Periprocedural Echocardiographic Guidance of Transcatheter Mitral Valve Edge-to-Edge Repair Using the MitraClip

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KEYWORDS

• Mitral regurgitation • Echocardiography • Heart failure

KEY POINTS

- Transcatheter mitral valve repair using edge-to-edge clip has been established as an alternative to open surgical repair in primary and secondary mitral valve diseases.
- Optimal periprocedural imaging using transesophageal echocardiography is critical to determine procedural candidacy and ensure safe and successful implantation.
- Multiplanar reconstruction can be used to display all key mitral views, including the long axis, bi-commissural, short axis, and 3-dimensional en face views.
- The use of this technique with and without color Doppler allows determination of MR mechanism and origin with precision.
- For optimal periprocedural imaging guidance, we recommend a detailed echocardiographic approach using the 7 steps outlined in this review article.

INTRODUCTION

In individuals with significantly increased surgical risk, a reduction of mitral regurgitation (MR) severity can be accomplished percutaneously by approximation of the anterior and posterior mitral leaflets, with transcatheter edge-to-edge mitral valve (MV) repair. The procedure is a percutaneous adaptation to the surgically performed Alfieri stitch and results in a double orifice valve (∞). Although the initial application of MitraClip was limited to patients with predominantly central MR and degenerative disease, recent clinical trials in addition to improved technical experience and advancements in 3-dimensional (3D) echocardiography has allowed successful application to those with noncentral MR and secondary valve disease.[1]

Optimal periprocedural imaging using transesophageal echocardiography (TEE) is critical to determine procedural candidacy and ensure safe and successful implantation. In this review, we present a step by step overview of echocardiographic imaging for transcatheter MV edge-to-edge repair using the MitraClip device.

MITRAL VALVE ANATOMY

A comprehensive appreciation of MV anatomy and surrounding structures is important to facilitate optimal imaging guidance for transcatheter edge-to-edge MV repair. A detailed discussion of this

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is beyond the scope of this review and has been covered elsewhere.[2]

In brief, the MV complex comprises the mitral annulus, anterior and posterior leaflets, chordae tendinea, and papillary muscles (Fig. 1). The annulus marking the hinge line of the valvular leaflets is D shaped rather than circular.[3] The aortic valve is in fibrous continuity with the anterior leaflet of the MV. The annulus opposite the area of valvar fibrous continuity lacks a well-formed fibrous cord and tends to be weaker and hence more significantly affected in annular dilation.

OVERVIEW OF DEVICES AND PROCEDURE

The MitraClip device (Abbott Vascular, Menlo Park, CA) is a clip made of 2 polyester-covered arms roughly 8 mm long and 4 mm wide that functions to grasp both the anterior and posterior MV leaflets (Fig. 2). The clip is delivered by means of a 24F steerable catheter and triaxial delivery system via a femoral venous and transseptal approach to reach the systemic side and thus the MV.

The MitraClip NT_R and XT_R systems were introduced in 2018 and are an updated version of the previous versions of MitraClip (MitraClip and MitraClip NT). The XT_R device has 3 mm longer arms (with 2 extra rows of frictional elements), that expand the reach of the device by 5 mm compared with the MitraClip NT_R device. In general, the NT_R system is favored in patients with short, restricted leaflets (functional MR) or if there is concern for smaller MV area (MVA). The XT_R device, is favored with degenerative MR with longer leaflet lengths, larger, wider flail width, and gaps. Indications and contraindications have previously been discussed elsewhere.[2,4]

MitraClip implantation is performed under general anesthesia owing to the need for a controlled environment that allows real-time and often prolonged TEE guidance. In addition, controlled breath holds can then be performed to maximize stability during leaflet grasping, a sensitive step of the procedure. In brief, after gaining transfemoral venous access, transseptal puncture (TSP) is performed to allow the MitraClip device to access the left atrium, where it is aligned with the mitral pathology, and then advanced into the left ventricle. The MitraClip system is then withdrawn toward the MV with the clip arms open and approximated to both the anterior and posterior leaflets. The grippers are then lowered to trap the leaflets between the grippers and the arms. Finally, the arms are then closed to oppose the anterior and posterior leaflets. If necessary, the device can be reopened for adjustment before device release and final deployment. Detailed echocardiographic evaluation is divided into 7 main steps which is covered step by step elsewhere in this article.

Procedural Guidance

Step 1: preprocedure evaluation

After the initiation of general anesthesia, TEE should be performed to complete a quick preprocedural checklist (Table 1). The first step is to

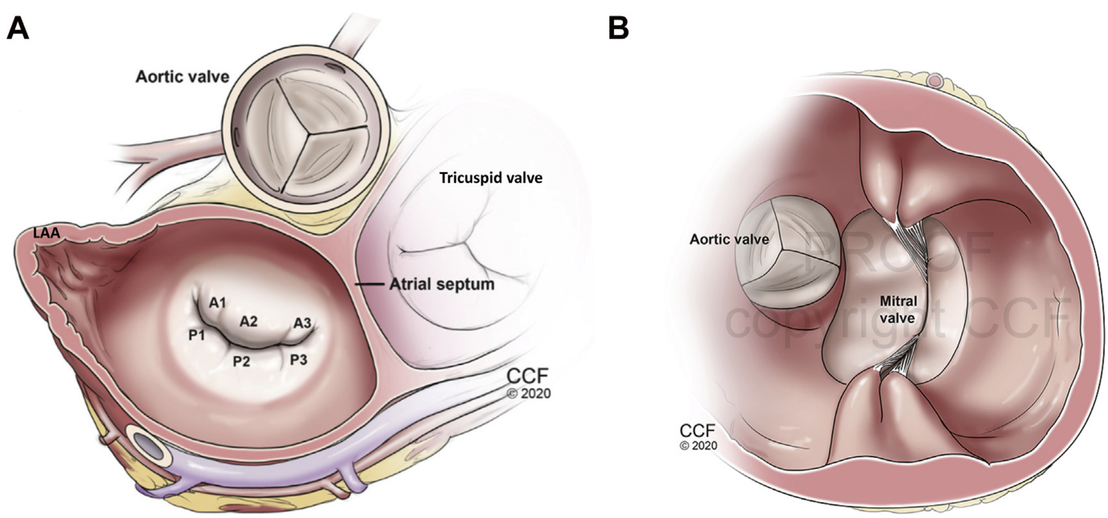

Fig. 1. MV anatomy. The MV as seen from the left atrial (*A*) and left ventricular (*B*) perspectives. The MV is composed of 2 leaflets, anterior and posterior, each of which is divided into 3 scallops, A1, A2, A3 and P1, P2, P3, as depicted. LAA, left atrial appendage. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2020. All Rights Reserved.)

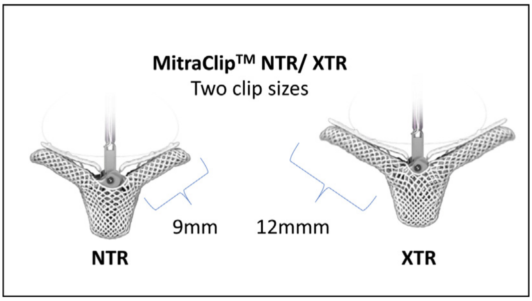

Fig. 2. MitraClip devices. The MitraClip NT_R and XT_R systems introduced in 2018 comes in 2 sizes. The MitraClip XT_R device has 3 mm longer arms that expand the reach of the device by 5 mm over that of the MitraClip NT_R device. (Images courtesy of Abbott Vascular, Menlo Park, CA.)

confirm MR mechanism and origin to ensure there are no significant changes compared with prior imaging that would alter the plan for device placement. The pulmonary veins should be assessed to evaluate for flow reversal. Mitral stenosis should be assessed with the MVA and mean gradient. A MVA of less than 4.0 cm^2 is considered a relative contraindication to the procedure because deployment of the MitraClip may potentially result in significant stenosis.[4] Detailed indications and relative contraindications have been previously published and is beyond the scope of this review.[4] Preprocedure imaging should also establish baseline ventricular function, exclude intracardiac thrombus, and determine the presence of baseline pericardial effusion. The imager should also optimize and become familiar with key echocardiographic views to facilitate swift intraprocedural imaging. The key views include the bicaval, aortic valve short axis, bicommissural, long axis, and 3D views. An on-axis bicommissural view is crucial to understand the medial–lateral origin of the MR jet, and biplane imaging allows simultaneous visualization of a long axis view to understand anterior and posterior leaflet anatomy and MR mechanism (Fig. 3A, B). A 3D en face view provides visualization of overall mitral anatomy, and pathology such as prolapse or flail (Fig. 3C). Multiplanar reconstruction (MPR) is a technique to simultaneously visualize multiple 2D imaging planes based on and along with a 3D dataset. The MPR planes can be aligned to display all key mitral views, including the long axis, bicommissural, short axis and 3D en face (Fig. 3D, E). The use of this technique with and without color Doppler allows a determination of the MR mechanism and origin with precision. A limitation to note when using 3D imaging is that there is some loss of spatial and temporal resolution compared with 2D imaging, and so 3D images should be used in conjunction with standard 2D views.

