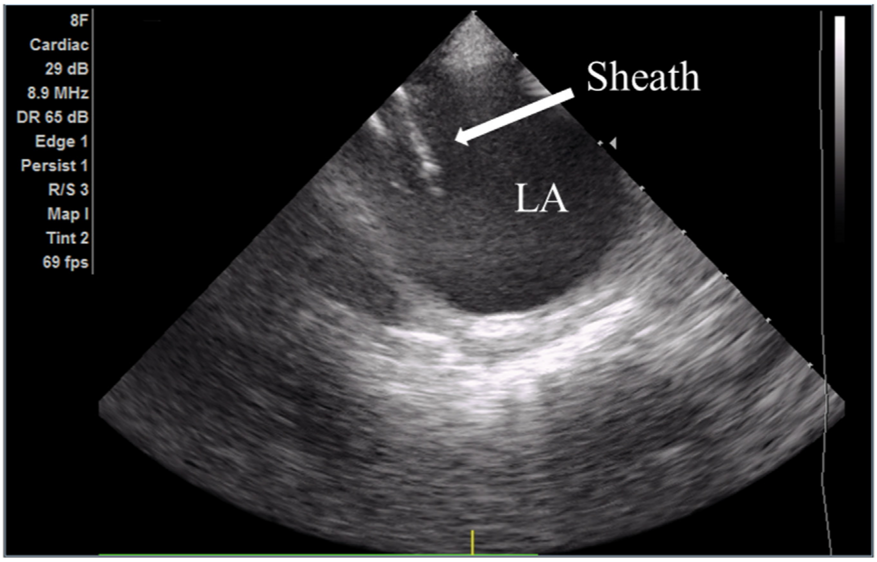

Figure 2 Two-dimensional ICE image obtained from the RA demonstrates the catheter position within the LA during transseptal puncture.

from the right femoral vein. The G4 XT-clip was selected based on the sufficient leaflet length and narrow chordal-free zone, as calculated by preprocedural TTE. First, the ICE catheter was initially positioned at the right atrium (RA) to perform transseptal puncture with ICE guidance. After successful transseptal puncture (Figure 2), device manipulation at the LA was done under both ICE and TTE guidance. Specifically, a steerable guide catheter was inserted deep into the LA by visualizing the LA roof with ICE from the RA catheter position. The steerable guide catheter was subsequently bent, using the TTE transapical view. The device was inserted into the left ventricle and targeted at the A2/P2 leaflet. Device angle was adjusted by checking the short-axis image of the TTE. Visualization of the leaflet-grasping view and leaflet-insertion check were conducted using ICE imaging. We placed the ICE catheter at the right ventricle (RV) and adjusted the catheter position to visualize the MV leaflets (Figure 3). After confirming that a sufficient length of leaflets was well stabilized on the device arms (Figure 4A, Video 3), the grippers were pushed down and the device was gradually closed (Video 4). After full closure, good leaflet insertion was confirmed by ICE image (Figure 4B, Video 5). The procedure was completed successfully without complications. The final mean pressure gradient was 2.0 mm Hg.

A comprehensive TTE check was conducted several days after the procedure. Three-dimensional (3D) TTE showed well-stabilized leaflets and a double-orifice MV (Figure 5, Video 6). Residual MR grade was classified as trace.

DISCUSSION

Here we report a successful case of ICE-guided M-TEER. Although TEE has been considered the most commonly used imaging modality

