# Advanced echocardiography and clinical surrogates to risk stratify and manage patients with structural heart disease

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# Chapter 5

## Tools and techniques: 3D-transesophageal echocardiography for selecting and guiding in percutaneous mitral valve repair using MitraClip

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## ABSTRACT

### Objectives

This report provides an illustrative and practical approach for screening of patients with mitral regurgitation who are candidates for MitraClip® therapy and for procedural guidance using 3D-transesophageal echocardiography (3D-TOE), providing state-of-the-art practice for imagers (what and how to assess mitral valve with 3D-TOE) and interventionalists (how to interpret and translate 3D-TOE images for the intervention).

### Summary

Superior anatomic performance and comprehensive evaluation of regurgitant jet characteristics represent cornerstones for eligibility assessment. Standardized mitral valve display, alternating 1-beat 3D full volume and bi-plane acquisitions, improves procedural guidance. Intensive communication between a skilled imager and a well-trained interventionalist with each understanding of 3D-TOE from a technical and practical point of view, respectively, are prerequisites to obtain high procedural success rates.

### Conclusions

3D-TOE has become indispensable for optimal candidate selection and procedural guidance in patients treated with MitraClip® therapy.

## INTRODUCTION

Mitral valve repair using the MitraClip® system (Abott Vascular) consists of a percutaneous approach to attach both leaflets of the mitral valve to each other by one or more cobalt-chromium clips where the regurgitant jet originates.[1] Thereby it resembles the surgical Alfieri-stitch technique, creating a double-orifice mitral valve.[2] This therapy has currently been adopted in over 15000 symptomatic patients with severe primary (organic) or secondary (functional) mitral regurgitation that are at high surgical risk or with contraindications for surgery. The EVEREST-II trial and large real-world registries have shown high feasibility (successful clip implantation achieved in >95%) and efficacy with reduction of mitral regurgitation to grade 2 or less (acute procedural success) in at least 80% of treated subjects.[1, 3-5] Adequate patient selection and procedural guidance is a prerequisite for procedural and clinical success of MitraClip® therapy. Although 2-dimensional transesophageal echocardiography (TOE) remains the reference standard to assess the anatomy of the mitral valve and the severity of mitral regurgitation of patients who are candidates for this therapy, 3-dimensional (3D) TOE has improved and standardized communication between interventionalists and imagers. This report provides a brief, illustrative and practical approach for screening of patients with mitral regurgitation who are candidates for MitraClip® therapy and for procedural guidance using 3D-TOE, providing state-of-the-art practice for imagers (what and how to assess mitral valve with 3D-TOE) and interventionalists (how to interpret and translate 3D-TOE images for the intervention), as summarized in Figure 1.



## PATIENT SELECTION

Selection of patients who are candidates for MitraClip® therapy includes thorough analysis of the anatomy of the mitral valve and mechanism as well as severity of mitral regurgitation.[6] Evaluation of anatomy requires high spatial resolution whereas accurate quantification of mitral regurgitation relies on high temporal resolution (high frame rate data). Using 3D TOE, anatomical and functional data can be obtained with 3 different acquisition modes (Figure 2):

- 1-beat full volume: provides in one beat the 3D rendering of the mitral valve. The spatial resolution is high while avoiding stitching artifacts that may distort the anatomy.
- Multi-beat full volume: the 3D rendering of the mitral valve is created from several pyramidal subvolumes obtained during 2-7 beats. This mode provides high temporal and spatial resolution data. The patient, however, needs to hold

the breath to avoid stitching artifacts during compilation of the subvolumes. Similarly, the presence of irregular heart rhythms (atrial fibrillation) may create stitching artifacts that will limit the analysis and visualization.

- Bi-plane view: This mode provides simultaneous visualization of 2-dimensional orthogonal planes. Using the bicommissural plane as reference, the perpendicular (left ventricular outflow tract) view can be displayed at specific levels of the mitral valve (anterolateral, central and posteromedial). This acquisition mode provides high temporal resolution data.

3D color Doppler data can be obtained with any of the above acquisition methods. However, high temporal resolution must prevail over spatial resolution and therefore, multi-beat color Doppler 3D full-volume and bi-plane view will be the acquisition modes of choice.

## 3D TOE for MITRACLIP

PATIENT SELECTION

**Mitral Valve anatomy analysis**

- High spatial resolution > temporal resolution
- 3D-zoom (to avoid stitching artefacts)
  * careful with drop-outs
- 3D full-volume (if regular heart rhythm)
- Bi-plane (gives better temporal resolution)

**Quantification of mitral regurgitation**

- High temporal resolution > spatial resolution
- Color Doppler 3D full-volume
- Bi-plane (gives better temporal resolution)

PROCEDURAL GUIDANCE

**Manipulation of catheters**

- High temporal resolution > spatial resolution
- Fast imaging (no full-volume data acquisition)
- Transseptal puncture (Bi-plane)
- Steering guiding catheter in left atrium: 3D-zoom
- Positioning and aligning MitraClip to target lesion: Bi-plane and 3D-zoom
- Grasping leaflets: Bi-plane

**Evaluation of procedural effects**

- Attachment of MitraClip to leaflets: 3D-zoom (high spatial resolution)
- Reduction of mitral regurgitation: color Doppler 3D full-volume
- Residual mitral valve leaflet area: 3D-zoom

**Figure 5.1**
Summary of 3D transesophageal echocardiography (3D-TOE) for patient selection and procedural guidance for MitraClip® treatment.

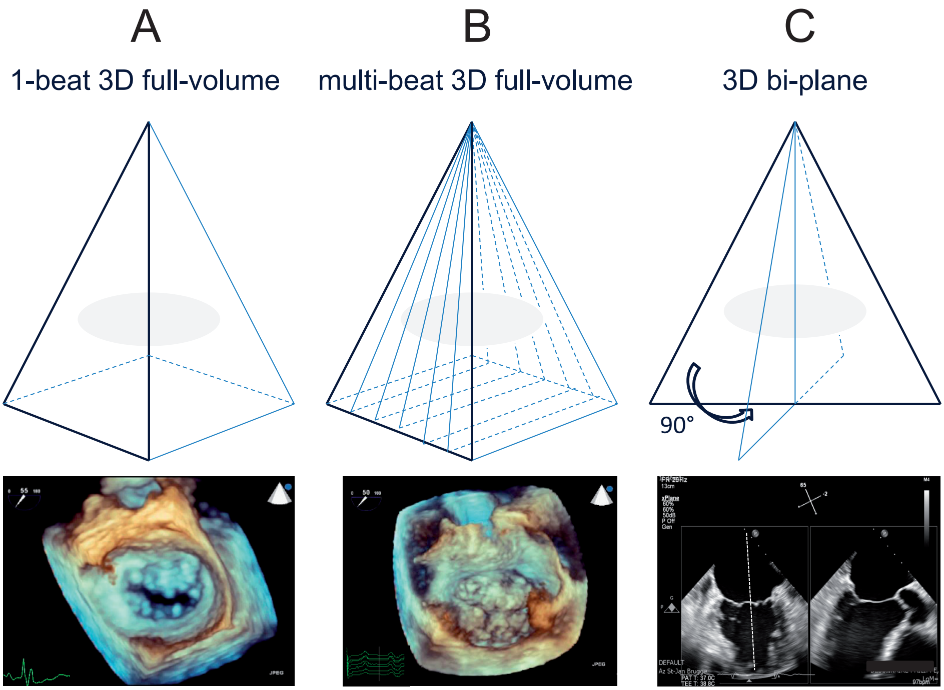


**Figure 5.2**
Principles of 3D (transesophageal) echocardiography. A: 1-beat 3D full volume acquires pyramidal volume in single beat. B: multibeat 3D full volume acquires pyramidal volume stitching sub-volumes together over multiple heart beats. C: 3D bi-plane shows a reference image (left) with corresponding 90 degrees perpendicular view (right).

