Echocardiographic Evaluation of Left Ventricular Size, Shape and Function

—Advantages and Limitations of This Method—

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Both M-mode and two-dimensional echocardiographies are now available in most institutions and hospitals. Correct understanding of the characteristics of M-mode and two-dimensional echocardiography, such as time resolution, will lead us to a successful application of each of these two displays. Detection of changes in ventricular wall and visualization of segmental wall motion are the most unique abilities in echocardiography. These characteristics permit echocardiographic evaluation of left ventricular function. Left ventricular size, shape and function are not independent parameters, but are interrelated. Various parameters on left ventricular function are calculated from the dimensions of the left ventricle. However, these estimations are valid only when the dimensional determination is optimized and all the assumptions on the model of the left ventricle are satisfied. The simultaneous display system of M-mode and two-dimensional echocardiograms on the same frame has been shown particularly useful for an optimization of the measurements. For ischemic heart disease, a knowledge of regional function of the left ventricle and the analysis of segment wall motion are indispensable. One of the major problems in evaluating the left ventricle using echocardiography is a limited acoustic window. A combination of standard parasternal approaches and other approaches is commonly required for obtaining an entire image of the left ventricle.

Methodological Limitations of Echocardiography

M-MODE echocardiography has been in clinical use for about 20 years, and its limitations imposed by its methodological principle have been commonly known since the early days of its practical application. However, despite its limited accuracy in quantitative measurement or calculation, it seems to be quite useful for some quantitative determinations and is used extensively in the clinical field.

The recently developed two-dimensional

echocardiography has been shown to be most significant in clinical cardiology, and both M-mode and two-dimensional echocardiography are now available in most institutions and hospitals.

Under these circumstances, it seems to be very important to establish how these two modes relate to each other. For this purpose, a system for simultaneously displaying M-mode and two-dimensional echocardiograms on a single screen has been designed¹ using two digital scan converters (Fig. 1).

This device permits an easy comparison between M-mode and two-dimensional echocardiograms. The cursor-line on two-dimensional echocardiogram indicates the beam direction of the M-mode echocardiogram, which can be adjusted by looking at the cursor-line on two-dimensional

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Fig.1. Block diagram of the newly developed device: simultaneous display system of M-mode and two-dimensional echocardiograms on the same frame.

Fig.2. Simultaneous displays of M-mode and two-dimensional echocardiograms in a patient with mitral prolapse. The cursor-lines on two-dimensional echocardiograms (in long-axis view) indicate the beam direction of the M-mode ones, and the cursor-lines on M-mode echocardiograms indicate the time points in each cardiac cycle when two-dimensional display have been frozen. LV = left ventricle, LA = left atrium

echocardiogram. The system is also capable of freezing two-dimensional display at any timing on ECG and thus provides a still image as well. Moreover, the cursor-line on M-mode echocardiogram indicates the time point in each cardiac cycle when two-dimensional display has been frozen.

Thus, the system clearly identifies the echo sources on the M-mode echocardiogram. It is no longer necessary to speculate about the echo sources on the M-mode echocardiogram. One example of this display obtained from a patient with mitral prolapse is shown in Fig. 2. A hammock-like pattern characteristic to this condition can be observed in this figure. This system

has been proven quite useful for various measurements of the left ventricle, such as the determination of short-axis dimension.

Another point for consideration in the comparison of M-mode with two-dimensional echocardiography is a matter for time resolution. The time resolution of M-mode echocardiography is excellent and this system can record a motion curve with several hundreds cycles per sec. On the other hand, two-dimensional echocardiography with usual phased array system is limited in this point (approximately 30 frames per sec) and its time resolution of 33 msec is much inferior to that of M-mode echocardiography. In Fig. 3, M-mode and two-dimensional echocardiography

Fig.3-1

Fig.3-2

Fig.3. M-mode and two-dimensional echocardiograms in a patient with aortic regurgitation.

3-1: M-mode echocardiogram (beam direction: aortic valve)

3-2: Magnified image of Fig. 3-1. Arrow shows diastolic vibration of the aortic cusps.

3-3: Two-dimensional echocardiograms in long-axis view. The right coronary cusp (arrow) is shown prolapsed into the left ventricular outflow tract in diastole. A = in systole, B = in early diastole, C = in mid-diastole

Fig.3-3

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Fig.4. Various formats for segmental wall motion analysis by echocardiography. left = by H. Feigenbaum, middle = segments equivalent to conventional angiographical analysis, right = by J. Weiss

grams in a patient with aortic regurgitation are shown. The difference of time resolution power in M-mode and two-dimensional echocardiography is clearly demonstrated in this figure.

