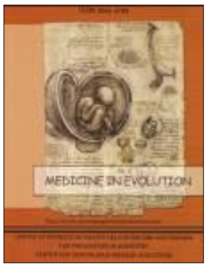
THREE-DIMENSIONAL ECHOCARDIOGRAPHY FOR MANAGEMENT OF MITRAL VALVE DISEASE



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ABSTRACT

Echocardiography is the most common noninvasive tool for assessing cardiac structure and function.

Three-dimensional echocardiography expands the diagnostic capabilities of cardiac ultrasound. The available literature suggests that three-dimensional echocardiography provides improved accuracy and reproducibility over two-dimensional methods for the assessment of mitral valve diseases.

The aim of this manuscript is to give a brief review of the development of the clinical applications of three-dimensional echocardiography.

Keywords*: three-dimensional echocardiography, mitral valve disease, clinical applications.*

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INTRODUCTION

Conventional two-dimensional (2D) echocardiography can evaluate cardiac structure and function by providing crosssectional views of the heart.

The examination requires one to mentally conceive a series of orthogonal, planar, or tomographic images as a multidimensional reconstruction. The mental reconstruction is often difficult and inadequate in understandding of complex cardiac structures. As repair techniques have advanced, so has the need to obtain accurate information prior to surgery. Three-dimensional (3D) echocardiography is a new emerging technique that allows recording of volumetric echographic data [1, 2]. This technique can provide views of the entire valve, allowing a complete assessment of the valve leaflets and commissures.

Several authors recommended already to integrate this new technique in the standard preoperative examination and become an important tool in the decision to process valvular repair /replacement [1-6].

THREE DIMENSIONAL RECONSTRUCTION

Three dimensional echocardiography can be done by two techniques [7]: transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE), using real–time imaging or offline postprocessing. Transesophageal acquisition is more useful in emphyseamatous, obese patients and its more likely to obtain more data of small cardiac structure which can not be visualized with TTE.

There are several ways to present the data in the 3D volumetric data set. The most used are anyplane echocardiography and volumetric rendering technique. Anyplane echocardiography allows the examiner to generate 2D tomographic images in any desired orientation which can be physically unobtainable by conventional 2D echocardiography [8]. 3D TEE is performed with image acquisition in multiple 2D image planes and automatic rotational image acquisition on every 2-3 degrees from a complete 180 degrees rotation. For this, a special omniplane transducer and special echocardiographic software for the sequential image acquisition is needed.

Bidimensional images are stored and then transferred to another computer where the reconstruction and 3D images are obtained. Unfortunately, this method is time-consuming.

Volumetric rendering technique creates images resembling the true anatomy of the heart [7]. The development of matrix transducers with more than 3000 crystals, together with new processors, has enabled the acquisition of real-time images without the need for off-line reconstruction. These new advances have allowed the application of 3D echocardiography to daily clinical practice.

Early 3D color Doppler echocardiography systems also required laborious reconstruction but full volume imaging has eliminated that need [8]. Seven heart beats are needed to acquire a full-volume image which is able to demonstrate the entire flow of interest.

This method is especially useful in complex mitral regurgitant flows, the severity of which is usually underestimated by 2D echocardiography.

THE EVALUATION OF MITRAL VALVE ANATOMY

Three-dimensional echocardiography allows for an understanding of the complex interrelationships among valve, chordae, papillary muscles, and myocardial walls, making it an excellent tool in the understanding of the mitral valve (MV) anatomy. Consequently, the morphology of muscular trabecula, the location of papillary muscles [7, 8], and spatial relations of various other structures can be observed very clearly.

The full-volume mode can be cropped using the elevational plane from the apex so that whole views of MV from the atrial and ventricular side and the relation with neighboring structures can be displayed [7].

Several 3D studies, it was confirmed the saddle-shape of the mitral annulus [4, 5].

