# Transcatheter Mitral Valve Repair Using the Edge-to-Edge Clip

Charles B. Nyman, MBBCh, G. Burkhard Mackensen, MD, PhD, FASE, Srdjan Jelacic, MD, FASE, Stephen H. Little, MD, FRCPC, FACC, FASE, Thomas W. Smith, MD, and Feroze Mahmood, MD, FASE,
*Boston, Massachusetts; Seattle, Washington; Houston, Texas; and Sacramento, California*

Percutaneous intervention for mitral valve (MV) disease has been established as an alternative to open surgical MV repair in patients with prohibitive surgical risk. Multiple percutaneous approaches have been described and are in various stages of development. Edge-to-edge leaflet plication with the MitraClip (Abbott, Menlo Park, CA) is currently the only Food and Drug Administration-approved device specifically for primary or degenerative lesions. Use of the edge-to-edge clip for secondary mitral regurgitation is currently under investigation and may result in expanded indications. Echocardiography has significantly increased our understanding of the anatomy of the MV and provided us with the ability to classify and quantify the associated mitral regurgitation. For percutaneous interventions of the MV, transesophageal echocardiography imaging is used for patient screening, intraprocedural guidance, and confirmation of the result. Optimal outcomes require the echocardiographer and the proceduralist to have a thorough understanding of intra-atrial septal and MV anatomy, as well as an appreciation for the key points and potential pitfalls of each of the procedural steps. With increasing experience, more complex valvular pathology can be successfully percutaneously treated. In addition to two-dimensional echocardiography, advances in three-dimensional echocardiography and fusion imaging will continue to support the refinement of current technologies, the expansion of clinical applications, and the development of novel devices. (J Am Soc Echocardiogr 2018;■:■-■.)

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Percutaneous intervention for mitral valve (MV) disease has been established as an alternative to open surgical MV repair, particularly in patients with increased surgical risk.[1,2] Multiple percutaneous approaches have been described and are in various stages of development.[3] Edge-to-edge leaflet plication with the MitraClip (Abbott, Menlo Park, CA) is currently the only Food and Drug Administration-approved device specifically for primary or degenerative lesions. Utilization of the edge-to-edge clip (E-EC) for secondary mitral regurgitation is currently under investigation and may result in expanded indications. During this procedure anterior and the posterior mitral leaflets are percutaneously "clipped" to convert the MV into a double orifice valve analogous to the surgically performed Alfieri stitch.[4] Transesophageal echocardiography (TEE) imaging is integral to the success of the procedure. Its role extends from assessing suitability, procedural guidance, confirming success, and exclusion of complications.

From the Department of Anesthesiology, Perioperative and Pain Medicine, Brigham and Women's Hospital (C.B.N.), and Department of Anesthesia and Critical Care, Beth Israel Deaconess Medical Center (F.M.), Boston, Massachusetts; Department of Anesthesiology and Pain Medicine, University of Washington (G.B.M., S.J.), Seattle, Washington; Department of Cardiology, Houston Methodist Hospital (S.H.L.), Houston, Texas; and Department of Internal Medicine, Division of Cardiovascular Medicine, UC Davis Medical Center (T.W.S.), Sacramento, California.

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Reprint requests: Charles B. Nyman, MBBCh, Brigham and Women's Hospital, Department of Anesthesiology, Perioperative and Pain Medicine, 75 Francis Street, Boston, MA 02115 (E-mail: *cnyman@bwh.harvard.edu*).

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## ANATOMICAL PERSPECTIVE

Anatomically, the MV is part of an apparatus that includes leaflets, annulus, chordae tendineae, and the papillary muscles with the underlying myocardium.[5,6] The MV has an anterior and a posterior leaflet, which are continuous with an anterolateral commissure and a posteromedial commissure where the leaflets merge. Centrally, the leaflets overlap by approximately 10 mm (coaptation height), and reduction of this overlap by annular dilatation or tethering of one or both leaflets may result in valvular incompetence. The leaflets are enclosed in a saddle-shaped annulus and attached to the papillary muscles via chordae tendineae.[5] The anterolateral papillary muscle and the posteromedial papillary muscle support both leaflets. The lateral half of the MV including the lateral commissure is supported via chordae tendineae attached to the anterolateral papillary muscle. The medial half of the MV including the medial commissure is supported via chordae tendineae attached to the posteromedial papillary muscle. The central portion of each leaflet is relatively free of chordal insertion, making it an ideal location for E-EC placement. Leaflet attachments to the annulus are continuous with commissures formed where both leaflets merge. Echocardiographically, the MV is examined to assess its function, that is, competence during systole and nonrestriction during diastole. The anterior leaflet is longer than the posterior leaflet that has indentations along its free edge,

**Abbreviations**

**2D** = Two-dimensional
**3D** = Three-dimensional
**AP** = Anteroposterior
**CDS** = Clip delivery system
**CFD** = Color flow Doppler
**E-EC** = Edge-to-edge clip
**GA** = General anesthesia
**HOCM** = Hypertrophic obstructive cardiomyopathy
**iASD** = Iatrogenic atrial septal defect
**IAS** = Intra-atrial septum
**LA** = Left atrium
**LAX** = Long axis
**LV** = Left ventricle
**LVOT** = Left ventricular outflow tract
**MAC** = Mitral annular calcification
**ME-LAX** = Midesophageal long axis
**MR** = Mitral regurgitation
**MV** = Mitral valve
**MVA** = Mitral valve area
**PLAX** = Parasternal long axis
**PSAX** = Parasternal short axis
**SAM** = Systolic anterior motion
**SGC** = Steerable guide catheter
**TEE** = Transesophageal echocardiography
**TTE** = Transthoracic echocardiography
**VC** = Vena contracta

giving it a scalloped appearance (Figure 1). The degree of coaptation between the two leaflets determines the extent of mitral annular dilation that can be sustained without overt Mitral regurgitation (MR).