## Analysis of mitral anatomy

The mitral valve 'en face' or 'surgical view' comprises 3D-visualization of the entire mitral valve as seen from the left atrium, including mitral annulus, all anterior (A1-A2-A3) and posterior (P1-P2-P3) leaflet scallops as well as both anterolateral and posterolateral commissures (Figure 3). To orient the 3D volume rendering several anatomical landmarks need to be included: the left atrial appendage indicating the anterolateral region and the aorta indicating the anterior region of the mitral valve. By displaying the 3D volume rendering with the aortic valve at 12 o'clock position and left atrial appendage at lateral (left) side the communication between interventionalists and imagers may be facilitated. The mitral valve can be also analyzed using the bi-plane view using as reference the bicommissural mitral valve view, mostly found at about 60º, and bisecting each level of the mitral valve (from anterolateral – P1 scallop –, central – A2 scallop – and to posteromedial –P3 scallop) to display the simultaneous left ventricular outflow tract view with the anterior and posterior scallops of the mitral valve at each level (Figure 4).

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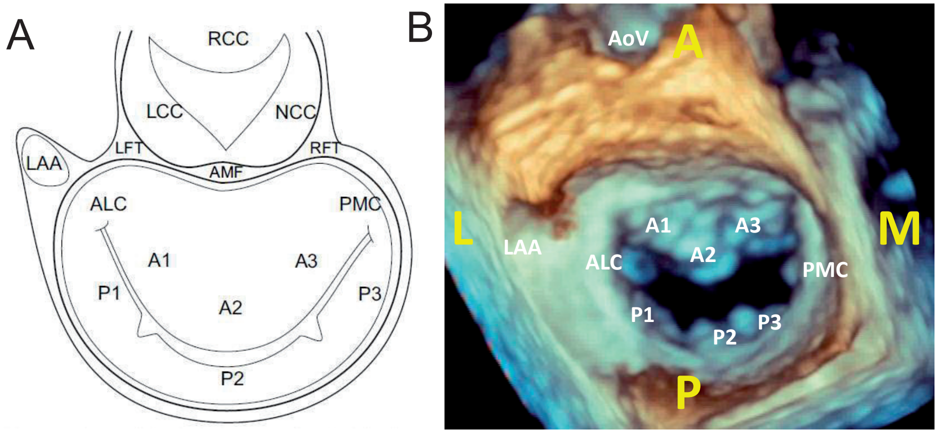


**Figure 5.3**
Mitral valve anatomy on 3D 'surgical' or en 'face view' of mitral valve. A: schematic mitral valve anatomy. B: Corresponding 1-beat 3D full volume view. A: anterior, ALC: antero-lateral commissure, anterior mitral valve leaflet with lateral (A1), middle (A2) and medial (A3) scallop, AMF: aortic-mitral fibrosa, AoV: aortic valve with left (LCC), right (RCC) and non coronary (NCC) cusp, L: lateral, LFT: left fibrous trigonum, M: medial, P: posterior, PMC: postero-medial commissure, posterior mitral valve leaflet with lateral (P1), middle (P2) and medial (P3) scallop, RFT: right fibrous trigonum. *Adapted with permission*[10].

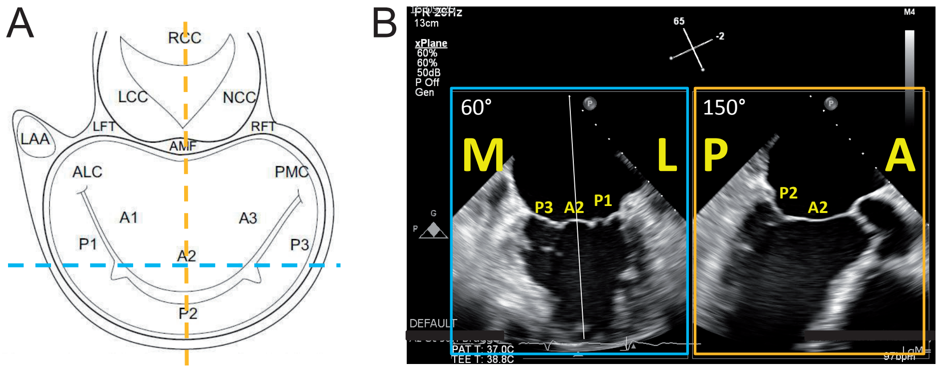


**Figure 5.4**
**Mitral valve** anatomy on 3D bi-plane view, at bi-commissural level. A: schematic mitral valve and B: bi-plane view. The blue dashed line corresponds to the bi-commissural view on bi-plane (left panel) and the orange dashed line corresponds to the 90 degrees perpendicular antero-posterior view on bi-plane (right panel). This bi-plane view allows for simultaneous orientation in latero-medial direction (L-M) as well as antero-posterior direction (A-P). See figure 2 for abbreviations.

Adherence to initial EVEREST-II criteria for technical feasibility (Table 1) yields high procedural success rates.[1] Based on the underlying pathophysiological mechanisms, mitral regurgitation can be classified as organic or primary, when the lesion affects the mitral valve leaflets, or functional or secondary, when the mitral leaflets are anatomically normal but left ventricular remodeling and dysfunction or atrial remodeling lead to dilatation of the mitral annulus, leaflet tethering and restriction as well as coaptation failure. In patients with organic mitral regurgitation, the exact location of the lesions (prolapse/flail) and numbers of leaflet scallops involved should be assessed (Figure 5).

**Table 5.1**
Technical echocardiographic requirements for MitraClip® treatment, adapted from EVEREST-II trial.[1]

| Mitral valve assessment | Measurements | 3D acquisition |
|---|---|---|
| Anatomy | | |
| organic: flail width | < 15 mm | full-volume |
| flail gap | < 10 mm | bi-plane |
| functional: coaptation depth | <11 mm | bi-plane |
| coaptation length | ≥ 2 mm | bi-plane |
| excluding cleft, calcification in grasping area | - | full-volume, bi-plane |
| excluding asymmetrical leaflet thickness | ≤ 5 mm | full-volume, bi-plane |
| area (cm²) | ≥ 4.0 cm² | full-volume |
| mean gradient (mmHg) | < 5 mmHg | *(Continuous wave)* |
| mobile leaflet length at jet origin | ≥ 8 mm | bi-plane |
| Regurgitation | | |
| jet location | preferably A2-P2 | color full-volume, bi-plane |
| severe functional, EROA | ≥ 20 mm² | color full-volume |
| severe organic, EROA | ≥ 40 mm² | color full-volume |