Table 1
Immediate preprocedural checklist to be performed after anesthesia and endotracheal tube placement, before initiation of procedural steps

	Immediate Preprocedural Checklist
1	Confirm MR severity, mechanism and origin. Become familiar with key TEE guidance views: bicommissural, long-axis, 3D en face, MPR, bicaval, AV short axis
2	Evaluate for pulmonary vein flow reversal
3	Measure MV gradient, and area using 3D planimetry
4	Rule out left atrial appendage thrombus
5	Evaluate for pericardial effusion
6	Evaluate interatrial septum for challenging anatomy

Step 2: transseptal puncture

The TSP is a critical step because the location establishes the trajectory of the device for the rest of the procedure. An optimal puncture will facilitate maneuvering of the device within the left atrium (LA) to establish an ideal alignment and trajectory with the MV (Fig. 4), whereas a suboptimal TSP can create multiple challenges that need to be overcome during the course of the procedure. The standard TEE views during TSP guidance are the bicaval view for visualization of the superior–inferior axis, the short axis aortic valve view for the anterior–posterior axis, and the 4-chamber view for measurement of TSP height (Fig. 5).

During the first step of the procedure, the catheter starts in the SVC. The interventionalist then slowly withdraws the catheter inferiorly into the right atrium to approach the interatrial septum (IAS). The primary imaging view at this point is the bicaval view to find the tip of the catheter, indicated by tenting of the IAS (see Fig. 5, arrows). The ideal TSP location is within the mid to superior portion of the fossa ovalis. Once the superior–inferior position is satisfactory, one moves to the short axis aortic valve view for anterior–posterior positioning. This maneuver can be done by changing the primary image to a short axis of the aortic valve or with the use of biplane imaging or live MPR (see Fig. 5). A posterior puncture is preferred to optimize height above the MV and the trajectory

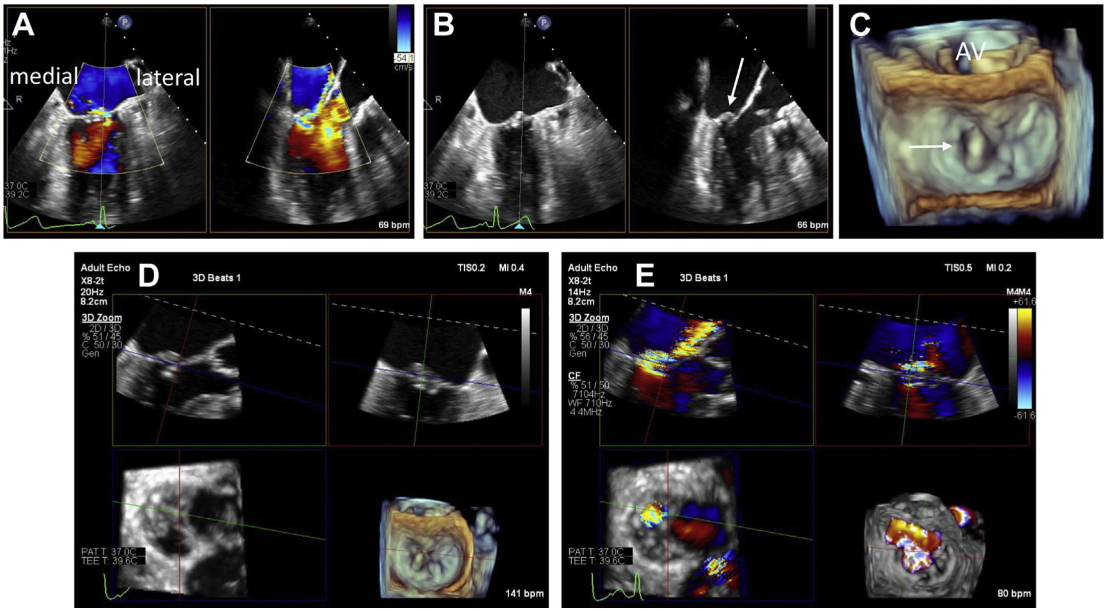

Fig. 3. Preprocedural evaluation of MR. (*A*) The MR origin is identified in the bicommissural view, which lays out the valve from medial to lateral. Biplane imaging is used to visualize the long axis view of the MR jet at this location. (*B*) Color Doppler is turned off to evaluate the underlying MV anatomy and determine the MR mechanism, in this case posterior leaflet prolapse and flail (*arrow*). (*C*) Three-dimensional en face view demonstrates P2 prolapse and flail (*arrow*). (*D*) Three-dimensional MPR shows all key views simultaneously, long axis (*upper left*), bicommissural (*upper right*), short axis (*lower left*) and 3D en face (*lower right*). (*E*) Three-dimensional MPR with color shows MR origin in all key views simultaneously (*E*).

in the LA. Last, the height is measured, as visualized at 0°, in the mid esophageal 4-chamber view (see Fig. 5B). The ideal TSP height is 4 to 5 cm above the target grasping zone of the MV.

Note that very medial pathology requires a high TSP to allow enough room for the clip delivery system (CDS) to bend back toward the septum without crossing into the left ventricle. Conversely,

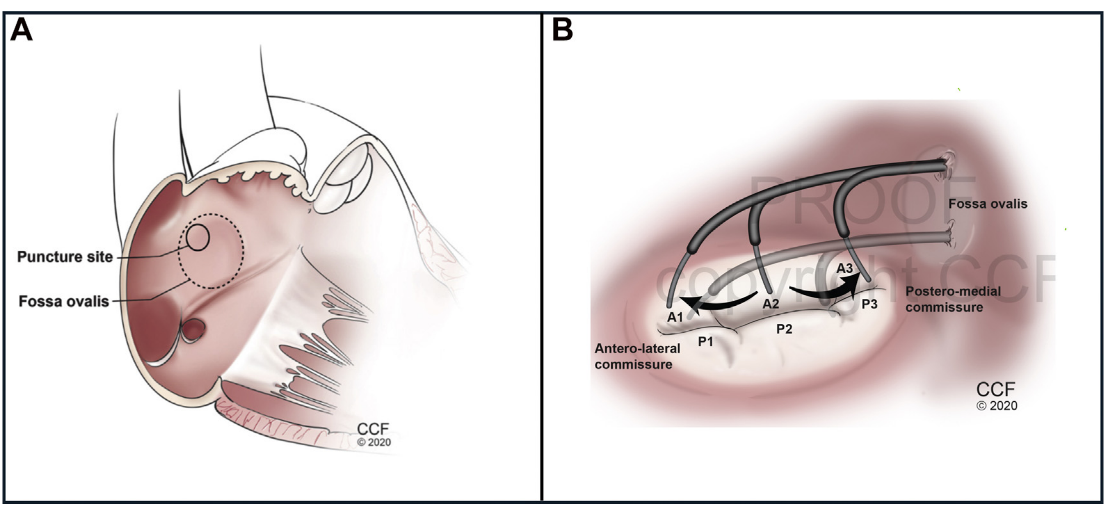

Fig. 4. Optimal TSP height showing trajectory toward the MV. (*A*) Optimal TSP within the fossa ovalis as seen from the right atrium. (*B*) Demonstration of TSP height for medial versus lateral pathology. If the TSP is too low (too close to the valve), there will not be room to adjust the device in the left atrium without crossing into the left ventricle. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2020. All Rights Reserved.)

