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EDITORIAL COMMENT

Comprehensive Periprocedural Transesophageal Echocardiography Is a Key to Success in Transcatheter Mitral Valve Repair*

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Since the initial approval for MitraClip (Abbott, Abbott Park, Illinois) (2008 in Europe; 2013 for degenerative and 2019 for functional mitral regurgitation [MR] in the United States), the number of implantations have been continuously increasing, exceeding 80,000 procedures performed to date (1).

Having proved to be safe and efficacious even in high-risk patients with severe MR (2), MitraClip requires careful patient selection and thorough periprocedural assessment using imaging techniques.

Preprocedural transthoracic (TTE) and transesophageal echocardiography (TEE) are valuable tools to determine eligibility for intervention, diagnose the pathology that may preclude clip implantation, or indicate a need for an alternative management strategy (3). The ability of 3-dimensional (3D) echocardiography to display the mitral valve (MV) en face both from the atrial and ventricular perspective, to crop the dataset in any desired plane, and to provide precise anatomic and functional analysis of the MV and surrounding cardiac structures define its unique role in the assessment of MV pathology (4). When compared with 3D TTE, 3D TEE has a higher spatial resolution and a better trade-off between spatial and temporal resolution, allowing for high-quality real-time 3D imaging. It is also superior to 2-dimensional TEE in describing MV morphology, especially in identifying leaflet perforation, commissural lesions, and other complex MV pathology (3). The use of real-time 3D TEE has dramatically improved the guidance of the procedure and increased its safety, reproducibility, and reliability (5). Quantitative 3D TEE parameters were shown to be associated with favorable outcomes of MitraClip and optimization of patient selection (6,7). Additionally, 3D TEE was cost-effective compared with 2D TEE in patients with severe primary MR referred for surgical management (8). Its cost is outweighed by the advantages provided to the interventionalist in the context of MV percutaneous therapies, increased confidence in the technique, and further expansion of its indications to the most challenging cases (2,3).

To ensure successful MitraClip intervention, a thorough preprocedural MV evaluation is crucial. It must include identification of MR mechanisms, multiparametric quantification of its severity, and assessment of hemodynamic consequences of the regurgitation. These first steps, usually initially performed by TTE, should be followed by a detailed characterization of MV anatomy and function by TEE, including 3D techniques. The most important parameters include etiology and exact localizations of the regurgitant jet(s); leaflet length,

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TABLE 1 Echocardiographic Mitral Valve Evaluation Before the MitraClip Procedure

Parameters to Assess	Considered Contraindication
Mitral regurgitation evaluation	
Multiparametric quantification	
Mechanism	Carpentier type IIIA or Barlow disease
Location of regurgitation	Perforation or cleft
Hemodynamic consequences	
LA size	
LV size and systolic function	
SPAP	
Mitral valve morphologic evaluation	
Leaflet length, thickness and calcification	Severe calcification or short leaflet ($<$7 mm) at the grasping zone
Mitral annulus dimension	
Coaptation length	
Coaptation depth	
Commissure involvement	
Mitral valve area	
Planimetry, preferably 3D	$<$3.5 cm^2
Mean transmitral gradient	$\geq$4 mm Hg

Adapted from Khalique and Hahn (11).
LA = left atrium; LV = left ventricle; SPAP = systolic pulmonary artery pressure.

thickness, and calcification; mitral annulus, coaptation length, and coaptation depth measurements; commissure integrity; mitral valve area (preferably by 3D planimetry); and mean transmitral gradient (9).

Growing clinical experience with MitraClip has shown the possibility of successful implantation beyond the original inclusion criteria used in the EVEREST (Endovascular Valve Edge-to-Edge Repair Study): nonrheumatic valve morphology, mitral valve area $\geq$4 cm^2, flail gap $\leq$10 mm, flail width $\leq$15 mm, coaptation depth $\leq$11 mm, coaptation length $\geq$2 mm, and central regurgitation at the A2-P2 interface (10). Hence, after the initial echocardiographic screening, each individual case should be reviewed by the interventional cardiologist and the imaging team in order to assess the feasibility and plan the procedure. **Table 1** presents a summary of the MV screening protocol before MitraClip implantation.

