Mitral Valve Repair: An Echocardiographic Review: Part 1

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PRIMARY SURGICAL TREATMENT of mitral regurgitation (MR) includes either valve replacement or repair, the latter being associated with reduced risk of endocarditis, thromboembolism, bleeding complications, and breakdown or dysfunction of prosthetic material. Echocardiography has been a crucial part of the understanding of mitral valve function and dysfunction and aids in determining the feasibility and method of repair.[1–3] With improved imaging and surgical techniques, the durability of valve repair surgery is now described beyond 15 to 20 years.[4]

Advancements in repair techniques allow cardiac surgeons to repair mitral valves once considered unsuitable for this procedure. The demand for high-quality imaging has to match advancements in surgical technique. The prerepair echocardiographic examination provides a roadmap for the surgical valve repair and is performed prior to surgery and again during the intraoperative period immediately prior to cardiopulmonary bypass. The intraoperative transesophageal echocardiographic examination (TEE) provides an opportunity for a detailed valve examination without the same limitations encountered in an awake patient.

Drawing from the available literature and institutional experience, the authors have written a 2-part review presenting a comprehensive integrated presentation of the evaluation and repair of the regurgitant mitral valve. This first part describes normal mitral valve anatomy and function, the echocardiographic examination, and predictors of outcome after repair. The second part describes common surgical repair techniques and the postrepair echocardiographic assessment. The goal of this 2-part review is to provide a source of information for readers to draw from to help guide the prerepair examination and to understand the repair technique and how to assess the repaired valve.

MITRAL VALVE ANATOMY/FUNCTION

Mitral valve function is determined by its primary components and its interaction with the surrounding chambers. The mitral apparatus includes the mitral annulus, the leaflets, papillary muscles and attaching chordae. Information of the size, shape, and function of the left ventricle (LV) determine the systolic coapting force, the position of papillary muscles and chordae, and their effect on leaflet position and mobility. While it is known that mitral regurgitation will result in left atrial (LA) and left ventricular (LV) enlargement, it also is known that LV dysfunction and remodeling can result in mitral regurgitation. Understanding the mitral apparatus and its functional relationship with the ventricle has improved the understanding of mitral dysfunction, has helped develop repair techniques, and has increased understanding as to why repairs fail.[5–8]

The mitral valve lies in multiple planes anterior to posterior, medial to lateral, and superior to inferior (Figs 1–4) (Video clips 1 and 2).[9,10] The annular plane separates the atrium from the ventricle and is the reference plane for leaflet prolapse (>2 mm above the annular plane) and flail (leaflet edge above the annular plane). The annulus is a 3-dimensional, saddle-shaped unit with anterior and posterior segments. The anterior annulus makes up 1/3 of the annular circumference and forms part of the cardiac trigone, or cardiac skeleton, along with the aortic and tricuspid valves (Figs 1–3).[5,11–13] As part of the trigone, the anterior annulus consists mostly of continuous fibrous tissue with muscular portions toward the transition points with the posterior annulus. The posterior annulus, which makes up 2/3 of the annular circumference, is mostly membranous and muscular and is in continuity with the muscular walls of the LA and LV. The mitral annulus undergoes important conformational changes as a result of LA and LV contraction and relaxation that affect ventricular inflow and outflow. The 3 types of annular motion include translation, contraction, and folding (Fig 2).[5,11–14] Translation is the movement toward and away from the ventricular apex during ventricular diastole and systole, respectively. During ventricular systole, the annulus contracts posteriorly, mostly due to contraction or shortening of the posterior annulus, which effectively moves the mitral leaflets posterior and away from the left ventricular outflow tract (LVOT).[14] The anterior annulus appears to lengthen and elevate, effectively enlarging the LVOT.[14] Finally, the annulus folds along the intercommissural line from anterior to posterior, which enlarges the left ventricular outflow tract. These changes in the annulus help to create a large presystolic storage space during isovolumic contraction and reduce hindrance to systolic outflows during the ejection phase. The annular changes during ventricular systole optimize the closing and coaptation of the mitral leaflets by reducing mitral annular area, increasing the coaptation length or zone-creating leaflet overlap of ideally, ≥ 6 mm.[15] The posterior shift of the coaptation point exposes the ventricular surface of the dominant anterior leaflet to systolic outflow, which contributes to the coapting force (Figs 2 and 5).[15] These anatomic relations and functions minimize stress on the mitral leaflets during the entire cardiac cycle.[5,11,16,17]