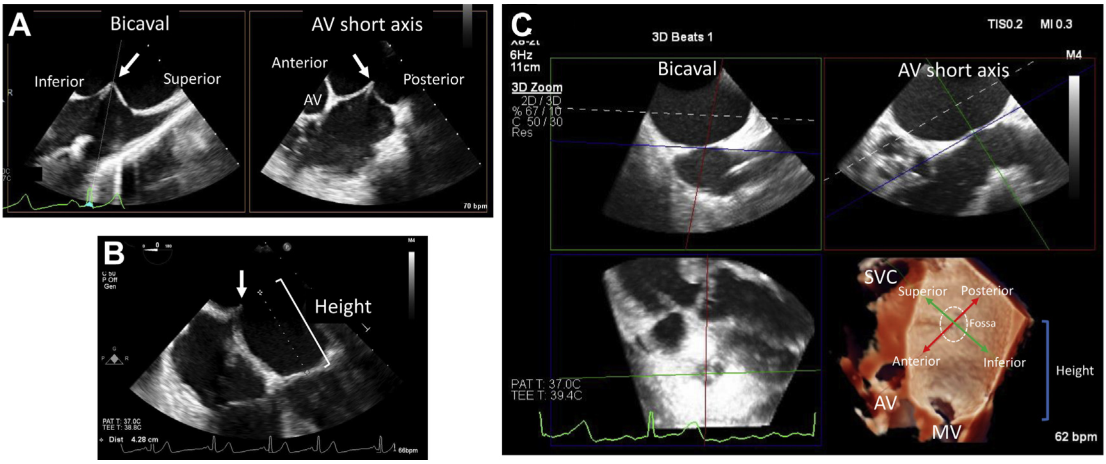

Fig. 5. Interatrial septal anatomy and guidance of the TSP. (*A*) The key views for guidance of the TSP include the bicaval view for superior–inferior axis (*left*) and the aortic valve short axis view for the anterior–posterior axis (*right*). The location of the needle is visualized by tenting of the septum (*arrows*). (*B*) The height is measured in the 4-chamber view from the tip of the mitral leaflets parallel to the septum until the level of the tenting. (*C*) Live MPR can be used to visualize all key views simultaneously. Movement along the superior–inferior and anterior–posterior axes in relationship to the MV height is demonstrated in the lower right image. Note that movement posteriorly, away from the AV, gains height above the MV. AV, aortic valve; SVC, superior vena cava.

the lateral pathology is more forgiving with regard to TSP height (see Fig. 4B).

Once the proposed TSP site is satisfactory, the needle is advanced across the IAS. In addition to visualizing the needle on the left atrial aspect of the IAS, other supportive findings of successful puncture include resolution of tenting and/or visualization of bubbles in the LA.

It is important that the TSP needle is continuously monitored to avoid inadvertent damage to adjacent structures such as the LA free wall and aortic root.

Other anatomic challenges to consider include a patent foramen ovale, atrial septal defect or aneurysm, or septal hypertrophy.[5] Crossing through a patent foramen ovale risks tearing the IAS and also may create a trajectory of the guide hugging the anterior and superior wall of the LA. In the case of a septal aneurysm or mobile septum, applying pressure with the transseptal needle may bring it dangerously close to the LA free wall. In the presence of atrial septal hypertrophy, it is important to find the thin central portion of the fossa ovalis or use of a radiofrequency needle to facilitate puncture without exerting excessive force.[6]

After successful TSP, the guidewire is advanced into the left upper pulmonary vein or curled in the LA for stability. A 24F SGC with a dilator is then advanced to the septum (Fig. 6A).[4] It is important to monitor the tip of the guide crossing the septum, indicated by a double-density sign, as opposed to the dilator, which is cone shaped with multiple ridges This step can be performed with 2D imaging

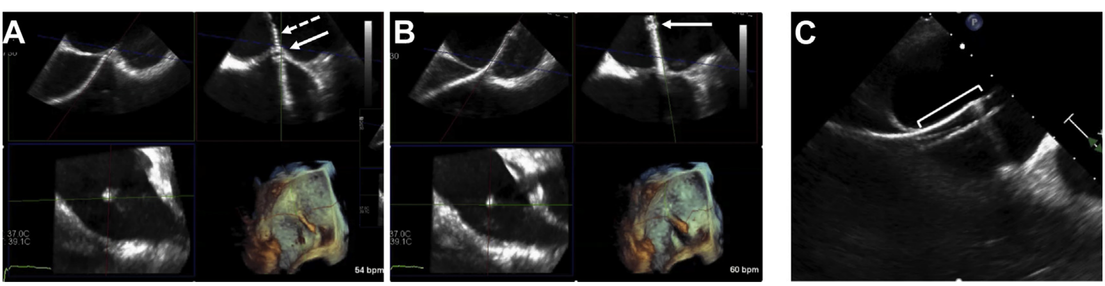

Fig. 6. Live MPR guidance of the SGC crossing the interatrial septum. (*A*) The guide tip is visualized on the right atrial side of the interatrial septum, indicated by the double density sign (*arrows*) along with tenting of the septum. The dilator is cone shaped with ridges (*dashed arrow*). (*B*) The guide tip has crossed into the LA with resolution of tenting. (*C*) The length of guide across the septum is measured.

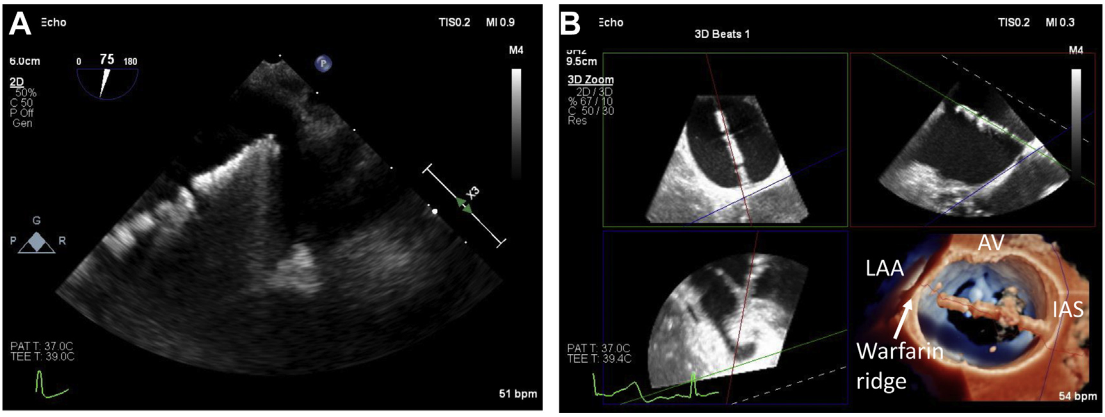

Fig. 7. Guiding the CDS within the LA. The clip must be continuously monitored to avoid injury to adjacent structures, specifically the roof of the LA, the warfarin ridge and the left atrial appendage. (*A*) 2D guidance keeping the tip of the clip in view to avoid injury to the LA free wall. (*B*) Live MPR guidance showing the CDS and key LA structures. AV, aortic valve; LAA, left atrial appendage.

from the bicaval view or with live MPR (see Fig. 6A) When the guide has crossed the septum, the tenting disappears, and the double-density will be visualized clearly within the LA (Fig. 6B). It is important to lay out the length of the guide from the tip to the septum and at minimum the catheter should be advanced approximately 2 to 3 cm into the LA. This positioning should be monitored consistently throughout the procedure to prevent inadvertent retraction into the right atrium (Fig. 6C).

