Editorial Comment

Heart Size: One-, Two- and Now Three-Dimensional Echocardiography*

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The importance of heart size. The intimate physiologic relation between structure and function makes assessment of cardiac size an important component of the evaluation of patients with known or suspected cardiovascular disease. Echocardiography is the most commonly used diagnostic tool in this regard because it can provide comprehensive measurements of chamber and wall dimensions, left ventricular mass and indexes of diastolic and systolic performance at relatively low cost with wide availability and in truly noninvasive fashion. Quantitative echocardiography quickly replaced electrocardiography for assessment of heart size because electrocardiography provides only a very rough guide to chamber size and ventricular wall thickness. Echocardiographically determined left ventricular hypertrophy is now recognized as the most powerful predictor, other than age, of cardiovascular morbidity and mortality in both men and women (1,2). Echocardiographically measured left ventricular mass has also proved more successful than conventional classification systems, including blood pressure level, in predicting future complications in hypertensive patients (3).

These observations suggest that echocardiographically determined left ventricular hypertrophy may be considered a "preclinical disease" that is more closely related to morbid and fatal events than are conventional risk factors, such as hypertension, hyperlipidemia or cigarette smoking (4). The implications for clinical research are obvious. First, echocardiographic left ventricular mass may be used to group study patients into strata of disease severity (3). Second, because the incidence of "hard end points" is severalfold greater in patients than in those without left ventricular hypertrophy, enrollment of the former in clinical intervention trials will allow a smaller sample size to demonstrate a significant reduction in hard end points (4). This advantage notwithstanding, the clinical use of echocardiographic left ventricular mass measurements in the serial evaluation and management of individual patients has been limited by important methodologic problems. These problems have been more effectively addressed by the advance from "one-dimensional," unguided M-mode to sector-guided M-mode and then two-dimensional echocardiography. The study utilizing three-dimensional echocardiography by Gopal et al. (5) in this issue of the Journal represents another step toward more accurate and reproducible echocardiographic assessment of heart size.

Historical perspective. Using one-dimensional, unguided M-mode echocardiography, Devereux and Reichek (6) were the first to show that estimates of left ventricular mass correlated closely with weight at autopsy. Their seminal work assumed that the left ventricle was a prolate ellipsoid with a chamber length equal to twice the diameter measured at the mid-papillary muscle level. Septal and posterior wall thicknesses measured at the same level were averaged to estimate the thickness of the entire left ventricle. Ventricular chambers that deviated from this assumed geometry posed an obvious limitation to the accuracy of these left ventricular mass estimates. The addition of two-dimensional sector guidance for M-mode measurements aided cursor placement and reproducibility but did not eliminate errors due to chamber distortion (7). Confirming theoretic considerations (8), a clinical study of terminally ill patients showed that two-dimensional echocardiographic area-length methods improved the accuracy of left ventricular mass estimates compared with the M-mode method (9). The ability of two-dimensional echocardiography to measure left ventricular chamber length directly and to estimate average wall thickness from short-axis myocardial area measurements improved its accuracy, especially in ventricles with distorted geometry. In their postmortem validation studies, Reichek et al. (9) noted a standard error of the estimate of 31 g and a correlation coefficient of 0.93 compared with "one-dimensional" sector-guided M-mode values of 59 g and 0.86.

Further refinement in two-dimensional echocardiographic assessment of left ventricular mass by Schiller et al. (10) and Byrd et al. (11) used a truncated ellipsoid model that more accurately describes left ventricular geometry. We subsequently showed superior serial reproducibility of mass measurements using two-dimensional echocardiography, as the mean difference among three serial studies in each normal subject was 4.2 ± 3% versus 14.9 ± 10% for M-mode estimates (12). The interobserver variability for these two-dimensional echocardiographic mass measurements was comparable to that reported by Gopal et al. (5). However, the test-retest variability is always higher in patients than in normal subjects (13,14) and also in laboratories not dedicated to quantitative mass measurements. This major problem has precluded useful serial comparisons in individual patients.

*Editorials published in Journal of the American College of Cardiology reflect the views of the authors and do not necessarily represent the views of JACC or the American College of Cardiology.

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The present study. The three-dimensional echocardiographic method described by Gopal et al. (5) provides two specific technologic improvements in the assessment of heart size. First, a novel "line of intersection display" is generated from an initial parasternal long-axis reference image of the left ventricle. This display provides real-time guidance during subsequent image acquisition to optimize orientation of the short-axis images. This is made possible by an external reference acoustic locator coupled to a personal computer that permits rapid and repeated on-line display of the three-dimensional spatial coordinates during image acquisition. King et al. (15) have recently used this "line of intersection display" to show a threefold improvement over conventional two-dimensional echocardiography in optimally positioning standard parasternal and apical images of the left ventricle. This guidance for image acquisition is likely to improve reproducibility during serial examinations significantly, reducing test-retest variability and errors in left ventricular mass measurements. Second, the three-dimensional method is independent of the geometric assumptions necessary for M-mode and two-dimensional measurements. The acoustic locator coupled to the conventional two-dimensional echocardiographic scanner allows determination of the three-dimensional spatial coordinates of each acquired image. Off-line analysis of the stored images and their spatial coordinates provides estimates of left ventricular mass that are comparable in accuracy to measurements made by magnetic resonance imaging. Theoretically, ventricles with distorted chamber geometry should be as reliably assessed by this three-dimensional technique as symmetrically contracting ventricles. This advance should significantly broaden the spectrum of patients in whom left ventricular mass measurements can be reliably assessed.

Another application of three-dimensional echocardiography will no doubt be the assessment of right ventricular size and function. The difficult geometry of the right ventricle has resisted all attempts at exact measurement by M-mode and two-dimensional echocardiography. Such measurements are often critical in managing patients with complex congenital heart disease, such as single ventricle, tricuspid or pulmonary atresia. One preliminary report suggests that this technology may prove a real breakthrough in this regard (16).

Limitations of the present study. Potential problems in clinical application of the method described by Gopal et al. (5) primarily involve limitations of the acoustic transducer locator. First, the sound emitters and overhead microphone array are relatively bulky, and the line of sight between them cannot be interrupted by monitoring cables, intravenous lines or the sonographer. The device also limits the portability of the echograph to a temperature-controlled environment, and it cannot be used near explosive gases (such as in the operating room). Second, the inability of this device to assimilate data from two or more orthogonal imaging planes presents another limitation. Ideally, a system unconstrained by geometric assumptions should permit imaging of the heart from all available acoustic windows to obtain the best endocardial and epicardial definition for three-dimensional integration of images. This constraint will become important when the method is applied in a patient population with increased prevalence of distorted ventricular shape or pulmonary disease. A different three-dimensional spatial locator without some of the aforementioned limitations appears to show some promise in accurate measurement of left ventricular cavity volume, but it has not been applied to the measurement of ventricular mass (17).

Finally, a major limitation of the present study, as with most available cardiac imaging modalities, remains the laborious task of manually identifying and tracing cardiac regions of interest. Advances in automated border detection (18,19) should help reduce the off-line analysis time as well the perceived difficulty of these technologies, which remain a major nindrance to their widespread clinical application.

Conclusions. Despite these limitations, Gopal et al. have provided further evidence that three-dimensional echocardiographic assessment of left ventricular mass is feasible, accurate and reproducible. This approach may also prove fruitful in the still challenging task of evaluating right ventricular structure and function. Further improvements in the acoustic locator design and prospective validation in patients will hasten clinical application of this exciting technology.

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