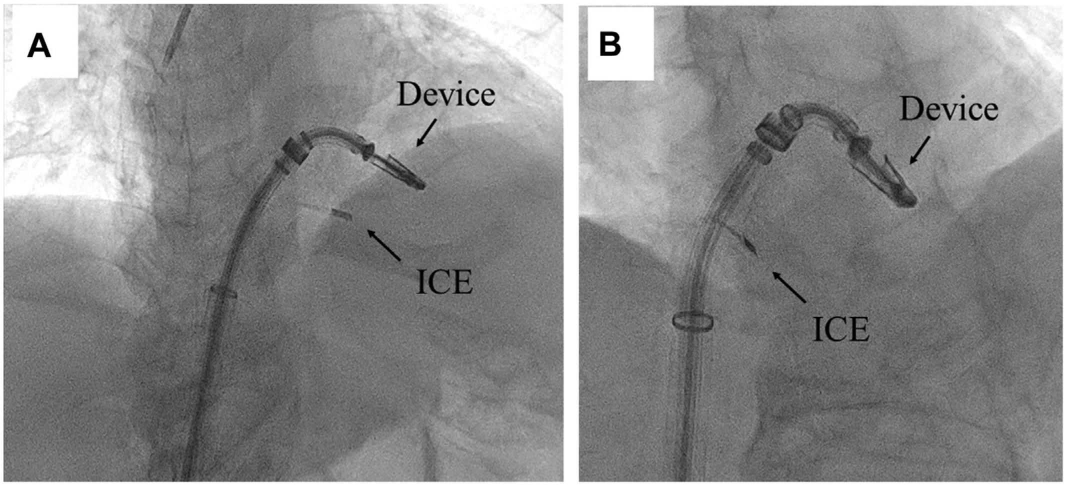

Figure 3 Fluoroscopic image, with straight anterior-posterior **(A)** and left anterior oblique (40°; **B**) views that demonstrate the positions of the device and ICE catheters. The ICE catheter is seen within the basal portion of the RV, where it was used to visualize MV leaflets.

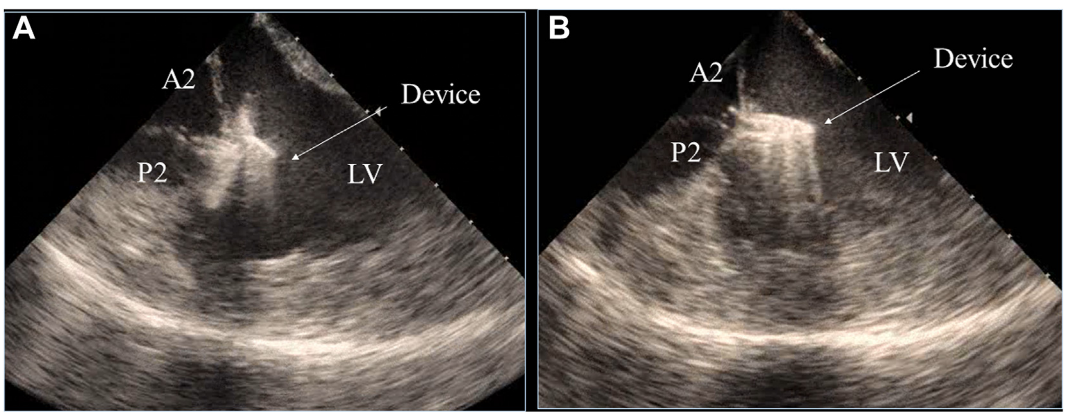

Figure 4 Two-dimensional ICE image, RV perspective, demonstrates that both leaflets were well stabilized on the device arms (**A**; diastole) and that after full leaflet closure in systole **(B)**, there is good leaflet insertion.

for M-TEER, there are situations in which TEE is contraindicated, such as esophageal varix, stenosis, or intolerance to general anesthesia. In this case, we demonstrated the feasibility of ICE-guided M-TEER for such situations.

Although several studies have reported ICE-guided M-TEER,[8-12] most of these were performed by 3D ICE. Three-dimensional ICE has the obvious merit of 3D views, such as 3D rotation of the imaging angle and X-plane mode, which enables comprehensive intraprocedural imaging guidance such as 3D TEE.[11] However, 3D ICE has several disadvantages such as highly limited availability, cost (ICE is basically considered to be single-use), and need for a bigger sheath size. On the other hand, two-dimensional (2D) ICE has been widely used all over the world for electrophysiology and structural heart disease intervention. Two-dimensional ICE-guided M-TEER therefore has the merits of higher generalizability in daily practice and less invasiveness than 3D ICE. On the other hand, the limitations of 2D ICE guidance should be acknowledged. Challenging cases, such as short posterior leaflet or noncentral lesion, are not amenable for TEER with 2D ICE guidance based on its limited imaging quality or the lack of 3D analyses.