Step 3: advance the clip delivery system into the left atrium

The CDS is then advanced out of the guide until straddling (as seen on fluoroscopy), at which point

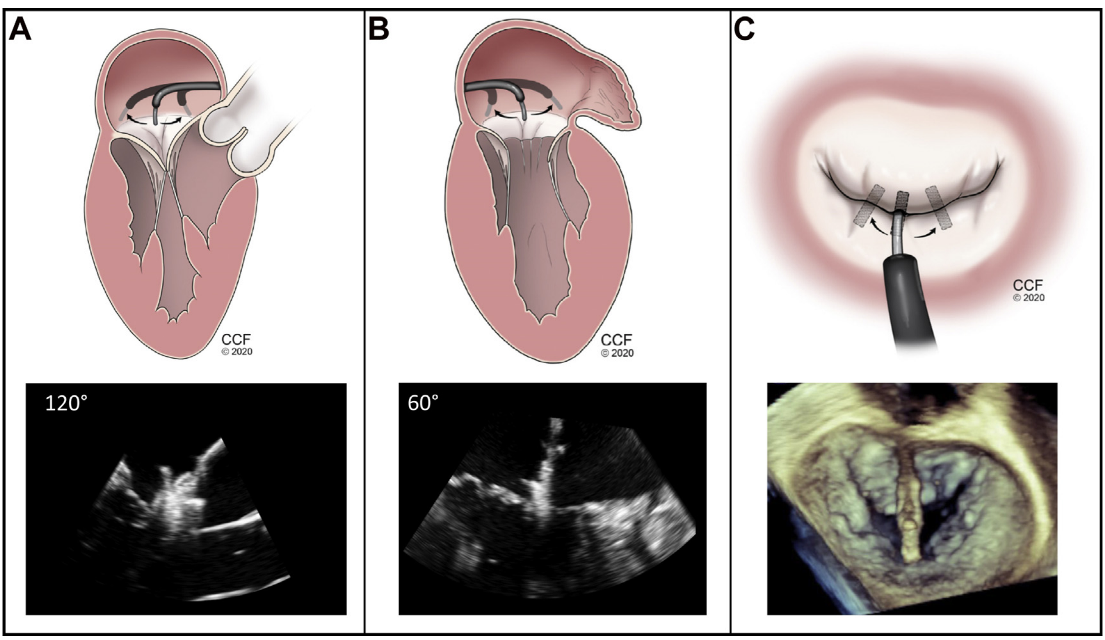

Fig. 8. Alignment of the CDS within the LA. (*A*) The long axis view is used for anterior-posterior adjustment, with anterior toward the AV and posterior away. (*B*) The bicommissural view is used for medial-lateral adjustment until the CDS is located above the target grasping zone. (*C*) The 3D *en face* view is used to adjust clip orientation with rotation of the clip clockwise or counterclockwise until perpendicular to leaflet coaptation. If the target is lateral, the clip typically needs clockwise rotation. Conversely, if the target is medial, the clip typically needs counterclockwise rotation. LA, left atrium. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2020. All Rights Reserved.)

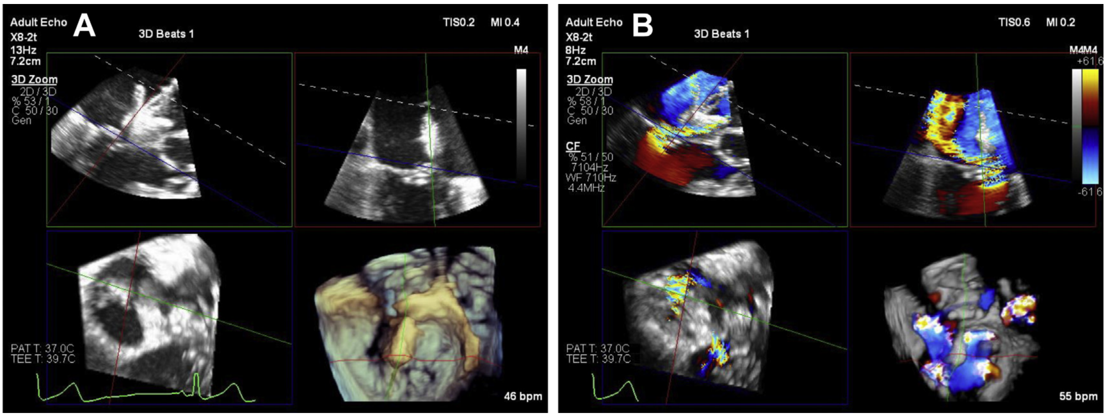

Fig. 9. Positioning and alignment of the clip in the LA using MPR. (*A*) Live MPR is used to simultaneously visualize all key views for alignment of the CDS in the LA: long axis view (*upper left*), bicommissural view (*upper right*), short axis view (*lower left*) and 3D *en face* lower right. The green plane is aligned with the clip arms in the short axis and 3D views to display the arms in the open position. (*B*) Once standard views are obtained and clip is aligned to target, color Doppler is added to confirm that the clip is aimed at the MR jet. LA, left atrium.

it can be steered down toward the MV. It is important to image the distal end of the CDS as it exits the SGC into the LA to avoid contact with the roof of the LA. Once the CDS is advanced sufficiently out of the guide, the clip is continuously tracked as it is steered down toward the MV. During this maneuver, the clip, LA appendage, and the warfarin ridge need to be visualized to ensure the clip does not catch the warfarin ridge or the left atrial appendage (Fig. 7A). Real-time 3D echocardiography can be useful to visualize the aforementioned structures in a single view (Fig. 7B).

Step 4: adjust the clip position and orientation

Once the CDS is advanced toward the MV, the next step is to position and orient the clip in the LA (Fig. 8). Manipulation within the left ventricle (LV) is minimized to prevent injury to the subvalvular apparatus. The key views for position the clip in

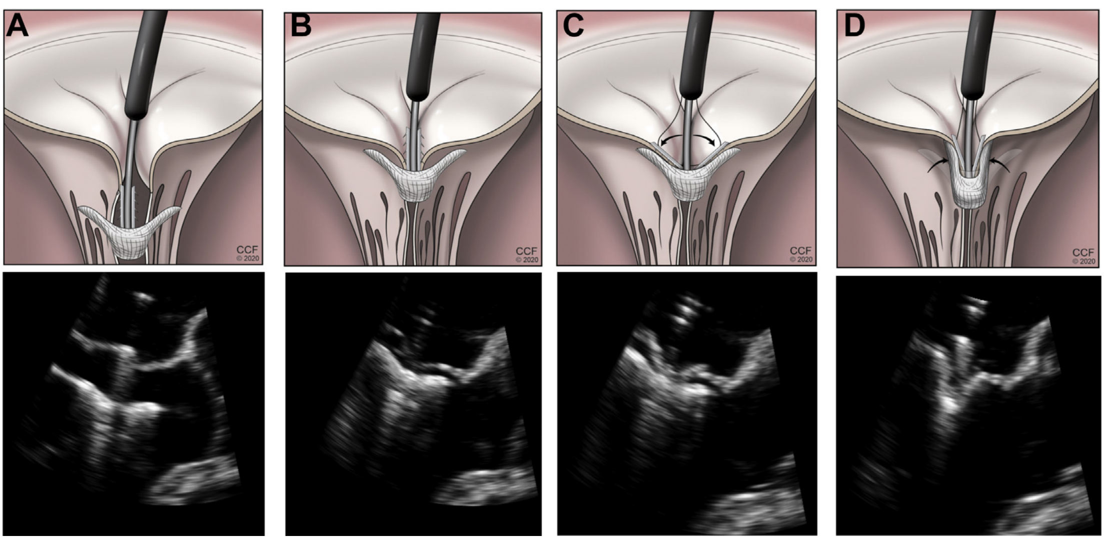

Fig. 10. Grasping sequence. (*A*) The clip is advanced into the LV. (*B*) The clip is slowly withdrawn back toward the LA until anterior and posterior leaflets are resting above clip arms. (*C*) The grippers are lowered to trap the leaflets between the grippers and the clip arms. (*D*) The clip arms are closed to appose the anterior and posterior leaflets. LA, left atrium; LV, left ventricle. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2020. All Rights Reserved.)

