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Three-Dimensional Echocardiography

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In the past, routine clinical use of three-dimensional echocardiography has been hindered by the prolonged and tedious nature of data acquisition. Image processing is time consuming and requires dedicated manpower to generate three-dimensional reconstructions of the heart. The recent introduction of real-time three-dimensional echocardiographic imaging techniques has revolutionized echocardiography, as images are obtained in just one beat.

Real-time three-dimensional imaging was initially performed using a sparse-array matrix transducer (2.5 or 3.5 MHz), which consisted of 256 non-simultaneously firing elements. This transducer acquired a pyramidal volume dataset measuring 60°x60° within a single heartbeat. Echocardiographic images were then displayed "on-line" using simultaneous orthogonal (B-scan images) as well as 2-3 parallel short-axis planes (C-scans).

Similar to other 3D methods, the sparse-array transducer resulted in accurate left ventricular volumes, ejection fraction and mass when compared to gold standard techniques, such as magnetic resonance imaging (MRI) and radionuclide angiography. The sparse-array transducer was also used advantageously during stress testing, because all post-exercise images were simultaneously acquired during a single heart beat which was at higher peak stress heart rates compared to conventional stress tests.

Full-matrix Array: A full-matrix array transducer (X4, Phillips Medical Systems, Andover, Massachusetts), which utilizes 3000 elements, has been developed. This has resulted in (1) improved side-lobe performance (contrast resolution), (2) higher sensitivity and penetration, and (3) harmonic capabilities which may be used for both gray scale and contrast imaging. In addition, this transducer displays "on-line" 3D volume-rendered images and is also capable of displaying two simultaneous orthogonal two-dimensional imaging planes (i.e., biplane imaging).

CLINICAL APPLICATIONS ARE MULTIPLE

One of the most important requests in cardiac imaging is the easy and accurate assessment of left ventricular (LV) function. With real-time 3D imaging, LV volumes can be obtained quickly and accurately. The left ventricle (apical 4-, 3- and 2-chamber views) is usually acquired from the apical window using a wide-angled acquisition. Images are displayed either using orthogonal long-axis views, or using multiple short-axis views, obtained at the level of the left ventricular apex, papillary muscles and the base.

In contrast to 2D echocardiography, real-time 3D echocardiography does not rely on geometric assumptions to calculate left ventricular volumes. This constitutes a real advantage in ventricles with odd shapes and wall motion abnormalities. Similarly, the unique geometrical shape of the right ventricle has precluded accurate quantification

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using traditional echocardiographic methods. Transthoracic three-dimensional echocardiography has the potential of overcoming these limitations resulting in accurate measurements of right ventricular size and function.

Quantification of left ventricular volumes and mass using real-time 3D echocardiography can be performed from an apical wide-angled acquisition using different methods. Currently, data analysis is performed on a desktop or laptop computer with dedicated 3D software (4D LV analysis, TomTec GMBH, Munich, Germany). Since a data set comprises the entire left ventricular volume, multiple slices can be obtained from the base to the apex of the heart to evaluate wall motion. This acquisition can be combined with the use of an infusion of contrast particularly in patients with difficult acoustic window in whom it might be of benefit to improve the delineation of the endocardial border.

Biventricular pacing in patients with severe left ventricular dysfunction has shown to improve symptoms, but the mechanism responsible for this benefit is still the subject of controversy. Three-dimensional echocardiography may be helpful to elucidate this mechanism due to its ability to clearly display changes in both global and regional volumes during different biventricular pacing settings. Preliminary observations demonstrate that regional contractility occurs during biventricular pacing in a more synchronized manner.

More accurate valve assessment: Mitral valve can now be readily displayed from transthoracic images and both leaflets can be described in a comprehensive manner. Thus, degenerative valves with or without prolapse can be evaluated and a decision to repair can be made in advance of the operation. Other applications include complex congenital heart disease, aortic valve and root pathology.

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