Recommendations for Quantitation of the Left Ventricle by Two-Dimensional Echocardiography

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Methods for quantitation of two-dimensional echocardiographic images of the left ventricle have been developed and validated[1-6] and have been highly useful. Their general application has been limited, however, by a lack of consensus regarding their optimum utilization. It is the intention of the Committee to advance guidelines that will foster uniformity and wider use of these techniques. The recommendations of the Committee are based on a consensus among the members. Where there are alternate approaches of similar merit, each is mentioned. In our desire for promotion of a uniform and widely accepted approach to left ventricular quantitation, the Committee does not intend to discourage further development of innovative alternative approaches that may be more accurate, reproducible, or easier to implement.

Because stand-alone M-mode instruments have nearly disappeared, the M-mode tracings in many laboratories are now generated from two-dimensional images. This article will not deal with quantitation of M-mode tracings generated from two-dimensional images but with the technique of obtaining and quantitating the two-dimensional images themselves.

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27/8/14789

QUANTITATION OF LEFT VENTRICULAR VOLUME, AREA, DIMENSIONS, AND THEIR DERIVED INDEXES OF CONTRACTILE FUNCTION

General and Technical Considerations

Two-dimensional echocardiography is used to quantitate the volume, area, and linear dimensions of the left ventricular cavity, and estimates of contractile function are derived from these measurements. Two-dimensional echocardiography is also used to determine left ventricular mass and to assess regional wall motion. Regardless of the type of measurement, a standardized approach is desirable so that accuracy and reproducibility are optimum.

Meticulous attention is required to obtain correct orientation of imaging planes with regard to internal landmarks. These planes will be described below. In general, a standardized long-axis view should maximize the size of the left ventricular cavity, whereas a standardized short-axis view should minimize it within the guidelines defining each particular view. Gain settings and gray scale should be optimized; too much overall gain will lead to "blooming" of the endocardial surface and too little will lead to "dropout." A precise endocardial definition is central to accurate quantitation.

The choice of transducer frequency and of focal length can also be an influence on endocardial definition. It is therefore recommended that the highest frequency that provides adequate penetration be chosen. The focus of the transducer should be as close as possible to the center of mass or volume of the ventricle.

The depth of the displayed image may also influence the precision of measurements. For example, a display depth of 20 cm may present the left ventricle as a smaller target. By reducing the distances between areas of endocardial dropout, the endocardium may appear more continuous, and this depth setting may facilitate endocardial identification. However, there is a potential for errors in the manual digitizing process to be magnified. Also, at this depth setting frame rates may be slower and endocardial definition blurred. Therefore it seems logical that the ventricle should be imaged and digitized in the most magnified presentation that allows endocardial definition. However, a major disadvantage of changing scale settings to suit individual patients is the need for frequent recalibration. The committee strongly recommends that optimum imaging of the endocardium be the first priority. Because endocardial border definition can be difficult, the Committee recommends the use of the black-white interface (or endocardial-cavity interface) rather than the leading edge for digitizing this surface.

Strategies for acquiring data can minimize error and interstudy variability. It is recommended that for obtaining optimum apical views, the patients be positioned in steep lateral recumbency for examination. Once this position has been achieved, it should be maintained with a wedge or pillow. The transducer should be applied toward the posterior axillary line, well posterior to the palpable apex impulse location, then slowly drawn anteriorly over the apex impulse until the qualitatively maximum image of the left ventricular chamber is achieved. By starting posteriorly, underestimation of an enlarged left ventricle with a diffuse apex impulse will be avoided. Regardless of the absolute size of the heart, the examiner should always seek to maximize the size of the heart chamber in the apical views and to minimize the cavity size in the widest short-axis view. In other words, portions of the study for measurement should be prospectively selected for analysis at the time of examination.

Because the patient is often in a steep left lateral position, it is frequently difficult to transect the true apex unless there is a mattress with a scoop or excavation at the point where the apex impulse is generally located. An alternate technique is to use a narrow examination table that allows free access of the transducer to the apex impulse without mechanical interference. These approaches are especially important with large transducers. Lack of specialized examining tables makes quantitative measurements more difficult in the critical care setting where modifying the bed is not practical.

Some members of the Committee recommend that examinations be conducted with the examiner seated while facing the patient who is in the left recumbent position. These members point out that this procedure avoids the need for leaning on or over the patient to reach the most posterior point of the apex, enables the technician to remain seated, and allows the use of both hands to manipulate the transducer.[7] However, other members point out that conducting the examination at the right side of the patient allows a right-handed technician to manipulate the transducer with the right hand and the equipment controls with the left. Flexibility in approach should be utilized especially in large or obese patients in whom examination from the right side may be impractical. Regardless of approach, the quantitative examination must maximize chamber size by use of the most posterior point of the apex impulse window.

