INTRODUCTION

During the last 20 years the importance of the left ventricular (LV) long-axis systolic shortening has been stressed[1,2] and during the last 12 years echocardiographic recording of the shortening, measured as the mitral annulus motion (MAM), has been introduced as a routine method in assessment of LV function[3].

The most widespread method for investigation of long-axis shortening is echocardiographic M-mode recording from apical views as described by Hoglund et al[4]. Recently however, the left coronary artery motion recorded from the left coronary ostium by routine coronary angiography has also been shown to be useful for assessment of LV systolic function[5]. The amplitude of the ostium however, was found to be much lower than the amplitudes previously reported from MAM[6]. The reason for the difference in amplitude between the mitral annulus and the left coronary ostium is probably that the atrial contraction counts for about 40% of the total MAM in middle-aged persons[6] while the coronary ostium is probably much less influenced by the atrial contraction.

The MAM represents the motion of the atrioventricular (AV) plane. As one part of the circumflex artery runs in the AV groove this part is also assumed to represent the AV plane. Therefore, the amplitude of the annulus motion, which represents the endocardial part of the basal part of the LV wall, has recently been compared with the circumflex artery motion (CAM), which represents the epicardial part of the AV plane[7]. It was found that the amplitude of CAM was higher than MAM in patients with normal LV function. The study suggests however, that CAM is also a useful index of LV systolic function.

AIM OF THE WORK

The main aim of the present study will be therefore to investigate the usefulness of the CAM and to compare it with left coronary ostium motion and to ejection fraction (EF) obtained by LV angiography. Another aim of the study will be to investigate whether the ratio between the CAM and the end-diastolic length of the ventricle, which can be denominated by long-axis fractional shortening (FS_L), is a better index of LV function than CAM per se.

ASSESSMENT OF LEFT VENTRICULAR SYSTOLIC FUNCTION

Introduction

Among patients with left ventricular systolic dysfunction, prognosis varies inversely with the left ventricular ejection fraction (LVEF). As a result, measurement of LVEF is a common procedure in patients with heart disease.

LV systolic function is usually assessed by the resting left ventricular ejection fraction (LVEF). In addition to resting LV function, both the absolute value of exercise LVEF and exercise-induced change from resting LVEF have prognostic implications [(8-11)]. However, it is unclear in the reperfusion era if the exercise value provides appreciable prognostic information beyond the resting value in patients with acute myocardial infarction [(12)].

The LVEF is expressed as the ratio of the stroke volume divided by the end-diastolic volume and is calculated as follows.

Stroke volume (SV) = LV end-diastolic volume - LV end-systolic volume

LVEF, percent = (SV ÷ LV end-diastolic volume) x 100

This discussion will review the advantages and disadvantages of six modalities used to evaluate left ventricular function:

1. Echocardiography, both two-dimensional and three-dimensional
2. Radionuclide ventriculography.
3. Gated single photon emission tomography.
4. Computed tomography.
5. Cardiovascular magnetic resonance imaging.
6. Left ventriculography.

Chapter One
ECHOCARDIOGRAPHY

Two-dimensional (2D) echocardiography allows real-time imaging of the heart and its various structures using ultrasonic waves. With the ultrasound beam directed perpendicularly to the myocardium, wall motion and thickening can easily be detected on the imaging plane. Several imaging windows, including parasternal, apical, and subcostal views, are used to visualize all ventricular walls (see figure (1)). Three dimensional (3D) echocardiographic images are generated by integration of information from multiple 2D imaging planes.