the LA include the long axis view for anterior–posterior position (see Fig. 8A) and the bicommissural view for medial–lateral position (see Fig. 8B). Last, the clip orientation is visualized using a 3D en face view (see Fig. 8C) and is rotated clockwise or counterclockwise until it is perpendicular to leaflet coaptation. It is important to note that, if the clip is placed centrally, along A2 to P2, the clip orientation will be straight up and down; however, if the clip is placed medially, along A3 to P3, the clip typically requires counterclockwise rotation to remain perpendicular to the coaptation zone. Conversely, clockwise rotation is necessary when targeting lateral pathology, such as A1 to P1 (see Fig. 8C)

Biplane imaging allows simultaneously visualization of the long axis and bicommissural views. Alternatively, live 3D MPR is a powerful tool because a single 3D dataset can be used to simultaneously visualize all key views, including the long axis, bicommissural, and short axis views, along with the 3D en face view (Fig. 9A). Before advancing into the ventricle, assessment using color Doppler should be used to confirm the clip position relative to MR origin (Fig. 9B).

Step 5: advancing the clip into the left ventricle and leaflet capture

With the clips arms and both mitral leaflets visualized, the clip is advanced across the MV into the LV. At this stage, it is critical to provide high-quality long axis images of the MV showing anterior and posteriorly leaflets as well as the anterior and posterior clip arms. This process can be done using single plane imaging, biplane imaging, or live MPR. Once in the LV, the clip is then slowly withdrawn back toward the LA until both leaflets are resting just above the clip arms in systole and diastole. The grippers are then lowered and one should pay close attention to the amount of anterior and posterior leaflets inserted in between the clip arms and grippers. The clip arms are then closed

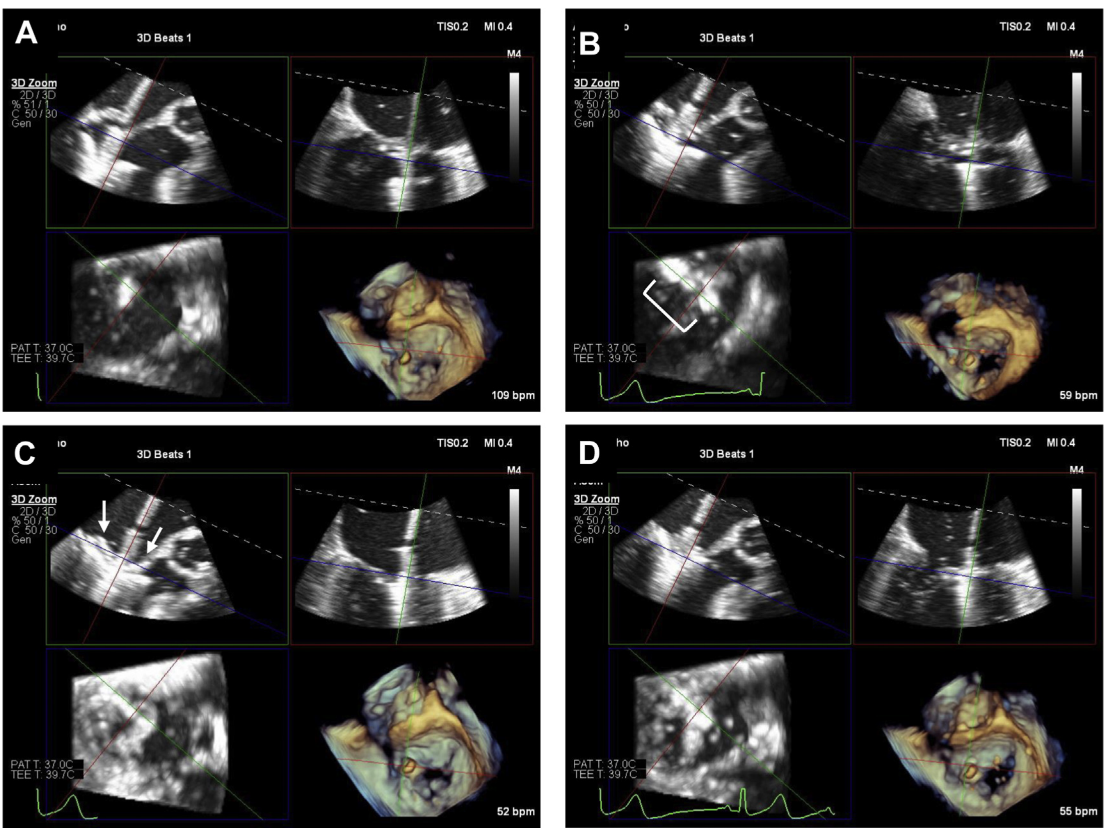

Fig. 11. Live MPR for guidance of leaflet grasping. (*A*) The green plane is aligned with the clip to show the long axis grasping view with clear visualization of both clip arms as well as anterior and posterior leaflets. (*B*) The clip is withdrawn back toward the LA until both mitral leaflets are resting on top of open clip arms. Note that within the blue plane, one can clearly visualize that the green grasping plane is aligned with the open clip arms (bracket) confirming on axis grasping views. (*C*) Grippers are lowered with leaflets inserted in between clip arms and grippers (*arrows*). (*D*) Clip is closed. Both anterior and posteriorly leaflets are immobilized.

(Fig. 10). Historically, these steps are guided using single or biplane imaging. Recently, live MPR has shown to be a powerful tool to simultaneously monitor all aspects of clip position and orientation during this crucial stage of the procedure (Fig. 11).[7]

If, during the grasping sequence, it becomes difficult to image the clip, it is important to recognize that the clip position or orientation may have changed as it crossed the valve. The bicommissural view and 3D en face views may be helpful to evaluate for any changes in device location. When using live MPR, as opposed to single plane or biplane imaging, the clip position and orientation are monitored continuously, so that if changes occur, they are recognized immediately and corrected.

If leaflet capture is challenging, there are several maneuvers that can be helpful. If there is a large flail gap in systole, prolongation of diastole with adenosine may be beneficial to bringing the leaflets closer together for grasping.[8] Conversely, if the problem is severe restriction of the leaflets in diastole, then rapid pacing to hold the leaflets closer together in the systolic phase may be helpful.[9] Breath-holding, with or without a Valsalva maneuver, may also be used to decrease the translational motion of the heart, which may in turn improve the ease of grasping.

Step 6: assessment of leaflet capture and residual mitral regurgitation

Once the leaflets are grasped, the next step is to determine if the device should be released (left in place) or repositioned. This decision is based on whether there is appropriate leaflet capture and adequate reduction in MR, while avoiding the development of mitral stenosis.

