The Mitral Valve: Characterisation by Real-Time Three-Dimensional Transesophageal Echocardiography. Current Status

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Abstract
The complex anatomy of mitral valve demands precise and sophisticated imaging during any intervention. Transesophageal echocardiography has been the most frequently used modality. With the advent of three-dimensional echocardiography a more comprehensive description of the mitral valve is now possible. This review aims to discuss the framework for imaging the mitral valve by three-dimensional echocardiography; its current status and the limitations of three-dimensional echocardiography in its current platform.

Introduction
The mitral valve apparatus is a complex structure whose components are organized to ensure unidirectional flow of blood from left atrium to left ventricle with minimal pressure gradient. An alteration in its structure is responsible for regurgitation or stenosis. Any interventional procedure on the mitral valve, surgical or percutaneous, demands precise imaging. Three-dimensional (3D) transthoracic (TTE) and transesophageal echocardiography (TEE) are being used for comprehensive evaluation of mitral valve. This article aims to discuss the assessment of mitral valve by 3D TEE, its present status and address the limitations of the technique.

Three-Dimensional Transesophageal Echocardiography
A miniaturized matrix-array transducer with approximately 3000 elements fitted into the tips of conventional TEE probes has resulted in fully sampled matrix-array TEE transducers (Philips Medical Systems, Andover, MA). Using the matrix–array 3D TEE probe, 4 different types of data sets can be obtained.

1. Large sector (Full Volume): A pyramidal volume of approximately $60^\circ \times 60^\circ$ to $100^\circ \times 100^\circ$ is acquired in 4-8 gated beats. It has a frame rate of 20-25 Hz and temporal resolution of 35-50 msec.

2. Narrow sector (Live 3D): It allows real-time 3D imaging of a pyramidal volume of approximately $30^\circ \times 60^\circ$; has a frame rate of 25-35 Hz and temporal resolution of 33-40 msec.

3. Wide sector focused (Live 3D zoom): The zoom mode allows real-time 3D imaging and the size of the pyramidal volume may vary $20^\circ \times 20^\circ$ to $90^\circ \times 90^\circ$; has frame rate of 5-10 Hz and temporal resolution of 160 msec.

4. Simultaneous biplane (X plane): It allows real-time imaging, has a frame rate of 25-30 Hz and temporal resolution of 30-35 msec.

Colour Doppler imaging is not possible with narrow sector and wide sector data sets. Pyramidal data sets are cropped along designated x, y, z axes or using a manually positioned cropping plane.

Fig. 1: 3D TEE assessment of the mitral valve. (A) Images showing simultaneous biplane format. (B) Images obtained with the large sector format with and without the cropping plane. The en face view of the mitral valve is shown. (C-D) Wide sector focused format needs to be turned to see the valve en face. (E) Narrow sector format showing the mitral valve.

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Simultaneous Biplane format: This allows optimization of the imaging plane. One can estimate the severity of mitral regurgitation (MR), size of the left atrium (LA) and left ventricle (LV) and their function.

Large sector format: Large sector data sets are obtained with and without colour Doppler after optimizing the mitral valve image using the biplane format. Because the data set is obtained in 4-8 gated beats, it may be affected by “stitching” artifacts. Although these artifacts do not pose any real diagnostic difficulty, they damage the image quality. These may be minimized by avoiding ectopic beats and deep breathing during image acquisition. A comprehensive assessment of morphology of LA, LV and quantification of MR is possible.

Narrow sector format: It does not permit full visualization of the mitral valve. The image needs to be rotated to analyse the valve in its en-face view. The visual plane needs to be optimised with different levels of anterior and posterior tilt and elevation. It is useful for characterization of leaflets and commissures. The left atrial appendage (LAA) can be adequately analysed. It finds specific application during balloon mitral valvotomy.

Wide-sector focused format: The truncated pyramidal data set obtained is seen from its side. This data set needs to be tilted to visualize the mitral valve. The image is rotated so as to place the aortic valve to about 12 o’clock position. The view is similar to that observed by a cardiac surgeon inspecting the mitral valve from the LA.

**Current Applications**

The saddle-shaped contour of the mitral annulus and leaflets has been demonstrated by 3D echocardiography. There is flattening of the mitral annulus during dilatation of left ventricle, with resultant functional MR. Each commissure is inspected from the LA and LV for fusion and calcification. The funnel shaped narrowing of the mitral valve in mitral stenosis can be appreciated by viewing from the LA. Best visualization of the subvalvular apparatus (chordae and papillary muscles) is gained from transgastric views. Real-time 3D TEE is uniquely suited for assessment of LA and LAA (Figure 3).

A detailed analysis of mitral valve commissures is of particular interest in patients undergoing balloon mitral valvotomy. Each commissure is inspected from the LA and LV for fusion and calcification. The funnel shaped narrowing of the mitral valve in mitral stenosis can be appreciated by viewing from the LA. Best visualization of the subvalvular apparatus (chordae and papillary muscles) is gained from transgastric views. Real-time 3D TEE is uniquely suited for assessment of LA and LAA (Figure 3).

The use of colour Doppler has the potential to improve the characterisation of MR jets and estimate its severity. 3D TEE provides additional information to that obtained from 2D examination (Figure 4). The importance of 3D TEE in the arena of prosthetic mitral valve deserves special mention. Thrombosis of a prosthetic valve (Figure 5), repair of paravalvular leaks and infective endocarditis has been studied.

However, the greatest impact of 3D TEE has been for planning mitral valve surgery and percutaneous interventional procedures like balloon mitral valvotomy (Figure 6), mitral valve repair and device closure of LAA.
Limitations

The major limitations of the current platform are the small field of view in real-time modes and slow frame rate. Another drawback has been lack of colour Doppler in real-time formats. There is considerable room for improvement of both spatial and temporal resolution. Very fine and highly mobile structures are not adequately visualised. In its current platform, 3D TEE prolongs examination time.

Conclusion

Real-time 3D TEE offers a detailed understanding of the mitral valve geometry. The en face view of the valve permits precise identification of individual leaflet scallops and characterisation of the commissures. Precise definition and location of mitral valve abnormalities is feasible. It is being used for guidance and decision making in surgical and interventional procedures of the mitral valve. With improvement, it is likely to have a profound clinical impact in the management of patients with mitral valve disease.

References