EROA: effective regurgitant orifice area

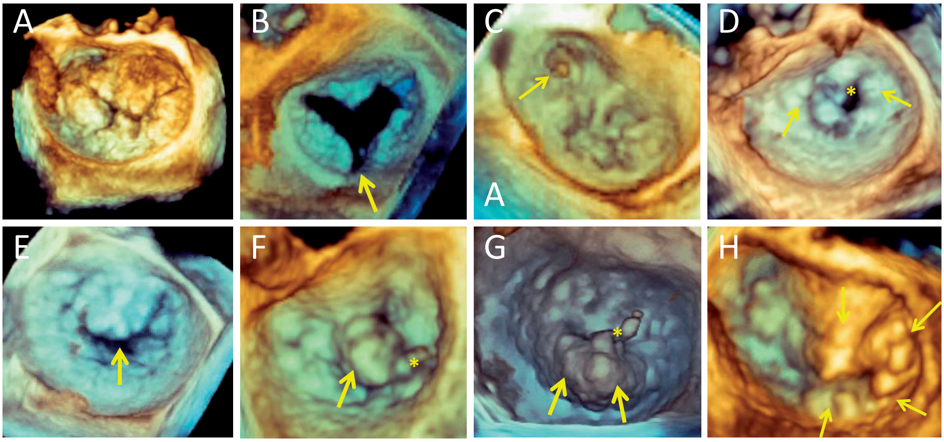


**Figure 5.5**
Additional value of 3D mitral valve echocardiography for anatomic and morphologic assessment in screening for MitraClip® therapy. All patients presented with severe mitral regurgitation but are anatomically not eligible for MitraClip® therapy. A: Complex Barlow degeneration involving prolapse of all mitral segments. B: Posterior leaflet cleft. C: Anterolateral commissural prolapse. D: Severe rheumatic stenosis (*) with diffuse calcifications and commissural fusion (arrows). E: Loss of central coaptation during systole. F: A2 flail with chordal rupture (*), flail width 17 mm. G: P2 flail with chordal rupture (*), flail width 22 mm. H: Complex Barlow with prolapse of A2, A3, posteromedial commissure and P3 scallops.

From 3D volume rendering, the type of lesion and number of valve segments involved are readily assessable. Using the multiplanar reformation planes, the 3D volume rendering can be analyzed and the flail width and gap can be measured. The flail width, comprising the width of the prolapsing segment(s), can be measured on the surgical view and should be ≤15 mm (Figure 6). The flail gap, reflecting the distance between both leaflet tips during mid-systole needs to be ≤10 mm (Figure 6). In patients with functional mitral regurgitation a coaptation length (apposition of both leaflets in systole) of ≥2 mm should be present at the level of the mitral regurgitant jet origin during mid-systole to allow for grasping of both leaflets (Figure 6). In addition the coaptation height between the leaflet tips and the annular plane, reflecting leaflet tethering severity, should be ≤11 mm to avoid excessive

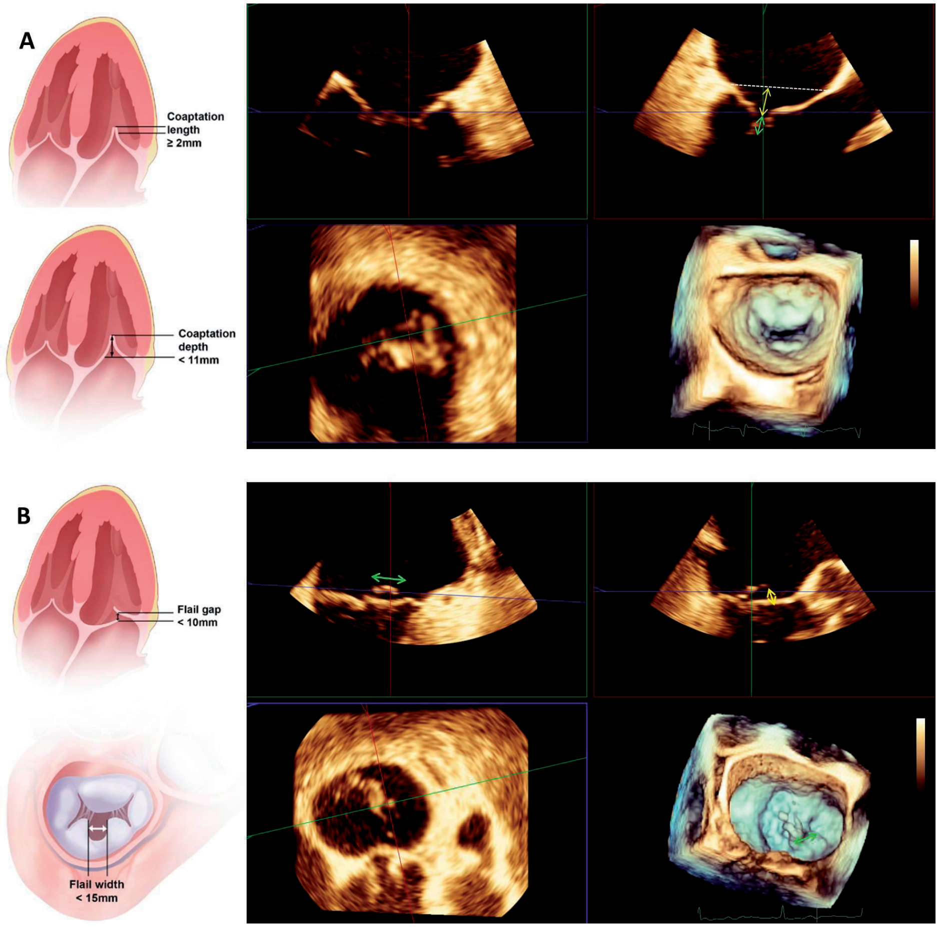


**Figure 5.6**
Mitral valve geometric measurements for evaluation of technical feasibility for MitraClip® therapy in patients with functional (A) or organic (B) mitral regurgitation. See text for details. *Adapted with permission.*[11]

tension in the system and mitral leaflets (Figure 6). Patients with rheumatic valve disease, calcification in the leaflet grasping area or cleft (congenital defect in or between leaflet scallops reaching the mitral annulus) are not ideal candidates for MitraClip® therapy (Figure 5). In addition, asymmetrical leaflet thickness at the origin of the regurgitant jet implies technical ineligibility due to risk of future clip detachment (Figure 7).

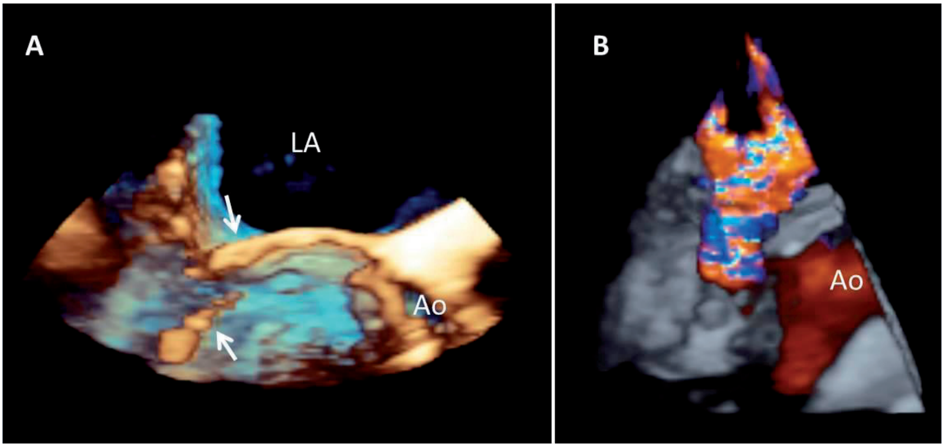


**Figure 5.7**
Mitral valve thickening. Panel A: Asymmetrical thickened A2 leaflet (arrow) with thickened subvalvular chordae (arrow) which challenges MitraClip® therapy. Panel B: 3D-color Doppler data showing severe mitral regurgitation.

Second, the mitral valve area should be evaluated. MitraClip® therapy reduces mitral valve area about 25 to 50% and therefore mitral valve area should be ≥4.0 $cm^2$ to avoid development of significant leaflet stenosis (Figure 8).[7] Apart from 2D-planimetry, mitral valve area can be assessed on 3D-planimetry at multi-plane reformation analysis at the maximal opening of the tip of the leaflets during systole. The mean valvular gradient should be <5 mmHg, assessed by tracing the diastolic mitral inflow on continuous wave Doppler acquisition.