Leaflet grasp should be carefully assessed with multiple 2D and 3D views. The key 2D views are the long axis and 4-chamber views, demonstrating immobilization of both leaflets within the device (Fig. 12A, B). Another technique is to find the clip in the bicommissural view and then biplane through the device to show the long axis view in

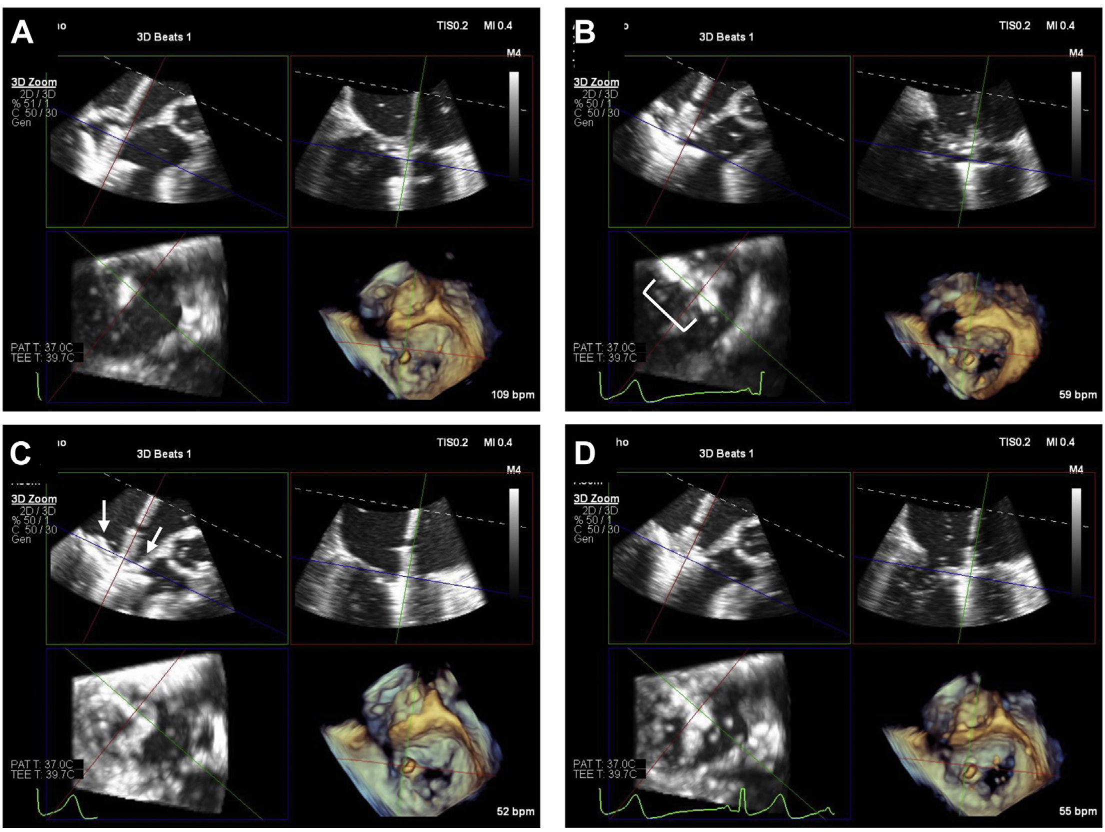

Fig. 12. Assessment of leaflet grasp. Grasp of anterior and posterior leaflets should be confirmed by demonstrating immobilization of leaflets within the device in multiple views, including (*A*) 0°, (*B*) long axis, (*C*) bicommissural view with biplane imaging, and (*D*) live MPR. Note that within the blue plane in panel B, one can clearly visualize that the green grasping plane is aligned with the open clip arms (bracket) confirming on axis grasping views. In panel C, capture and immobilization of the leaflets are demonstrated after lowering of the grippers (*arrows*).

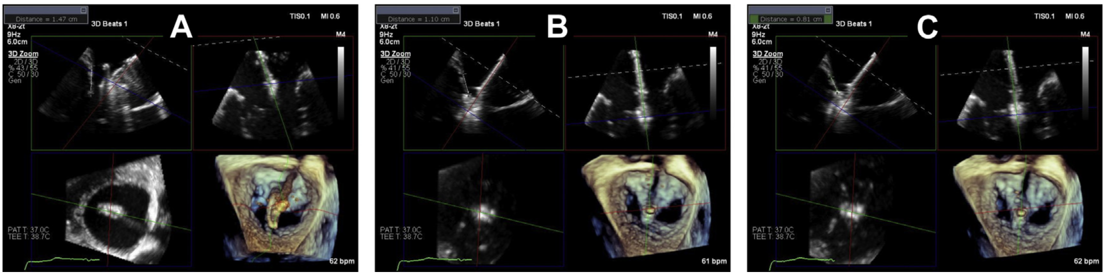

Fig. 13. Measurement of leaflet length to determine leaflet insertion. (*A*) The length of the posterior leaflet was measured before grasping, 1.5 cm. The remaining leaflet outside of the device was measured after grasping, 1.1 cm (*B*). The difference between leaflet length pre and post grasp was used to estimate the amount of leaflet inserted in the device. In this case, inadequate leaflet insertion was noted, only 4 mm. (*C*) Leaflet grasp was optimized and the posterior leaflet was remeasured, 0.8 cm, for over 0.6 cm leaflet insertion within the device.

the orthogonal plane (Fig. 12C). Again, live MPR is a particularly useful too at this juncture, given its ability to simultaneously display all the key views (Fig. 12D). Of note, a 3D en face view is helpful to show clip position and creation of a double orifice valve; however, this view alone cannot demonstrate degree of leaflet insertion. If the amount of leaflet insertion is questionable, one technique is to measure the baseline leaflet length before grasping and then compare it with the residual leaflet length outside of the clip after grasping (Fig. 13). Examples of poor leaflet capture are provided in Fig. 14. Single leaflet detachment can occur in between 1% and 5% of cases,[10,11] and so it is critical to confirm appropriate leaflet grasp before device deployment.

Residual MR is assessed using conventional methods,[12] including evaluation of proximal flow convergence and pulmonary venous flow pattern. A recent study has also demonstrated the utility of 3D vena contracta in assessing residual MR after MitraClip.[13] Invasive hemodynamics, including change in LA pressure after MitraClip placement, is also an important metric to consider.[14]

Significant residual MR (>2+) should be evaluated carefully to determine the mechanism and etiology, as well as exact location, and specifically whether the origin is medial or lateral to the device. Either a bicommissural view with biplane imaging or live MPR are the best imaging tools to answer these questions (Fig. 15). A 3D view from the ventricle to visualize the proximal isovelocity surface area (MR origin) can be particularly useful in localizing residual MR.

If the residual MR is felt to be secondary to poor leaflet capture or incorrect placement, then the clip should be removed and repositioned. If clip position and leaflet capture are felt to be adequate, but additional pathology remains, then the anatomy should be evaluated to determine the suitability for additional clip placement. One must consider 2 factors in this situation: is the residual pathology graspable and is the residual MV orifice sufficient to accommodate an additional device without development of mitral stenosis. The target mitral gradient is less than 5 mm Hg because a mean mitral gradient of more than 5 mm Hg after the MitraClip is associated with adverse long-term outcomes.[15] If the gradient is more than 5 mm Hg, one may try to slow the heart rate and reassess. In addition, 3D planimetry can be used to directly measure residual MVA. Because the 2

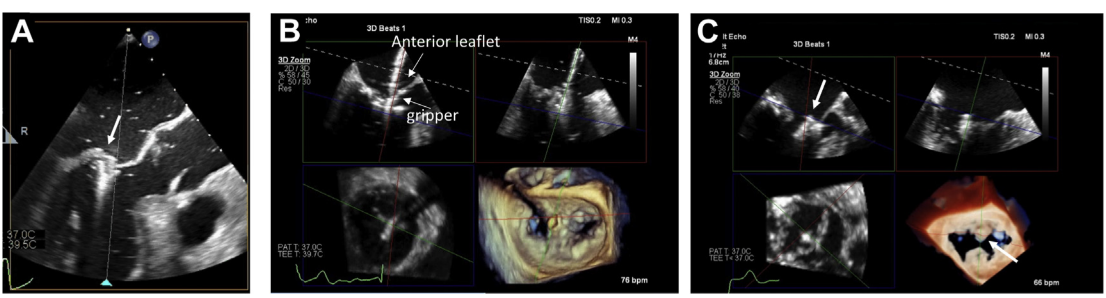

Fig. 14. Examples of poor leaflet insertion. Only tip of posterior leaflet captured (*A*, *arrow*). Anterior leaflet inserted above, not below gripper (*B*). Single leaflet detachment with clip only attached to anterior and not posterior leaflet (*C*, *arrows*).

