Transoesophageal Echocardiographic Evaluation of the Mitral Valve

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ABSTRACT
Transoesophageal echocardiography allows the precise assessment of mitral valve pathology. Perioperative assessment of the mitral valve provides valuable support for the cardiac surgical team in planning a repair or replacement of this unique three-dimensional structure. This article will review the echocardiographic methods and views that allow a systematic assessment of the mitral valve apparatus.

Keywords: Transoesophageal echocardiography, Mitral valve, Anaesthesia.


INTRODUCTION
The mitral valve is located close to the oesophagus which makes this valve ideal for assessment by transoesophageal echocardiography (TOE). Before the development of perioperative TOE techniques and technology, diseases of the mitral valve were replaced by a prosthesis only when severe stenosis or regurgitation was present.1 Current multiplane TOE transducer technology allows a detailed evaluation of the mitral valvular structure and the subvalvular apparatus, and allows a quantification of the severity of mitral valve disease.

The information obtained by perioperative imaging techniques provides the surgeon with vast amount of information about the precise mechanism of mitral valve structural abnormalities and the suitability for repair. This has allowed the development of surgical reparative techniques that have improved outcomes and the longevity of patients with mitral valve disease2-4 compared with valve replacement. In addition, this tool is invaluable in assessing the quality of mitral valve repair or replacement post-cardiopulmonary bypass.

NORMAL ANATOMY OF THE MITRAL VALVE
The mitral valve separates the left atrium from the left ventricle, and forms part of the fibrous skeleton of the heart. It was named for its resemblance to a bishop’s mitre as depicted in the works of Leonardo da Vincin in the 16th century. He was one of the first to highlight the complex three-dimensional architecture of the valve and the subvalvular apparatus from the dissection of bovine and human hearts.5,6 The shape of the mitral annulus changes during the cardiac cycle. During diastolic relaxation, the mitral annulus is shaped like a saddle, whereas during systole, the structure of the mitral annulus flattens, and the mitral annulus circumference contracts by 20 to 40%.7

The normal mitral valve comprises of two leaflets, the anterior and posterior, which are attached at its bases to the mitral annulus (Fig. 1). The anterior leaflet is also known as the septal or aortic leaflet and has a semi-circular shape with a convex free edge. The posterior or mural leaflet is quadrangular in shape and is narrow with a concave free edge. It encloses a greater part of the mitral annular circumference (approximately 70%), compared with the anterior leaflet.

Both the anterior and posterior leaflets are further subdivided into different segments, which have been described by Carpentier8 and adopted by the American Society of Echocardiography/Society of Cardiovascular Anaesthesiologists (ASE/SCA).9 The posterior mitral valve leaflet is divided by indentations and is named based on three distinct anatomical scallops: P1 designates the anterolateral scallop, P2 the middle scallop and P3 the posteromedial scallop. These indentations are believed to assist with the opening of the leaflet during diastole. The anterior leaflet has less clearly defined segments designated as A1, A2 and A3, which correspond to the anterior segments adjacent to the posterior leaflet segments.

The anterior and posterior leaflets are joined together by the commissures, which provide continuity at their insertion into the mitral valve annulus. The commissure that joins the A1 and P1 segments are referred to as the anterolateral commissure, whereas the posteromedial commissure joins the A3 and P3 segments.

On the atrial side of each of the leaflets, there are two distinct areas. The rough zone, or coaptation zone is a coarse area near the free edge, which acts as the coaptation surface of the valve. An adequate coaptation zone is critical, as this maintains valve competency during systole. The remaining part of the leaflet does not participate in the coaptation and is smoother and is known to as the smooth zone.

SUBVALVULAR APPARATUS
The integrity of the whole mitral apparatus is important, as valve function is dependent on both the mitral valve as well as the subvalvular apparatus. The subvalvular apparatus...
consists of the chordae tendineae, papillary muscles and the left ventricle.

The chordae tendineae are fibrous bands of tissue that maintains the position and tension on the valve leaflets at end systole. They originate from the papillary muscles and are classified based on their insertion site on the leaflets. The primary chordae insert to the free edge of the leaflet and ensures coaptation of the leaflet tips. The secondary chordae attach to the ventricular surface of both leaflets to redistribute tension across leaflet tissue and also contribute to ventricular valve continuity by maintaining ventricular function and shape. The tertiary chordae attach to the posterior leaflet base and the mitral annulus and also contributes to ventricular valve continuity.

The chordae are attached to one of two papillary muscles: The anterolateral and posteromedial. Each papillary muscle provides chordae to both leaflets. The anterolateral papillary muscle has a dual blood supply from both the left anterior descending and the circumflex coronary arteries. The posteromedial papillary muscle is usually supplied solely by the posterior descending coronary artery and thus, is more susceptible to ischaemia and infarction.