These data make 3D echocardiography a new clinical standard for the evaluation of the MV: a fast and reproducible technique with detailed anatomic information and orifice assessment that is relatively independent of confounding hemodynamic variables[6].

THE EVALUATION OF MITRAL VALVE STENOSIS

The utility of 3D echocardiography in the evaluation of mitral stenosis and accuracy of MV area measurements has been established by multiple studies [4, 5, 7, 9]. This technique is a rapid and precise for determining the valvular orifice area, as it facilitates the orientation of any slice plane to locate the minimal MV area. Thus, it eliminates one of the principle limitations of 2D echocardiography in determining MV area by planimetry [7]. In a 3D homogeneous data set using anyplane echocardiography it is possible to pinpoint the cut plane to the tips of the MV so that the true anatomic valve area can be measured. The most optimal way of MV area measurement is: two long-axis views through the MV, nearly perpendicular to each other, are defined by navigation of the lines of intersection [8]. Short-axis cut plane is further positioned at the MV cusp tips, which is selected for area measurement by planimetry. With 3D reconstruction there is less inter- and intra-observer variation when calculating MV area [7]. In MV stenosis, the severity of stenosis, the position and degree of leaflet fusion and thickening, as well as the fused and thickened chordae tendineae can all be visualized clearly on 3D technique (figure 1) [9].

The 3D echocardiography assessment of MV area showed better agreement with the invasively derived method before and after percutaneous mitral valvuloplasty[2].

THE EVALUATION OF MITRAL VALVE REGURGITATION

Accurate evaluation of mitral regurgitation (MR) severity is a challenging task in daily practice. The current 2D echocardiographic methods used to quantify MR have their well-known limitations. Three-dimensional echocardiography has the potential to improve the assessment of MR by facilitating the visualization of complex mitral anatomy in three dimensions and providing more accurate quantification of regurgitant color Doppler flow events [1]. Some authors have quantified by 3D echocardiography the severity of MR by calculating mitral regurgitant orifice area on virtually reconstructed valve. 3D color flow imaging recognized different patterns of eccentric regurgitant jets, not described previously, such as cylinder, tongue, spiral and spoon-like patterns [8]. This improved technique provided information on the origin and extent of the dehiscence in case of paravalvular leaks, as well as insight into the direction of the regurgitant jets.

The flow convergence or proximal isovelocity surface area (PISA) method is based on the phenomenon that flow accelerates towards the regurgitant orifice and forms a series of concentric hemispheric shells of increasing velo-city [10]. Since 3D can display the entire flow convergence region en face viewing from the left atrium, a more accurate assessment of its area can be done without the need to make geometric assumptions. Three-dimensional flow convergence based methods have been shown to accurately predict the flow rate [8].

Furthermore, 3D echocardiography has provided important mechanistic insights into functional and ischemic MR resulting from derangements of the normal spatial relationships of the MV leaflets to its chordal attachments, papillary muscles, and left ventricle [3-5]. Distortion of the normal spatial relationship between the left ventricle and MV apparatus results in outward and apical displacement of the papillary muscle with secondary tethering of the MV leaflets, leading to incomplete closure of the leaflets and MR. MV tethering has been found as a strongest determinant of MR severity and the pattern of MV deformation was asymmetrical in ischemic heart disease, whereas it was symmetrical in dilated cardiomyopathy [8].

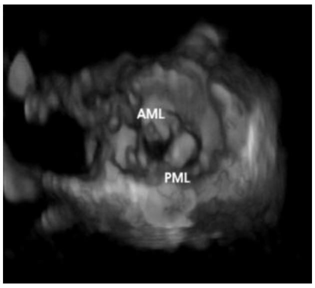

Fig.1 Diastolic frames of the 3D reconstruction of the mitral valve orifice as seen from the left atrium. AML = anterior mitral leaflet, PML = posterior mitral leaflet.