During the procedure, TEE guidance starts with qualitative and quantitative reassessment of MR to establish a baseline for comparison. TEE is crucial during every step of the procedure, starting with trans-septal puncture, steering of the system, straddling of the clip, alignment and clipping of the leaflets, confirmation of MR reduction with maintenance of adequate MV anterograde flow, and final release (11). Throughout most of these stages, 3D biplane imaging is a critical tool because it allows for the correct localization and advancement of the clip system.

Post-procedural MR evaluation by conventional echocardiographic parameters may be complicated because of the frequent presence of multiple MR jets and possible acoustic shadowing from the device. Again, a multiparameter approach is advocated. A critical point is that the proximal isovelocity surface area method is not recommended because the assumption of hemispheric proximal flow convergence is violated by the device (12). Pulmonary vein flow should be re-evaluated and compared with baseline because it is a more objective evidence of success, and it may predict rehospitalization and mortality (13). Three-dimensional multiplanar reconstruction allows for vena contracta planimetry of residual MR, another parameter with proven prognostic value (14). Mitral stenosis presence is assessed through the measurement of the transmitral gradient and 3D anatomic area evaluation (added planimetry of both orifices). Finally, color Doppler evaluation of the interatrial septum is performed to evaluate the iatrogenic atrial septal defect and left-to-right shunt. **Figure 1** shows the most relevant imaging steps in the MitraClip procedure.

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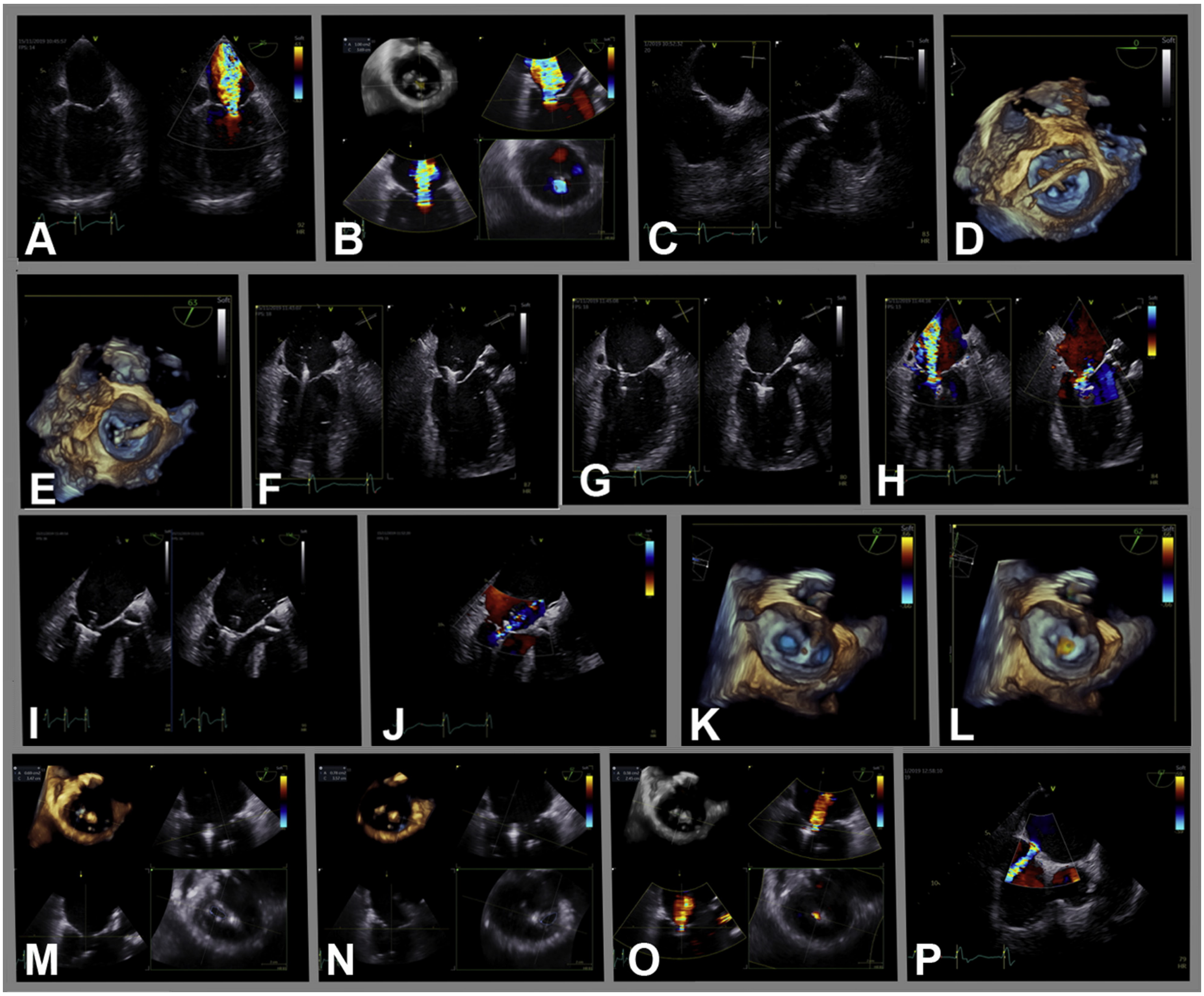
In this issue of *JACC: Case Reports*, Wang et al. (15) present a patient referred for the elective percutaneous MitraClip procedure in which the role of echocardiography is clearly illustrated. Intraprocedural 3D TEE revealed an anatomic feature that totally altered the planned intervention—a perforation of posterior MV leaflet. Identification of this unexpected underlying mechanism of severe MR led to a change in the treatment strategy, and the patient underwent successful percutaneous closure of the perforation with the Amplatzer device (Abbott). In fact, percutaneous closure of an MV perforation, even though challenging, was previously reported in the literature and might present an option for some selected cases in experienced centers (16).