Images are selected at end-diastole and end-systole for computation of end-diastolic and end-systolic volume. The identity of the video frame closest to end-diastole is made by reference to the simultaneously recorded mitral valve; the frame at or before initial systolic coaptation of the mitral valve marks end-diastole. The first frame in which the QRS complex appears may also be used as end-diastole.

End-systole is marked by the frame preceding initial early diastolic mitral opening. If the mitral valve is not seen, the smallest visible cavity area is a less satisfactory alternative. If a phonocardiogram is available, the first high frequency component (aortic) of the second heart sound is a reliable marker of end-systole.

If a cine or gating mode is available on the examining instrument, the recording can be performed to capture only frames at end-systole and end-diastole. If the technician uses this mode, recorded segments in real-time should be available for review. The appearance on the recording of segments in the gated mode provides a convenient marker for the reader to identify the prospectively recorded portion of the study specifically intended for measurement.

For measuring dimensions and volumes it is recommended that the apical four-chamber view be obtained from a plane through the middle lateral wall

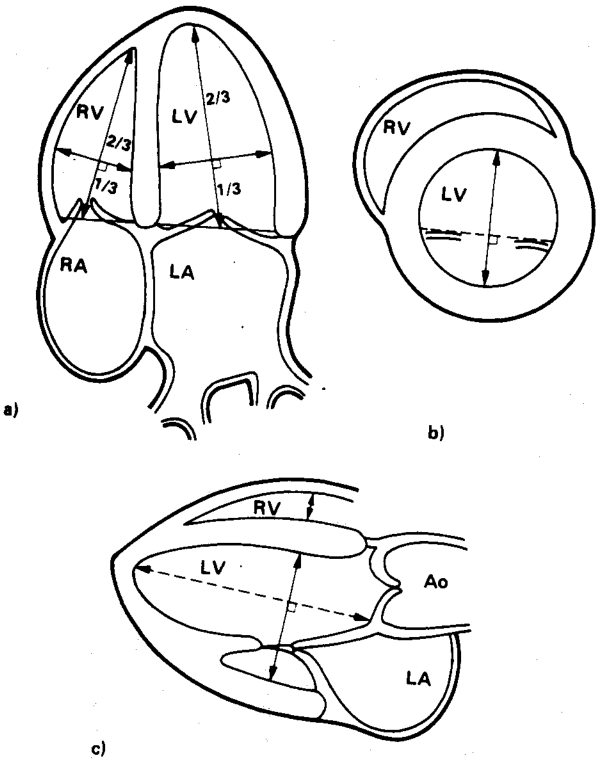


Figure 1 Intracardiac dimensions were obtained from three different echocardiographic views: apical four-chamber view **(a)**, parasternal short-axis view at level of chordae tendineae **(b)**, and parasternal long-axis view **(c)**. *Long-axis view is shown as if it includes true LV apex, but in this view it almost never does.* Various minor and major axes were obtained as *arrows* indicate. *Ao,* Aorta; *LA,* left atrium; *LV,* left ventricle; *RA,* right atrium; *RV,* right ventricle.

of the left ventricle where the right ventricle is at its widest. It should be noted that the apical two-chamber view used for quantitation does not include the aorta and outflow tract. This view is assumed to be nearly orthogonal (60 to 90 degrees) to the four-chamber view. At times the apex will be seen to curve out of the sector because the apex impulse arises from the distal anterior wall of the left ventricle rather than from the true apex.[8] The error introduced by the exclusion of the apex is smaller than the error introduced by foreshortening the basal portion of the cavity. The Committee recommends that segments that leave the image plane not be fabricated; tracings should terminate at the limits of the sector. However, when noncontiguous endocardial dropout is encountered, bridging of small (less than 20% of the entire endocardial outline) gaps may be used.

For the convenience of the user, efficient programs should be provided that derive the maximum quantitative information from the fewest possible steps. These same programs, if properly written, will also enhance accuracy by allowing several beats to be traced for the generation of final values. The mathematically and statistically optimum method of handling these data is to derive final parameters from the mean of several measurements.