Transthoracic echocardiography–guided M-TEER has also been used in previous case reports in which TEE was contraindicated.[6,13] However, the imaging quality of intraprocedural TTE is not always sufficient for the grasping of the MV leaflet in terms of low resolution. However, ICE can provide superior image quality based on higher spatial resolution than TTE due to the closer distance between the probe and MV. In fact, we were able to visualize the leaflet grasp with sufficient imaging quality by ICE (Figure 4, Videos 3-5), increasing the utility of this procedure. Although ICE-guided M-TEER carries the risks of inducing arrhythmia, injury to the heart, and need for additional puncture sites, higher imaging quality is an obvious merit of using ICE. Transthoracic echocardiography was useful for preprocedural measuring of MV anatomies and the device-angle adjustment during procedure. Thus, the hybrid

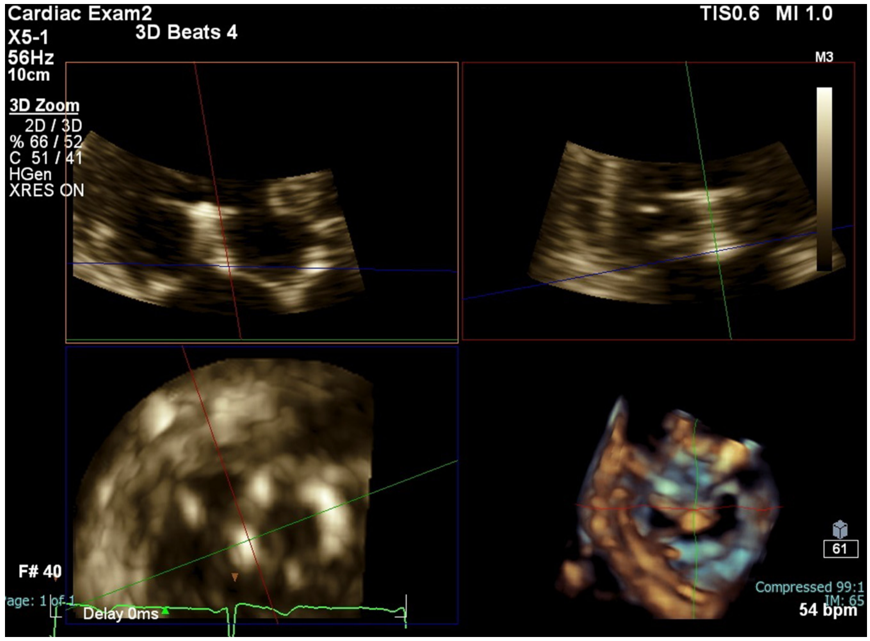

Figure 5 Postprocedural 3D TTE, apical 3-chamber, 4-beat (breath-held) acquisition view, multiplanar reconstruction display, diastolic phase, demonstrates well-stabilized leaflets in 3 orthogonal 2D displays and the residual double-orifice MV in the volume-rendered 3D display (*bottom right panel*).

approach is an important component to making your ICE guidance successful.

The catheter position of ICE is an important consideration. In previous case reports, the MV leaflets were observed from the left atrial perspective.[8,9] This is probably because LA catheter position might provide images with less shadowing due to device shaft. On the other hand, we selected the RV catheter position in this case. This is because we could visualize both leaflets simultaneously stabilized on the device arms from the RV catheter position (Video 3) by delicately optimizing the catheter position to avoid the shadow overlapping on the posterior leaflet. Furthermore, we could visualize the device with the long-axis view from the RV perspective. Because the anatomical conditions of patients vary widely, both methodologies should be considered, depending on the case. Especially in cases with considerably decreased posterior leaflet image quality due to device shadowing, changing from the RV perspective into the LA catheter position might be considered.

Finally, we consider that ICE usage is not necessarily restricted to situations in which TEE cannot be inserted. Sonographers often encounter situations in which TEE cannot provide sufficient imaging quality for various anatomical reasons, such as various artifacts or rotation of the heart. Although several informal solutions are available, such as the leaning left decubitus position, use of the transgastric view, and differential lung ventilation,[14] these are sometimes not sufficient. We consider that ICE guidance might be an additional solution to complement TEE imaging in such situations and enhance the quality of intraprocedural imaging guidance.

CONCLUSION

We report here a successful case of ICE-guided M-TEER, with concomitant use of TTE, which was effective in a situation in which TEE was contraindicated.

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.

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.

FUNDING STATEMENT

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DISCLOSURE STATEMENT

The authors report no conflict of interest.

SUPPLEMENTARY DATA

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