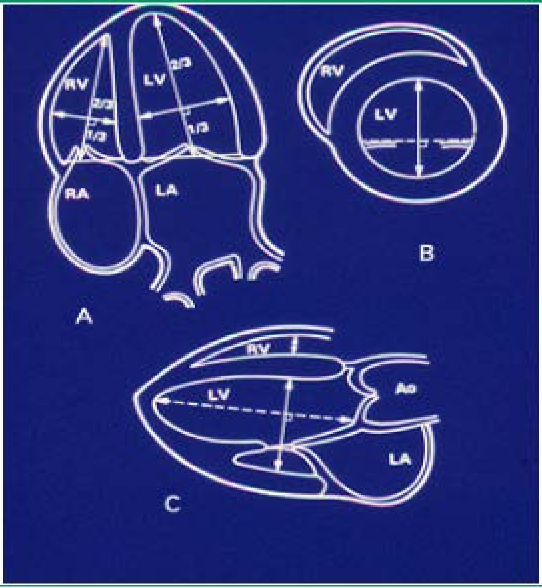

Figure (1): Sites for left ventricular measurements
Measurements of left ventricular (LV) dimensions can be obtained from various views obtained from the two dimensional echocardiogram. Panel A is the apical four chamber view; M-mode tracings cannot be made from an apical view and thus measurements must be made directly from the two dimensional image. The dimensions of the right ventricle (RV) can also be obtained from this view. Panel B is the short axis parasternal view; measurements from the short axis can be made interchangeably from either M-mode or two dimensional image. Panel C is the long axis parasternal view; measurements of LV dimension can be made from either the two dimensional image or the M-mode tracing. Ao: aorta; LA: left atrium; RA: right atrium.

The introduction of harmonic imaging and the use of echocardiographic contrast media for improved endocardial border definition have significantly improved image quality, thereby enhancing the accuracy of assessment of the left LVEF, particularly in patients with poor acoustic windows [13-16].

Estimation of the LVEF by 2D echocardiography can be done either qualitatively by visual inspection of global and regional function or quantitatively, using geometric assumptions regarding the shape of the LV cavity. Simplified analyses have been developed and are currently used to facilitate the acquisition of important indices. Global and regional LV systolic function can both be accurately assessed by experienced readers.

Qualitative global function — Global function is typically described as normal, depressed, or hyperdynamic.

- Depressed systolic function may be characterized both by severity (mild, moderate, severe) and focality (global or regional).
- Hyperdynamic function is frequently associated with high-output syndromes (eg, anemia, thyrotoxicosis), hypertrophic cardiomyopathies, or in response to exercise or pharmacologic stress (e.g., dobutamine).

The visual assessment of global LVEF is typically reported in intervals of 5 or 10 percent and within a range (eg, 35 to 40 percent).

Qualitative regional function — the regional assessment of LV systolic function is assessed by dividing the entire left ventricle into segments. For the purposes of localizing segmental wall motion abnormalities in a standardized format, the American Society of Echocardiography (ASE) has recommended dividing the ventricle into 16 segments (see figure (2)) [17]. The American Heart Association (AHA), as part of an effort to unify wall motion analysis among different imaging modalities, concluded that a 17 segment model was preferred [18]. Most centers have migrated to this 17-segment model (see figure (3)).

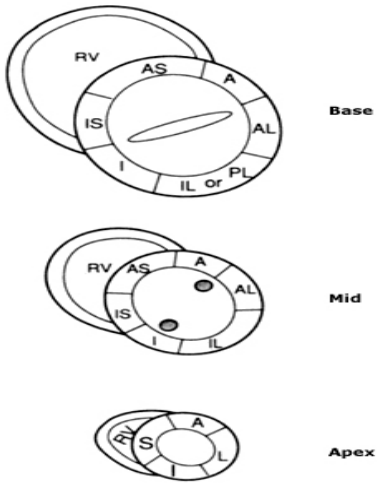

Figure (2): Analysis of wall motion.

The 16-segment model for the analysis of left ventricular wall motion, recommended by the American Society of Echocardiography, is shown.
A: anterior; AL: anterolateral; IL: inferolateral; I: inferior; IS: inferior septum; AS: anterior septum; PL: posterior lateral. Reprinted with permission of the American Society of Echocardiography.

A score is then assigned to each segment:

- 0 = normal 1 = hypokinesis
- 2 = akinesis 3 = dyskinesis

The total score (0 = normal) permits a semiquantitative assessment of left ventricular systolic function.

Quantitative evaluation — Although qualitative assessments are more widely used in clinical practice, echocardiography can also generate a number of quantitative assessments of LV size and function. Quantitative measurements are available for uni-dimensional (M-mode), two-dimensional (2D), and three-dimensional (3D) techniques.