Computational Equipment

The analog video format of echocardiography mandates the use of dedicated computers for quantitation. Video tape recorders and players have been improved to the point where excellent stable stop frame images can be instantly retrieved in both forward and reverse modes. It is essential to employ one of these instruments for successful off-line quantitation. It should be noted that video freeze frames cause 50% of the video information to drop out. Higher resolution S-VHS or newer digital storage methods may partially ameliorate this problem. One solution to the problem of image degradation is to make quantitative tracings directly from digital images at the bedside (see below).

A manually operated light pen or digitizing tablet is used to define the X-Y coordinates of line segments and parameters. From these calibrated overlays, geometrically based programs compute dimensions and volumes. Thus the issue of calibration of all loops in this operation is critically important. The Committee believes that reliance on internal electronic calibration markers of instruments is not adequate unless these have been calibrated by in vitro imaging and measurement of an object of known dimensions, such as a standard American Institute of Ultrasound in Medicine phantom or a water-filled balloon of known volume.

In addition to the advantages stated above, the on-line (bedside) measurement method also allows fewer calibration steps and better resolution. A variation in the on-line measurement technique is digital acquisition of images intended for measurement and interpretation. With a video acquisition computer it is possible to store all the necessary views for calculation of mass and volume on a high density floppy diskette or other storage medium. The advantages of this approach are that it reduces the amount of information that the reader must process and presents that information in a flexible format. For routine clinical use, this method enables the laboratory to rapidly generate quantitative information. Its disadvantages include a need to rely on an expert technician to acquire the data and the lack of alternative views to measure.

Changes in the position of the chest wall during

Table 1 Heart chamber measurements by two-dimensional echocardiography

View	Normal range (cm) (Mean ± 2 SD)	Mean (cm)	Index (cm/m²)	Absolute range (cm)
Apical four-chamber				
LVed major	6.9-10.3	8.6	4.1-5.7	7.2-10.3
LVed minor	3.3-6.1	4.7	2.2-3.1	3.8-6.2
LVes minor	1.9-3.7	2.8	1.3-2.0	2.1-3.9
LV FS	0.27-0.50	38	—	0.26-0.47
RV major	6.5-9.5	8.0	3.8-5.3	6.3-9.3
RV minor	2.2-4.4	3.3	1.0-2.8	2.2-4.5
Parasternal long-axis				
LVed	3.5-6.0	4.8	2.3-3.1	3.8-5.8
LVes	2.1-4.0	3.1	1.4-2.1	2.3-3.9
FS	0.25-0.46	36	—	0.26-0.45
RV	1.9-3.8	2.8	1.2-2.0	1.9-3.9
Parasternal short-axis				
Chordal level				
LVed	3.5-6.2	4.8	2.3-3.2	3.8-6.1
LVes	2.3-4.0	3.2	1.5-2.2	2.6-4.2
LV FS	0.27-0.42	34	—	0.27-0.41
Papillary muscle level				
LVed	3.5-5.8	4.7	2.2-3.1	3.9-5.8
LVes	2.2-4.0	3.1	1.4-2.2	2.5-4.1
LV FS	0.25-0.43	34	—	0.25-0.43

LVed, Left ventricle, end-diastole; *LVes,* left ventricle, end-systole; *LV FS,* left ventricular fractional shortening; *RV,* right ventricle.
Note: Although it is a common and useful practice in adult cardiology to correct values for body surface area, for pediatric applications or for smaller or larger than average subjects, charts based on subjects of a wide range of body sizes should be consulted.[26]
(Data from Schnittger I, Gordon EP, Fitzgerald PJ, Popp RI. Standardized intracardiac measurements of two-dimensional echocardiography. J Am Coll Cardiol 1983;2:934-8.)

the respiratory cycle can induce major changes in the location of the beam plane relative to the left ventricle and in lesser changes in left ventricular filling. For these reasons the Committee recommends that measurements be made during suspended respiration at or near end-expiration.

The technique for digitizing areas or measuring linear dimensions requires an optimally resolved image. As stated above, images recorded on videotape are degraded when compared with the original images, therefore it is recommended that linear measurements also be made on-line, taking advantage of the undegraded first generation digital image. This approach also demands that personnel select the frames with care. The Committee recommends that instruments be programmed with uniform algorithms validated for off-line and on-line measurements.

Measurement of Dimensions and Areas

Depending on the measurement sought, one or more standardized tomographic planes is or are measured at end-diastole and end-systole.[9] Linear dimensions and areas are obtained directly from the image by segment length measurement and cavity or wall boundary planimetry.