Finally, the function of the papillary muscle depends not only on its blood supply, but also on the integrity of the left ventricular wall. Any change in the ventricular geometry, such as ventricular remodelling or regional wall motion abnormalities from ischaemic, can change the relationship of the chordae and the leaflets, resulting in valvular dysfunction.

TRANSOESOPHAGEAL VIEWS TO ASSESS STRUCTURE AND FUNCTION

A systematic review of the mitral valve is essential to obtain a comprehensive and accurate description of the valve structure and function. There are four mid-oesophageal and two transgastric views that allow the echocardiographer to assess the segments of the mitral valve and the subvalvular apparatus.9

However, it is also important that a complete diagnostic study of the heart and great vessels should be performed as incidental findings, such as severe atherosclerotic aortic disease, undiagnosed aortic insufficiency, and regional wall motion abnormalities associated with myocardial ischaemia often significantly affect surgical planning.

MID-OESOPHAGEAL MITRAL COMMISSURE (60-70°)
The mitral commissure view is obtained by rotating the scan plane angle to between 60 and 70°. The mitral commissure view cuts across the mitral commissure twice and provides a ‘sea-gull’ view of the mitral valve with the P3, A2, P1 segments with the P3 scallop appearing on the left and the P1 scallop on the right of the image (Fig. 3). The A2 segment moves up and down in between the two scallops during the cardiac cycle. This is useful in assessing which segments are involved in mitral regurgitation. The presence of P2 prolapse can be confirmed with the appearance of the prolapsing P2 segment above the A2 segment in the centre of the mitral annulus. This view allows the diameter of the major axis (commissure to commissure) of the mitral annulus to be measured at end systole. Rotating the probe counterclockwise brings the entire posterior leaflet into view and rotating the probe clockwise allows the anterior leaflet can be evaluated.

MID-OESOPHAGEAL TWO-CHAMBER (80-100°)
The two-chamber view is achieved by rotating the angle of the scan plan to between 80 and 100°. The posteromedial leaflets can be evaluated. This view is particularly useful as with small movements of the TOE probe, the echocardiographer can assess all six segments of the mitral valve. By withdrawing the TOE probe and bringing the left-ventricular outflow into view, gives us the five-chamber view. This allows the visualisation of the anterolateral part of the commissure and the A1/P1 coaptation point can be assessed. Advancement of the probe and slight retroflexion, the A2/ P2 coaptation point can be assessed. Further advancement and retroflexion of the probe and the A3/P3 coaptation point can finally be seen together with the posteromedial commissure.

MID-OESOPHAGEAL FOUR-CHAMBER (0-20°)
The mid-oesophageal four-chamber view allows analysis of the A2 and P2 leaflets of the mitral valve. In this view, the P2 leaflet appears on the lateral side of the heart on the right side of the image, whereas the A2 leaflet appears on the medial side (Fig. 2). It is important to optimise the image so that the coaptation line between the anterior and posterior leaflets can be evaluated. This view is particularly useful as with small movements of the TOE probe, the echocardiographer can assess all six segments of the mitral valve. By withdrawing the TOE probe and bringing the left-ventricular outflow into view, gives us the five-chamber view. This allows the visualisation of the anterolateral part of the commissure and the A1/P1 coaptation point can be assessed. Advancement of the probe and slight retroflexion, the A2/ P2 coaptation point can be assessed. Further advancement and retroflexion of the probe and the A3/P3 coaptation point can finally be seen together with the posteromedial commissure.

Fig. 1: The normal mitral valve comprising of two leaflets (the anterior and posterior which are attached at its bases to the mitral annulus), commissures (anterolateral and posteromedial)
end of the mitral commissure is viewed with the P3 segment on the left of the image and A3, A2, and A1 segments from the left to the right of the image (Fig. 4). The A1 segment lies closest to the left atrial appendage. By rotating the probe clockwise and counter clockwise the entire coaptation line can be assessed.

**MID-OESOPHAGEAL LONG AXIS (120-160°)**

The angle of the multiplane transducer is rotated to between 120 and 160° to obtain the long-axis view. The scan plane in this view passes through the mitral valve perpendicularly at the A2 and P2 coaptation point (Fig. 5) and thus, allows the optimum view to assess the vena contracta in the case of mitral regurgitation. The mid-oesophageal long-axis view also allows the diameter of the minor axis (anterior to posterior) of the mitral annulus to be measured at end systole from the base of the leaflets. In this view, the length of the anterior mitral valve leaflet should be measured at its maximal extension.

