Guidelines for the Intraprocedural Imaging for Mitral Valve Transcatheter Edge-to-Edge Repair (M-TEER): Recommendations from the American Society of Echocardiography

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As the number of mitral valve transcatheter edge-to-edge repair procedures increases, there are catheter operators and interventional echocardiography operators performing these procedures with variable expertise. Expert imaging is paramount for the success of these procedures and requires knowledge of mitral valve anatomy, the ability to quickly manipulate two-dimensional (2D) and three-dimensional (3D) images in real time, and sufficient procedural experience to anticipate challenges and offer imaging solutions. There are currently no standard algorithms for the interventional echocardiographer to direct a successful mitral valve transcatheter edge-to-edge repair procedure. This guideline sets forth imaging views and the standard procedural steps and defines the imaging content that must be communicated using 2D, biplane, 3D volume, and/or multiplanar reconstruction 3D formats. (J Am Soc Echocardiogr 2026;39:529-50.)

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INTRODUCTION

As the number of mitral valve transcatheter edge-to-edge repair (M-TEER) procedures grow and more interventional echocardiographers, implanters, and institutions become involved, there is the potential for significant variability in intraprocedural imaging. The volume-outcome relationship has been well described for M-TEER, with increasing institutional experience associated with improvements in procedural success, procedure time, and procedural complications.[1,2] As M-TEER is heavily dependent on transesophageal echocardiographic (TEE) guidance, variability in intraprocedural imaging can significantly affect procedural success, as defined by the Mitral Valve Academic Research Consortium, as well as patient outcomes.[3] The technical steps of the M-TEER procedure for the two commercially available devices have been standardized by their manufacturers, with multiple suggested algorithms for imaging protocols.[4-7] Currently, there are no up-to-date, unified guidelines for intraprocedural imaging during M-TEER procedures. The purpose of this guideline is to define a standard approach with options for different TEE imaging modalities. A central focus of this guideline is to standardize communication and information sharing between interventional echocardiographer and interventional cardiologist/surgical operators (Figure 1). The two commercially approved devices have different implantation systems with different functions (Table 1). Most recommendations in this guideline for the performance of M-TEER are supported by Level 2 evidence, reflecting the consensus of the writing group and the available observational data, as randomized controlled trial evidence specifically addressing individual procedural elements is typically limited or unavailable. Institute of Medicine (US) Committee on Standards for Developing Trustworthy Clinical Practice Guidelines. Clinical Practice Guidelines We Can Trust. Graham R, Mancher M, Miller Wolman D, Greenfield S, Steinberg E, editors. Washington (DC): National Academies Press (US); 2011. PMID: 24983061.

Abbreviations

2D = Two-dimensional

3D = Three-dimensional

AV = Aortic valve

CW = Continuous-wave

GA = General anesthesia

GC = Guide catheter

iASD = Iatrogenic atrial septal defect

LAA = Left atrial appendage

ME = Midesophageal

MPR = Multiplanar reconstruction

MR = Mitral regurgitation

M-TEER = Mitral valve transcatheter edge-to-edge repair

MV = Mitral valve

MVA = Mitral valve area

RK = Release knob

SAX = Short-axis

TEE = Transesophageal echocardiographic

TEER = Transcatheter edge-to-edge repair

TSP = Transseptal puncture

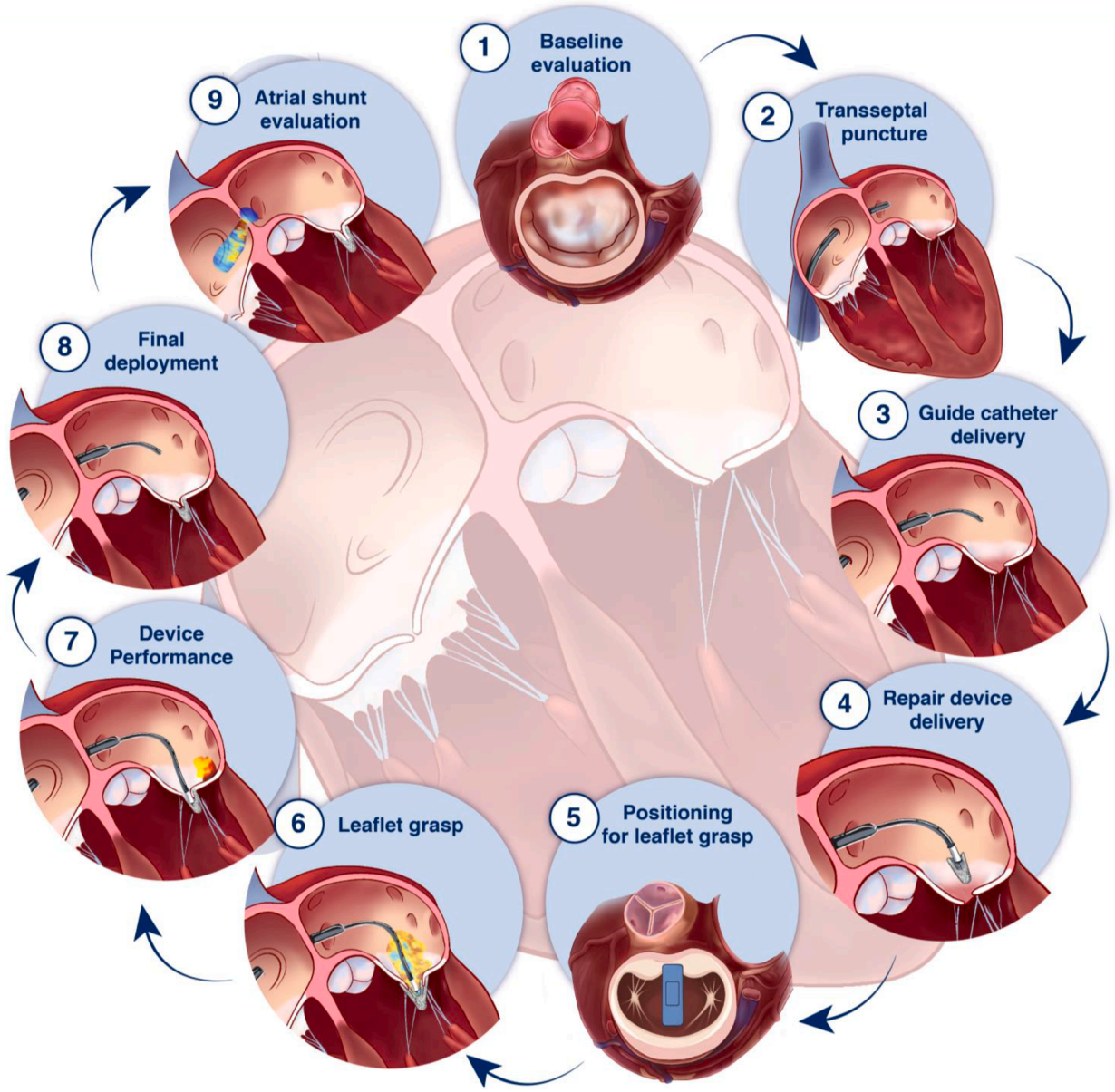

Figure 1 Summary of the recommended imaging steps for performance of M-TEER.

Key Points

- The interventional echocardiographer is an essential member of the heart team that performs M-TEER.
- Variability in imaging protocols along with inconsistency in experience of the operators can affect procedural results.
- This guideline provides a step-by-step protocol for intraprocedural imaging during M-TEER procedures.

STEPS FOR INTRAPROCEDURAL IMAGING FOR M-TEER PROCEDURES

Baseline Evaluation

The comprehensive TEE protocol for screening patients for M-TEER has been previously described in the American Society of Echocardiography (ASE) standards for the performance of TEE screening for structural heart intervention.[8] In addition to the comprehensive screening TEE examination, an additional focused TEE examination immediately before the procedure is necessary to confirm the mechanism, morphology, and severity of mitral regurgitation (MR), to exclude any contraindications, and to plan procedural steps, including device selection and implantation strategy. Additionally, this preprocedure TEE examination should establish baseline left and right ventricular function, determine the optimal site and feasibility for transseptal puncture (TSP), exclude left atrial appendage (LAA) thrombus, and detect any pericardial effusion.

The interventional echocardiographer should be competent in the acquisition, display, and manipulation of two-dimensional (2D), biplane, three-dimensional (3D; live/zoom), and 3D multiplanar reconstruction (MPR) imaging of native mitral valve (MV) anatomy and transcatheter implantation systems and devices. These methods have been previously

Table 1 Types of commercial devices for M-TEER

Device	Repair system parts	Acronyms for guideline	Functional components
MitraClip	MitraClip device (four sizes: NT/NTW, XT/XTW)	Implant	Cobalt chromium clip with two movable arms and grippers with frictional elements running the length of inner surface of each gripper
	Clip DS	DS	Locks and unlocks clip via lock line, raises and lowers grippers via gripper line, opens and closes clip arms, locks and unlocks DS translation/torque, controls removal of lock lines, prevents actuator knob turning, turns actuator shaft for clip deployment, controls removal of gripper line
	Steerable sleeve	SC	M/L knob and A/P knob for tip deflection
	Steerable GC	GC	With or without knob for tip deflection
PASCAL	PASCAL device (two sizes: P10 and PASCAL Ace)	Implant	Spacer, two broad/curved Nitinol paddles and two clasps with frictional elements running along the top of the clasp
	IC	DS	Attached to the implant (attached by sutures) and a threaded shaft: sliders control individual clasps, threaded AK controls the paddles, RK controls the implant release
	SC	SC	Actuates the flexion mechanism (end indicated by radiopaque marker band)
	GS	GC	Steerable GS and introducer; GS rotational knob allows steering to the target

AK, Actuation knob; *DS*, delivery system; *GS*, guide sheath; *RK*, release knob.

described.[9,10] Fundamental to the performance of M-TEER is an ability to quickly obtain optimized views of the midesophageal (ME) four-chamber view (0°-30°), the MV bicommissural view (50°-70°), bicaval views (80°-130°), and the long-axis three-chamber view (110°-140°).

As the M-TEER device can be positioned to effect coaptation of the anterior and posterior leaflets anywhere along the commissural line, the MV bicommissural view (50°-70°) is often considered a foundational view and can be imaged using 2D, biplane, and 3D imaging perspectives. This MV bicommissural view is best optimized with slight ME transducer depth adjustment and minor transducer right and/or retroflexion (depending on the exact cardiac position within the chest) and changes to the multiplane angle to achieve an image with the left ventricular apex at the bottom (6 o'clock position) and a horizontal mitral annular plane (i.e., perpendicular to the ultrasound beam). Following imaging of the entire left ventricle, image depth can then be reduced to improve spatial and temporal resolutions of the MV apparatus. From this imaging window, 3D MV volume data sets can be acquired and manipulated to generate the "surgeon's view," as recommended in current guidelines.[8] Because this en face view of the MV requires both Z- and X-plane rotations, some commercially available equipment can record and then automatically repeat the required image manipulation to recreate this view (or any other chosen view), as the "3D home" view.

Review for MR Mechanism and Severity. Currently, most M-TEER procedures are performed under general anesthesia (GA) with TEE guidance. After the induction of anesthesia, and before proceeding with the M-TEER procedure, it is necessary to confirm the MR mechanism (primary or secondary) and to define valve morphology using 2D and 3D imaging methods. MR severity should be confirmed using a multiparametric approach, including quantitative parameters, as recommended in the ASE guidelines for valvular regurgitation.[11] It is important to account for the potential impact of the patient's reduced oral intake, GA, and positive pressure ventilation on loading conditions and the appearance of the MR color Doppler jet. Briefly suspending respiration during GA may allow optimal 3D imaging with multibeat high-volume acquisition. If there is a significant discrepancy in MR severity compared with the screening TEE examination, an attempt should be made to restore near physiologic loading conditions, typically by pharmacologically increasing blood pressure or by volume loading. This allows not only the confirmation of disease severity but also the identification of the location(s) of regurgitation, which is essential for planning device selection, positioning, and orientation.

The success of M-TEER relies on several key anatomic factors. The anterior leaflet length is rarely a limitation for M-TEER. However, the posterior leaflet is radially shorter, and an adequate length for grasping should be confirmed The posterior leaflet length should be measured at the intended site of device implantation using single-plane imaging in a long-axis view, biplane imaging from a bicommissural view, or 3D MPR, which can be especially helpful to ensure that the measurement is performed at the correct device orientation (i.e., perpendicular to the leaflet coaptation zone) and position (i.e., at the site of intended device implantation). The anterior and posterior leaflet lengths should measure ≥6.0 mm for a MitraClip NT/NTW device (Abbott Cardiovascular), 9 mm for a MitraClip XT/XTW device, and ≥8mm for a PASCAL device (Edwards Lifesciences).