Left ventricular chamber size can also be assessed by multiple linear dimensions that are measured directly from the precordial long-axis, short-axis (papillary muscle tip level), and apical (long-axis, two, and four-chamber) views.[10,11] The major and minor axes from which these dimensions are constructed and measured are shown in Figure 1.[10] The length of the ventricle (apex to middle mitral valve plane) is obtained from the best approximation of the major (long) axis. The minor (short) axis is positioned one third of the length of the major axis from the base and orthogonal to it. We recommend that the black-white endocardial-cavity interface be used to determine the limits of these lines. Normal values with this method (n = 35, 19 men) are given in Table 1.[10]

With appropriately programmed computational devices it should not be necessary to measure manually the major axis (for left ventricular volume or mass determination) or to locate the widest point for division of the major axis into semimajor and truncated semimajor axes (for left ventricular mass determination) because these can be computed automatically from the diastolic area outlines traced during left ventricular volume measurement.

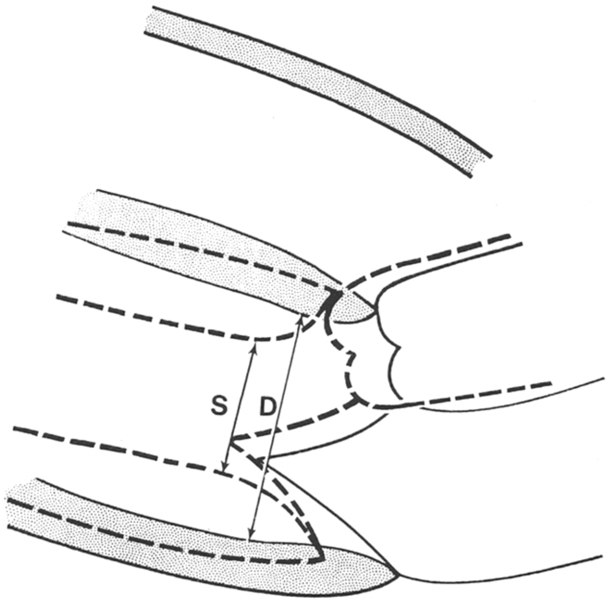


Figure 2 Method for measurement of basal left ventricular contractile function. Dimensions are aligned perpendicular to major axis of ventricular cavity at level of chordal mitral junction. This method differs from that in Figure 1 in that an anatomic landmark determines dimensional measurement rather than proportion of long axis.

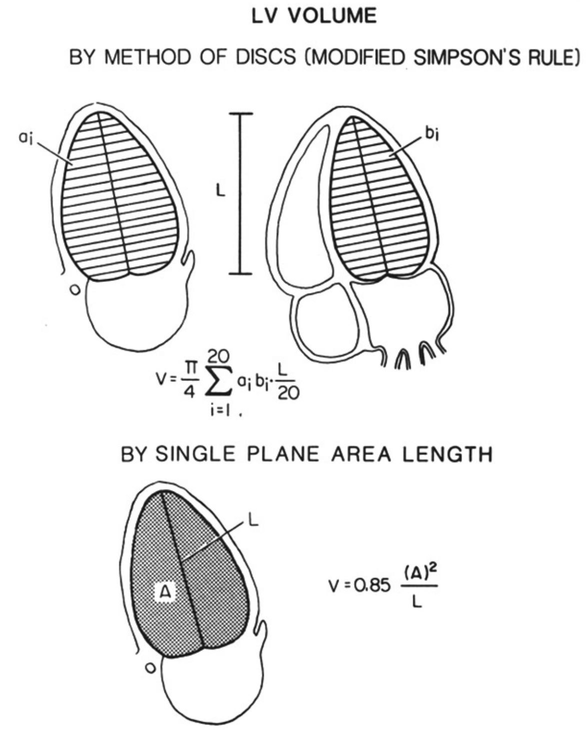


Figure 3 Biplane and single plane algorithms calculating chamber volume from two-dimensional echocardiograms. *Top panel,* Biplane method of discs or disc summation method (modified Simpson's rule) based on nearly orthogonal planes from apical two- and four-chamber views. (Although algorithm also is known as modified Simpson's rule, ***method of discs*** or ***disc summation method*** are preferable terms.) Calculation of volume (formula 1) results from summation of areas from diameters a_i and b_i of 20 cylinders or discs of equal height; these are apportioned by dividing left ventricular longest length into 20 equal sections. This method is preferred because it is less sensitive to geometric distortions. Although 20 slices are commonly employed in many laboratories, there are no data about the ideal number. Weiss et al.[6] suggest that the minimum number under experimental conditions is 4, whereas Erbel et al.[25] have used as many as 256. General formula for volume that does not designate number of slices is as follows:

$$V = \frac{\pi}{4}\sum_{i=1}^{n} a_i b_i \frac{L}{n}$$

Bottom panel, **Single plane area length method (formula 2). This is single plane method developed for angiography and is applicable if only one apical view is obtainable. V = volume of left ventricular cavity, A = area of left ventricular cavity *(shaded area),* L = length of left ventricular cavity.**