Finally, the length of the mobile leaflet part of both anterior and posterior mitral leaflets at the origin of the regurgitant jet should be ≥8 mm to allow ability to grasp, to avoid inducing valvular stenosis and to prevent from later clip detachment.

## Quantification of mitral regurgitation

Quantification of the regurgitant orifice area (EROA), most often by the proximal isovelocity surface area method (PISA), is the gold standard for quantifying regurgitation severity as it least depends on hemodynamic loading conditions.[8] An EROA of ≥40 $mm^2$ and ≥20 $mm^2$ defines severe mitral regurgitation for organic and

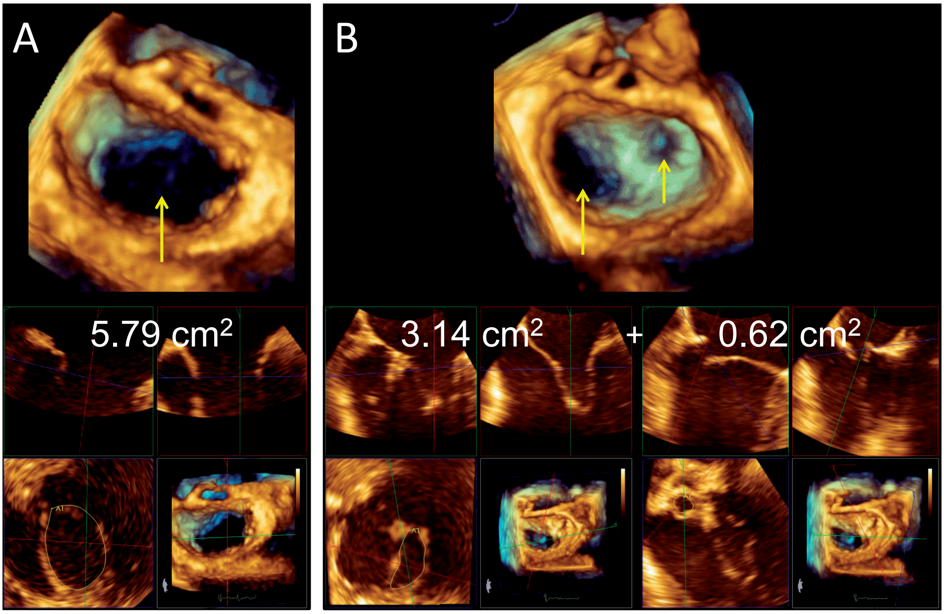


**Figure 5.8**
3D planimetry of mitral valve area before and after MitraClip® therapy. A: Mono-orifice valve before MitraClip® (upper panel) with valve area planimetry on multi-reformation planes (lower panel). B: Double-orifice valve after MitraClip (upper panel) with selective planimetry of lateral orifice (left lower panel) and medial orifice (right lower panel). Mitral valve area is reduced from 5.14 cm² to 3.76 cm², comprising mitral valve area reduction of 27% post MitraClip® therapy.

functional mitral regurgitation, respectively. The EROA of patients with functional mitral regurgitation, however, is often not circular as in organic mitral valve disease, explaining lower thresholds when applying the PISA method. Particularly for these subjects, 3D quantification of the vena contracta area can be performed, comprising direct anatomic measurement of the area of the vena contracta, namely the small neck of the regurgitant jet at the atrial level (Figure 9). This technique can also be applied in case of multiple jets by adding values obtained at the different jets (Figure 10).

Central regurgitant jet origin, at A2-P2 scallops, represents an ideal scenario for MitraClip® treatment. The origin, number and exact location of the regurgitant jet(s) is most easily evaluated on 3D-TOE, applying the 'en face view' as well as the bi-plane biplane mitral valve view (Figure 11). Building on experience by treatment of higher numbers of patients, more lateral or medial jet origins can be targeted, being the most challenging lesions those located at the commissures since they are associated with entangling into or rupturing of commissural mitral chords.

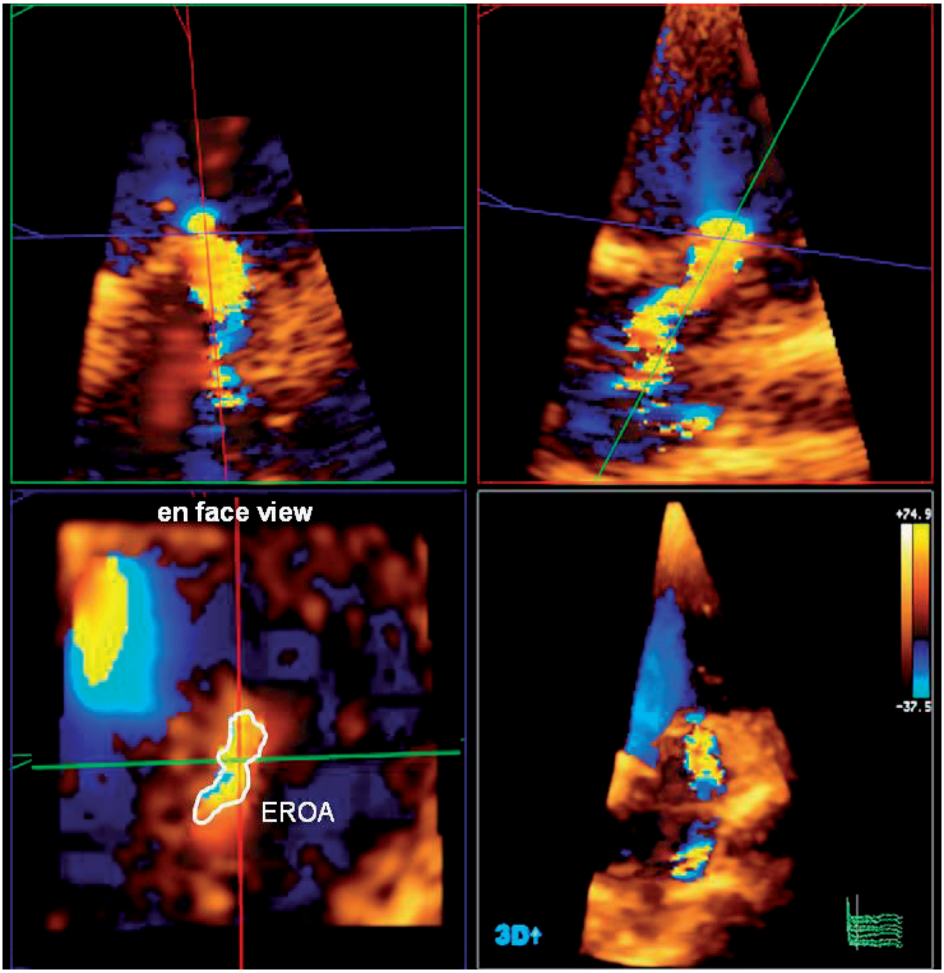


**Figure 5.9**
3D Vena contracta area assessment. After mid-systolic orthogonal alignment of the regurgitant jets on multi reformation planes (green and red planes) from a 3D color full-volume acquisition, the short axis plane (blue) is set at the level of the vena contracta. The non circular regurgitant orifice area of this functional mitral regurgitation is traced, measuring 45 mm², compatible with severe mitral regurgitation.