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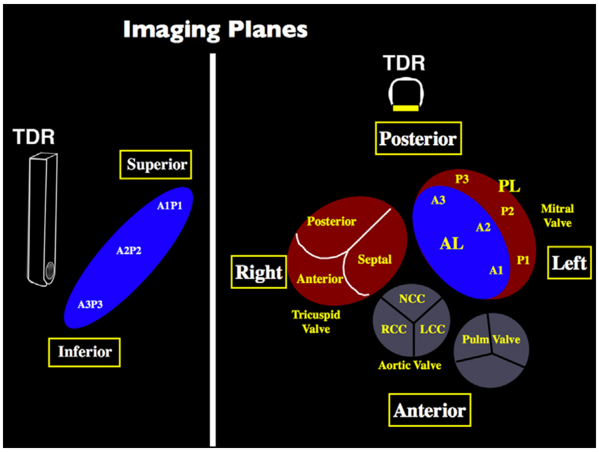

Fig 1. These 2 schematics show the vertical (left) and horizontal (right) position of the mitral valve, the latter in relation to other surrounding structures and as would be seen by the transducer (TDR) positions. AL, anterior leaflet; PL, posterior leaflet; LA, left atrium; LAA, left atrial appendage; LV, left ventricle; AoV, aortic valve; A1, A2, A3, scallops of anterior leaflet; P1, P2, P3, scallops of the posterior leaflet; TDR, transducer; NCC, RCC, LCC, non, right, and left coronary cusps of the aortic valve; Pulm Valve, pulmonary valve.

The anterior and posterior mitral leaflets insert into their respective annuli. Leaflet nomenclature has been described by both Duran and Carpentier (Fig 6).[18] Both describe the posterior leaflet as having 3 scallops or segments; anterior lateral and superior (P1), middle (P2), and posterior medial and inferior (P3). Duran describes the anterior leaflet is 2 larger segments (anterior [A1] and posterior [A2]) and 2 smaller commissural segments (C1 and C2). By contrast, Carpentier describes the anterior leaflet with relation to the posterior leaflet, A1, A2, and A3, lying in the same respective planes. Although the posterior annulus covers 2/3 of the annular circumference, the posterior leaflet covers 1/3 of the coapting area while the anterior leaflet is responsible for 2/3 of this space. Functionally, it appears that the posterior leaflet provides a coapting surface for the larger

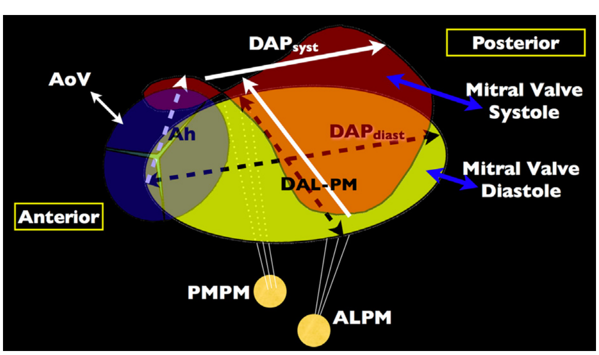

Fig 2. The schematic shows 3 measures of the mitral annulus and how they change during the cardiac cycle. The black dashed arrows represent the annular dimensions at end-diastole. During ventricular systole, the anterior-posterior distance (DAPsyst) decreases and moves laterally in the direction of the white arrow, ie, away from the left ventricular outflow tract. The intercommissural line (DAL-PM) decreases and moves posterior in the direction of the white arrow. The annular height increases and moves the anterior portion of the annulus away from the left ventricular outflow tract (LVOT). Altogether, the mitral annular area declines during ventricular systole and moves away from the LVOT to allow for unhindered systolic outflow. AoV, aortic valve; Ah, annular height; DAP, anterior-posterior diameter; Syst, systole; Diast, diastole; PMPM, posterior medial papillary muscle; ALPM, anterolateral papillary muscle.