In the current era where the possibilities of transcatheter structural heart intervention are increasingly broader, it is important to keep in mind that adequate candidate selection and

FIGURE 1 Echocardiographic Imaging Protocol During the MitraClip Procedure



First step: re-evaluation of mitral regurgitation (MR); this is a case of a severe functional MR with a large jet between A2 and P2 **(A)** and a large vena contracta area on 3-dimensional (3D) multiplanar reconstruction **(B)**. Second step: trans-septal puncture **(C)**; the ideal point is the midposterior fossa ovalis, 4 to 4.5 cm basal from the mitral annulus. Biplane imaging allows simultaneous visualization of the bicaval (90° to 110°) and the 4-chamber (180°) views. Tenting of the interatrial septum should be seen; 3D imaging can help to confirm the correct location for the puncture. Step 3: extrusion of the MitraClip device **(D)** under echocardiographic guidance to avoid injury to the atrial wall; the 3D surgeon's en face view of the mitral valve allows for the correct orientation. Step 4: after straddling the delivery system across the mitral valve the clip is opened; the 3D en face view of the mitral valve allows for the alignment of the clip perpendicular to the commissural line in the exact place of the MR jet **(E)**. Biplane commissural and 3-chamber views help to confirm the exact position **(F)**. Step 4: MitraClip is advanced into the left ventricle, which is guided in the 3-chamber view **(G)**, with color Doppler confirming the position over the MR jet; the clip position perpendicular to the commissure line can be confirmed by turning down the gain in the 3D en face view, so the leaflets disappear and only the clip image remains **(H)**. Step 5: grasping of the leaflets; this step is guided in a 3-chamber view, with confirmation of insertion of each leaflet into each clip arm **(I)**. After clip closure, color Doppler is used to confirm the reduction of MR magnitude **(J)**; an adequate grasp should be confirmed in the 3D en face view of the mitral valve, which usually shows a tissue bridge between the leaflets **(K)**. The 3D en face view with color Doppler allows for appreciation of mitral inflow through the double orifice **(K)** as well as residual MR evaluation **(L)**. Step 6: final evaluation of mitral valve function; transmitral gradient should be measured; adequate mitral valve area is confirmed through 3D added planimetry of each orifice **(M and N)**. MR is reassessed with multiparameter evaluation, including pulmonary vein flow and vena contracta area measurement after 3D multiplanar reconstruction **(O)**. Step 7: residual interatrial left to-right shunt is evaluated after complete extrusion of the system **(P)**.

heart team discussion could account for a lion's share of procedural success. In this setting, as highlighted by the case of Wang et al. (15), quality imaging guidance can really become a game changer.

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