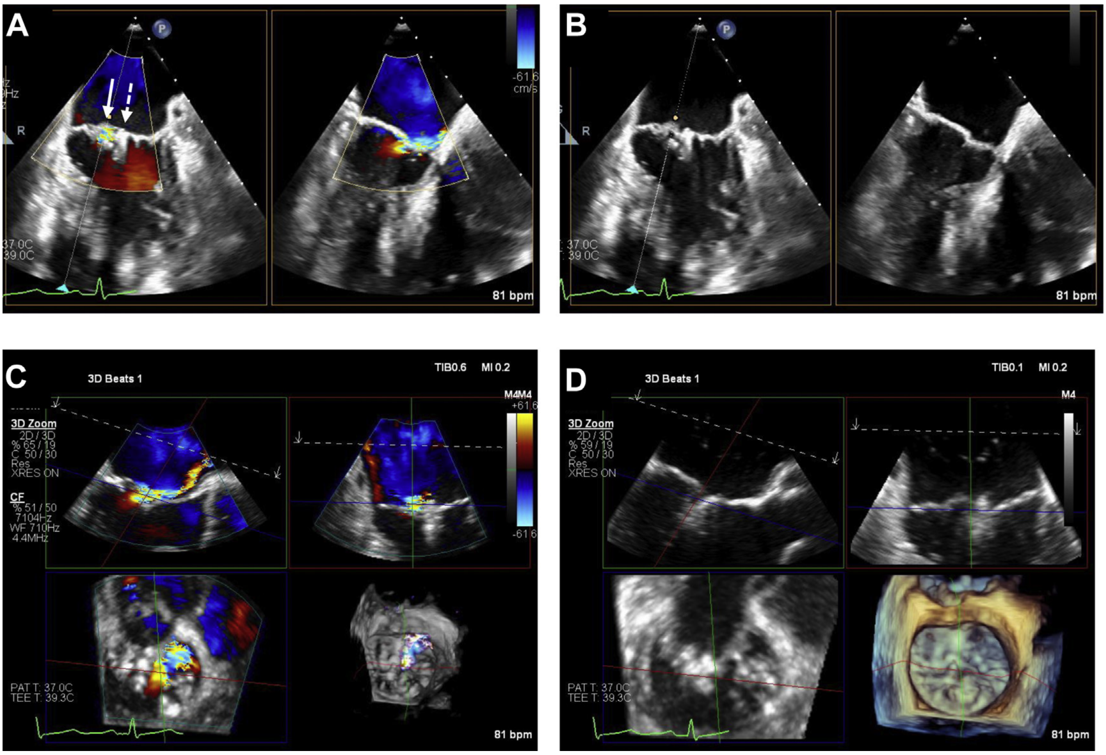

Fig. 15. Localization of residual MR and simulation of grasping view. (*A*) The bicommissural view demonstrates residual MR (*arrow*) medial to the device (*dashed arrow*). Biplane imaging shows the MR in long axis. (*B*) When color Doppler is turned off, MV anatomy can be assessed to understand mechanism of MR and suitability of anatomy for additional device. (*C*) Live MPR can be used to assess residual MR by aligning the green and red planes through the MR origin. (*D*) Color Doppler is then turned off to assess underlying leaflet anatomy at the MR origin to assess graspability at that location. Note that Live MPR shows a precise grasping view (green plane) compared with the biplane long axis view that appears off axis without clear LVOT and AV in view. AV, aortic valve; LVOT, left ventricular outflow tract.

orifices may lie in different planes, each mitral orifice should be measured independently using 3D MPR, and then the 2 areas can be added for total residual MVA (Fig. 16). To answer the question of graspability of the residual pathology, one can simulate a potential grasping view by first localizing the residual MR with color Doppler, using either biplane imaging from the bicommissural view or live MPR, and then turning color off to understand the underlying leaflet anatomy (see Fig. 15). This assessment should be performed before releasing the clip. If an additional clip is

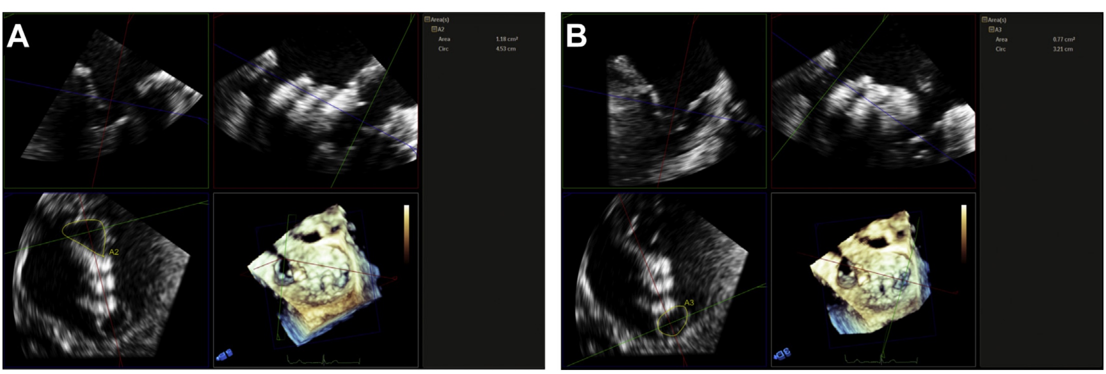

Fig. 16. Assessment of residual MVA by 3D planimetry. The (*A*) lateral and (*B*) medial orifices should be measured individually to calculate residual MVA.

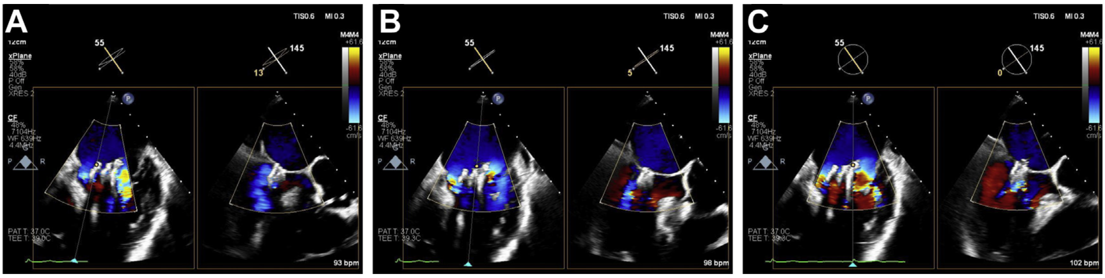

Fig. 17. Assessment of individual clips using biplane imaging. The bicommissural view was used to visualize 3 clips from medial to lateral, and then biplane imaging individually confirmed leaflet grasp of each clip. (*A*) Medial clip. (*B*) Middle clip. (*C*) Lateral clip.

not possible, then one may wish to consider adjusting the current clip for a better result.

In summary, clip placement is felt to be adequate for release if (1) good leaflet grasp at the target pathology (2) Mitral gradient and residual MVA is adequate (post clip MVA of >1.5 cm^2 with a mean transmitral gradient of <5 mm Hg), and (3) a significant decrease in MR by at least 1 grade to no more than moderate (2+) MR,[16] or if there is significant residual MR, an additional clip is anatomically feasible.

Step 7: releasing the clip and closing views

After the clip is released, the MV should be reassessed because residual MR and the mitral gradient may change after tension from the CDS is removed. The LV ejection fraction may also decrease after clip deployment given the increased afterload as a result of decreased regurgitant flow into the LA. For this reason, with each clip, both before and after, the degree of residual MR, pulmonary venous Doppler and LV function should be reassessed.

Once satisfied with the mitral result, the CDS and SGC are withdrawn across the IAS under TEE guidance.

SPECIAL CONSIDERATIONS

Placement of Additional Clips

Imaging guidance for placement of additional clips can be technically challenging because artifact from the first clip can make visualization of adjacent leaflets challenging. The additional clip is positioned and oriented in the LA, then advanced into the LV with arms closed (instead of open) to avoid disrupting the prior clip. It is important to ensure that the correct clip is being visualized during grasping and assessment of leaflet capture, because it is easy to confuse 2 adjacent clips, especially once closed. Both biplane (Fig. 17) and 3D MPR (Fig. 18) imaging are essential to allow detailed assessment of each individual clip. The sole use of single plane 2D imaging increases the possibility of evaluating the incorrect clip and missing inadequate leaflet capture.

