IN THE PRECEDING ARTICLE in this issue of Circulation, Wann et al. compare features of M-mode and two-dimensional echocardiography as used in patients with infective endocarditis. Their discussion should arouse curiosity about the implied conflict between M-mode and the newer, two-dimensional approach for general ultrasonic imaging of the heart.

M-mode echocardiography has well-known capabilities. Clinician-echocardiographers can master this method in most diagnostic situations. This favorable milieu prevails because of the 15 or 20 years of intensive study into the capabilities of the technique that preceded its widespread, rapid acceptance in clinical practice. No other diagnostic modality based on modern electronic methods provides the “hands-on” characteristics that allow a physician to examine cardiac anatomy, confirm diagnostic impressions and immediately direct and accomplish further clinical examination.

Now there is similar clinical enthusiasm for two-dimensional echocardiography, but there has been no luxury of time to develop a mature understanding of the technique. Practical systems for clinical use were developed only 4 years ago, and the demand for two-dimensional echocardiographic services has accelerated rapidly. The ultimate clinical capabilities of this method are still uncertain, and some confusion exists regarding its indications for use, particularly in comparison with M-mode procedures. This is an appropriate time to reflect upon several features of M-mode and two-dimensional echocardiography that serve to characterize and direct the use of both imaging methods.

Cardiac Imaging

The use of any cardiac imaging procedure should be based on an appreciation of the type of information it provides. Cardiac images based upon common static (chest x-ray) or dynamic (fluoroscopic, cineventriculographic or radioisotope angiographic) approaches represent the heart and chambers as silhouettes. Both ultrasound techniques can image chambers, valves and walls, but two-dimensional echocardiography provides additional cross-sectional information.

Silhouette techniques have been especially successful, for example, in evaluating the left ventricle by measuring ejection fraction, as their overall integrative character readily permits determination of length-area measurements. Similar calculations from two-dimensional echocardiographic images have been unrewarding because this approach does not easily provide length-area information. This does not mean that cross-sectional echocardiography is clinically useless in evaluating ventricular function. Rather, the unique information from the two-dimensional approach must be directed toward evaluating new descriptors of cardiac performance that cannot be obtained by any other technique.

M-mode and Two-dimensional Comparisons

Both M-mode and two-dimensional echocardiography rely on pulsed ultrasound methods to image the heart. The general operating frequencies and ability to detect target information in any given patient are similar. M-mode and two-dimensional echocardiography differ in the display of the ultrasonic information.

The unique characteristic of M-mode is its familiar strip-chart display. M-mode possesses high ultrasonic sampling rates in the time domain that are directed forward and back along a single path. Thus, it can record the most rapid cardiac events, such as valve opening or closing. Being a time-histogram record, the strip-chart recording facilitates measurement of time-related events, such as valve opening intervals and slopes. The simultaneous display of a series of sequential cardiac cycles allows for rapid visual and mental integration of data that speeds interpretation.

The two-dimensional echocardiographic display relates more closely to familiar gross anatomic presentations of cardiac structures. It creates spatial characteristics in the image by rapidly steering the ultrasound beam back and forth through a given field of view. Because this image anatomically resembles the heart, potentially more useful information may be derived from two-dimensional echocardiography than M-mode. This fact does not detract from the current capabilities of M-mode, which provides useful information for patient care. Lessons learned from two-dimensional echocardiography will probably enhance the meaning of some M-mode data that are now confusing.

When formulating clinical questions, the echocardiographer must judge the comparative value of M-mode and two-dimensional echocardiography in relation to some logical progression of thought that acknowledges the capabilities and limitations of each approach. Failure to recognize this point detracts from the value of either method in acquiring useful information.
Advantages of the Two-dimensional Approach

Two-dimensional echocardiography has some clear advantages over M-mode, because it can gather and display anatomic data in a form that all physicians are familiar with. Its spatial characteristics are such that target recognition is greatly enhanced, resulting in rapid, accurate identification of valves and chambers. Its ability to localize and identify such cardiac structures as the recesses or commissures of valves or portions of the right and left ventricles is superior to that of M-mode. This is of particular value when sound transmission qualities may not only be detected, but also sized and characterized morphologically. Relative movements of various cardiac structures are clearly visualized by two-dimensional echocardiography. Analysis of movements of the mitral ring, leaflets and other supporting structures of the mitral apparatus will probably provide new descriptive criteria for characterizing mitral prolapse.

Physicians who do not have facilities for two-dimensional echocardiography should not find these arguments as compelling evidence to acquire this equipment immediately, for there are responsibilities inherent in this decision. The role of the physician interested in echocardiography is clearly changing with the advent of two-dimensional methods and will require increased physician interaction. The time when technicians alone are responsible for acquiring echocardiographic data is past. Two-dimensional echocardiography is best used when the physician is prepared to interact during the procedure to assess the clinical problem at hand and redirect the examination to maximize the ability of two-dimensional echocardiography to provide an answer. This practice is currently used during catheterization procedures and experience has shown that the most profitable information results when it is also used with echocardiography.