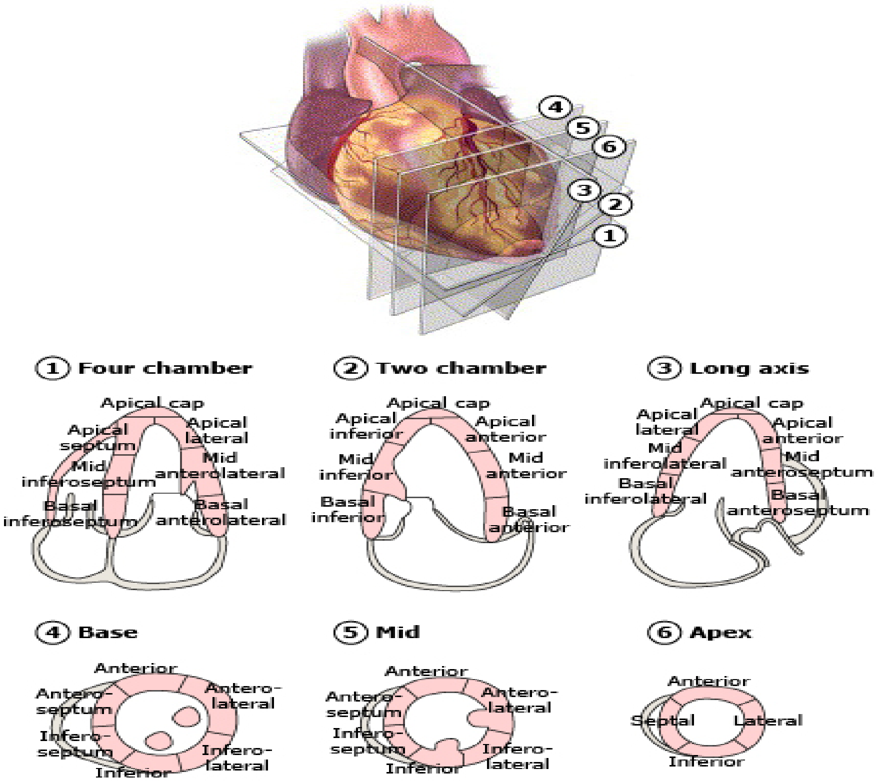

Figure (3): Left ventricular segmentation.

Segmental analysis of LV walls based on schematic views, in a parasternal short- and long-axis orientation, at three different levels. The "apex segments" are usually visualized from apical 4-chamber, apical 2- and 3-chamber views. The apical cap can only be appreciated on some contrast studies. A 16-segment model can be used, without the apical cap, as described in an ASE 1989 document[17]. A 17-segment model, including the apical cap, has been suggested by the American Heart Association Writing Group on Myocardial Segmentation and Registration for Cardiac Imaging[18].

The linear measurement estimations of ventricular volumes and ejection fraction assume that the left ventricle can be described by the revolution of a prolate ellipse. Thus, the ventricular volume is approximately D^3, where D is the short-axis diameter of the left ventricle at the tips of the mitral valve ("cube formula").

Two-dimensional estimations of left ventricular function can be performed based on the assumption that the left ventricle has the shape of a truncated-ellipsoid ("area-length" or "bullet" formula). The method of discs (Simpson's rule) and the method of multiple diameters generally provide more accurate measurements of ventricular volumes and ejection fraction than the linear (M-mode) techniques, and are the recommended techniques for transthoracic quantitative evaluations (19,20).

With 3D echocardiography, a polyhedral surface reconstruction algorithm can be used to more accurately represent the geometry of the left ventricle and quantify measures of systolic function. Systems for automated comprehensive quantitative assessment of the entire left ventricle have been developed but have limited availability.

Speckle tracking has evolved as a method to mark small segments of the myocardium and track their motion throughout the cardiac cycle, thereby allowing to measure not only the systolic shortening but also the rotation of the left ventricle and stress-strain of the myocardium in the circumferential and longitudinal directions [21]. With echocardiography, quantitative indexes of ventricular volumes, ventricular mass, and wall stress can be derived [20].

