European Heart Journal (1996) **17**, 487–489

Editorials

Three-dimensional echocardiography: the virtual reality in cardiology — luxury or useful technique?

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In recent years, technical advances have equipped the cardiologist with a wide array of sophisticated diagnostic techniques to help him/her explore cardiac structures and functions. Thanks to digital computers, complex imaging systems as such cross-sectional echocardiography with integrated Doppler techniques, colour-coded flow mapping and tissue Doppler imaging, nuclear cardiac imaging, ultrafast cine computer tomography and dynamic magnetic resonance imaging have become a reality. However, all these imaging modalities provide two-dimensional visualization of a three-dimensional object. A sequence of two-dimensional images provides data concerning spatial configuration, but a three-dimensional reconstruction of the heart can be performed only by the investigator.

Thus, techniques with high spatial and temporal resolution are expected to be the most successful in the future, as they allow the best three-dimensional reconstructions from tomographic images. Ultrasound, ultrafast cine-computed tomography, and magnetic resonance imaging are now ready for the three-dimensional reconstruction of the heart. However, ultrafast cine-computed tomography and magnetic resonance imaging, while promising, require prolonged acquisition time, limiting temporal resolution of the moving heart, and are less accessible to the cardiologist than conventional two-dimensional echocardiography. By automatic echocardiographic border detection, volumetric data may be derived but complete reconstruction of the heart is not feasible. Intravascular ultrasound can provide three-dimensional images of the vessels, but not intracardiac structures.

Echocardiographic three-dimensional image reconstruction techniques were developed during the late 1980s and early 1990 using several methods. The three-dimensional reconstruction of real-time transthoracic two-dimensional images of the left ventricle using an apical rotation method was first described in 1982[1]. By this method, the transducer was placed on the patient's chest wall in the region of the apex to obtain the standard four-chamber view. The transducer was then rotated in 30° increments from 0°–360° to obtain various planes passing through the apex. Other attempts at three-dimensional reconstruction of the heart involved the use of an external device such as a spark–gap system to obtain the spatial coordinates of the echocardiographic planes studied[2]. The major limitations of the above techniques were the inadequate delineation of the endocardium due to the non-perpendicular relationship of the ultrasound beam to the left ventricular walls. Furthermore, reconstruction from transthoracic echocardiographic images is restricted by the presence of chest wall artifacts, the limited number of acoustic windows and inadequate image quality in some patients.

The development of monoplane and multiplane transoesophageal echocardiography has resulted in the production of higher quality two-dimensional images allowing a better three-dimensional reconstruction. The ideal mode of three-dimensional imaging would be to directly acquire a three-dimensional image of the heart from transoesophageal echocardiography, on-line, in one heart beat, or to obtain data in multiple dimensions simultaneously. However, at the present time, on-line three-dimensional data acquisition is not ready for clinical application. Recently, a prototype echocardiographic unit has become available using a modified monoplane transoesophageal probe (outer diameter = 17 mm) with a sliding movable transducer[3]. Image acquisition can be random or sequential. The latter method shows the best promise for clinical application. The transoesophageal echocardiography probe is advanced over the length of the heart at a described rate and distance to obtain multiple, parallel tomographic echocardiographic slices of the heart throughout the cardiac cycle. The data obtained are fully integrated with a computer used to store, analyse and manipulate data to form three-dimensional constructs of the heart. With the addition of the time domain, these three-dimensional images can be displayed in real time (four-dimensional echocardiography)[3].

Scanning with a biplane probe using a step-motor to rotate the entire probe has provided

0195-668X/96/040487+11 $18.00/0

volume-rendered images; however, the method previously described may be better for quantitative measurements. Multiplane transoesophageal echocardiographic variation of the ultrasound beam angle without changing the transducer position has been successfully used for rotational scanning in patients. However, software is not yet available to provide volume-rendered images using the rotational method.

From experimental evidence to clinical relevance

The main problems in the clinical application of three-dimensional information are the suboptimal morphology obtained as a result of beat-to-beat changes, the too-long image acquisition and reconstruction time, the reduction of high-resolution image data to a small number of spatial points in wire-frame diagrams and the complex hardware system needed. New sophisticated computer algorithms and hardware systems have been recently developed to partially overcome these problems. Several emerging experimental and clinical studies suggest that at present three-dimensional echocardiography is on the threshold of routine clinical use[3–5]. Major clinical advances obtained by this method are related to a better understanding of the topographical aspects of pathology, and to a better definition of the spatial relationships of cardiac structures. Potentially, this new imaging modality might provide information on cardiac anatomy and pathology that has not been possible until now and might provide more accurate quantitative data than those currently available. Since the shape of the ventricles may be irregular and left ventricular contraction and relaxation may be non-uniform, it should also be possible to obtain newer quantitative information and functional indices. Finally, the three-dimensional visualization of intracavitary flow jets could be helpful in optimal evaluation of flow abnormalities.