Additionally, a baseline transmitral gradient <5 mm Hg (heart rate of 60-80 beats/min) and an MV area (MVA) of ≥4.0 cm^2 are desirable to minimize the risk for mitral stenosis. Although an MVA <3.5 cm^2 is often a contraindication for transcatheter edge-to-edge repair (TEER), an MVA of 3.5 to 4.0 cm^2 may be feasible depending on the patient's body size, the anticipated number and location of devices implanted, and the expertise and experience of the operators. The transmitral gradient should be interpreted in the context of heart rate, regurgitant flow volume, and forward flow. Increased heart rate, severe MR, and high flow rate will increase transmitral diastolic gradients, whereas bradycardia and low flow may reduce gradients. The MVA ideally should be measured with planimetry using 3D MPR to locate the tips of the leaflets, understanding that the curvilinear valve opening may be a source of error. Two-dimensional planimetry can overestimate the valve area if oblique imaging planes fail to image the leaflet tips, and measurement on a 3D-rendered image (en face) is strongly discouraged because of both increased slice thickness and parallax. The reduction in diastolic valve area can be anticipated on the basis of TEER device type and size (e.g., reduction in valve area is ~47% for a P10 device [Edwards Lifesciences], ~52% for a shorter

	IDEAL FOR M-TEER	CONSIDER M-TEER IN EXPERIENCED CENTERS		TMVR OR ALTERNATIVES
Anatomic Feature	**Optimal**	**Complex**	**Very Complex**	**Likely Prohibitive**
Location of Pathology	Pathology in A2/P2	Pathology in A1/P1 or A3/P3	Pathology involving multiple scallops	Cleft or perforation Endocarditis
Calcification	No calcification	Annular calcification without leaflet involvement	Calcification of leaflets outside grasping zone	Severe calcification of leaflets in grasping zone
Subvalvular Apparatus	Chord-free grasping zone	Minimal chords in grasping zone	Annuloplasty ring s/p SLDA HCM	Severely calcified subvalvular apparatus including chords
Mitral Valve Area	MVA > 4cm^2	MVA 3.5-4 cm^2	MVA 3-3.5 cm^2	MVA < 3 cm^2 Mean Gradient > 5 mmHg
Posterior Leaflet Length*	Posterior leaflet length > 10 mm	Posterior leaflet length 8-10 mm*	Posterior leaflet length 6-8 mm*	Posterior leaflet length <6 mm*
Leaflet Mobility and Thickness	Normal leaflet mobility and thickness	Excessive or normal leaflet mobility and thickness	Excessive or slightly restrictive leaflet mobility Barlow's disease Increased leaflet thickness	Rheumatic thickening and leaflet restriction

Figure 2 Anatomic considerations for optimal to complex anatomies for M-TEER. Considerations for M-TEER eligibility are based on a multiparametric assessment, including regurgitant jet location, calcification distribution, subvalvular apparatus morphology, MVA, leaflet length, and leaflet mobility. Complex anatomies may be suitable for treatment at experienced, high-volume centers following multidisciplinary heart team evaluation. Patients with likely prohibitive features should be considered for alternative therapies when clinically appropriate. *Minimum leaflet length requirements are device specific. *HCM*, Hypertrophic cardiomyopathy; *SLDA*, single-leaflet device attachment; *s/p*, status post; *TMVR*, transcatheter MV replacement.

	Optimal	Complex
Primary MR	Flail width <15 mm Flail gap <10 mm	Flail width >15 mm Flail gap >10 mm
Ventricular-Secondary MR	Coaptation reserve > 3 mm Tenting height < 11 mm	Coaptation reserve < 3 mm Tenting height ≥ 11 mm
Atrial-Secondary MR	Isolated annular dilatation (Carpentier I) LAVI < 85 ml/m^2	Restricted posterior leaflet motion (Carpentier IIIb) LAVI > 85 ml/m^2

Figure 3 Morphologic criteria associated with procedural success of M-TEER, stratified by mechanism of MR. In primary MR, smaller flail width (<15 mm) and flail gap (<10 mm) are associated with favorable outcomes, as defined in EVEREST (Endovascular Valve Edge-to-Edge Repair Study). Secondary MR is further subdivided into atrial and ventricular phenotypes. In ventricular secondary MR, features such as a coaptation reserve > 3 mm and tenting height < 11 mm, reflecting less severe leaflet tethering and more favorable valve geometry, have been associated with improved procedural success. In atrial secondary MR, favorable characteristics include isolated annular dilatation without leaflet restriction (Carpentier I), left atrial volume index (LAVI) < 85 mL/m^2, and a leaflet-to-annulus index. Not all MR pathology can be categorized exclusively into one category or the other. Likewise, some MV pathology may demonstrate a mixture of optimal and complex anatomic features.

MitraClip NT device, and ~57% for a larger MitraClip XTW device); however, other important factors, such as leaflet pathology (myxomatous or fibrotic) and the location of MR, may influence diastolic valve area following M-TEER device deployment.[12-14] The recommended anatomic and morphologic suitability criteria for M-TEER are detailed in Figures 2 and 3.[7,15-17]

Screen for Procedural Contraindications. It is crucial to exclude any absolute or relative contraindications to M-TEER, such as unsuitable valve morphology, left atrial thrombus or mass, abnormalities of the interatrial septum that could complicate or prevent an adequate TSP, or a transmitral gradient >5.0 mm Hg (unless believed to be secondary to MR). Inability to safely advance the TEE transducer into the esophagus and stomach is another relative contraindication, although smaller TEE transducers and/or 3D intracardiac echocardiographic probes can be used to guide the procedure instead.[18,19]

Device Selection and Implant Strategy. Two U.S. Food and Drug Administration–approved systems are currently available for M-TEER: the MitraClip system, which includes four device sizes, and the PASCAL system, which offers two device sizes. Device selection is influenced by factors such as leaflet length, coaptation or flail gap size (longer devices may be preferred for larger gaps), the location of the intended grasping site (shorter and narrower devices may be favored for noncentral or commissural locations), jet or flail width (wider devices or multiple devices may be necessary), and baseline MVA (shorter and narrower devices or nitinol-based devices may be preferred in situations of borderline MVA). The final device choice and implantation strategy should be made on a case-by-case basis after careful review of the baseline images and discussion among the heart team. Operator experience with the available M-TEER devices should also be considered, especially if more challenging anatomy and pathology are encountered.

Key Points

- Baseline evaluation during M-TEER should include assessment of MR etiology, severity, mean diastolic gradient, MVA, leaflet lengths and morphology (deep folds or clefts), and location of MR jets.
- Any relative or absolute contraindications to the procedure must be identified and communicated within the heart team.
- Device selection and implantation strategy should be based on an informed discussion between interventional echocardiographer and interventional cardiologist operators.

Transseptal Puncture

Achieving an optimal TSP is crucial for the success of M-TEER (Figure 4). The ideal site of the TSP should be approximately 4.5 to 5.0 cm above the anticipated point of device deployment at the coaptation zone of the leaflets. The three main objectives of the TSP for M-TEER are to remain within the fossa ovalis, to align the device guide above the posteromedial commissure, and to achieve an adequate height above the desired coaptation plane. The mechanism and site of MR is an important consideration when determining TSP height above the annulus. For secondary MR with leaflet restriction, the final deployment of the TEER device may be below the annulus; for primary MR with prolapsing leaflet tissue the final deployment of the TEER device may be at or slightly above the annular plane. In addition, the desired device landing zone along the commissural line also may influence the required TSP height. A targeted deployment on the lateral side of the MV can be achieved with a lower TSP height because height can be gained while the catheter traverses the width of the left atrium. Conversely, a medial target for M-TEER deployment will typically require a TSP height within the higher range (≥4.5 cm).

Height is gained by clockwise rotation of the TSP catheter, bringing the tip into the mid to superior fossa ovalis and at the appropriate height measured from a four-chamber view (~0°-15°). To avoid an anterior or "aorta-hugging delivery catheter," the puncture site within the fossa ovalis will be further from the aorta as seen in the ME short-axis (SAX) view (~60°). To be at the commissural line, the puncture will be as posterior as possible (toward the inferior vena cava) in the bicaval view (~120°). These three planes, each about 60° from one another, will allow a precise location of the TSP. From an en face 3D-rendered view from the left atrium, the puncture will be within the 12 to 3 o'clock zone of the fossa ovalis (Figure 5).

In general, a TSP site that is 4.5 cm above this deployment site will provide adequate room for catheter and TEER device maneuvering within the left atrium (Figure 6). Puncturing outside the fossa ovalis risks entering the pericardial space between the walls of the left atrium and right atrium and subsequent pericardial effusion.

The interventional cardiologist will gradually withdraw the transseptal sheath and needle from the superior vena cava toward the inferior vena cava and fossa ovalis, causing the interatrial septum to "tent" into the left atrium. There are multiple ways for the interventional echocardiographer to monitor the withdrawal of the transseptal sheath, but it is important that the imager always confirm the position using three planes about 60° apart: the bicaval view, the SAX aortic valve (AV) view, and the posterior-medial four-chamber view. If using a single-plane image, then the three views must be systematically acquired while imaging the "tenting" by the transseptal catheter. If a biplane image is used, then care should be taken to also confirm the three planes by using the mechanical rotation of the secondary image. To acquire the three imaging planes required to precisely position the TSP, either using the ME four-chamber view (0°-30°) as primary and rotating the secondary image by +60° (to the SAX view) and then +120° (to the bicaval view) or using the bicaval view (80°-110°) and rotating the secondary image by −60° (to the SAX view) and +60° to the reversed or mirror-image four-chamber view, can be used. Both versions of biplane imaging demonstrate the same anatomy and are equally appropriate to follow catheter movements. However, using 3D MPR may make localizing the TSP more intuitive, by creating a SAX 3D-rendered view of the fossa ovalis with the mitral annulus positioned at the bottom of the image. In this "clock-face" view of the fossa ovalis, the ideal TSP site for M-TEER is often within the 12 to 3 o'clock portion of the outer rim of the fossa ovalis (Figure 7). When visualized in three dimensions, the distance from the site of needle tenting to the desired coaptation zone (below, at, or slightly above the mitral annular plane depending on MR pathology) should be reviewed using MPR imaging. Accurate measurement of a 2D distance on a 3D image is challenging because of potential image parallax that may create under- or overestimation of true anatomic distance. MPR with measurements made in a 2D projection plane avoids this limitation. The implantation team should choose one imaging convention to use consistently to optimize safe and efficient communication.

Measuring from the coaptation point, rather than the annulus, ensures accurate device height, accounting for the specific mechanism and location of the coaptation relative to the annulus. The ideal distance is 4.0 to 4.5 cm, with the higher end of this range preferred for medial pathologies, and a slightly shorter distance for lateral pathologies, where the delivery system naturally gains height as it advances laterally.

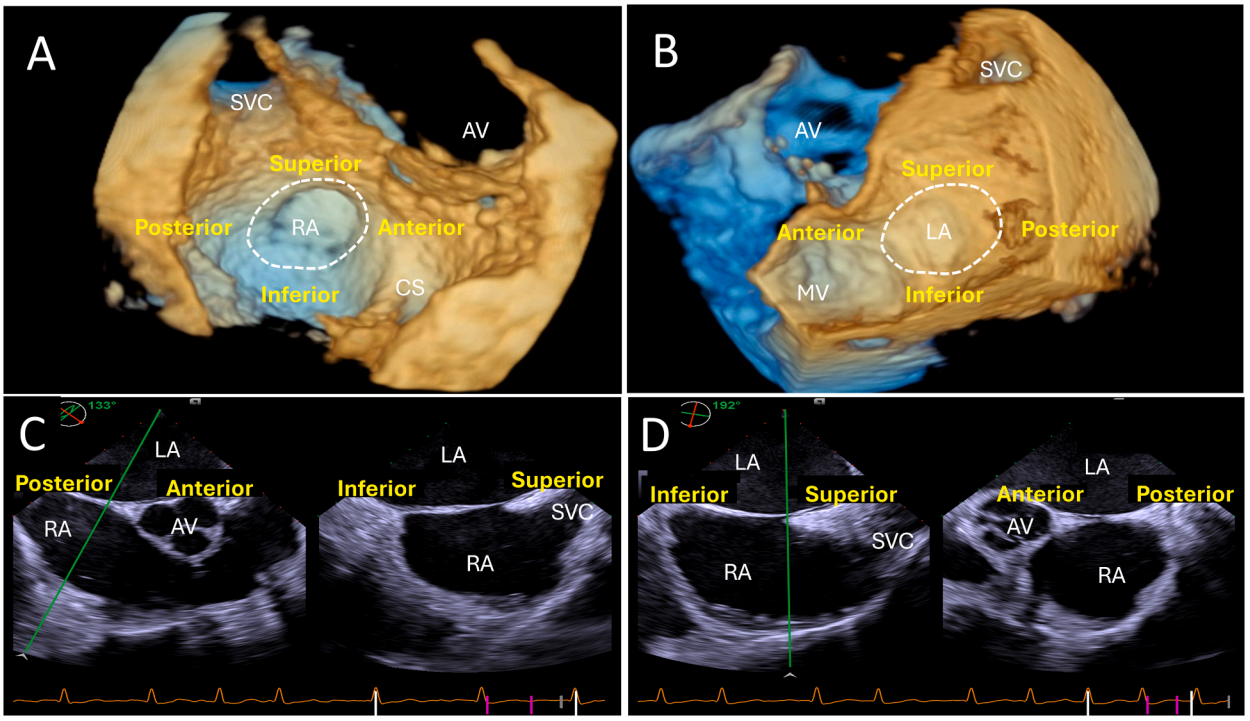

Figure 4 A properly located transseptal puncture is critical to device success, and 3D visualization is key. The atrial septum can be visualized on real-time 3D imaging from both the right atrial **(A)** and left atrial **(B)** sides (dotted area indicates the fossa). Biplane imaging can also be used to evaluate the anterior-posterior and inferior-superior portions of the septum. Biplane imaging can be performed using the esophageal SAX view at the AV **(C)** or using the esophageal bicaval view **(D)**. *LA*, Left atrium; *RA*, right atrium; *SVC*, superior vena cava.

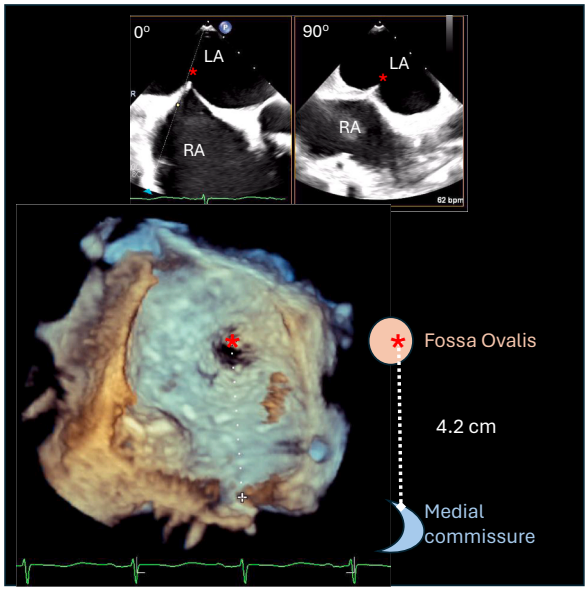

Figure 5 Two-dimensional and 3D assessment of transseptal puncture. TSP depicted using biplane imaging *(inset)* and 3D en face imaging from the left atrial perspective. The 3D LA view clearly shows tenting within the fossa ovalis *(red star)* and allows measurement of height to the medial MV commissure. To minimize potential imaging parallax, the view must be optimized to view horizontally "across" the plane of the MV. TSP height measurement should always be confirmed using a 2D image. *LA*, Left atrium; *RA*, right atrium.