Precise understanding of these characteristics of M-mode and two-dimensional echocardiography will lead us to a successful application of each of these two displays. At the present time, M-mode and two-dimensional displays are regarded as complementary to each other, and echocardiography at present should consist of these two systems.

Advantages of Echocardiography

In an attempt to identify "the unique abilities" in echocardiography, in addition to its non-invasive nature, the followings are briefly listed:

- 1) Detection of the changes in the ventricular wall such as scar, infarction, wall thickness and segmental wall motion.
- 2) Visualization of valvular tissue, subvalvular structure and the papillary muscle.
- 3) Display of an extremely rapid motion of intracardiac structures such as a vibration of the valvular leaflet.
- 4) Variable cross-sectional planes which can be selected freely and repeatedly.
- 5) Detection of an intracardiac abnormal mass such as left atrial thrombus and myxoma.

- 6) Detection of pericardial effusion and echo-guided pericardial puncture.

Echocardiographic Evaluation of Left Ventricular Function

Left ventricular size, shape and function are not independent parameters, but are interrelated. A great number of studies have been carried out in this field using echocardiography²⁻⁶. For the estimation of the left ventricular volume based on the short-axis determined by M-mode echocardiography, several calculation methods have been proposed.⁷ Various parameters on left ventricular pump function, such as ejection fraction, percent fractional shortening rate and mean velocity of circumferential fiber-shortening, are likewise calculated approximately from the dimensions of the left ventricle. However, these estimations are valid only when the dimensional determination is carried out optimally and all the requirements are satisfied. The simultaneous display system of M-mode and two-dimensional echocardiograms on the same frame is particularly useful for an optimization of the measurements. The major assumption for volume calculation from dimension is the presence of a symmetrical and uniform contraction of the left ventricle. Here, segmental wall motion analysis of the left ventricle becomes crucial^{8,9} and regional func-

Fig.5. Two-dimensional echocardiograms in anteroapical myocardial infarction (in long-axis view). Above: in diastole. The cursor-line 1 runs through the intact inter-ventricular septum (IVS), the cursor-line 2 through aortic valve (Ao), and the cursor-line 3 through infarcted IVS (scar). Below: in systole. RV = right ventricle, AMV = anterior leaflet of mitral valve, PLVW = posterior wall of the left ventricle

tion of the left ventricle should be differentiated from global function. Particularly in ischemic disease, a knowledge of regional function of the left ventricle and the analysis of segmental wall motion are indispensable.

Two-dimensional echocardiography can be very useful for segmental motion analysis. In some cases, however, several segments of the left ventricle may be poorly demonstrated by two-dimensional echocardiography. Usually, a combination of parasternal and apical approaches provides an adequate segmental wall motion analysis. Various formats^{10,11} have been proposed for segmental wall motion analysis using two-dimensional echocardiography (Fig. 4), and echocardiographical examinations have been shown to be a reliable method for detecting the

Fig.6. Two-dimensional echocardiograms in a patient with large left ventricular aneurysm (in apical four-chamber view). Above: in diastole. Below: in systole. RA = right atrium, TV = tricuspid valve, IAS = interatrial septum

presence and the location of regional abnormalities of the wall motion. However, this method has one major drawback, a narrow acoustic window width. In this respect, echocardiography is inferior to X-ray angiography, which can visualize the "entire" left ventricle. In Figs. 5 and 6, two-dimensional echocardiograms in patients with myocardial infarction are shown.

Limitations and Problems in Evaluating the Left Ventricle by Echocardiography

The limitations and shortcomings of this method, some of which were already mentioned, can be summarized as follows:

- 1) The acoustic windows are limited and narrow. The visualization field is often reduced, being masked by the ribs or the lung. It is extremely difficult to display the entire left ventricle in one vision. The com-

bination of the standard parasternal approach and other approaches are commonly required for obtaining the entire image of the left ventricle, and they are very helpful for segmental wall motion analysis of the left ventricle.

- 2) The calculations of various cardiac parameters using echocardiographic dimensional measurements are valid only when the assumptions of the model of the left ventricle are satisfied in each case.
- 3) A small error in minor dimensional measurements may be magnified in farther calculations.¹²
- 4) The spatial resolution of echocardiography is inferior to that of X-ray angiography. Visualization of coronary artery is so far difficult with the exceptions of the basic portion of the coronary artery or the dilated coronary artery in Kawasaki disease.

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