The chordae tendineae are attached to the free edge (marginal chords) and ventricular surface (strut chords) of the leaflets and serve to prevent excessive leaflet motion during systole and to maintain the ideal geometry of the left ventricle (LV) during papillary muscle contraction. Leaflet prolapse is defined as the coaptation point moving above the plane of the mitral annulus in the anteroposterior (AP) axis of the annulus. The leaflet is considered flail when there is chordal rupture with the ventricular surface of the leaflet exposed to the left atrium (LA; Figure 2). The Carpentier nomenclature for description of MV anatomy is generally followed both for transthoracic echocardiography (TTE) and TEE.[7,8] It is based on the surgical exposure of the MV through the LA.

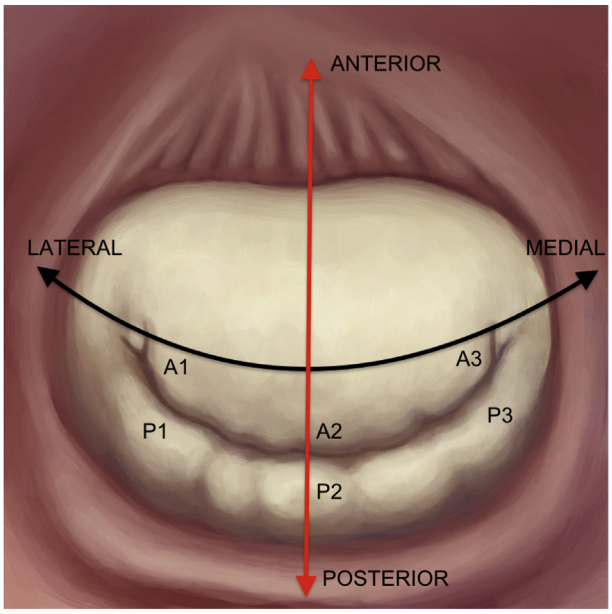


Figure 1 Schematic demonstrating the Carpentier nomenclature of the segments of the MV. The lateral, middle and medial scallops of the posterior leaflet are termed P1, P2, and P3, and the corresponding anterior leaflet A1, A2, and A3, respectively. The central A2/P2 portion of each leaflet is relatively free of chordal insertion, making it an ideal location for clip placement.

## PREPROCEDURAL TRANSTHORACIC IMAGING

### Patient Selection and Preprocedural Imaging

For percutaneous MV repair, TEE is the primary imaging modality for qualitative and quantitative assessment of the MV apparatus and procedural guidance. However, TTE has value as screening tool.[9,10] Screening TTE is used to classify the severity of MR, including both qualitative and quantitative assessment of MR per the current guidelines,[11] distinguish the etiology as primary (degenerative) or secondary (functional), and establish the initial suitability for an intervention, including possible E-EC based on the EVEREST trial criteria.[12-15]

### Transthoracic Views

Of the standardized views, the following views provide the most relevant information that is integral for preprocedural planning and establishing suitability for E-EC (Figure 3).

### Parasternal Long-Axis View

In the parasternal long-axis (PLAX) view, malcoaptation involving the middle scallops of the MV (A2/P2) can be visualized, annular and LV diameter can be measured, and subvalvular apparatus can be evaluated. Visual qualitative estimation of the MR jet and its physical characterization (direction) can help elucidate the etiology. Since the coaptation zone is orthogonally displayed, the vena contracta (VC) can be accurately measured in this view.

### Apical Four-Chamber View

Besides structural assessment, the apical four-chamber view enables quantitative assessment of MR through proximal isovelocity surface area derived effective regurgitant orifice area, measurement of trans-valvular gradient and calculation of MV area (MVA). A baseline transvalvular gradient of $< 3$ mm Hg has been associated with improved outcomes after E-EC[16] Conversely, patients with a large baseline (effective regurgitant orifice area $> 70$ mm$^2$), small MVA ($<3.0$ cm$^2$), and an elevated baseline gradient ($>4$ mm Hg) had poorer procedural outcomes.[17] Primary MV pathologies such as thickening, restriction, prolapse, and flail can also be appreciated in this view. Calcification of the leaflet at the potential grasp point should be described.

### Two-Chamber View

With the scan plane parallel to the zone of coaptation, the entire width of the MR jet from medial to lateral commissure and the likelihood of deploying multiple clips is evaluated. As the coaptation zone is curved, a sweep from the anterior leaflet through to posterior leaflet will allow visualization of the entire coaptation zone.