Once the optimal puncture site is confirmed, the cutting or radiofrequency needle or wire is advanced through the septum under direct TEE visualization, ensuring a stable position with avoidance of the aorta and left atrial wall. After advancing the transseptal sheath into the left atrium, the needle is removed, and a guidewire is introduced into the left atrium toward the left upper pulmonary vein under fluoroscopic and/or TEE guidance (or, in the case of a radiofrequency transseptal wire, the wire is simply advanced directly into the left upper pulmonary vein). The interventional echocardiographer should confirm that the guidewire has not entered the LAA or left ventricle.

Key Points

- A posterior or mid to superior TSP site is preferred for M-TEER of most MR pathologies.
- TSP can be performed under single-plane, biplane, 3D live, and/or 3D MPR image guidance, although 3D modalities are recommended.
- Multiple confirmatory views are required to confirm the precise height above the annular plane and alignment with the commissural line, while remaining within the fossa ovalis.
- TSP height is typically 4.5 to 5.0 cm above the mitral annulus plane but may be lower for lateral commissural pathology or markedly restricted leaflets of secondary MR or higher for medial commissural pathology or significant leaflet prolapse or flail.

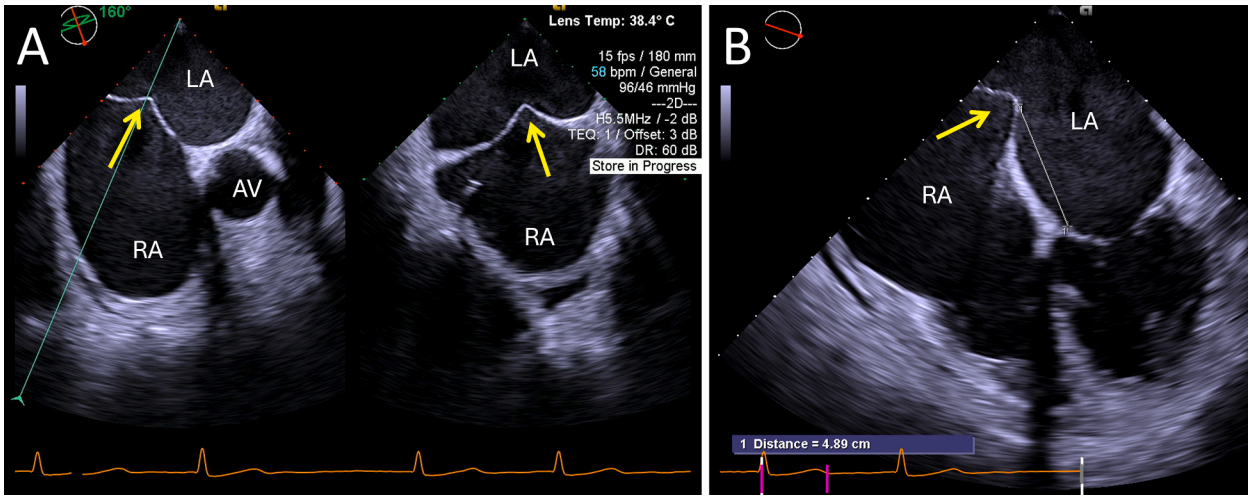

Figure 6 Transseptal puncture height is critical to device success. Tenting during TSP *(yellow arrow)* can be visualized on both 2D and 3D imaging. Tenting can be seen in biplane imaging **(A)**. From a 2D view at 0° (four-chamber view), the height of TSP to the MV leaflets can be measured **(B)**. *LA*, Left atrium; *RA*, right atrium.

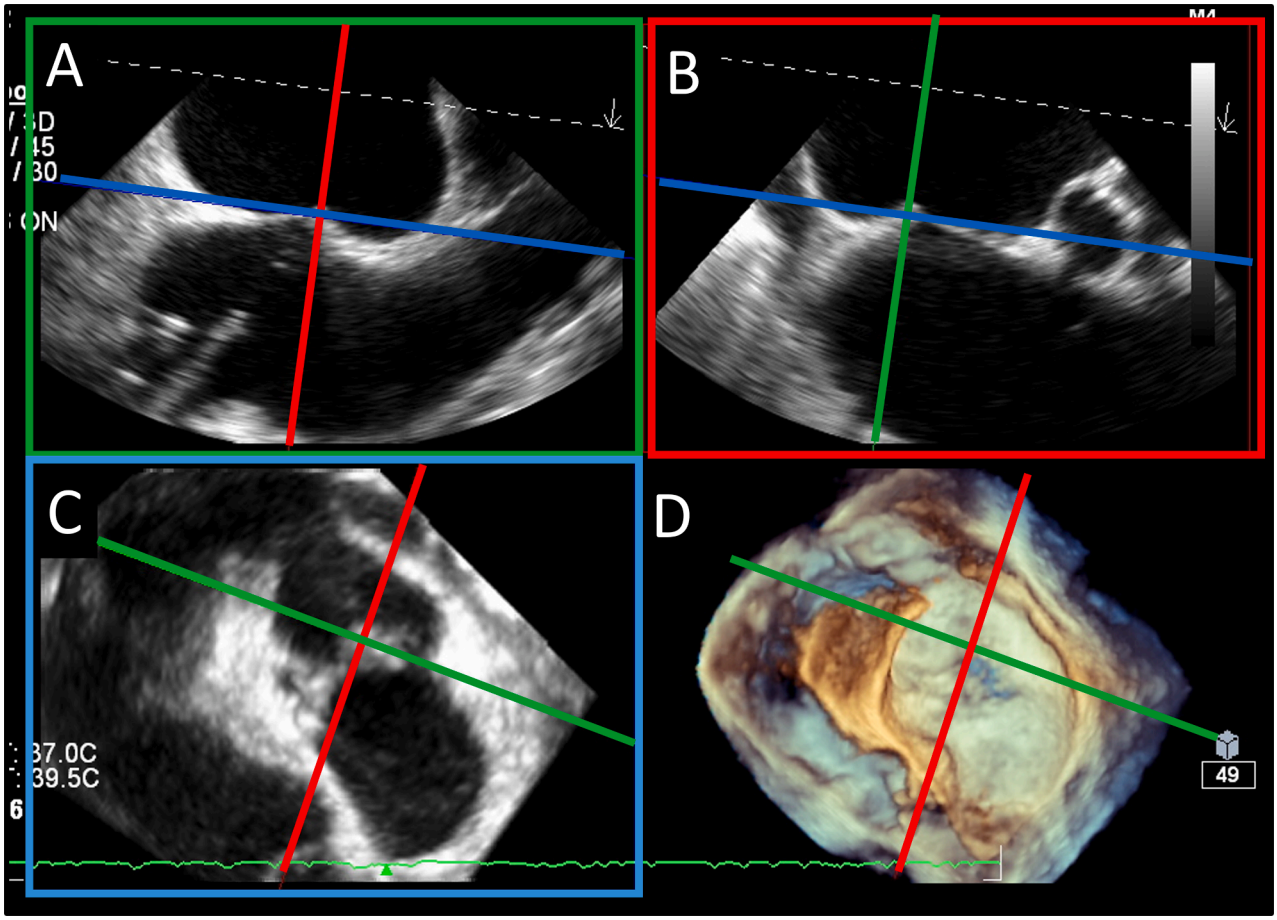

Figure 7 Utility of live 3D MPR. Live 3D MPR assists in confirming the location of the TSP by simultaneously visualizing three 2D planes and a 3D-rendered image. Starting from a bicaval view of inferior and superior landmarks **(A)**, the orthogonal 2D view identifies anterior and posterior landmarks **(B)**, and the SAX view confirms central position **(C)**. The en-face 3D view confirms TSP site over the medial commisure of the mitral valve **(D)**.

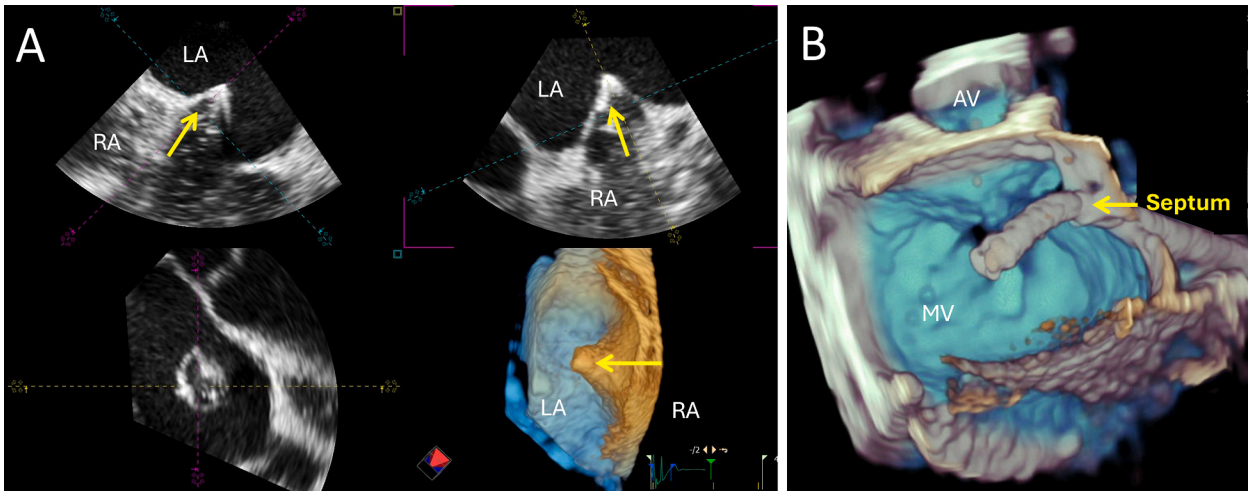

Figure 8 Delivery of the guide-catheter across the septal puncture. Catheter-based tenting (*yellow arrow*) is demonstrated in multiple image planes by using MPR format **(A)**. Tenting resolves as the septal tissue slides over the guide-catheter **(B)**. Three-dimensional imaging reveals the trajectory of the catheter within the left atrium. *LA*, Left atrium; *RA*, right atrium.

DELIVERY OF GUIDE CATHETER AND GUIDE CATHETER POSITIONING

The steerable guide catheter (GC) and dilator are advanced over the wire into the left atrium under continuous TEE guidance until approximately 2 cm of the catheter (which should be distinguished from the dilator) is across the septum (Figure 8). The dilator and guidewire are then retrieved. The appropriate length of the GC inside the left atrium is approximately 2 cm, and the orientation of the GC toward the mitral annular plane is confirmed using 2D, biplane, 3D, and/or MPR imaging (Figure 9).

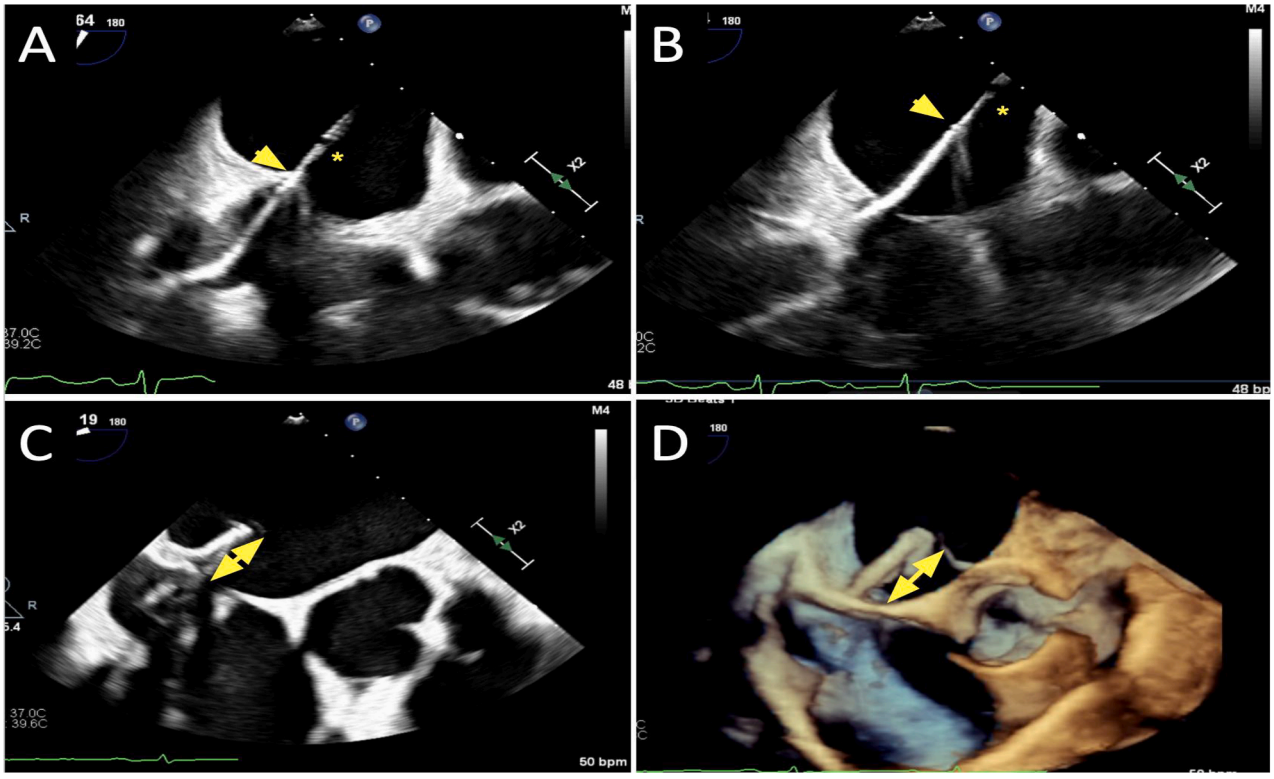

Figure 9 Dilator crossing septum, measuring catheter in two and three dimensions. The steerable guide-catheter and dilator are advanced into the left atrium over the wire under direct TEE visualization **(A** and **B)**. The dilator *(yellow asterisk)* has a characteristic thinner appearance that must be distinguished from the tip of the thicker guide-catheter *(yellow arrow)*. The dilator and guidewire are then retrieved, and the appropriate length of the guide-catheter inside the left atrium (approximately 2 cm) and its orientation toward the mitral annular plane are confirmed **(C)**. Live 3D imaging can also assist in visualizing the whole length of the guide-catheter within the left atrium **(D)**.