Clinical Examination

When facilities for both M-mode and two-dimensional echocardiography are available, an unfortunate sense of competition between the techniques often results. It is now clear that if patients are to receive maximum benefit from ultrasonic procedures, the two methods cannot be viewed as mutually exclusive. To obtain the maximum amount of information from the ultrasound study, the physician must determine whether M-mode or two-dimensional study or both would provide the most satisfactory results. The physician may choose to add postural position changes, amyl nitrite inhalation or contrast materials to enhance the ultrasound study.

Initially, most patient studies will probably derive more data from the two-dimensional approach, with the M-mode study added for selected purposes. In a patient with aortic insufficiency, for example, the two-dimensional examination would first evaluate valve configuration and ventricular morphology and contraction; the M-mode would supplement these findings by documenting mitral oscillations and the relative timing of valve closure.

In most forms of ischemic, cardiomyopathic or left-sided valvular heart disease, complete evaluation of the status of the left ventricle is required. Two-dimensional echocardiography is indicated over M-mode because it can interrogate the entire ventricle. For ischemic heart disease, a supplemental M-mode evaluation is rarely required. To evaluate the left ventricle successfully, the unique ability of twodimensional echocardiography to examine the heart chambers and walls must be directed toward evaluating new descriptors of cardiac performance. One such approach may be to relate systolic minor-axis shortening and wall thickening along specific segments of ventricular muscle in order to characterize contractility. It is impossible to derive this information by any other technique.

For congenital heart disease, two-dimensional rather than M-mode echocardiography is also indicated because the interrelationships of cardiac structures can be identified with greater certainty. Often, contrast two-dimensional echocardiography is also useful.

When rheumatic valvular heart disease is suspected, two-dimensional echocardiography is often more helpful than M-mode because individual leaflet thickening and mobility may be assessed with greater certainty. In the case of mitral stenosis, direct assessment of severity is possible. M-mode is added to answer specific questions of valve mobility and timing. Detection of valvular or nonvalvular cardiac mass lesions, such as are seen in endocarditis or mural thrombus, is often facilitated by the two-dimensional approach. Differentiation of valvular thickening from suspected mass lesions of endocarditis is more easily accomplished by recording oscillations in the mass by M-mode.

The value of either method for the delineation of mitral prolapse is uncertain. The descriptors of this disorder are inadequate for both techniques.

Routine examination of patients for pericardial effusion is satisfactorily accomplished in most cases with M-mode alone. Evaluation of patients with suspected idiopathic hypertrophic subaortic stenosis is usually accomplished better by M-mode, as the strip-chart recording facilitates documentation of abnormal systolic anterior movement of the mitral valve. When information concerning the spatial morphology of the outflow tract is required, the two-dimensional procedure must be used.

Complete interrogation of the right heart is limited by M-mode. When right-sided disease is suspected, the two-dimensional approach is more likely to yield useful results. Frequently, contrast material will also aid in defining anatomic or functional defects of the right heart.

Precise spatial location of the areas for measurement of chamber size and wall thickness is more easily accomplished by the two-dimensional approach. Left
ventricular circumference or some other spatially related index may in time provide better descriptive information regarding ventricular size than diameter alone.

**Future Improvements**

There is no consensus concerning suitable image quality for two-dimensional echocardiography. The questions of mechanical or phased-array approaches, dynamic or fixed-focal capabilities, gray scale or high contrast are still unresolved. These controversies are not detrimental, for they have provoked considerable investigation into improving the ability of ultrasound to display reliable target information. Digital scan conversion of the two-dimensional display is now possible and will ultimately eliminate cumbersome video cameras and provide a wide variety of possibilities for manipulating image quality and presentation by various processing schema. When two-dimensional systems are combined with Doppler, localization of the Doppler sample volume may provide means for obtaining more reliable flow-velocity data.

Two-dimensional echocardiographic systems cost more than M-mode systems and, at present, vary widely in price. The cost-benefit ratio of this new procedure must be judged by its ability to provide the information necessary for a correct diagnosis. In rare cases, the results of some echocardiographic procedures are so dramatic that patients are referred for surgical intervention without catheterization. More often, this technique enhances the clinician’s ability to select appropriate patients for catheterization. When physical or historical evidence for heart disease is equivocal, two-dimensional echocardiography may provide enough negative information to convince the clinician to desist from further, expensive patient evaluation.

Historically, new developments in electronics have been followed by reductions in costs. This is likely to occur for two-dimensional echocardiographic equipment as well. New instrumentation features may, however, compete with this trend.

**Limitations**

Ultrasonic techniques are fundamentally limited by the quality of sound transmission characteristics in a given patient. Images are impaired by chronic lung disease, abnormal chest wall configuration, patient age or other factors. Cross-sectional echocardiography offers almost no advantage over M-mode in this regard except that spatial integration occasionally aids in the identification of poorly defined targets. More effort must be directed toward identifying the sources of sound transmission difficulties and developing methods to overcome them. Unless these problems are solved, the diagnostic potential of ultrasound will never be achieved in all patients.

**A Lesson from the Past**

M-mode echocardiography resulted directly from the enthusiasm of Edler and Hertz to establish a method for evaluating mitral insufficiency. Twenty-five years after their invention, no such method is yet available. The ultimate accomplishments of Edler and Hertz resulted from their ability to formulate alternative questions. This should remind us to reorder our thinking constantly, as new techniques and capabilities for all imaging methods are developed.
Comparison of M-mode and two-dimensional echocardiography.
J Kisslo

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