Now the time has come to find out whether these theoretical advantages may be transferred to clinical practice. In this issue, Binder *et al.*[6] report their experience with three-dimensional echocardiographic reconstruction using a monoplane transoesophageal echocardiography probe. The potential and limitation of this method were evaluated in 104 patients with a large spectrum of pathology. The success rate for reconstruction of anatomical structures and pathological features was calculated.

This study demonstrates that cardiac structures with high natural contrast on two-dimensional images have the best results after three-dimensional reconstruction. In particular, mitral and aortic valve leaflets, the left ventricular outflow tract, the left atrium, interventricular and interatrial septa and the ascending aorta were best displayed. Conversely, since the original grey value is partially lost after three-dimensional reconstruction, information from these sources will be of less value. Thus, Binder *et al.*[6] confirm the high diagnostic accuracy of three-dimensional echocardiography in obtaining detailed information on the pathology of the mitral apparatus (i.e. valve prolapse or flial leaflets), in the assessment of the size and location of interventricular and interatrial septal defects and in the identification of aortic dissection[3,4]. However, the degree of valve calcification and the relationship between the prosthetic valve ring and surrounding tissue were incorrectly evaluated. Further, the success rate of three-dimensional echocardiography in identifying wall motion abnormalities was surprisingly low (43%)[6].

In agreement with previous studies[3,4], the three-dimensional approach was used to visualize known pathologies since the correct diagnosis was first made by two-dimensional echocardiography. No studies have been published until now on the diagnostic accuracy of the three-dimensional as compared to the two-dimensional approach, in a blinded manner. Similarly, no data exist to show that the three-dimensional approach provides more accurate quantitative measurements than conventional echocardiography. Thus, it is impossible to know yet the real impact of this new diagnostic technique in the clinical arena. Awaiting future improvements in computer technology, three-dimensional echocardiography should be used as a complementary diagnostic tool to improve our understanding of the spatial relationship between cardiac structures. Another three-dimensional advantage should be the ability to simulate intra-operative visualization[5]. The surgeon should be able to visualize diseased mitral valves, complex congenital defects, ventricular aneurysms and aortic dissections intra-operatively.

In conclusion, in the present stage of development, three-dimensional echo reconstruction must still be viewed as experimental. We will have to wait another 2 or 3 years before deriving benefits from the introduction of virtual reality into clinical practice.

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European Heart Journal (1996) **17**, 489–490

Assessment of myocardial damage in dilated cardiomyopathy

See page 545 for the article to which this Editorial refers

Dilated cardiomyopathy is associated with impairment of systolic function. Damage to cardiac myocytes, including disruption of the sarcolemma, can be demonstrated by enhanced myocardial binding of monoclonal antibody to cardiac myosin in a large proportion of patients with dilated cardiomyopathy. Binding of an ^{111}In-labelled Fab fragment of antimyosin antibody to myocardium can be quantitated by scintigraphy and compared to uptake by other tissue such as lung. This heart-to-lung ratio has been used to assess the degree of myocardial damage in patients with acute inflammation resulting from myocardial infarction, myocarditis or rejection of the transplanted heart[1]. The histological changes in dilated cardiomyopathy are nonspecific and similar to those in patients with end-stage heart failure from causes such as valve disease, hypertensive heart disease or coronary heart disease. Unlike patients with dilated cardiomyopathy, however, enhanced uptake of antimyosin is not seen in end-stage heart failure due to these other causes.

Enterovirus infection of myocardium has been shown to be associated with myocarditis and the subsequent progression to dilated cardiomyopathy[2,3]. Virus can persist in myocardium to end-stage dilated cardiomyopathy requiring transplantation and its presence is a powerful independent predictor of poor prognosis[4]. In this issue Martí and colleagues[5] address the question of whether the detection of enterovirus in myocardium from patients with dilated cardiomyopathy correlates with enhanced antimyosin uptake, suggestive of continuing myocardial cell damage. Sixteen of 19 (84%) dilated cardiomyopathy patients showed enhanced antimyosin uptake and enterovirus RNA was detected by quantitative slot-blot hybridization in myocardial samples from four of these (25%): this is comparable with the frequency of detection of enterovirus in myocardium in several previous studies of patients with so-called idiopathic dilated cardiomyopathy[6,7]. Virus was not detected in dilated hearts without increased antimyosin binding, or in ten samples of normal myocardium. This may be one example of an insult to the myocardium leading to increased cell permeability and exposure of cardiac myosin. A further consequence may be to elicit the formation of cardiac autoantibodies reported by many groups and presumed to be pathogenic[8,9].

Martí and colleagues demonstrate the value of ^{111}In-antimyosin uptake in assessment of myocardial cell damage and support the concept of the pathogenic role of persistent enterovirus infection of myocardium in the development of some cases of dilated cardiomyopathy. It remains to be determined what other aetiologies may be correlated with myocardial damage in dilated cardiomyopathy.

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