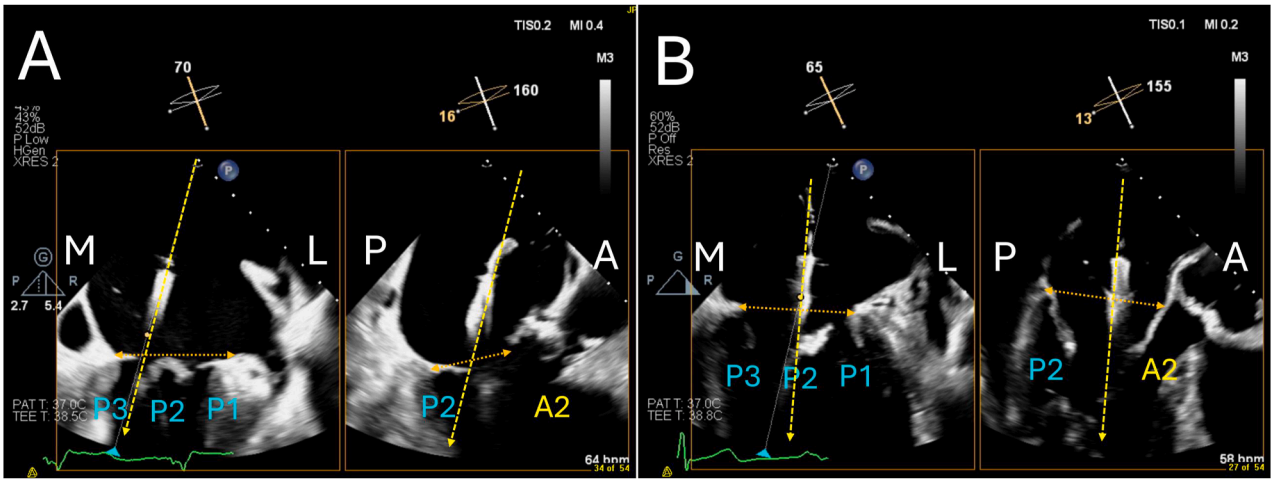

Figure 10 Catheter position and trajectory. Using biplane imaging with the commissural view as the primary image (**A**; *left image*) and the anterior-posterior view as the secondary image (**(A)**; *right image*), device position within the annulus *(orange dotted arrow)* and its trajectory *(yellow dashed arrow)* can be determined. The commissural view shows that the device position is medial (over P3) but midline in the orthogonal view, but there is both a medial and posterior trajectory. The catheter trajectory is corrected to be orthogonal to the annulus in both the commissural *(left)* and anterior-posterior views *(right)* **(B)**. *A*, Anterior; *L*, lateral; *M*, medial; *P*, posterior.

Delivery of M-TEER Device

The device delivery system is advanced through the GC into the left atrium under fluoroscopic and continuous TEE guidance, ensuring it does not forcefully contact the walls of the left atrium or LAA. The interventional echocardiographer should carefully track the device as it enters the left atrium and is positioned over the mitral annulus. This can be accomplished with single-plane, biplane, 3D, or MPR imaging. If using single-plane images starting from the bicaval view, the trajectory of the device moving toward the annular plane can be tracked by gradual counterclockwise rotation of the transducer (toward the MV) while reducing the mechanical rotation from the bicaval angle (90°-120°) toward a four-chamber view (0°-20°) to ensure that the device does not interfere with the limbus of the pulmonary vein, or the lateral annulus. Alternatively, the catheter positioning can be guided using large volume 3D "zoom" images or 3D MPR of the entire left atrium. Three-dimensional views allow more complete visualization of the catheter within the left atrium and permit immediate reorientation to medial, lateral, anterior, and posterior landmarks. The depth of the catheter in relation to the MV is also readily apparent. Simultaneous viewing of the fluoroscopy screen may at times assist the interventional echocardiographer in ensuring appropriate depth of the TEE transducer to monitor the tip of the GC and device (Video 1).

M-TEER Device Positioning. There are three different tasks for the interventional imager: (1) identify the trajectory of the implantation catheter, (2) identify the position of the device, and (3) determine the orientation of the device.

Implantation Catheter Trajectory. After the TEER device has safely entered the left atrium, multiple catheter manipulations (e.g., flexion knobs, medial-lateral knobs, movement into and out of the left atrium) are used to position the delivery system approximately 1.0 cm above the MV, ensuring perpendicular alignment of the GC to the MV annulus (i.e., correct trajectory). This can be visualized with a combination of 2D, biplane, and 3D en face views of the MV. Trajectory refers to the guide's orientation in relation to the mitral annulus, whereas the position of the device is determined by location along the commissural line (i.e., in the anterior-posterior and medial-lateral planes; Figure 10). The TEE esophageal views at 0° to 15° or 120° to 150° (with left ventricular outflow tract visualization) are essential for anterior-posterior positioning and trajectory, whereas the TEE esophageal view at 50° to 70° (bicommissural view) is essential for medial-lateral positioning and trajectory. This can also be accomplished using 3D (Figure 11) and 3D MPR (Figure 12) views, which are particularly useful for following the device trajectory in noncentral pathology, or situations in which aligning the ultrasound plane with the trajectory of the delivery system can be challenging (Video 2).

Device Position. The ideal position of the GC and device is typically determined from the preprocedural TEE examination and confirmed on the baseline intraprocedural TEE examination. Planning the position of the first device includes not only identifying the location of the pathology and MR jet but also predicting how many devices may be required. If two devices are anticipated, then the first device will typically be the more medially positioned device. This strategy will reduce shadowing and delivery catheter manipulation for the second device deployment. Positioning the GC can be performed with biplane imaging, typically using the commissural view as the primary view. However, 3D MPR is very useful in allowing both 2D and 3D en face views to be imaged throughout the positioning process.

Device Orientation. Once an optimal trajectory and position of the GC and device have been achieved, the next step is orienting the M-TEER grippers or paddles: (1) perpendicular to the zone of coaptation and (2) above the pathology. Although the coaptation zone of the MV is typically curvilinear, patient-specific variations in the degree of the curve are important to recognize. Flexion, medial-lateral, and positioning functions on the catheter are required to align the TEER device perpendicular to the zone of coaptation. These maneuvers must be visualized using TEE imaging.

In primary MR with leaflet prolapse, positioning the device directly over the prolapsing segment ensures that the M-TEER device will adequately capture the leaflet. With MR from secondary etiologies,

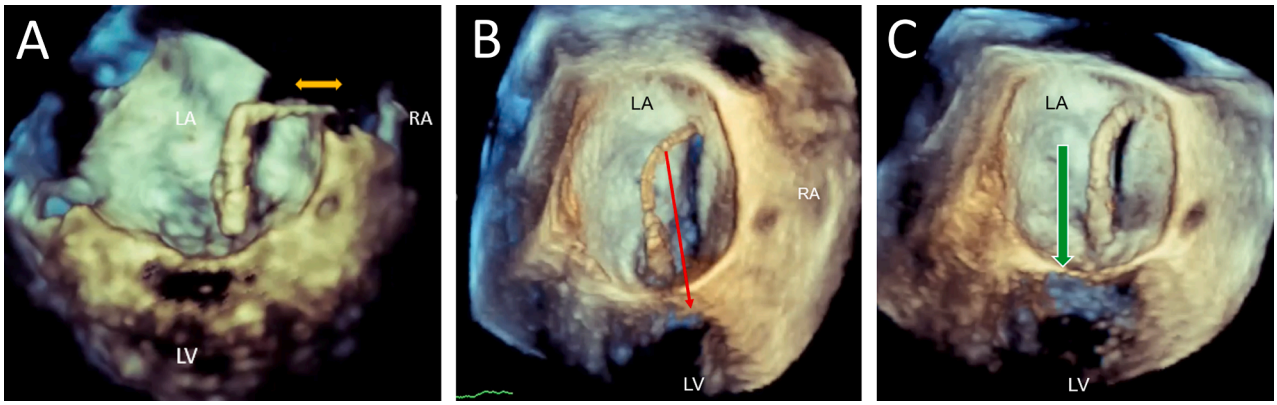

Figure 11 Position and trajectory of the catheter is communicated using 3D LA imaging. The device crossing the interatrial septum is shown and positioned over the medial commissure **(A)**. Advancing or withdrawing the device *(orange double-headed arrow)* will position the device laterally or medially, respectively. Device trajectory is pointed to the medial wall of the left ventricle (*red arrow*; **B**), and applying more lateral flexion will correct this trajectory (*green arrow*; **C**). *LA*, Left atrium; *LV*, left ventricle; *RA*, right atrium.

different strategies are deployed; these can include the "zipper" technique, in which multiple devices are placed from one commissure to another, or the "central" technique in which an initial device is placed at A2-P2 and followed by additional devices according to the location of residual MR. Through "clocking" and "counter-clocking" maneuvers, the device is oriented perpendicular to the line of coaptation (Video 3). Relative to the 12 o'clock to 6 o'clock orientation of a midline A2/P2 device deployment, lateral and medial TEER targets will have more clockwise, and counterclockwise orientation, respectively, to reflect the natural curvature of the leaflet coaptation zone as viewed on 3D TEE imaging from the left atrial perspective.

The 3D en face or MPR display (rotation) of the MV should be standardized so that the medial and lateral commissures are located at the 2 o'clock and 10 o'clock positions, respectively.

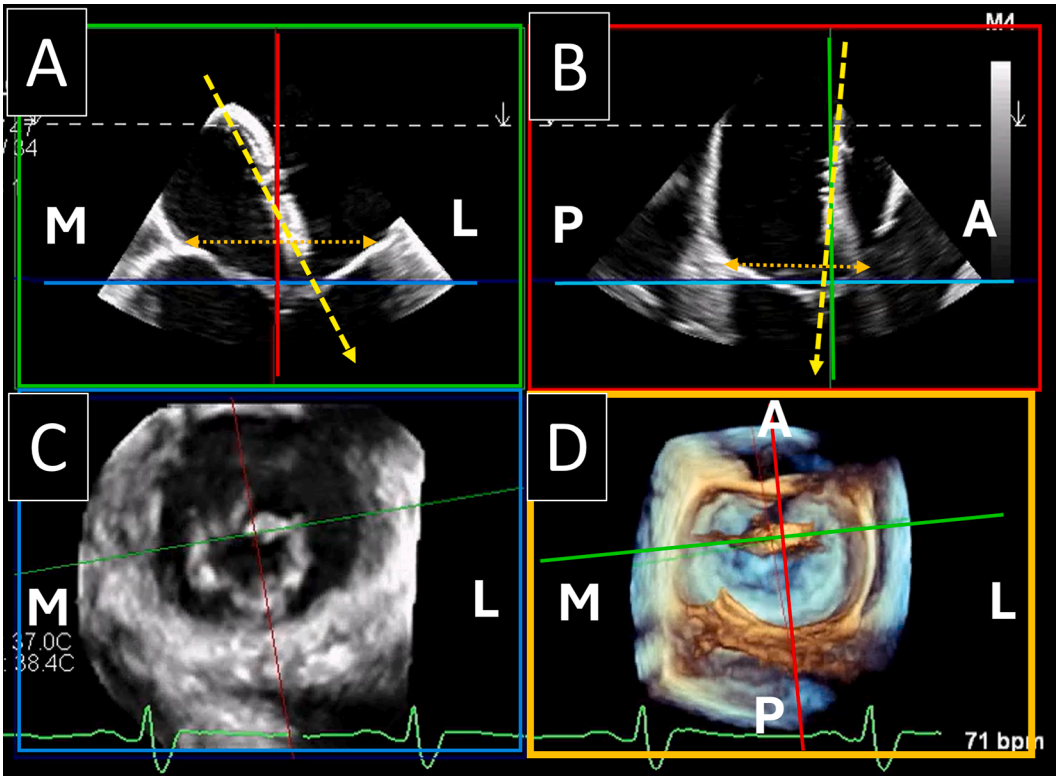

Figure 12 Position and trajectory with 3D rendering. MPR can be used to image the precise location of the device in 3D space. The 3D en face view *(orange box)* is used to generate the 2D commissural view **(A)** and the orthogonal anterior-posterior view **(B)**. The trajectory to the annulus *(yellow dashed arrow)* and position within the annulus *(orange dotted arrow)* can be precisely determined **(C)**. In this example, the trajectory is markedly lateral and slightly posterior with the position lateral and anterior **(D)**. MPR allows easy tracking of the device in real time. *A*, Anterior; *L*, lateral; *M*, medial; *P*, posterior.