A variation of the above linear dimension method has been developed and has been used to show that residual basal left ventricular function predicts the outcome of myocardial infarction or aneurysmectomy.[12] This modification uses a parasternal long-axis view with a line drawn and measured from the posterior left ventricular endocardium at the level of the chordae to the interventricular septum, paralleling the minor axis (Figure 2). This approach has some advantages over the M-mode linear dimension measurements, which are often not truly parallel to the minor axis. The normal values for this method are smaller (Table 2)[13] than those reported in Table 1,[10] since the dimensions are obtained from a more proximal or basal portion of the ventricle.

Areas obtained in systole and diastole from the short-axis papillary muscle view can be used to compute another independent index of left ventricular function, fractional area change (Table 2). Even though endocardial definition by this approach may be better than by the apical views, it does not include the apex, which is often abnormal in patients with coronary artery disease. The Committee recommends using ejection fraction based on biplane volumes in heterogeneously contracting ventricles (that is, those with important wall motion abnormalities).

Cavity Volume Measurements

The Committee recommends that left ventricular volumes be computed from the dimensions and area measurements obtained from paired apical views

Table 2 Linear dimensions and areas from the left ventricular base (normal values) (50 subjects; age range, 19 to 63 years; mean age, 31.2 ± 10.0 years; BSA, 1.44 to 2.48 m²; mean BSA, 1.84 ± 0.18 m²)

	Range	Range corrected for BSA	No.
LV diameter—diastole	3.6-5.2 cm	2.0-2.8 cm/m²	49
LV diameter—systole	2.3-3.9 cm	1.3-2.1 cm/m²	49
Fractional shortening	0.18-0.42		49
LV short-axis area—diastole	9.5-22.3 cm²	5.5-11.9 cm/m²	44
LV short-axis area—systole	4.0-11.6 cm²	2.4-6.4 cm/m²	44
Fractional area change	0.36-0.64		44

BSA, Body surface area; *LV,* left ventricular.
(Data from Feigenbaum H. Echocardiography. 4th ed. Philadelphia: Lea & Febiger, 1986.)

Table 3 Left ventricular end-diastolic volumes (normal values)

Algorithm	Mean ± SD (range) ml	Mean ± SD (range) ml/m²
Four-chamber area length		
Male patients	112 ± 27 (65-193)	57 ± 13 (37-94)
Female patients	89 ± 20 (59-136)	
Two-chamber area length		
Male patients	130 ± 27 (73-201)	63 ± 13 (37-101)
Female patients	92 ± 19 (53-146)	
Biplane disc summation (modified Simpson's rule)		
Male patients	111 ± 22 (62-170)	55 ± 10 (36-82)
Female patients	80 ± 12 (55-101)	

(Data from Wahr DW, Wang YS, Schiller NB. Left ventricular volumes determined by two-dimensional echocardiography in a normal adult population. J Am Coll Cardiol 1983;1:863-8.)

(that is, four-chamber and two-chamber), which may be considered nearly orthogonal (60 to 90 degrees) for purposes of quantitation. In this regard, it is important to note that it is possible to obtain four-chamber views that are not orthogonal to the two-chamber view. The echocardiographer recording images for quantitation should rotate the transducer approximately 90 degrees from the position used for the first view recorded. The algorithm applied to these measurements is properly termed the *method of discs* or the *disc summation method,* since it treats the ventricle as a stack of discs or slices. This algorithm, also known as modified Simpson's rule, (Figure 3, upper panel) is recommended because it is independent of preconceived ventricular shape and can be as rapidly performed as any other method.[1,2,14]

Formula 1 is the biplane method of discs or modified Simpson's rule (Figure 3, upper panel).