## PROCEDURAL GUIDANCE

Comprehensive guiding of MitraClip® implantation procedure requires extensive use and switching between different 3D-TOE modalities; fluoroscopy guiding is limited since the non-calcified mitral valves are not well depicted. Catheter manipulation requires accurate visualization of the mitral valve and surrounding anatomical structures and high temporal resolution. One-beat 3D full volume and bi-plane acquisitions are the most common 3D modes of visualization (Figure 2).

Procedural results, reduction of mitral regurgitation severity and clip attachment, require high temporal and spatial resolution, respectively.

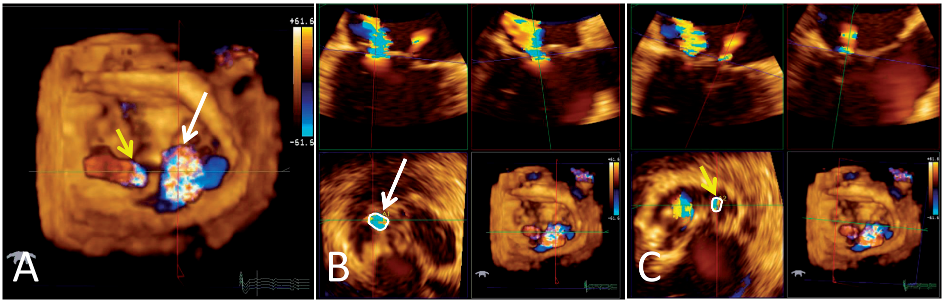


**Figure 5.10**
3D Vena contracta area assessment in multiple jets. A: Mitral regurgitation with a small centrolateral jet (yellow arrow) and large centromedial jet (white arrow). Selective assessment of the vena contracta area of the centromedial jet (B, 29 mm²) and of the centrolateral jet (C, 11 mm²). The total vena contracta area of the entire regurgitation measures 40 mm².

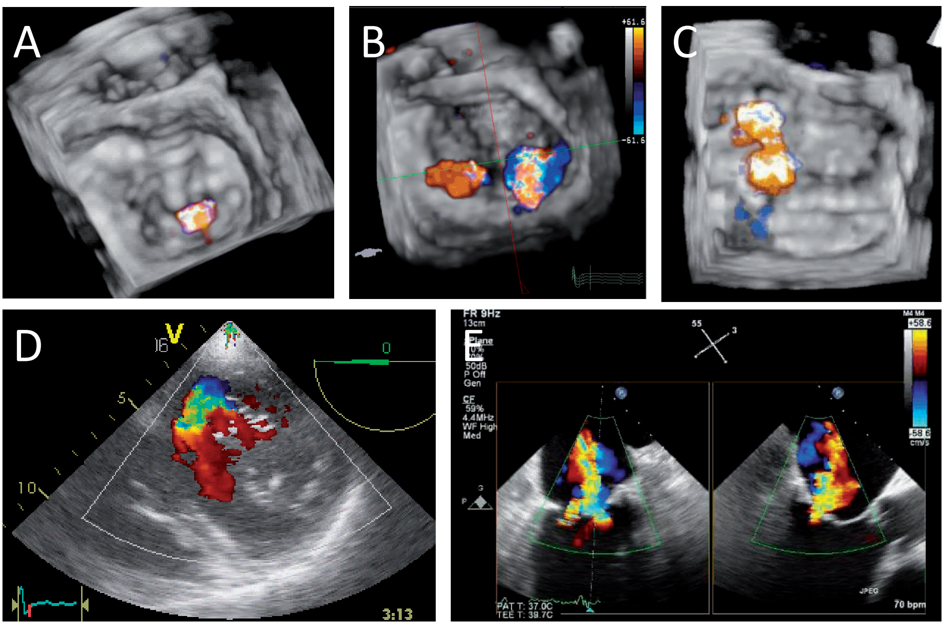


**Figure 5.11**
Assessment of regurgitant jet characteristics and location. A: central jet origin at A2-P2 level on en face mitral view. B: Double jet at centromedial (large) and centrolateral (small) level. C: Anterolateral commissural and lateral jet origin, unsuitable for MitraClip® therapy. D: Short axis transgastric 2D mitral view indicating posteromedial commissural jet origin, contra-indication for MitraClip® treatment. E: Bi-plane view at bicommissural level, displaying central jet origin at A2-P2 level, ideal target for MitraClip® therapy.

## Manipulation of catheters

*Transseptal puncture.*

The location of the transseptal puncture is crucial as it determines further clip delivery system manipulations needed to obtain the optimal angle for subsequent alignment and grasping mitral valve leaflets. Ideally the puncture should target the middle to slightly superior part of the non-muscular part of the interatrial septum at a slightly posterior level (Figure 12). The bi-plane interatrial septal view allows for simultaneous posteroanterior and inferosuperior guiding on the short-axis aortic valve view and bicaval view respectively. By slightly pressing with the Brockenbrough or Verres needle on the targeted area, tenting of the interatrial septum can be observed which allows for subsequent measurement of puncture height from the mitral annular plane in 4-chamber TOE view. This height should ideally range between 3.5 and 4.0 cm (Figure 12). Of note, the maximal length of the

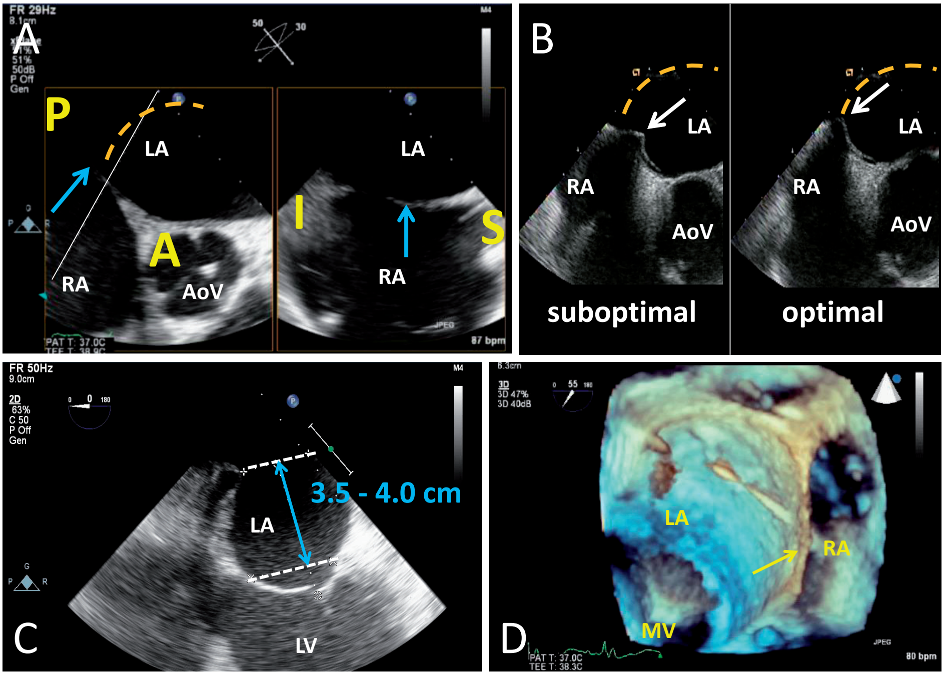


**Figure 5.12**

Ideal location and guiding transseptal puncture. A: bi-plane view of interatrial septum showing short axis aortic valve (left panel, anteroposterior direction) and bicaval view (right panel, inferosuperior direction). The dashed orange line indicates the location of mitral leaflet coaptation. The blue arrow points out the ideal puncture side: slightly posterior and mid-to-slightly-superior. B: suboptimal (too anterior) and optimal position seen by tenting of the needle (arrows). C: Measuring puncture height from tenting to mitral annular plane on 4-chamber view. D: 3D view of wire (black arrows) across interatrial septum (yellow arrow). A: anterior, AoV: aortic valve, I: inferior, LA: left atrium, LV: left ventricle, MV: mitral valve P: posterior, RA: right atrium, S: superior.