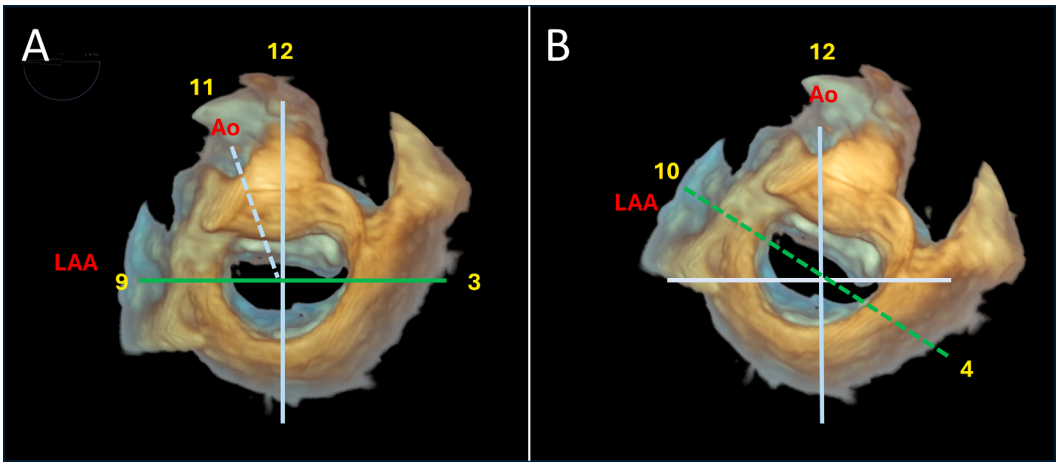

Figure 13 Three-dimensional display of the MV rotated to align commissures along a horizontal plane. The recommended method is to display the commissures as symmetrically and horizontally positioned (**A**), facilitating perpendicular transcatheter edge-to-edge repair device alignment. Classically, the aorta (Ao) is aligned at 12 o'clock, creating a commissural plane from 4 to 10 o'clock (green-dashed line) **(B)** which can make M-TEER device alignment more challenging.

This will often position the AV at 12 o'clock, but patient-specific variation in the normal anatomy often leads to an AV or aortic root being more laterally positioned. For consistent communication and device alignment perpendicular to the zone of leaflet coaptation, image display relative to commissural clock position is recommended (Figure 13).

Gripper/Clasp Function. Before the TEER device enters the left ventricle, the device grippers or clasps are checked (Figure 14). In the currently available commercial devices, the grippers or clasps can be controlled and deployed individually; therefore, it is important to identify which gripper or clasp is oriented anteriorly, and which gripper or clasp is oriented posteriorly. This can be evaluated using either 2D or 3D imaging with rotation of the 3D en face view to an oblique view or by using MPR (Figure 15).

Device Delivery Across the MV. Once the trajectory, position, and orientation of the device have been optimized with the device in the left atrium, the GC is advanced across the MV annulus and below the leaflet tips under continuous visualization. This can be performed with the device in the open or closed conformation. In the setting of a restricted anatomic orifice such as a commissural

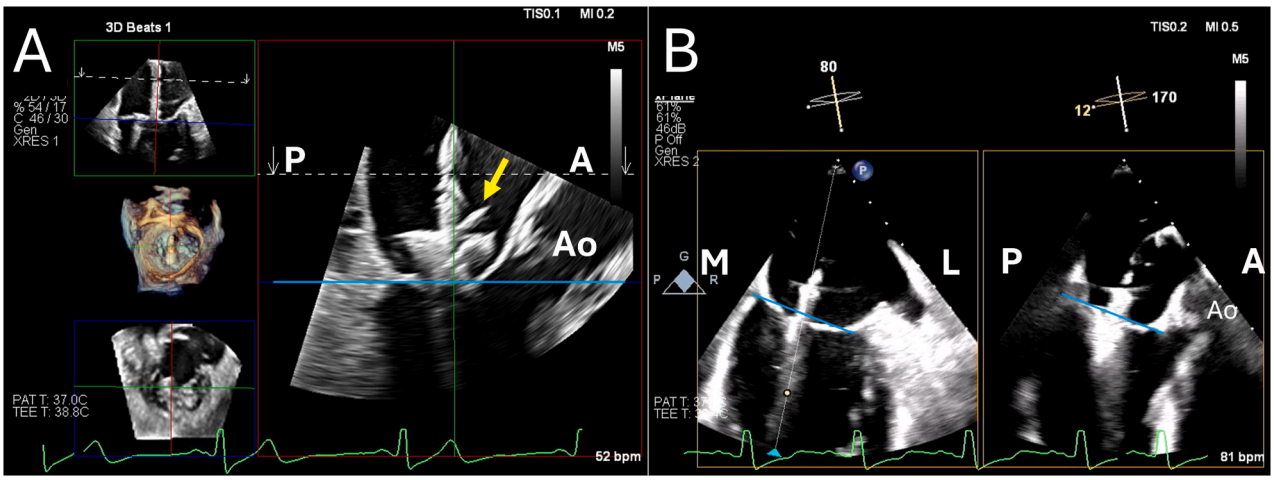

Figure 14 Gripper or clasp identification and crossing the annulus. Once the device is oriented, the individual grippers or clasps should be identified. The anterior gripper is identified *(yellow arrow)* from a view aligned with the device arms **(A)**. Following identification of the individual gripper or clasps, the device is advanced across the MV annulus *(blue line)* either in the open position **(B)** or in the closed position if there is a risk for interaction with either native structures or a previously deployed device. *A*, Anterior; *Ao*, aorta; *L*, lateral; *M*, medial; *P*, posterior.

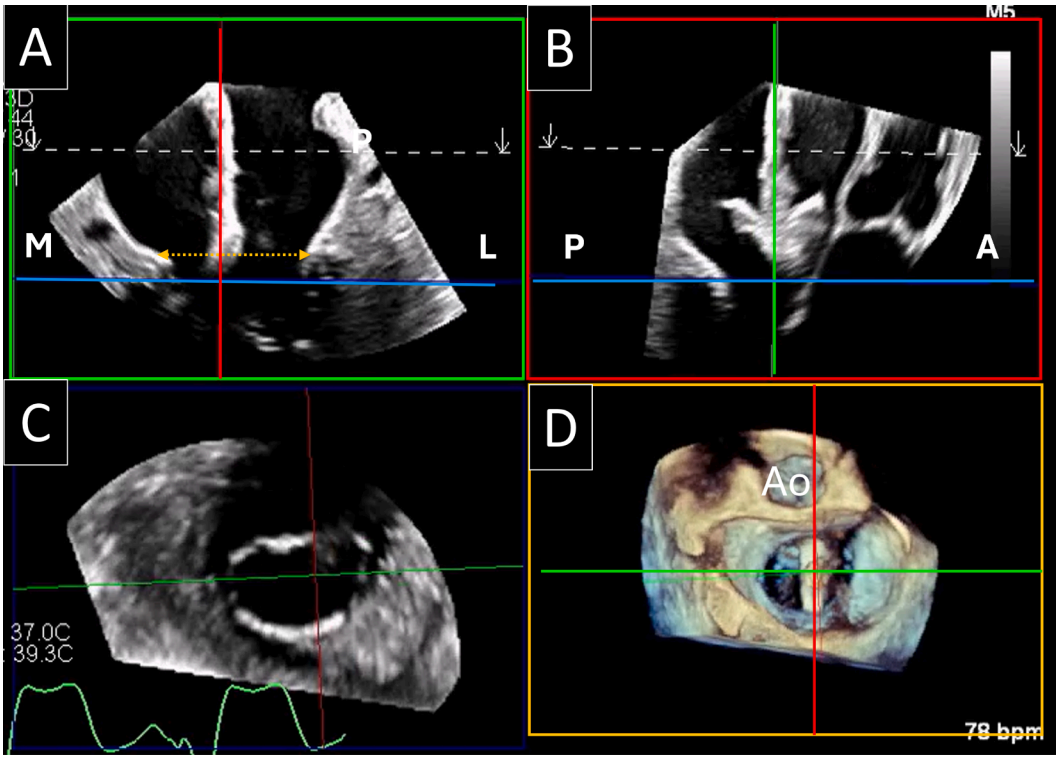

Figure 15 Device orientation. Using either 3D MPR or a dedicated 3D-rendered en face image, the open device arms or paddles can be precisely oriented to optimize MR reduction. In this example of 3D MPR, the 3D-rendered en face view **(D)** is used to generate the 2D commissural view **(A)** and the orthogonal anterior-posterior view **(B)**. The device arms or paddles are oriented perpendicular to the commissural line **(B)** and over the A2-P2 scallops **(A)**. Short axis view confirms that the M-TEER device is above the open valve plane **(C)**. *A*, Anterior; *Ao*, aorta; *L*, lateral; *M*, medial; *P*, posterior.

position or prior TEER device, closing the device arms will reduce the interaction with the tissue.

Key Points

- Catheter and device delivery is crucial: both 2D and 3D TEE imaging are used to guide trajectory and orientation.
- The TEER device must be aligned perpendicular to the zone of leaflet coaptation.
- The leaflet coaptation zone should be displayed using 3D imaging, with the commissures located at symmetrical clock positions (e.g., 2 o'clock and 10 o'clock), irrespective of whether the AV is at the 12 o'clock position or not.

Positioning for Leaflet Grasp

As the device is advanced across the mitral annular plane, either 2D with biplane imaging of the commissural view or 3D MPR is used for continuous imaging of the orientation of the device; reducing gain once below the leaflets will result in dropout of the leaflets but allows the strong ultrasound-reflecting device to be seen (Figure 16, Video 4); readjustment may be required if orientation changed as the device was advanced. During this phase of device advancement into the left ventricle, nonperpendicular trajectory may result in a medial or lateral shift of device position. This may be resolved when the open device is withdrawn toward the mitral leaflets, but consideration of device retraction into the left atrium and catheter trajectory correction may be required if significant changes in orientation of the device have occurred.

Leaflet Grasp

The device is positioned below the tips of the leaflets, and under continuous imaging guidance using either 2D or 3D MPR imaging the device is retracted until the leaflets are positioned lying on top of the grippers or paddles (between the paddles or clip arms and the clasps or grippers). Three-dimensional MPR is ideal to align one of the 2D imaging planes with the device arms and thus can easily change the imaging views for commissural vs midline devices (Figure 17). However, 2D imaging from a bicommissural primary image and appropriately aligned secondary image (using mechanical rotation to optimize imaging of the arms) or a single-plane 2D image from the long-axis view may be sufficient (Figure 18). To grasp the leaflets, the gripper or clasps are lowered onto the paddles or clip arms; this can be performed simultaneously, or individually (Video 5). Following grasping, and before fully closing the device, the TEER device can also be closed partially to interrogate the adequacy of leaflet insertion. As the device is fully closed, color compare is used to assess device function and grasp. Four echocardiographic characteristics should be confirmed to identify adequate leaflet insertion: (1) draping of the leaflets over the arms or paddles of the device, (2) immobility of the residual leaflet tissue at the site of grasp, (3) shortening of visible leaflet tissue at the device compared with the area immediately adjacent medial and laterally, and (4) a "tissue bridge" on 3D or transgastric en face imaging.

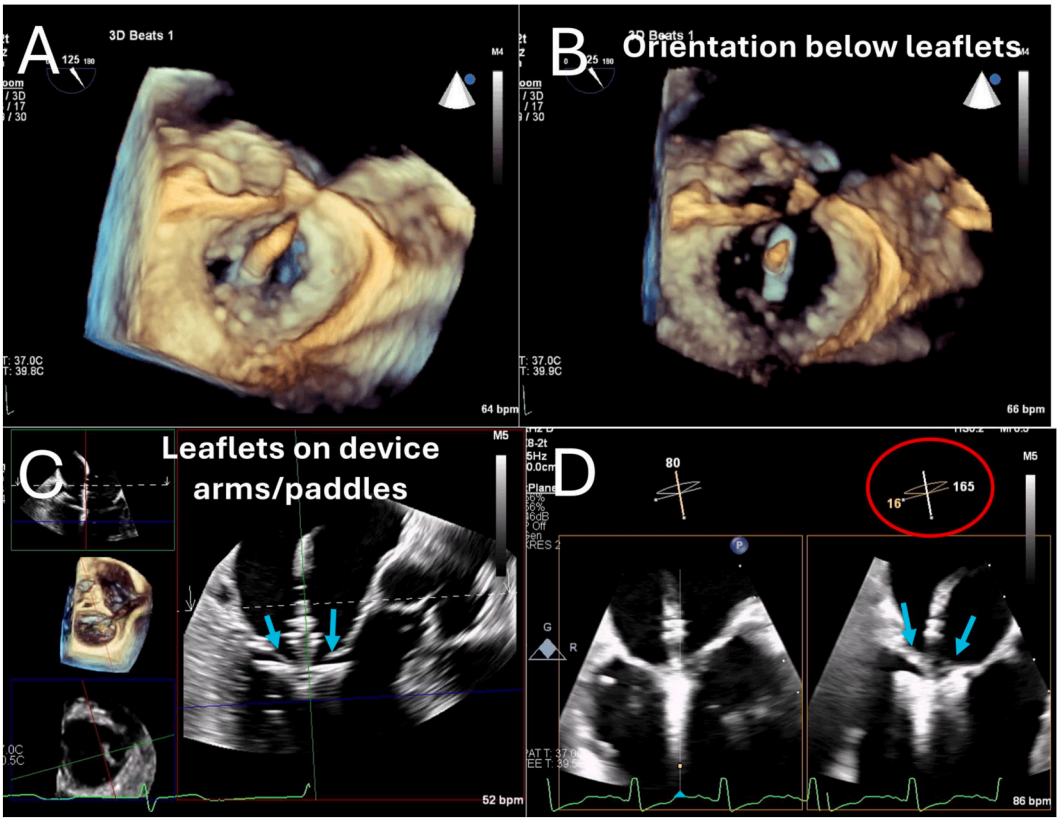

Figure 16 Capture-ready positioning. The implant is positioned below the tips of the leaflets **(A)**, and orientation is confirmed by reducing the gain on the 3D en face image **(B)**. Under continuous imaging guidance, 3D MPR imaging **(C)**, or 2D imaging (biplane imaging; **D**), the implant is retracted until the leaflets are positioned lying on top of the paddles or device arms *(blue arrows)*. Note that with biplane imaging from a primary commissural view, the appropriately aligned secondary image can be achieved by changing the mechanical rotation to optimize imaging of the arms (*red circle*, **D**).