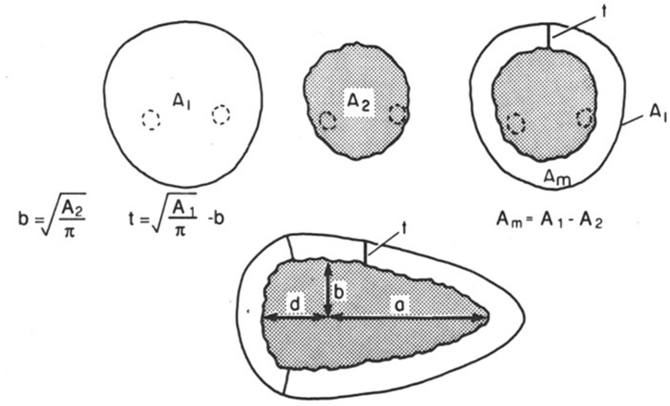
The Committee does not favor the use of methods that require multiple short-axis images because it is usually difficult to obtain the required number of high quality short-axis views,[6] and the method is quite time consuming.

When only one apical view is of adequate quality for assessment, it is acceptable but less accurate to use a single plane area length algorithm (Figure 3, lower panel, and Table 3).

Formula 2 is the single plane area length (Figure 3, lower panel).[1]

The Committee recommends that equipment manufacturers provide built-in quantitative programs that allow the user to compute volumes according to the biplane method of discs or single plane area length. These programs should automatically measure the long axes and should provide for the situation that arises when the long axes of the two views are unequal. This inequality occurs when, in a biplane measurement, one view is foreshortened[8]; it can be corrected in a number of ways. These corrections are based on the assumption that the long axis can never be too long. For example, the segments in the fore-

LV MASS BY AREA LENGTH (AL) AND TRUNCATED ELLIPSOID (TE)



$$\text{LV Mass (AL)} = 1.05 \left\{ \left[\tfrac{5}{6} A_1 \ (a + d + t) \right] - \left[\tfrac{5}{6} A_2 \ (a + d) \right] \right\}$$

$$\text{LV Mass (TE)} = 1.05 \pi \left\{ (b + t)^2 \left[\tfrac{2}{3} (a + t) + d - \frac{d^3}{3 (a + t)^2} \right] - b^2 \left[\tfrac{2}{3} a + d - \frac{d^3}{3a^2} \right] \right\}$$

Figure 4 *Upper panel,* Diagram of left ventricular short axis at level of papillary muscle tip demonstrating epicardial and endocardial perimeters that are traced to calculate myocardial thickness *(t),* short-axis radius *(b),* and areas (A_1 and A_2). Note that papillary muscles are excluded (left within ventricular cavity) when measuring these perimeters. Formula 6 computes b from A_2, formula 7 computes t from A_1 and b, and formula 8 computes Am from A_1 and A_2. Both methods of computing left ventricular mass use short axis in this manner. *Lower panel,* Left ventricular mass by area length (*AL,* formula 9) and truncated ellipsoid (*TE,* formula 10). Where a = long or semimajor axis from widest minor axis radius to apex, b = short axis radius and is back-calculated from short-axis cavity area (formula 6), t = myocardial thickness back-calculated from short-axis epicardial and cavity areas (formula 7), d = truncated semimajor axis from widest short-axis diameter to mitral anulus plane.

shortened view are proportionally lengthened to match those in the longest view. A second solution would employ an algorithm that can allow the apical slice terminating the figure to be wedge-shaped rather than of uniform thickness. It is recommended that ventricles with two-chamber long-axis lengths that differ from the four-chamber by more than 20% not be submitted to volume analysis by the method of discs.

Most authors[1,2,8] have found that echocardiographic volumes are smaller than angiographic volumes. Explanations for this relationship include foreshortening of the apex, exclusion of the papillary muscles, and inherent volume overestimation of contrast techniques resulting from contrast filling of trabecular interspaces. Nonetheless, the ultrasound technique has been highly accurate in water bath studies.[4,6] Thus if the method is used in a careful, consistent manner,[15] the Committee believes it is logical to use published echocardiographic values without correcting them for this underestimation. It is cautioned that these values come from relatively small normal population samples. Table 3 gives diastolic volume values from two studies (n = 52 and n = 84) of normal adults.[14,16] Table 4 gives normal ejection fraction values derived from a normal population.[17]

Evaluation of Systolic Function

As a measure of systolic function, dimensional fractional shortening, fractional area change, and ejection fraction are computed according to the following formulas.