MitraClip® delivery system in the left atrium is limited to 5.0 cm and one should be aware that the clip needs to be advanced distally from the leaflet tips into the left ventricle to allow for proper leaflet grasping. Severe tenting in functional mitral regurgitation might lead to choose a slightly lower puncture site. Likewise, organic mitral regurgitation caused by prolapse or flail might benefit from a slightly higher puncture site. The puncture is guided on bi-plane interatrial septal view and subsequent advancement of the wire into the left atrium and secured into the left upper pulmonary vein can be visualized with 3D full volume views (Figure 12).

***Steering the guiding catheter in left atrium.***

Over the wire across the interatrial septum, a septal dilator is inserted. After dilatation, the guiding catheter is advanced into the left atrium, guided by alternating 1-beat 3D full volume and bi-plane imaging to accurately follow the advancement and avoiding perforation of the posterior atrial wall, aortic puncture and impingement of the left atrial appendage (Figure 13. Subsequently the clip is introduced into the left atrium through the guiding catheter. 3D-TOE is useful for catheter

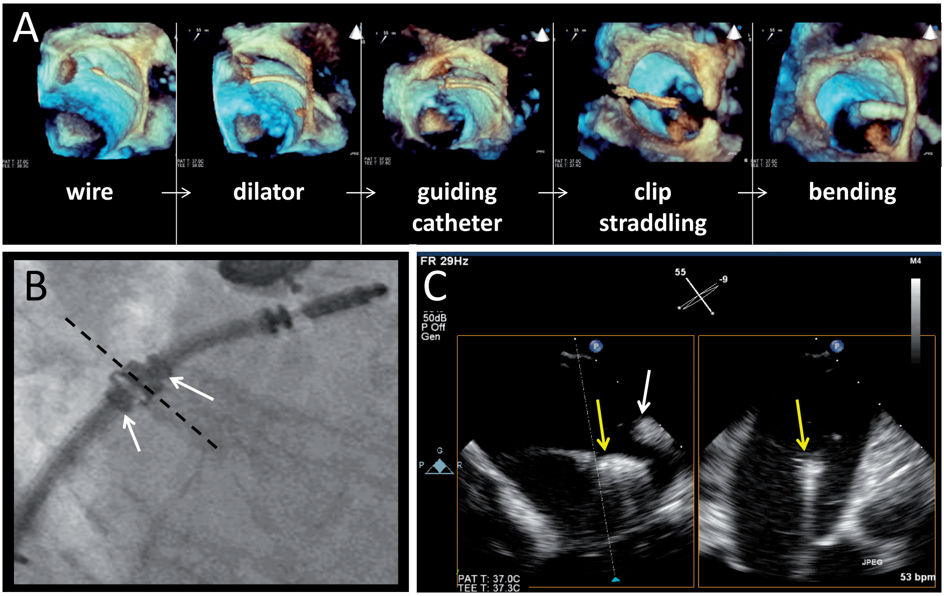


**Figure 5.13**
Steering guiding catheter in left atrium. A: Large 1-beat 3D full volume views of interatrial septum and mitral valve showing consecutive steps of introducing the guiding catheter into the left atrium and bending towards the mitral valve. This anatomic overview is used for orientation and to make sure no anatomic structures are damaged during manipulation. B: straddling position: sleeve markers (white arrows) are paired on the guide marker (black dashed line). C: bi-plane bicommissural central view showing clip (yellow arrow), avoiding to hook on the pulmonary vein ridge (white arrow).

manipulation avoiding any damage to left atrial structures or aorta, particularly since the clip system must be introduced further until straddling position is obtained (Figure 13). Following straddling, using 1-beat 3D full volume or bi-plane views, the clip is bended medially and inferiorly towards the mitral valve, avoiding damage of the pulmonary vein ridge.

*Positioning and aligning MitraClip® to target lesion.*

The clip system is manipulated into mediolateral and anteroposterior direction to obtain a position on top of the target lesion. Color Doppler and bi-plane views at the bicommissural level and 1-beat 3D full volume acquisitions are the most frequently used views to guide this step (Figures 3, 4 and 14). It is important to notice that when the target regurgitant lesion on the color Doppler bi-plane view is identified, the system should be steered to appear in this view without further adjustments of the image.

Once the clip is at the target region, slight advancing and retracting of the system towards and away from the mitral leaflets and left ventricle is repeatedly tested in order to verify the system follows the correct path and angle, remaining at the target lesion site. Then the clip is opened and oriented perpendicular to the line

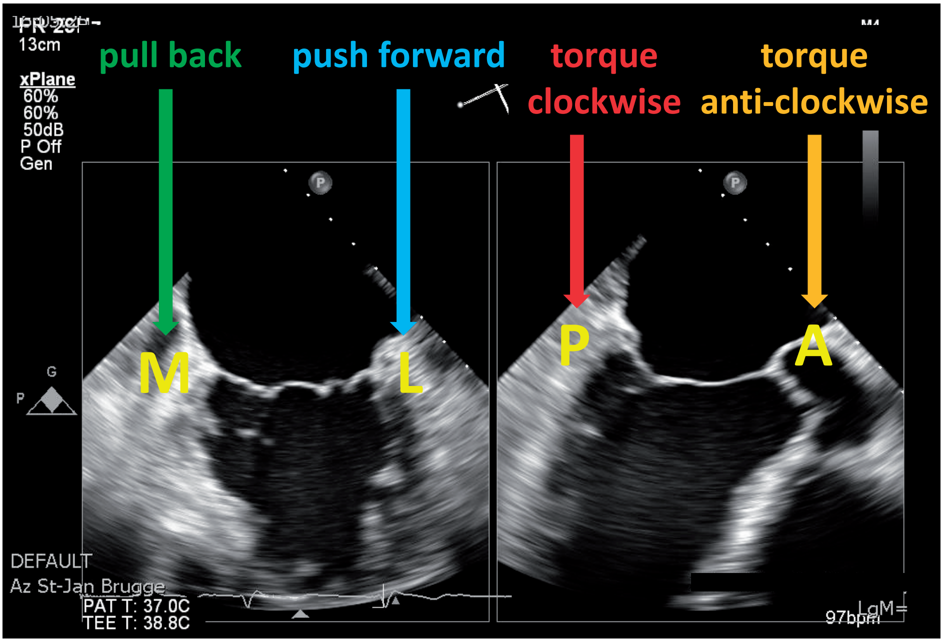


**Figure 5.14**
Device manipulations and resulting effects on bi-plane bicommissural view. Pulling back and pushing forward results in medial (M) and lateral (L) device orientation, respectively. Clockwise and anti-clockwise torque leads to posterior (P) and anterior (A) relocation, respectively.

of coaptation of the mitral valve leaflets. This step is crucial as non-perpendicular clip attachment yields a significant risk of future clip detachment or leaflet laceration. Bi-plane bicommisural view is used to adapt the clip orientation until perpendicularity is ascertained by absence of clip arm visualization on the bicommissural view, and symmetric appearance of both clip arms on the corresponding outflow tract view (Figure 15). Similarly, 1-beat 3D full volume acquisition allows for easy clip orientation (Figure 16). Once a satisfactory alignment is achieved, the clip is gently introduced into the left ventricle guided by bi-plane mode with simultaneous visualization of the bicommissural and long-axis views of the mitral valve, and maintenance of clip alignment should be vigorously checked as leaflet motion tends to affect clip arm alignment.