Three-Dimensional Imaging of the Tissue Bridge. Initially following grasping, the 3D en face imaging of the MV is presented in the usual "surgeon's view." Care is taken to optimize frame rate and line density, providing maximal image resolution of leaflet tissue. The "tissue bridge" is immediately obvious, representing capture of the anterior and posterior leaflets (Figure 19). The "base" of the tissue bridge on the anterior and posterior leaflets should be approximately twice as wide as the central area of the device. A narrow tissue bridge base (anteriorly, posteriorly, or both) suggests a more tenuous leaflet insertion and prompts diligent biplane interrogation of leaflet insertion (Figure 20). An improper leaflet capture will allow one or both leaflets to move freely. Closing and deploying the M-TEER device in this situation may result in loss of leaflet capture and insertion. Using this initial 3D en face view, appropriate device orientation can also be confirmed. This is especially important when devices with longer arms are being used as any rotation may lead to leaflet distortion.

Using MPR and/or biplane imaging, the valve is then "swept" medially and laterally repeatedly. With the bicommissural view as "index,"

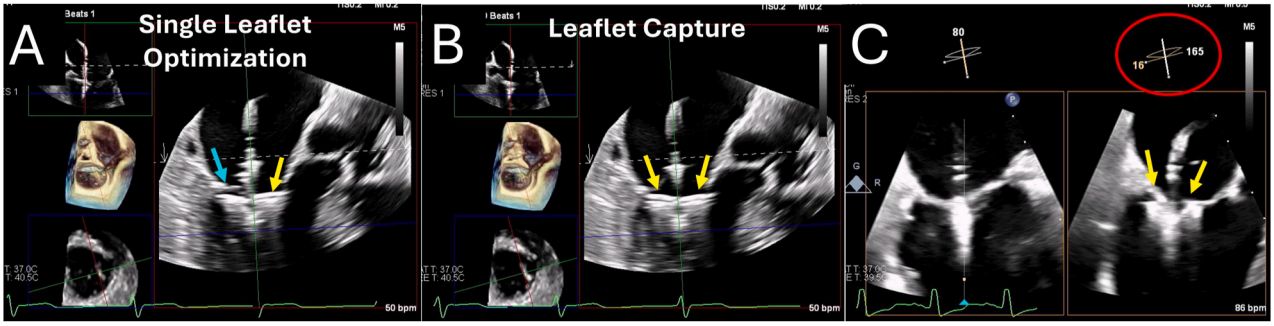

Figure 17 Leaflet capture. Once the leaflet position on the device arms or paddles has been confirmed, the grippers or clasps are lowered to capture the leaflets. A PASCAL Ace device is shown with single anterior leaflet capture *(yellow arrow)* and repositioning and optimization of posterior leaflet capture (*blue arrow*; **A**). Leaflet capture **(B)** can be confirmed by several methods: (1) separation of the grippers or clasps from the arms or paddles during systole, (2) sufficient measured leaflet lengths within the device, (3) tissue bridge imaged with 2D or 3D imaging, and (4) reduction of MR seen on color Doppler. A 2D biplane image of leaflet capture is shown with optimization of device imaging using mechanical rotation (*red circle*; **C**).

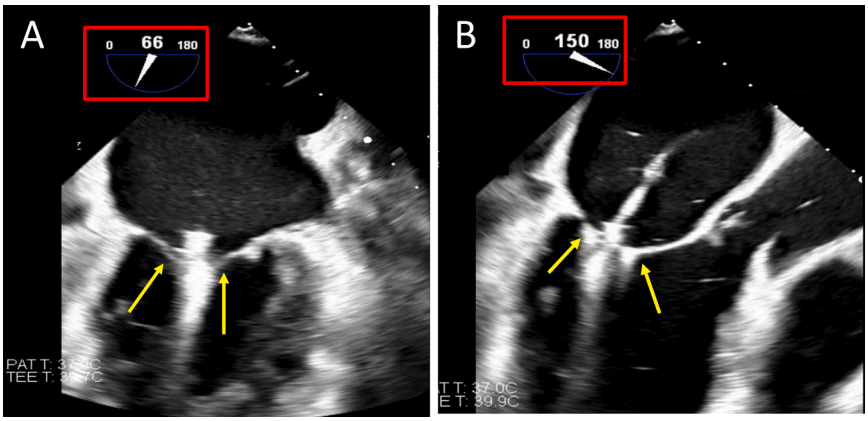

Figure 18 Two-dimensional imaging for leaflet insertion. Biplane imaging through the bicommissural view **(A)** is used along with the orthogonal long-axis image **(B)** to ensure adequate leaflet insertion (*yellow arrows*). This is performed with and without color Doppler.

the perpendicular plane is slowly moved from commissure to commissure. With magnification and optimization of line density, both leaflets are observed to drape over the arms or paddles and enter the TEER device. It is often difficult to visualize how far the leaflets extend into the arms of the device. Biplane imaging or MPR is directed through the device. A measure of leaflet length is made from annulus to insertion point within the closed device. This plane is then moved 2 to 3 mm laterally and medially from the device, allowing measurements of leaflet length adjacent to the insertion. Subtracting these measurements allows a rough estimation of leaflet length in the device. Device insertion and function can also be assessed by initially carefully assessing leaflet insertion on 2D imaging and then adding color Doppler to evaluate function. If there is any doubt about the adequacy of leaflet insertion, the arms or paddles of the device should be reopened, the appropriate frictional elements or clasp(s) raised under echocardiographic guidance, and insertion optimized and reconfirmed.

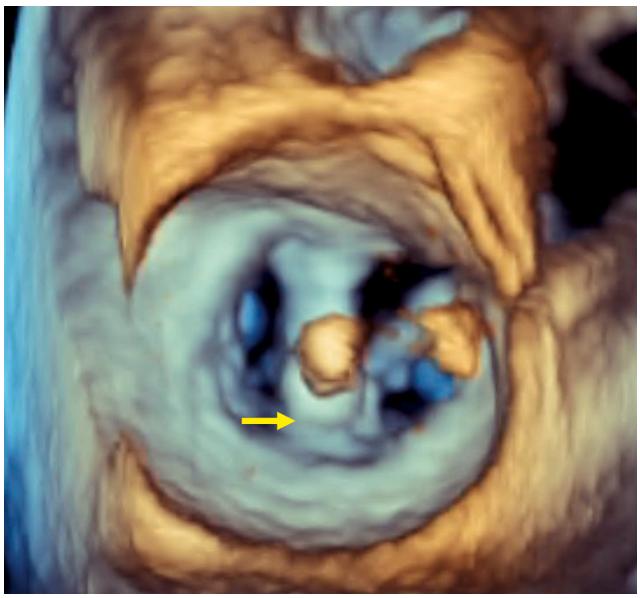

Figure 19 Ensuring adequate tissue bridge. Once leaflet insertion is confirmed with 2D imaging, a 3D en face image is used to ensure that there is an adequate tissue bridge. The *yellow arrow* demonstrates adequate leaflet insertion of the posterior leaflet.

In primary MR cases, it is important to determine whether all pathologic segments of both leaflets are captured by the device. Small areas of residual prolapse or flail are mechanically likely to be associated with residual regurgitation immediately adjacent to the device arms (Figure 21). Again, using the sweep of either biplane or MPR imaging, the leaflets are assessed from commissure to commissure, highlighting any areas of residual pathologic leaflet motion.

Color Doppler Evaluation of Leaflet Grasp. A 3D color Doppler en face view is acquired, again from the surgeon's view (Figure 22). It is often advantageous to increase the low-velocity filters. This maneuver will remove some of the low-velocity blue color, which can "flood" the image, making visualization of residual jets more difficult. Color Doppler imaging is best appreciated in still images and stepped through in cine mode, allowing frame-by-frame assessment. Diastolic forward flow is first examined to determine the size, shape, and number of orifices. In cases in which devices are placed near the commissures, forward flow may be limited to a single diastolic orifice.

The 3D color image is advanced frame by frame to mid-systole, choosing an image that best profiles any remaining regurgitant jets. The 3D volume is rotated, allowing determination of jet number, direction, and origin. Using the option to hide grayscale allows the jet to be seen without obscuration by anatomic structures. Rotating the 3D volume with the trackball will demonstrate the proximal flow convergence and the vena contracta (Figure 23). Using proximal isovelocity surface area to calculate residual regurgitant area is not recommended given the irregular shape of the orifice and proximal flow convergence following device placement.[11]

Two-dimensional biplane and/or MPR imaging can then be used to focus more specifically on jet origin, direction, and volume. Using the bicommissural plane as index, a long-axis view is generated, initially through the device. The long-axis plane is then moved medially and laterally slowly until regurgitant jets' origin and direction are profiled. The vena contracta area can be estimated using MPR tools, as a quantitative measure of degree of regurgitation.[20] Manipulation of the MPR plane will provide a long-axis view "along the jet." Orthogonal sectioning of this long-axis view will allow direct measurement of 3D vena contracta area. This method requires a high-quality (medium to high line density and often smaller) 3D color data set. It also requires careful identification of the true vena contracta perpendicular

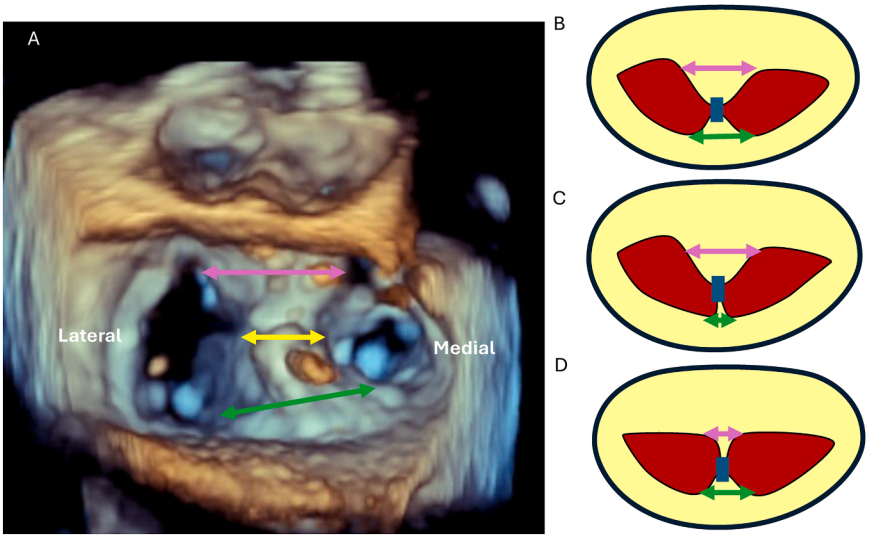

Figure 20 Assessment of tissue bridge. Tissue bridge between anterior and posterior mitral leaflets. The base of the bridge on the anterior leaflet (purple arrow) and posterior leaflet (green arrow) should be approximately twice as wide as the narrowest position at the transcatheter edge-to-edge repair device (**A**; yellow arrow). Adequate anterior and posterior tissue bridge width as in **(B)**. Adequate anterior with deficient posterior tissue bridge width as in **(C)**. Deficient anterior with adequate posterior tissue bridge width as in **(D)**.

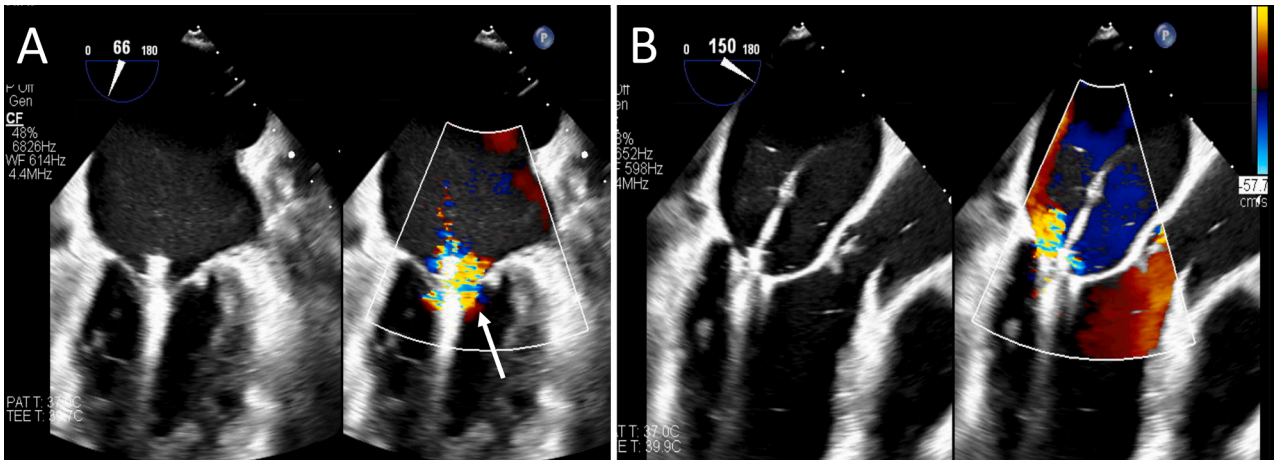

Figure 21 Residual MR assessment can be performed with 3D MPR, but a useful tool is still 2D with color Doppler and biplane imaging using the bicommissural view **(A)**, which produces the orthogonal long-axis image **(B)**, permitting localization of the residual jets. In this example, the larger of the two jets is lateral to the TEER device (*arrow*). The team should then decide if the TEER device needs to be repositioned slightly laterally if the residual MR is significant.