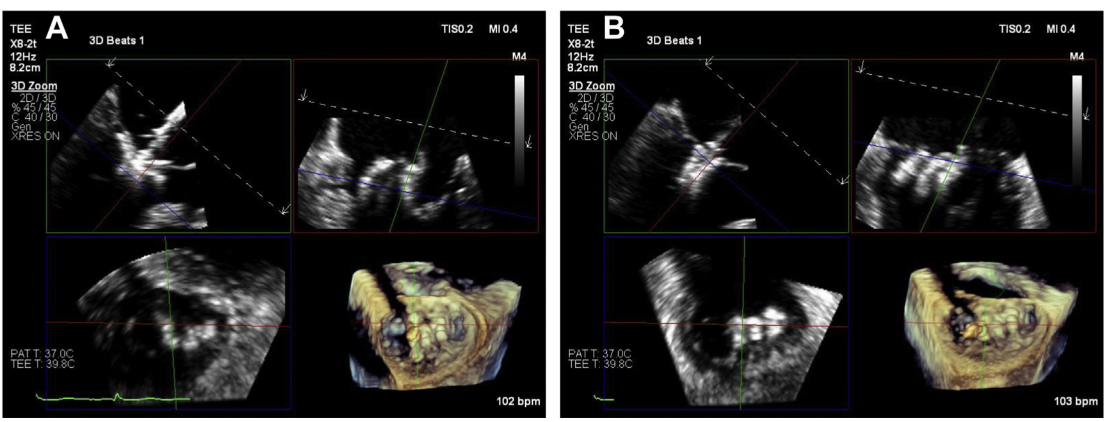

Fig. 18. Live MPR for placement of additional clips. (*A*) Live MPR was used for grasping during placement of a third MitraClip device laterally. The grasping plane (*upper left*) shows insertion of anterior and posterior leaflets within the arms and grippers. (*B*) Leaflet grasp was confirmed using Live MPR. All 3 devices are clearly seen on bicommissural (*upper right*) and short axis (*lower left*) views, with the long axis green plane (*upper left*) aligned to confirm grasp of anterior and posterior leaflets.

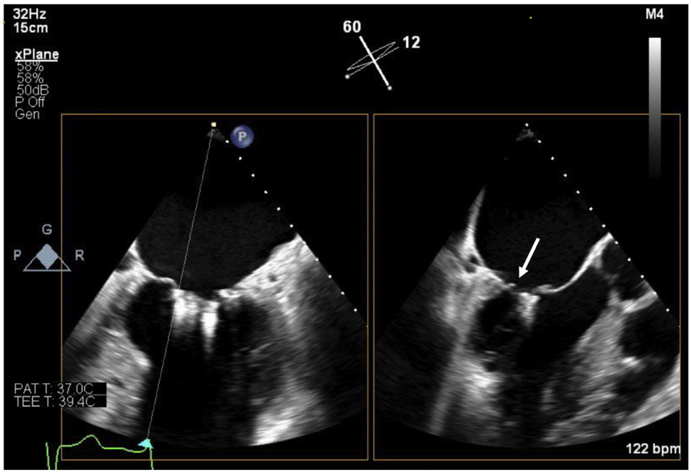

Fig. 19. Leaflet tear. Biplane imaging through the medial clip shows the grasp of this clip, which in this case demonstrates a leaflet tear (*arrow*), as indicated by the very short residual posterior leaflet with flail.

Immediate Complications

The MitraClip procedure is overall a very safe procedure; however, there are several complications of which one must be aware. There is a risk of LA injury during TSP and with the movement of the equipment in the LA. For this reason, if hypotension occurs, one should quickly evaluate for the development of pericardial effusion and tamponade. When the clip is manipulated in the LV, it is possible for injury to the subvalvular apparatus to occur, which could lead to a chordal tear. This complication should be considered if MR changes in character or severity during the procedure. Another potential etiology of worsening MR is leaflet injury, such as leaflet tear, that can occur during grasping (**Fig. 19**). If MR worsens after clip release, then it is also important to consider the possibility of single leaflet detachment, which can occur secondary to either a leaflet tear or poor leaflet insertion (see **Fig. 14**C).

At the completion of the procedure, the residual iatrogenic atrial septal defect should be evaluated for size and direction of shunt flow. A previous study of a small series of patients showed an association of large residual defect (>10 mm) with increased morbidity and mortality, so atrial septal defect closure may be considered in these patients.[17] Significant right-to-left shunting with hypoxia is another indication for closure.

DISCLOSURE

The authors have nothing to disclose.

REFERENCES

1. Stone GW, Lindenfeld J, Abraham WT, et al. Transcatheter mitral-valve repair in patients with heart failure. N Engl J Med 2018;379:2307–18.
2. Ramchand J, Harb SC, Krishnaswamy A, et al. Echocardiographic guidance of transcatheter mitral valve edge-to-edge repair. Struct Heart 2020;4:397–412.
3. Ho SY. Anatomy of the mitral valve. Heart 2002;88(Suppl 4):iv5–10.
4. Wunderlich NC, Siegel RJ. Peri-interventional echo assessment for the MitraClip procedure. Eur Heart J Cardiovasc Imaging 2013;14:935–49.
5. Ramchand J, Harb SC, Miyasaka R, et al. Imaging for percutaneous left atrial appendage closure: a contemporary review. Struct Heart 2019;3:364–82.
6. Tokuda M, Yamashita S, Matsuo S, et al. Radiofrequency needle for transseptal puncture is associated with lower incidence of thromboembolism during catheter ablation of atrial fibrillation: propensity score-matched analysis. Heart Vessels 2018;33:1238–44.
7. Harb SC, Krishnaswamy A, Kapadia SR, et al. The added value of 3D real-time multiplanar reconstruction for intraprocedural guidance of challenging MitraClip cases. JACC Cardiovasc Imaging 2020;13:1809–14.
8. Borgia F, Di Mario C, Franzen O. Adenosine-induced asystole to facilitate MitraClip placement in a patient with adverse mitral valve morphology. Heart 2011;97:864.
9. Hahn RT. Transcathether valve replacement and valve repair: review of procedures and intraprocedural echocardiographic imaging. Circ Res 2016;119:341–56.
10. Maisano F, Franzen O, Baldus S, et al. Percutaneous mitral valve interventions in the real world: early and 1-year results from the ACCESS-EU, a prospective, multicenter, nonrandomized post-approval study of the MitraClip therapy in Europe. J Am Coll Cardiol 2013;62:1052–61.

11. Sorajja P, Mack M, Vemulapalli S, et al. Initial experience with commercial transcatheter mitral valve repair in the United States. J Am Coll Cardiol 2016;67:1129–40.
12. Zoghbi WA, Adams D, Bonow RO, et al. Recommendations for noninvasive evaluation of native valvular regurgitation: a report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance. J Am Soc Echocardiogr 2017;30:303–71.
13. Avenatti E, Mackensen GB, El-Tallawi KC, et al. Diagnostic Value of 3-dimensional vena contracta area for the quantification of residual mitral regurgitation after MitraClip procedure. JACC Cardiovasc Interv 2019;12:582–91.
14. Siegel RJ, Biner S, Rafique AM, et al. The acute hemodynamic effects of MitraClip therapy. J Am Coll Cardiol 2011;57:1658–65.
15. Neuss M, Schau T, Isotani A, et al. Elevated Mitral Valve Pressure Gradient after MitraClip implantation deteriorates long-term outcome in patients with severe mitral regurgitation and severe heart failure. JACC Cardiovasc Interv 2017;10:931–9.
16. Stone GW, Adams DH, Abraham WT, et al. Clinical trial design principles and endpoint definitions for transcatheter mitral valve repair and replacement: part 2: endpoint definitions: a consensus document from the mitral valve academic research consortium. J Am Coll Cardiol 2015;66:308–21.
17. Schueler R, Ozturk C, Wedekind JA, et al. Persistence of iatrogenic atrial septal defect after interventional mitral valve repair with the MitraClip system: a note of caution. JACC Cardiovasc Interv 2015;8:450–9.