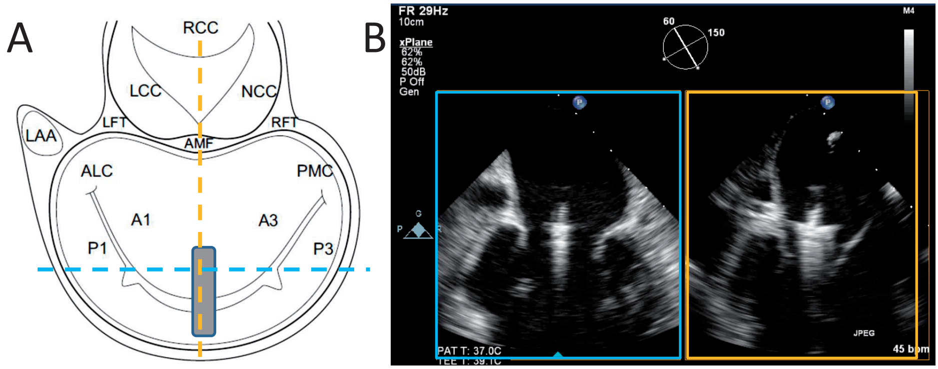


**Figure 5.15**
Clip orientation and alignment on bi-plane imaging. A: The clip (grey) should be perpendicular to the line of coaptation. B: Perpendicularity is ascertained when on bicommisural bi-plane view (blue) no clip arms are seen and when both clip arms appear symmetrically on the corresponding left ventricular outflow tract view (orange).

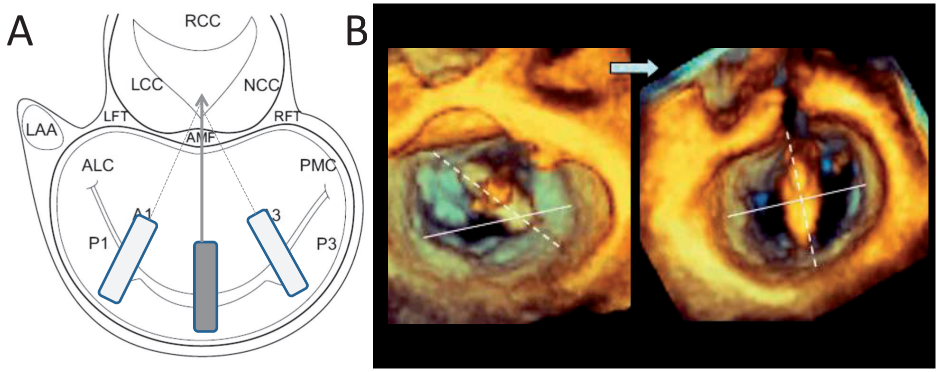


**Figure 5.16**
Clip orientation and alignment on 1-beat 3D full volume imaging. A: Perpendicularity to the line of coaptation is found when on the en face mitral view the clip points towards the center of the aortic valve. B: Left panel shows clip non-perpendicularity. After clockwise rotation of the clip, perpendicularity at central leaflet level is obtained, depicted on the right panel.

*Mitral leaflet grasping.*

In order to grasp both leaflets the clip system is pulled back gently with discrete manipulations by the interventionalist mainly in anteroposterior direction until both leaflets land on the clip arms, maintaining the perpendicular alignment and central position of the clip (Figure 17). Once both leaflets are on the clip arms, the grippers are lowered and the clip is closed (Figure 17). It is important to record this grasping procedure by a long cine run acquisition as a reference to re-evaluate in case of doubt about accurate grasping. Ideally both leaflets need to be in the clip for about 5 mm.

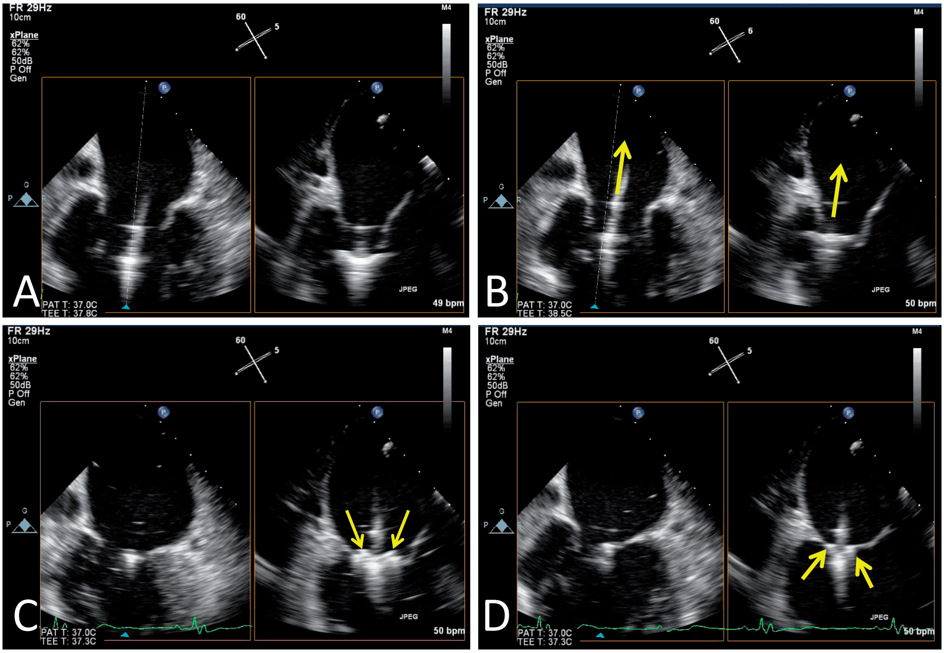


**Figure 5.17**

Leaflet grasping guided by bi-plane imaging. A: Clip in left ventricle with open arms, perpendicular orientation. B: Clip system is pulled back (arrows) with manipulations in anteroposterior direction to grasp both mitral leaflets. C: Grippers are lowered (arrows) when both mitral leaflets are on the clip arms. D: The clip is closed (arrows), approximating both the posterior and anterior mitral valve leaflet.

## Evaluation of procedural effects

*Mitral regurgitation reduction.*

At first, reduction of mitral regurgitation should be evaluated. A double orifice mitral valve is created by MitraClip® therapy (Figure 19), often splitting the original jet into two small residual jets. Although qualitative interpretation of jet severity reduction can easily be assessed by evaluation of reduction in jet width and jet area, these measures inherently are load dependent (Figure 18). No specific method for quantification of acute regurgitation reduction after MitraClip® therapy has been validated so far. As pointed out in Figure 10, 3D vena contracta area assessment of a single or multiple residual jets can be performed as a quantitative approach. A 3D vena contracta area reduction of >50 % has been suggested as the best quantitative parameter relating to subsequent reverse left ventricular remodeling after MitraClip® therapy.[7] In addition semi-quantitative evaluation such as increased systolic forward pulmonary vein flow, increased left ventricular stroke volume and amelioration of pulmonary artery systolic pressures indirectly reflect adequate reduction of severity of mitral valve regurgitation (Figure 18). Acute procedural success is defined as reduction of mitral regurgitation ≤grade 2.