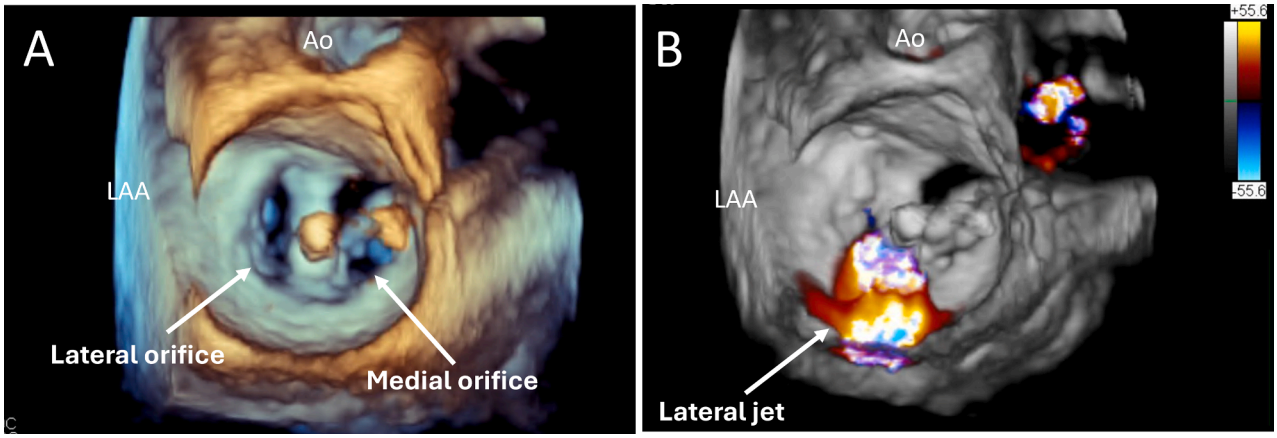

Figure 22 Three-dimensional en face view for assessment of residual MR. The 3D en face view helps identify not only the tissue bridge but also the medial and lateral orifice **(A)**. After confirmation with 2D and color Doppler, 3D with color Doppler is used to assess the location of the residual jet **(B)**. In this example, the large residual jet is noted on the lateral aspect (from the lateral orifice). *Ao*, Aorta.

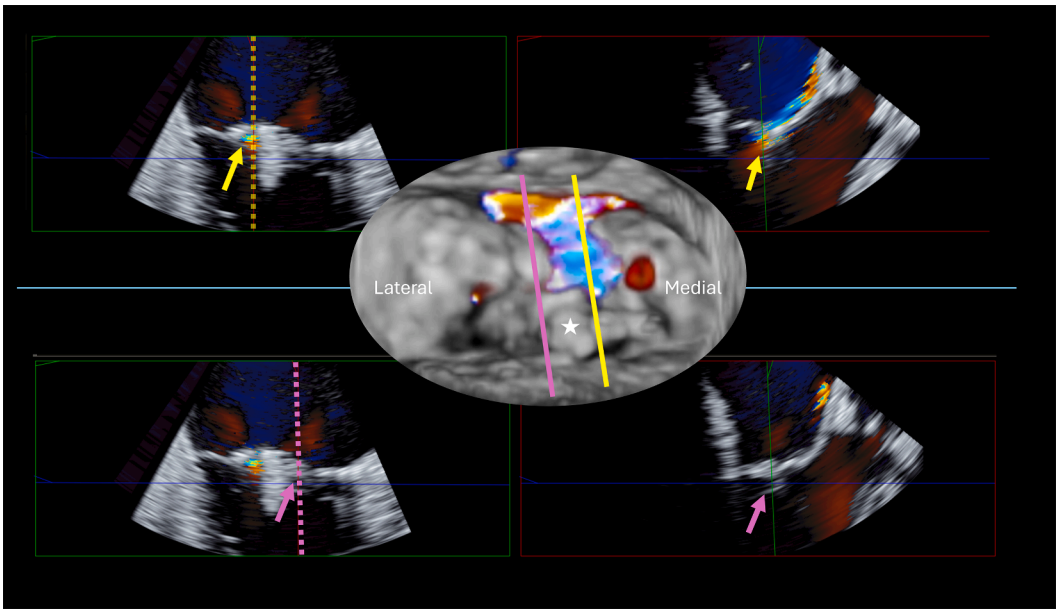

Figure 23 Three-dimensional en face color Doppler. The figure shows an image of the MV with a TEER device *(white star, central panel)*. A long-axis view plane lateral to the device *(purple line)* shows no regurgitation in that area *(lower panels, purple arrow)*. The long-axis plane is then moved medially (in this case) to intersect the jet *(yellow line)*. This generates a long-axis view of the jet *(upper right panel)* with the proximal isovelocity surface area visible *(yellow arrows)*.

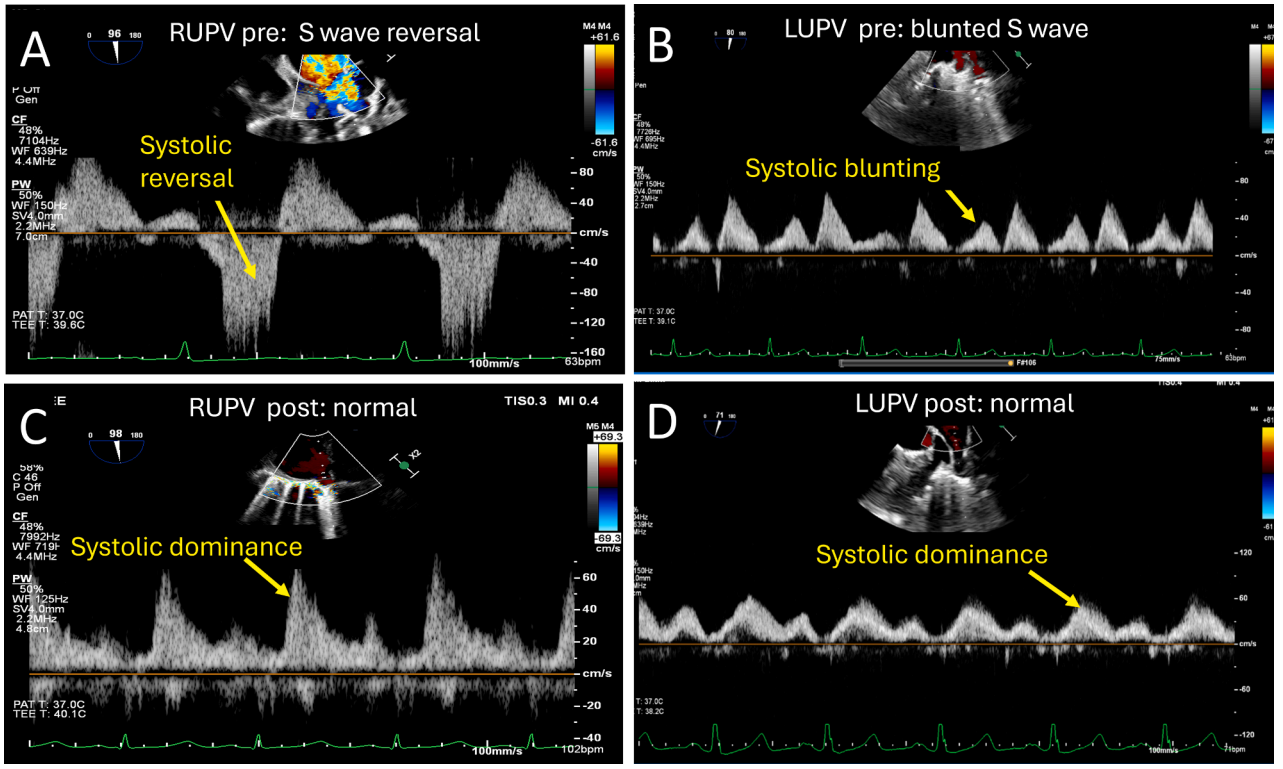

Figure 24 Pulsed-wave Doppler pattern of pulmonary veins. Right upper pulmonary vein (RUPV) and left upper pulmonary vein (LUPV) before mitral clip deployment. Patient with severe eccentric MR directed anteriorly resulting in systolic S-wave reversal in the RUPV **(A)** and blunted S wave in the LUPV **(B)**. After successful deployment, both pulmonary vein flows show systolic flow dominance **(C** and **D)**.

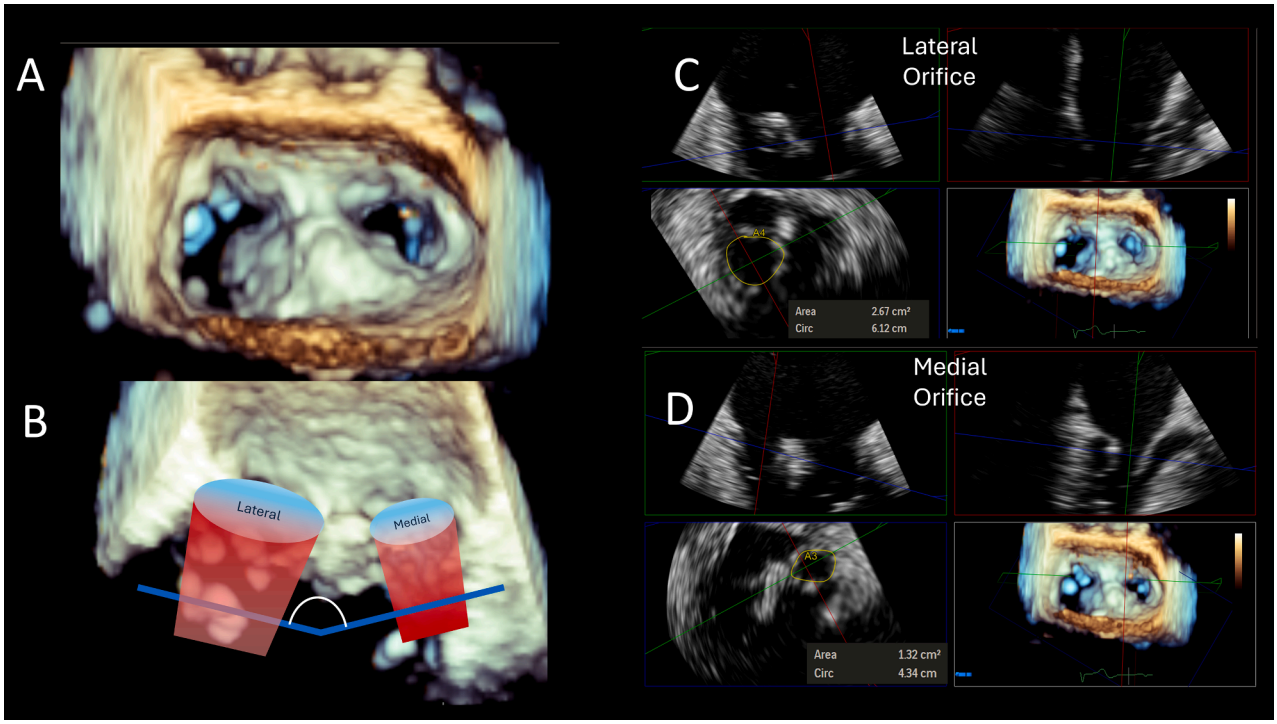

Figure 25 Three-dimensional en face image of the MV. The image is frozen in peak diastole to demonstrate the medial and lateral orifices **(A)**. The functional inflows through these two orifices are not parallel **(B)**. The MPR SAX plane for each are the two orifices that should be set individually, usually with an obtuse angle of approximately 160°. Individual planimetry of the lateral **(C)** and medial orifices is then performed using the orthogonal SAX multiplanar view **(D)**. The total effective orifice area is the summation of all measured individual orifice areas. *Circ*, Circumference.

to the jet direction. It should be noted that if this technique is used incorrectly, it can lead to large errors and overestimation of the vena contracta area.

Key Points

- Leaflet grasp is performed under 3D MPR, single plane long-axis 2D imaging, or 2D biplane imaging from the bicommissural view.
- Orientation of the optimal plane for leaflet grasp is dependent on the grasp location.
- It is important to identify an adequate leaflet grasp and tissue bridge and rule out device rotation.
- Three-dimensional and 2D color Doppler are used to assess residual MR jets and their location.
- Residual orifice area should be assessed if more than one device needs to be deployed.

EVALUATION OF DEVICE PERFORMANCE BEFORE DEVICE DEPLOYMENT

Before release, assessment of residual MR and degree of mitral stenosis is performed. Currently, there are no specific guidelines for the evaluation of MR severity following the deployment of an M-TEER device. As such, the quantification of residual MR is performed using the same integrative methodology as is recommended for all forms of native MR.[11] At each step, comparison with baseline is imperative, as reduction in MR severity is the goal of M-TEER. Loading conditions and instrument settings should be the same as at baseline. Interrogation should be conducted during periods of hemodynamic stability. Invasive monitoring may help decipher the degree of MR reduction. Decreases in left atrial pressure and/or resolution of a "v" wave are helpful to confirm reduction in MR severity. Additionally, an increase in forward stroke volume, because of a decrease in MR, may increase blood pressure. Conversely, MR reduction, leading to a significant increase in afterload, may initially decrease left ventricular ejection fraction.[21]

Color Doppler

Color Doppler is the first-line method and mainstay modality to assess MR severity after leaflet grasp. The site, number, and eccentricity of jets are interrogated by 2D and 3D imaging modalities. Sweeping through the bicommissural view with biplane imaging can elucidate and pinpoint any residual MR. The 3D vena contracta area of both orifices can be measured and summed. Prominent proximal flow convergence provides rudimentary information, but proximal isovelocity surface area measurements for effective regurgitant orifice area calculation are not accurate nor recommended as valve geometry is variable after M-TEER.