Formula 3 is as follows:

$$\text{Fractional shortening} = \frac{\text{End-diastolic dimension} - \text{End-systolic dimension}}{\text{End-diastolic dimension}}$$

Formula 4 is as follows:

$$\text{Fractional area change} = \frac{\text{End-diastolic area} - \text{End-systolic area}}{\text{End-diastolic area}}$$

Formula 5 is as follows:

$$\text{Ejection fraction} = \frac{\text{End-diastolic volume} - \text{End-systolic volume}}{\text{End-diastolic volume}}$$

Table 4 Left ventricular ejection fraction (normal values) biplane disc summation (modified Simpson's rule)

Sex	Mean ± SD (%)
Males (n = 44)	70 ± 7
Females (n = 40)	65 ± 10

SD, Standard deviation.
(Data from Shiina A, Tajik AJ, Smith HC, Lengyl M, Seward JB. Prognostic significance of regional wall motion abnormality in patients with prior myocardial infarction: a prospective correlative study of two-dimensional echocardiography and angiography. Mayo Clin Proc 1986;61:254-62.)

Table 5 Left ventricular mass (normal values) truncated ellipsoid method

	Mean ± SD	
Mass	Males (n = 44)	Females (n = 40)
Grams	148 ± 26	108 ± 21
Index (gm/m^2)	76 ± 13	66 ± 11

(Data from Helak JW, Reichek N. Quantitation of human left ventricular mass and volume by two-dimensional echocardiography: in vitro anatomic validation. Circulation 1981;63:1398-1407.)

QUANTITATION OF MYOCARDIAL MASS

M-mode methods have been widely used for estimating left ventricular mass but have important limitations arising from the unidimensional nature of the technique. Although the M-mode methods are useful for studies of populations,[18] they may not be optimally sensitive to detect serial changes in individuals. Hence, two-dimensional echocardiographic methods for left ventricular mass have been developed. Two such methods, an area length model[19-21] and a truncated ellipsoid model have been reliable in both animal models[22] and adult humans.[16] Both algorithms are suitable for clinical use.

A fundamental step in two-dimensional left ventricular mass measurement is the determination of myocardial cross-sectional area at a representative level in the ventricle. Because this determination requires that as much of the endocardium as possible be perpendicular to the ultrasound beam path, short-axis images are used. Both methods recommended by the Committee use the midventricular short-axis view at the level of papillary muscle tips, generally the widest short-axis left ventricular diameter. End-diastolic frames should be selected and traced on a microcomputer digitizer to determine total area (A1) subtended by the epicardium, cavity area (A2), and the difference (A1 − A2) myocardial area (Am). Assuming a circular cross section, the cavity short-axis radius (b) and the mean wall thickness (t) can be calculated from the mean area values (Figure 4, top panel).

Formula 6 calculates the short-axis radius (b) (Figure 4, upper panel, left).

Formula 7 calculates the short-axis wall thickness (t) (Figure 4, upper panel, left).

Formula 8 calculates the myocardial area (Am) (Figure 4, upper panel, right).

In tracing the endocardium, the papillary muscles are considered part of the cavity (Figure 4, top panel).

Apical four- and two-chamber views at end-diastole must also be recorded with an effort to maximize the length of the ventricular image. If these views have been previously analyzed for left ventricular volume determination, a well written program will recall the maximum major axis dimension and use it to calculate mass.

Formula 9 calculates the left ventricular mass by area length (Figure 4, lower panel).

Formula 10 calculates the left ventricular mass by truncated ellipsoid (Figure 4, lower panel).

In the area length technique of calculation of left ventricular mass, the entire major axis is used, whereas the truncated ellipsoid technique divides the major axis into two parts at the level of the widest minor axis. These two segments are called the semimajor axis (a) and the truncated semimajor axis (d) (Figure 4). Both methods calculate the volume of the myocardium. The product of this volume and the specific gravity of myocardium, 1.05 gm/ml is left ventricular mass. Table 5 provides normal values for the population of sedentary (nonathletic) subjects computed by the truncated ellipsoid method.[16]

SEGMENTAL WALL MOTION ANALYSIS

Two-dimensional echocardiography is a real-time tomographic technique, especially suitable for study of regional wall motion. Several studies[23,24] using a variety of segmental divisions and different methods of analysis of wall motion have been published. Among these, the American Society of Echocardiography offered a 20-segment model for wall motion analysis. However, it has not been widely adopted.