**TRANSGASTRIC BASAL SHORT-AXIS VIEW (0-20°)**

The transgastric basal short-axis view allows the visualisation of the entire mitral valve in its short axis. The tip of the TOE probe is advanced into the stomach and is ante flexed, which gives us the ‘fish-mouth’ view of the mitral valve in short axis (Fig. 6). On cardiopulmonary bypass, the surgeon views the valve in its entirety in a flaccid state from the left atrium looking down toward the left ventricle. In the surgical view, the patient’s left and right sides correspond to the surgeon’s left and right sides. The orientation of the mitral valve as seen on TOE is approximately 180° rotated as compared to the surgeon’s view of the mitral valve. The posteromedial segments (A3/P3) are seen in the superior part of the image closest to the probe, and the anterolateral segments (A1/P1) are seen in the inferior part of the image (Fig. 6). All segments of the mitral valve and the whole coaptation line can be examined. This view is useful to assess and confirm the origin of regurgitation jets.

**TRANSGASTRIC TWO-CHAMBER VIEW (80-100°)**

The transgastric two-chamber view provides an image of the long axis of the left atrium and the left ventricle, with the mitral valve is seen on the right of the image (Fig. 7). To obtain this view, the transgastric mid-papillary view is obtained, and the multiplane probe angle is rotated to between 80 and 100°. This view is particularly useful in
assessing the subvalvular apparatus and allows the assessment of the anatomy of the chordae tendineae papillary muscle.

**EVALUATION OF THE MITRAL VALVE**

The primary goal of pre-cardiopulmonary bypass TOE examination is to define the etiology and dysfunction of the mitral valve apparatus. Once the presence of significant mitral regurgitation has been confirmed, the echocardiographer must investigate the precise location and mechanism of the lesion. By using the above four mid-oesophageal views and two transgastric views, the mitral valve can be systematically examined.

This will give the surgeon valuable information to assess the suitability for repair or replacement of the mitral valve. Mitral valve repair is the optimal surgical treatment for MR whenever feasible. There are several advantages associated with mitral valve repair when compared with mitral valve replacement: Better preservation of LV function, freedom from long-term anticoagulation therapy, and lower risk of thromboembolism and endocarditis.

Occasionally, assessment of severity will be required. However, it is important to remember that loading conditions of the heart may result in an underestimation of disease severity. The approach to the evaluation of mitral valve severity ideally integrates multiple parameters rather than dependence on a single measurement.

**TWO DIMENSIONAL ECHOCARDIOGRAPHY**

The assessment of the mitral apparatus should involve a detailed and systematic analysis of each part of the mitral valve and the subvalvular apparatus. The mitral valve leaflets should be assessed for thickening, calcification, fusion, perforations, clefts or attached vegetations. Any billowing, prolapse, or flail of the leaflets should be noted and the mechanism investigated. Prolapse occurs when one or both leaflet tips excurse above the level of the annulus. Flail of the leaflet is reserved for the situation when a leaflet tip is flowing freely into the left atrium during systole and occurs usually as a result of one or more ruptured chordae tendineae. Billowing occurs when part of the leaflet appears above the level of the annulus and the coaptation point remains below the annulus.

The mitral valve annulus should be assessed for the degree of annular dilatation and the length of the anterior mitral valve leaflet should be measured in the mid-oesophageal long-axis view to assess for feasibility of mitral valve repair. The chordae should be assessed for thickening, fusion, calcification, elongation and rupture. Finally, the papillary muscles should be evaluated for rupture, and for left ventricular papillary muscle dysfunction.

Pulse wave and continuous wave Doppler are used to add more information during evaluation of mitral valve.

**THREE DIMENSIONAL ECHOCARDIOGRAPHY**

Although two-dimensional echocardiography remains the cornerstone of assessment of the mitral valve, three-dimensional echocardiography can contribute additional information that aids in the evaluation of mitral valve pathology. Three-dimensional imaging allows the mitral valve to be viewed at different angles and improves the understanding of the interaction of the different elements of the mitral valve apparatus (Fig. 8).

Multipane TOE three-dimensional probes incorporate steering logic for image acquisition to produce a matrix of two-dimensional images. A series of two-dimensional rotational images are obtained along a fixed axis and are combined by the echo software to create a three-dimensional dataset, resulting in a 3D reconstruction and display. Several clinical trials have demonstrated that 3D echocardiographic planimetry can provide a good correlation with an invasively determined mitral valve area.
CONCLUSION

It is important that echocardiographers involved in mitral surgery to have an understanding for the functional anatomy and nomenclature of the mitral valve. This allows the echocardiographer to correctly interpret the two-dimensional TOE images and communicate with the surgeon the precise location and nature of the pathology of the mitral valve apparatus.

The assessment of a complex structure like the mitral valve can be difficult. It requires a thorough understanding of not only the anatomy but also the spatial relationship of the two-dimensional scan plane to the valvular apparatus. The information that is obtained from the TOE provides invaluable information to the surgeon to plan their repair technique.

REFERENCES


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