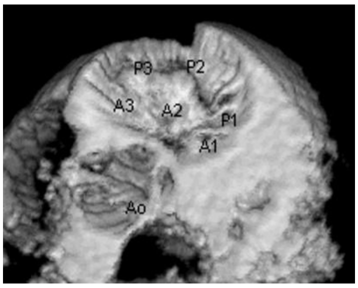

Fig.2 Transesophageal off-line three-dimensional echocardiography: view of the mitral valve prolapse as seen from the left atrium.

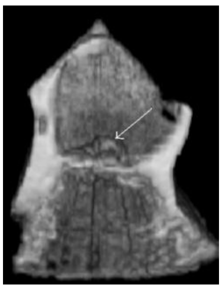

Fig.3 Transesophageal off-line three-dimensional echocardiography: prolapse of the mitral valve (longitudinal view).

Fig.4 Infective endocarditis of mitral valve: real–time three-dimensional transthoracic echocardiography showing vegetation (veg) and perforation (perf).

MV prolapse is often under- or overestimated using 2D echocardiography because of its non-planar leaflet–annular relations[1]. In patients with MV prolapse, the degree of prolapse, stereoscopic views, and spatial relations of anterior and posterior mitral leaflets in systolic closure can be observed in the left parasternal long-axis view much more clearly on 3D echocardiography than on conventional 2D technique (figure 2 and 3) [7]. For a bird's eye view of the MV from the left atrium or left ventricle side, 3D echocardiography can also provide more accurate images, showing the location, range, and changes of phases in cardiac cycles of the prolapsing leaflet[6]. Probably due to its greater size, the anterior leaflet was more easily seen, both in the parasternal and apical views. The posterior leaflet was better identified from the parasternal view. 3D TEE performs best when compared with anatomic examination by the surgeon during the intervention, with correct localization of the prolapsed segment in 96% of cases [8]. Rapid, single-image acquisition with a 3D TEE probe enables the evaluation of each mitral scallop from any angle without the necessity of mental reconstruction of different echocardiographic slices.

In patients with prosthetic MV we are able to delineate actual site, size, and shape of the paravalvular leak and its relation to the surrounding structures [8]. In patients with infective endocarditis, 3D echocardiography is able to show the stereoscopic configuration, attachment, and mobility of vegetations, as well as potential complications, such as valve prolapse and perforation (figure 4) [7].

NEW APPLICATION IN MITRAL VALVE DISEASES

New prosthetic mitral annuloplasty devices are being designed to attempt to recover the original shape of the mitral annulus. In this new context, 3D echocardiography may be used for a detailed evaluation of the geometry of the annulus and possibly help select the most appropriate prosthesis [8]. In addition, similar studies can be conducted post-implantation to evaluate the changes in annular geometry.

Cardiac resynchronization therapy is a therapeutic alternative in patients with advanced heart failure that is refractory to medical treatment. Three-dimensional echocardiography could help improve the understanding which mechanisms that lead to functional MR reduction in patients receiving resynchronization therapy and perhaps optimize the selection of patients that benefit most from this therapy [11].

The application of echocardiography in the cardiac catheterization laboratory has facilitated certain interventions and has allowed the timely detection of procedural complications.

Similarly, 3D TEE could be of use in guiding the interatrial wall puncture needed in mitral device implantation [7, 8].

3D visualization of the entire mitral annulus prosthesis in patients with periprosthetic leaks obviates the mental reconstruction necessary to localize their origin and, consequently, improves diagnostic precision [7].

Although there is minimal scientific evidence to support it, the application of 3D technique may provide a great advance in the guidance of percutaneous closure procedures for periprosthetic leaks.

Moreover, it will be able to guide MV procedures such as the Alfieri percutaneous repair technique or mitral annuloplasty ring implantation via the coronary sinus [12].

CONCLUSIONS

The application of 3D echocardiography to the study of the MV contributes unique information about its anatomy that can be of great use in improving the knowledge and treatment of MV pathologies. It appears that 3D echocardiography has the potential for planning operations and assessing interventional or surgical results.

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