Continuous-Wave Doppler

Before device release, evaluation of the transmitral gradient with continuous-wave (CW) Doppler is essential. Diastolic mean gradients through either orifice should be similar, although the orifice areas may differ. Discretion should be used in interpretation of gradients alone, as residual MR contributes to Doppler-acquired gradients.

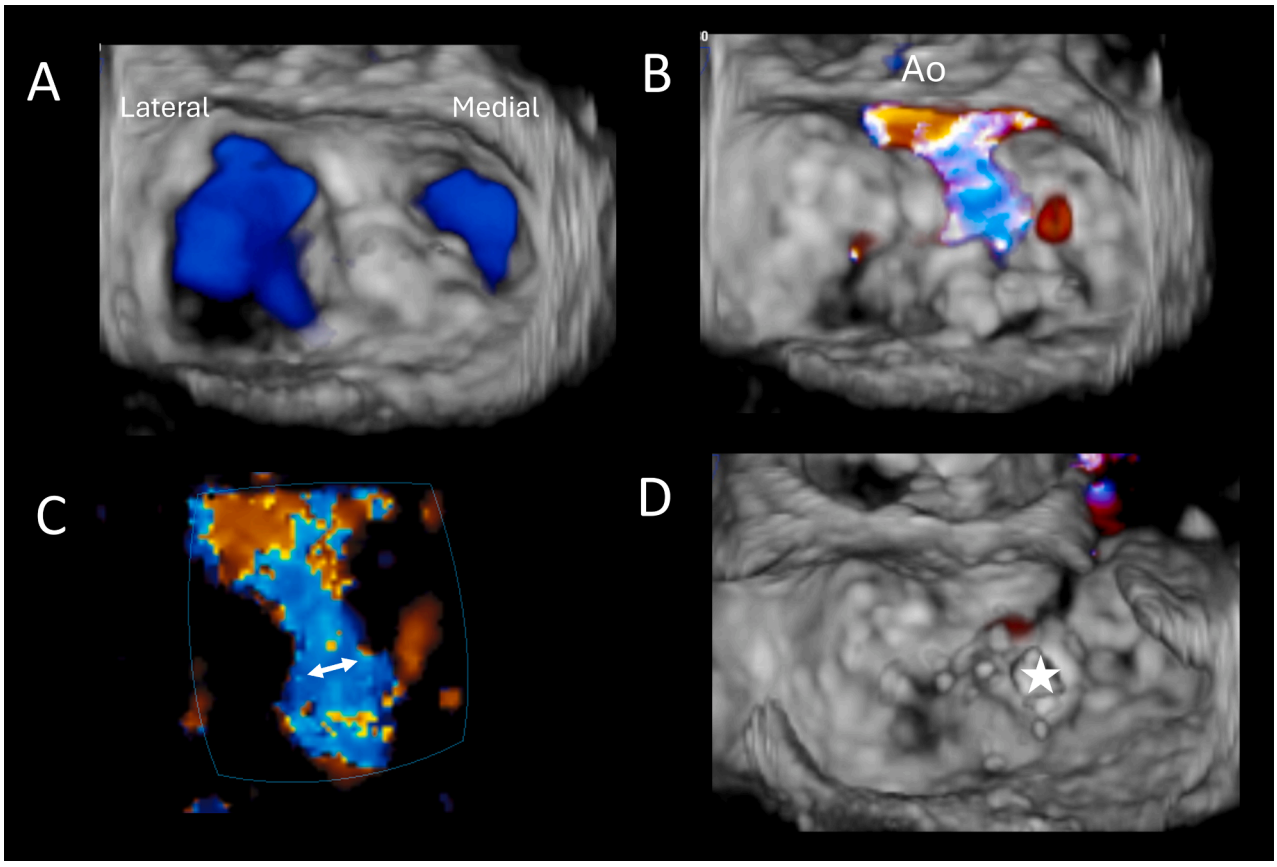

Figure 26 Three-dimensional en face color Doppler imaging from the surgeon's view. The image is frozen in diastole. The case shown has the device slightly medial to the midline, and the blue forward flow clearly demonstrates a slightly larger lateral orifice and smaller medial inflow **(A)**. Three-dimensional en face color Doppler imaging from the surgeon's view, frozen in systole. The image demonstrates an anteriorly directed moderate jet of residual regurgitation, reaching the anterior left atrial wall, near the aortic root (Ao) **(B)**. While frozen, it is useful to tilt and swivel the image block, looking at the jet from above (as shown), from the side, and from the left ventricular aspect. The latter will often demonstrate a proximal isovelocity surface area dome, helping localize the origin of the jet. Toggling the "hide grayscale" button will allow the jet(s) to be seen without obscuration by anatomic structures, with direct visualization of the vena contracta *(white arrow)*, which can be measured by MPR tools **(C)**. In this case, a second device *(white star)* was deployed to eliminate the residual jet **(D)**.

Pulsed-Wave Doppler

Pulsed-wave Doppler is used to assess pulmonary vein flow pattern: if systolic flow reversals were noted at baseline, after successful M-TEER, one should note their absence (Figure 24). Stroke volume can also be assessed by pulsed-wave Doppler of the left ventricular outflow tract to ensure that an increase is noted after successful M-TEER (under similar hemodynamic loading conditions).

Orifice Area Assessment

Orifice areas can be measured via 3D MPR (Figure 25). In most cases, there are two inlet orifices, though depending on anatomy, there can be one, two, or three effective inflow areas. It is important to note that the anatomic effective orifices are not necessarily parallel. Indeed, in most cases, planimetry should be performed on each orifice individually, with the perpendicular plane being adjusted for each set. The total effective orifice area is the summation of the individually measured values. In general, a residual gradient <5 mm Hg and a residual MVA ≥ 2.0 cm^2 are preferred. MVA assessment by pressure half-time is not recommended. A patient's age and functional status may influence decisions regarding an acceptable final MV diastolic gradient.

Before release of any device, the balance of reduction of MR vs change or increase in gradient must be evaluated. If the balance is unfavorable, consideration should be given to moving or optimizing the grasp or position of the device before release.

Key Points

- Before device deployment, care should be taken to interrogate residual MR by color Doppler.
- It is important to assess mean mitral gradient using CW Doppler, orifice area using 3D MPR, pulmonary vein flow pattern, and stroke volume.
- A residual gradient <5 mm Hg and a residual MVA ≥ 2.0 cm^2 are ideal.
- Many conventional indices of MR assessment may be unreliable after TEER, and using a multiparametric approach for assessment of residual MR is recommended.

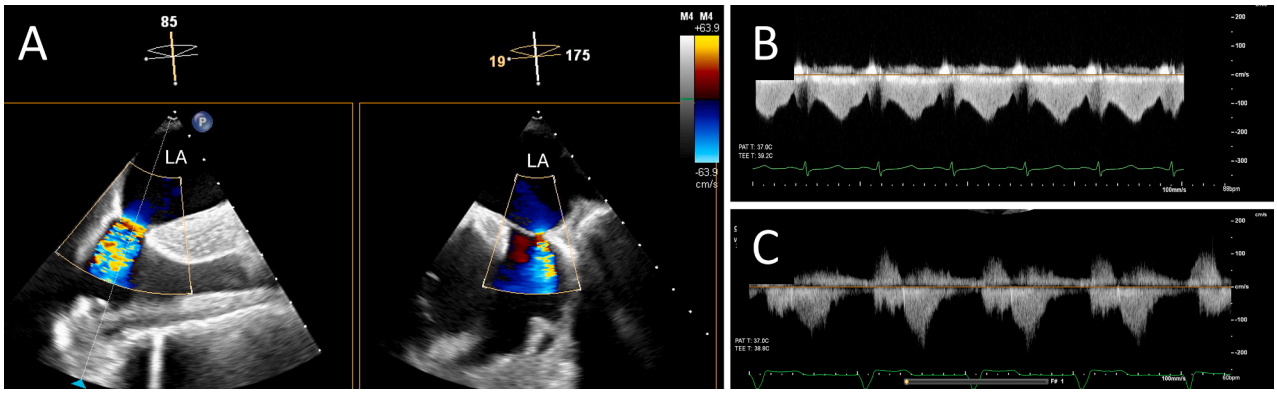

Figure 27 Assessment of septal defect flow **(A)**. Biplane depiction of an atrial septal defect (ASD) using color Doppler indicates left-to-right flow **(B)**. Spectral Doppler confirms continuous left-to-right flow **(C)**. Spectral Doppler indicates some bidirectional flow between the atria, which warrants consideration of ASD closure. *LA*, Left atrium.

Table 2 Summary of key imaging steps during M-TEER

Number	Step	Purpose of the step/imaging considerations
1	Baseline evaluation	Review severity and mechanism of MR
		Note any contraindications
		Establish device implantation strategy
2	Transseptal puncture	2D bicaval or 3D MPR is used to guide TSP
		Note adequate height of TSP relative to coaptation point of mitral leaflets
		Care should be taken to note that TSP is not directed anteriorly
3	Delivery and positioning of GC	TEE guidance is used to position approximately 2.0 cm of the GC into the LA
4	Delivery of repair device	Repair device positioning
		Gripper/clasp function
		Delivery of repair device across the MV
5	Positioning for leaflet grasp	3D MPR can be very helpful in visualization of device positioning and orientation
		3D en face imaging to align device arms/paddles orthogonal to the plane of coaptation at the planned site of grasping
6	Leaflet grasp	3D MPR, single-plane long-axis 2D imaging, or 2D biplane imaging through the bicommissural view is useful
		Identify adequate tissue bridge
		Assess residual MR jets and location of the jets
		Assess residual gradient and orifice area
7	Evaluation of device performance before device deployment; the following modalities should be used	CW Doppler for mean mitral gradient assessment
		PW Doppler for stroke volume and pulmonary vein assessment
		Color Doppler for residual MR assessment
		Residual orifice area assessment
8	Final deployment of repair device	Residual MR and mean mitral gradient should be reassessed
		Any decision about further device placement is made once this assessment has been done
9	Evaluation of iASD	2D, 3D, and color Doppler imaging are used to determine if iASD needs to be closed
		Shunt closure may be performed with large defects, bidirectional shunting, right-to-left shunt, pulmonary HTN, or severe RV dysfunction

LA, Left atrium; *PW*, pulsed wave.

FUNCTIONAL EVALUATION AFTER DEVICE DEPLOYMENT

With the deployment of the edge-to-edge device and release of catheter tension, the TEER device may undergo some reorientation within the coaptation zone. It is common for the device to descend 1 to 2 mm toward the left ventricle. Axial rotation of the device also may occur, as stored rotational torque is removed. Thus, the anatomic configuration and functional status must then be reassessed. In the initial seconds after release, stability and mobility are assessed in biplane or MPR imaging. Postrelease imaging aims to assess the adequacy of leaflet insertion, robustness of the tissue bridge, capture of all pathologic segments of both leaflets, effective office area, forward gradient, and, most important, residual regurgitation (Figure 26).

After the deployment of any M-TEER device, there is a decision about the requirement for an additional device, considering the trade-off between reduction in MR volume and potential increase in transmitral diastolic pressure gradient. Decisions regarding deployment of an additional device are guided by goals of achieving minimal residual regurgitation (mild or less) with acceptably low gradients (<5 mm Hg in most cases).

Key Points

- Decisions regarding deployment of an additional device are guided by goals of achieving minimal residual regurgitation with acceptably low gradients.

Evaluation of Iatrogenic Atrial Septal Defect

Iatrogenic atrial septal defects (iASDs) may resolve over time, but at 6 months persistent postprocedural iASDs are common: 27% when imaged with transthoracic echocardiography and nearly 50% with TEE imaging.[22,23] Larger catheter size, longer duration of procedure, extensive sheath movement, high left atrial pressure, and left ventricular hypertrophy have been suggested as predictive factors for this higher rate.[24]

Routine closure of iASDs is not recommended, because (1) many iASDs resolve with time, (2) a septal closure device may complicate subsequent procedures requiring a TSP, and (3) supporting evidence is unclear. Indications for immediate atrial septal defect closure at the time of M-TEER may include (1) right-to-left shunt, (2) bidirectional shunt, (3) pulmonary hypertension, and (4) new right ventricular dysfunction and/or severe tricuspid regurgitation. The size and shape of an iASD may also play a part in closure consideration. Eccentric, as opposed to round, defects are more likely to close spontaneously.[25] Generally, defects that are >1.0 cm are closed, although this should be considered on a case-by-case basis.

Evaluation of M-TEER-Associated iASDs.

Initial 2D evaluation of an iASD can be completed via the ME four-chamber view (slightly rotated to the right), the ME AV SAX view, and the ME bicaval view. Color Doppler is added to evaluate flow direction and relative size of the lesion. CW Doppler is added to confirm flow direction and to measure velocity-time integral, needed for shunt volume calculations. The ME bicaval view offers coaxial alignment for CW Doppler, but other views can be used. Simultaneous orthogonal views add additional perspective (Figure 27).

Three-dimensional acquisition of the interatrial septum can be rendered via narrow angle, zoomed, or wide-angle gated acquisition data sets. Non-MPR 3D evaluation of the interatrial septum provides rudimentary information on the iASD. Color Doppler adds information on shunt direction and location of the defect. iASDs may change in size throughout the cardiac cycle; images should be reviewed in systole and diastole. MPR is necessary for accurate measurements of iASD size and shape.

CONCLUSIONS

Intraprocedural imaging is essential to the safety, precision, and overall success of M-TEER procedures. By standardizing imaging steps, these recommendations aim to reduce procedural variability across the multitude of centers involved in this procedure.

This guideline provides a unified step-by-step framework for the effective use of 2D, biplane, 3D, and MPR imaging to ensure procedural success. Table 2 summarizes the key imaging steps during M-TEER. As M-TEER technology and clinical experience continue to evolve, consistent imaging practice and standardization will remain central to optimizing results.

NOTICE AND DISCLAIMER

REVIEWERS

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.echo.2026.03.003.

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