In current clinical practice, a semiquantitative method that derives wall motion score based on a visual impression of regional wall motion is commonly utilized. The Committee recommends this

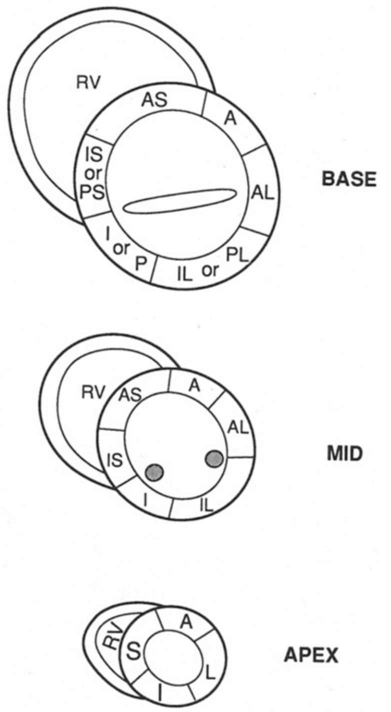


Figure 5 Proposed 16-segment model for wall motion analysis. *A,* Anterior; *AL,* anterolateral; *IL,* inferolateral; *I,* inferior; *IS,* inferior septum; *AS,* anterior septum; *PL,* posterior lateral; *P,* posterior; *PS,* posterior septum.

method, with modifications, believing it will facilitate communication among clinicians and clinical investigators. Although recognizing that this proposed approach is not quantitative, the Committee encourages its use until a practical, widely applicable quantitative method is developed.

The Committee recommends this 16-segment model based on the following considerations:

1. Anatomic logic
2. Easy identification of the segments using internal anatomic landmarks
3. Relationship of the segments to known coronary arterial supply
4. A uniform scoring system for grading the severity of segmental wall motion abnormalities

Classification and Nomenclature

As a practical approach, the left ventricular mass can be divided into three nearly equal levels along the apex to base length resulting in its partition into basal, middle, and apical levels. The left ventricular free wall has three anatomic surfaces (wall segments): the anterior, lateral, and inferior. The most basal segment of the inferior wall is the anatomically true posterior segment, and because the term *posterior infarct* is well ingrained in the literature on heart disease, we propose that this particular wall segment along with the corresponding level of the ventricular septum be referred to as the *posterobasal left ventricular* and *posterobasal ventricular septal segments.* The segments at the midventricular (papillary muscle) level should be referred to as *inferior left ventricular* and *inferior septal segments.*

Segmental Subdivision

A 16-segment model (Figure 5) is offered as a preferred alternative for visual semiquantitative wall motion analysis to the 20-segment model originally recommended by the American Society of Echocardiography.[9] This 16-segment approach represents a minor modification of the model proposed in 1981.[23] The Committee believes that decreasing the number of divisions to 16 may encourage wider clinical utilization. Future developments in automatic endocardial detection and automatic segmental wall motion analysis may eventually allow increasing the number of segments analyzed.

Scoring Scale

Another area that has been the source of confusion and frustration pertains to the different scoring schemes for regional wall motion abnormalities. The following scheme is offered for standardization. A normally contracting segment (or hyperkinetic segment) is assigned a score of 1, hypokinesis 2, akinesis 3, dyskinesis 4, and aneurysmal (that is, diastolically deformed) segment 5. In this scoring scheme hyperkinesis is not distinguished from normal. A wall motion score index can be derived representing the sum of all scores divided by the number of segments visualized. For this index to be reliable and meaningful it is important that all or nearly all segments be visualized. The above described scoring and weighting systems for segmental analysis of the left ventricle can allow calculation of the percent of abnormally and/or percent of normally contracting myocardium. It, however, should be realized that the percent of abnormally contracting myocardium should not be equated with the percent of infarcted myocardium.

SUMMARY

We have presented recommendations for the optimum acquisition of quantitative two-dimensional data in the current echocardiographic environment. It is likely that advances in imaging may enhance or supplement these approaches. For example, three-dimensional reconstruction methods may greatly augment the accuracy of volume determination if they become more efficient. The development of three-dimensional methods will depend in turn on vastly improved transthoracic resolution similar to that now obtainable by transesophageal echocardiography. Better resolution will also make the use of more direct methods of measuring myocardial mass practical. For example, if the epicardium were well resolved in the long-axis apical views, the myocardial shell volume could be measured directly by the biplane method of discs rather than extrapolating myocardial thickness from a single short-axis view.

At present, it is our opinion that current technology justifies the clinical use of the quantitative two-dimensional methods described in this article. When technically feasible, and if resources permit, we recommend the routine reporting of left ventricular ejection fraction, diastolic volume, mass, and wall motion score.

The Committee acknowledges the extraordinary contributions to this document made by Alfred Parisi, MD, and Benjamin F. Byrd III, MD. We also thank Mary Helen Briscoe for medical illustrations and Regina Daniels and Valerie Helmhold for editorial assistance.

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