THREE-DIMENSIONAL ECHOCARDIOGRAPHY – RECENT ADVANCES

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INTRODUCTION

Transthoracic echocardiography is the most used noninvasive technique for the assessment of cardiovascular apparatus. With the passing of the time and the advances of the echocardiographic machines, the physicians’ expectations to obtain more accurate images were higher.

After M mode evaluation and bidimensional (2D) echocardiography in the 60’s, there was a revolution in the 70’s with Doppler echocardiography. These combined techniques were able to provide a better understanding of etiopathogeny, physiology of cardiovascular diseases and a better treatment for these diseases.

Above all this, there was a new development of these echocardiographic techniques in the last years of the 20th century: three-dimensional (3D) echocardiography. This is a recent and advanced method analyzing the structures of the heart starting from bidimensional images obtained in three different planes (sagittal, frontal and transversal). These images are then processed by special software to reproduce the real three dimensional structures of the heart. It is always necessary to correlate images with electrocardiographic record and breathe to avoid artifacts.
For the first time in echocardiography, this technique allows an accurate view of the cardiac structures (valvular aspect, size and shape of interatrial defect, intracardiac masses, and prosthetic valves) and helps to identify the most favorable type and timing of surgical treatment. Furthermore, transvalvular jets can be assessed more accurate not only by their velocity measurement by standard 2D echocardiography. Three-dimensional reconstruction of the left ventricle really brings more data about its contractility, mechanical activity and systolic function.

**How to obtain three dimensional images**

Three dimensional echocardiography can be done by two techniques: transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE).

**TEE off line 3D reconstruction**

Three-Dimensional 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: image acquisition lasts for 10-25 minutes and post processing and three-dimensional reconstruction takes another 45-60 minutes.

Transesophageal acquisition is more useful in emphysematous, obese patients and it's more likely to obtain more data of small cardiac structure which can not be visualized with TTE.

There are some situations in which the ultrasounds cannot penetrate and the image quality is poor and the structure situated posteriorly cannot be seen (prostheses, massive valvular calcification). In these scenarios, TEE is the method of choice.

There are few centers in our country which currently use three-dimensional reconstruction in the preoperatory assessment of the patients and our Institute is one of the pioneers of this technique. These are some of our images obtained in our Laboratory of Echocardiography. (Fig. 1)

**3D real time TTE**

3D real time TTE is another acquisition method developed in 2003. The key element of this technique is a xMatrix transducer of 3000 active crystals (unlike 128 crystals of a 2D classic transducer). This transducer is able to make bidimensional acquisition without changing the probe position and switching from 2D mode to 3D mode is made by pressing one button. (Fig. 2)
Acquisition image takes few seconds and it has a pyramidal form (pyramidal volume). Then, the image is post processed and the 3D image is obtained by choosing the three sectional planes (frontal, capital and transversal).

**3D Real time TEE**

The most advanced method in medical practice which proved its benefits on obese or pulmonary patients is 3D real time transesophageal echocardiography. The 5Mz probe is a cylinder with 24 small transducers, the opening for each one of them being 8 mm. These small transducers are organized in 3 linear groups inside the probe and can obtain 8 planes in the same time and 24 sections at a complete rotation.

The probe diameter is 14 mm and the length is 8 cm. (Fig. 3) This is the reason why the intubation is more difficult than with the standard 2D transducer, because of the large diameter and the increase in rigidity. Images are transmitted to a specialized computer which can generate 20 frames/sec.

**CLINICAL UTILITY OF 3D ECHOCARDIOGRAPHY**

Assessment of valvular morphology and pathology

Valvular disease is a very common pathology and often requires surgical treatment. Actual diagnostic methods allow making a precise and early diagnosis of these diseases, before irreversible destruction of the leaflets and make possible the interventional or surgical valvular repair. Therefore, echocardiography is the ‘gold standard’ diagnostic method in valvular disease.

3D Echocardiography allows the surgeon to view on the computer the valvular morphology either from the atrium (surgical perspective), or from the ventricle (ventriculotomy perspective), making his decision easier. (Fig 4)

In other countries there is a special interest in the assessment of mitral valvulopathy with this method. In 1996, at Meinz University, Kupferwasser et al., one of the pioneers of this technique, used 3D TEE for the evaluation of mitral stenosis. The result proved the superiority of this method compared to classic transthoracic and transesophageal echocardiography, especially in patients with severe aortic regurgitation or massive aortic calcification.

Professor Veiga from University of Medicine from Lisbon successfully used the same method for the assessment of mitral valve morphology and interatrial septum.

In 2003, Dr. Qin et al. published an interesting paper which cleared up the importance of the mechanism of ischemic mitral regurgitation using 3D transesophageal echocardiography, with direct results in subsequent treatment approach.

In the same period, Lange et al. from Echocardiography Department from Brisbane, Australia, have quantified by 3D echocardiography the severity of mitral regurgitation by calculating mitral regurgitant orifice area on virtually reconstructed valve. This method was then generally accepted and now it is the most accurate technique for assessment of mitral regurgitation severity.

The most important role of 3D echocardiography in mitral valve disease is morphology information in mitral valve prolapse.

But valvulopathy assessment did not stop here. There was an increased interest for jets analysis by this
method. In 2005 it was possible to reconstruct and calculate precisely mitral regurgitant volume with the same accuracy as MRI. It was really necessary and helpful in eccentric jets where 2D both transthoracic and transesophageal echocardiography had many limits. (Fig. 5)

This is the reason why some patients who are not candidates for cardiac surgery because of the severity of valvulopathy end up on surgeons’ table, while others, who really need surgery are medically treated.

Three-dimensional echocardiography is also more accurate than bidimensional echocardiography in aortic valve evaluation (aortic valve area) or mitral and tricuspid regurgitation (severity quantification).14-18

**Congenital heart disease assessment**

The most used technique in congenital heart disease is 2D echocardiography with good results and accurate diagnosis, although the correct anatomy, compatible with intraoperative aspect is rarely obtained. In contrast, 3D echocardiography images are much closed to intraoperative aspects.19

The great evolvement of new percutaneous technique for atrial or ventricular septal defects closure needed also a new imaging method for a better analysis of this pathology.20-22 The use of 3D echocardiography clearly decreased early postoperative mortality and also decreased the number of re-interventions after complex surgery of congenital heart disease.

**Left ventricle assessment**

Precise evaluation of left ventricular function and morphology is essential for management of cardiac patient. 2D Echocardiography has many limits because it does not take into account the ventricular geometry and heart rotational movement. These limits were left behind with the new software for 3D analysis. Automatic Border Detection technique along with 3D analysis allowed the assessment of global and segmental left ventricular motility and contractility. (Fig. 6) With all these techniques, with or without contrast echocardiography, it is possible to measure precisely left ventricular volumes and ejection fraction.23-26

Also, it permits more accurate evaluation of intraventricular dissyncrony and response of biventricular pacing.27,28 Left ventricular mass can be correctly measured for the prognosis and diagnosis of hypertensive patients and hypertrophic cardiomyopathy.20,22

**Intracardiac masses assessment**

Although there are not clear data regarding the exact number of cases of intracardiac masses, three-dimensional echocardiography was reported to contribute of an early and correct diagnosis. It was useful in determination of implant site of myxomas, extension of cardiac tumors, vegetations diameters.

Recently, there was an increase of interest in other pathology assessment: hypertrophic cardiomyopathy and left ventricular volumes measurements.

**REFERENCES**


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