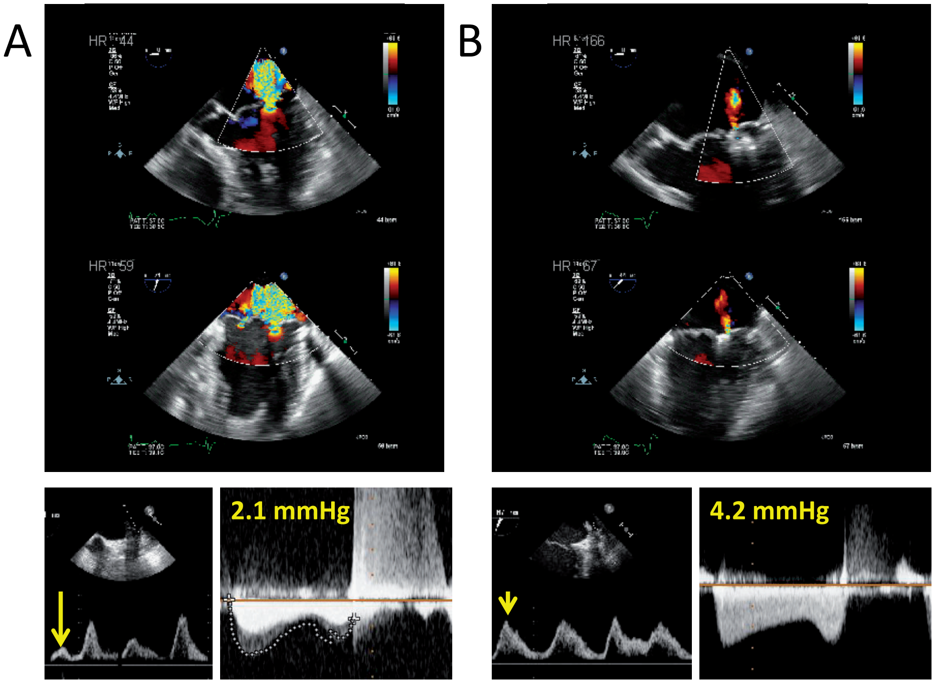


**Figure 5.18**
Acute procedural effect evaluation. A: Before MitraClip® therapy. B: After MitraClip® therapy. Significant reduction of mitral regurgitation based on reduced jet area and jet width is depicted. The blunted forward systolic pulmonary vein flow is significantly increased after the procedure (yellow arrows at left lower panels), indirectly reflecting adequate reduction of mitral regurgitation severity. No significant transmitral gradient developed after the intervention (right lower panel).

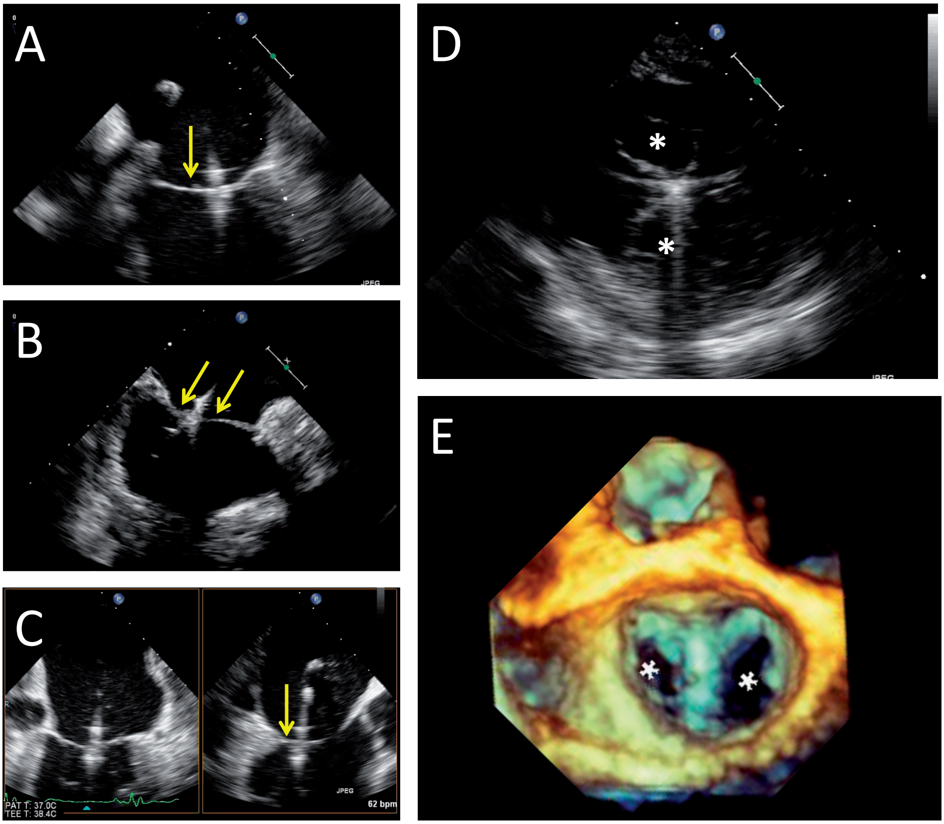


**Figure 5.19**
Mitral leaflet insertion evaluation. A: Anterior mitral leaflet (arrow) evaluation on 4 chamber view. B: Angel's view at bicommissural mitral valve level. C: Posterior mitral leaflet (arrow) evaluation at outflow tract view. D: Transgastric view showing dog-bone or figure eight pattern of double orifice (asterisks) mitral valve. E: 3D-zoom of double orifice (asterisks) mitral valve, indicating perpendicular clip alignment. See text for details.

*Leaflet insertion.*

Secondly, to avoid the risk of future clip detachment, it is essential to assure both leaflets are adequately captured and inserted between the grippers and both clip arms. Re-evaluation of the cine run of the grasping step can be particularly helpful. Anterior leaflet insertion is best seen on a 4-chamber mid-esophageal TOE view and the posterior leaflet insertion can adequately be visualized on the long-axis view. Both leaflets should be seen as going over the tip of both clip arms and at this point leaflet motion throughout the cardiac cycle needs to be restricted or absent to assure adequate leaflet insertion. The leaflet length inserted into the clip arms (ideally about 5 mm) can be assessed by subtracting the remaining mobile leaflet length from the preprocedual mobile leaflet length. At the bicommissural mitral valve level the clip should be visualized transecting the mid portion by the leaflets. On short-axis transgastric view the double orifice can be appreciated, similar to a 1-beat 3D full volume view, resembling a figure eight or dog-bone pattern. Additionally, the 1-beat 3D full volume view is essential to confirm perpendicular alignment of the clip arms to the mitral coaptation line.

*Mitral valve area reduction.*

Finally transmitral gradient and mitral valve area are evaluated to ascertain no functional mitral stenosis is created by the MitraClip® intervention. Continuous wave Doppler through one of the orifices created by the clip permits measurement of the mean mitral valve gradient, which ideally remains below 5 mmHg (Figure 18). As the flow velocities across asymmetrical mitral orifices are equal, the choice of orifice for Doppler alignment is no issue.[9] Less load and flow dependent quantification is provided by summing mitral areas of the orifices by planimetry at the tips of both leaflets during mid diastole, which can easily be obtained on 3D-TOE post-processing on-line or off-line (Figure 8).

## CONCLUSION

3D-TOE has become indispensable for optimal candidate selection and procedural guidance in patients treated with MitraClip® therapy. Superior anatomic performance and comprehensive evaluation of regurgitant jet characteristics represent cornerstones for eligibility assessment. Standardized mitral valve display, alternating 1-beat 3D full volume and bi-plane acquisitions, improves procedural guidance. Intensive communication between a skilled imager and a well-trained interventionalist with each understanding of 3D-TOE from a technical and practical point of view, respectively, are prerequisites to obtain high procedural success rates.

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