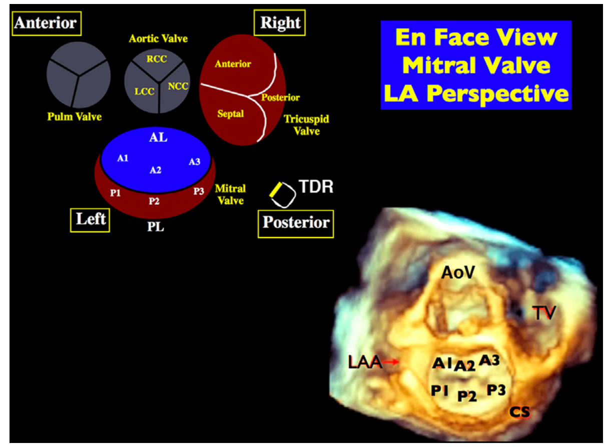

Fig 3. The top left of the figure shows a schematic with the mitral valve in the en face view and the surrounding valves to show a flat (2-dimensional) relationship among the valves. The transducer (TDR) is placed to resemble where the esophagus really is. The image shown in the right lower corner is an en face 3-dimensional view of the mitral valve and the surrounding tissues. AL, anterior leaflet; PL, posterior leaflet; LA, left atrium; LAA, left atrial appendage; LV, left ventricle; AoV, aortic valve; A1, A2, A3, scallops of anterior leaflet; P1, P2, P3, scallops of the posterior leaflet; RCC, LCC, NCC, right, left, and non-coronary cusps; TDR, transducer; Pulm Valve, pulmonary valve; TV, tricuspid valve; CS, coronary sinus.

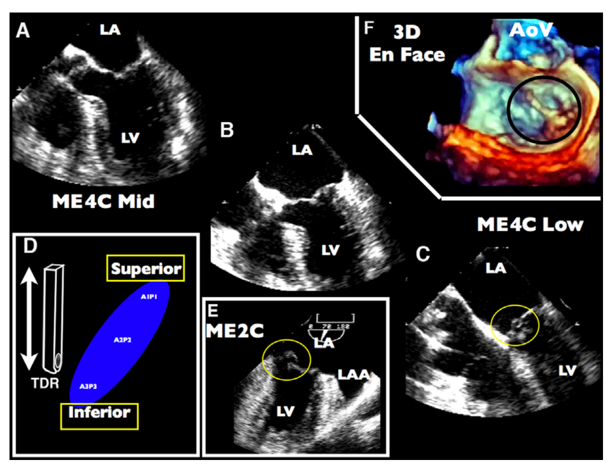

Fig 4. (Associated with Video clip 2). From multiple views, a flail of the posterior (P3) portion of the posterior leaflet with a torn chord is seen. The images shows how the mitral valve also exists in a vertical plane as imagined in the schematic in panel D. Images A, B, and C were obtained by advancing the transesophageal echocardiography (TEE) probe from the mid-esophageal (ME) 4-chamber (4C) level to a lower esophageal level, the last of which shows the P3 defect (yellow circle). The lesion is further highlighted in the ME 2-chamber view in panel E (yellow circle) and in the 3-dimensional (3D) en face views in panel F, the latter of which shows the defect and the torn chord (black circle). AL, anterior leaflet; PL, posterior leaflet; LA, left atrium; LAA, left atrial appendage; LV, left ventricle; AoV, aortic valve; A1, A2, A3, scallops of anterior leaflet; P1, P2, P3, scallops of the posterior leaflet; TDR, transducer.