Assessment of myocardial strain and strain-rate — The term "strain" refers to an object's fractional or percentage change from its original, unstressed, dimension (ie, a change in length corrected for the original length) [22,23]. It reflects deformation of a structure, and when applied to the myocardium, strain directly describes the contraction/relaxation pattern. Strain can be calculated in several dimensions; longitudinal, circumferential, or radial [23]. Strain rate is the rate of this deformation [22].

Myocardial strain has been measured with cardiovascular magnetic resonance imaging, two-dimensional echo, tissue Doppler and speckle-tracking imaging. Despite the promise that strain and strain rate imaging offer, a number of challenges limit clinical utility, including[23]:

- Complex methodology
- Technical challenges of image acquisition
- Susceptibility to artifact
- Lack of consensus regarding optimal methods and parameters

Accuracy — A number of studies have evaluated the accuracy of 2D echocardiography for measurement of LVEF compared to RVG and/or contrast ventriculography [19, 24, 25]. In a review of published studies, it was concluded that the three techniques exhibited a high correlation but only moderate agreement [24]. As will be described, three-dimensional echocardiography provides values comparable to RVG that may be superior to 2D echocardiographic measurements [26]. (See 'Three dimensional echocardiography' below.)

Advantages — Two-dimensional echocardiography offers the following advantages:

- It is noninvasive and does not involve radiation. The vast majority of patients do not require intravenous access or use of an exogenous contrast agent.
- Current equipment allows easy portable (e.g., bedside) studies at relatively low cost.
- It accurately evaluates regional wall motion, which is of particular importance in assessing patients with coronary disease.
- Various indices of diastolic LV function (isovolumic relaxation time, deceleration time, E to A wave ratio, etc) can be reproducibly measured with echocardiography.
- All other cardiac structures, including valves, can be visualized, and the anatomic and functional integrity can be thoroughly evaluated. The additive information of Doppler echocardiography may be of fundamental importance.

- Echocardiography is not limited by arrhythmias, because it is an inherently real-time imaging technique. However, ventricular function may be adversely affected by the arrhythmia.
- As with RVG, echocardiography can be used in conjunction with exercise or pharmacologic stressing, to evaluate stress-induced ischemia. Wall thickening can also be used to assess myocardial viability.

Disadvantages — 2D echocardiography has several disadvantages:

- Accuracy may be limited by geometric assumptions regarding the shape of the left ventricular cavity.
- It requires an experienced sonographer and echocardiographer. A variety of artifacts can be generated by improper positioning of the imaging transducer or incorrect setting of the equipment's gain controls.
- Although interpretation by an experienced reader is reproducible, this is not the case with more novice readers. Even in the best of hands, the interobserver and intraobserver variability are in the range 10 to 30 percent, clearly greater than those seen with RVG or cardiovascular magnetic resonance.
- Although quantitative approaches are generally more accurate than qualitative assessment, such methods are time consuming and rely on assumptions regarding the LV shape.

- The diagnostic value of echocardiography is limited in patients with poor acoustic windows, such as obese individuals, patients with hyperinflated lungs (e.g., due to obstructive or other lung diseases), patients with musculoskeletal deformities (e.g., kyphosis, pectus excavatum), or patients that cannot be properly positioned for a thorough study (e.g., postoperative).

Three-dimensional echocardiography — 3D echocardiography appears to produce LVEF values similar to RVG and cardiovascular magnetic resonance, and offers incremental benefit over 2D techniques and improved accuracy and reproducibility(26-30).

One study, for example, compared LVEF measurements obtained by 3D echocardiography, quantitative and qualitative 2D echocardiography, and RVG in 51 patients with heart disease; there was an excellent correlation between 3D echocardiography and RVG (r = 0.94 to 0.97) without significant overestimation or underestimation(26). 3D echocardiography was superior to both quantitative and qualitative 2D echocardiographic techniques. In other studies, 3D echocardiography correlated well with measurements made using cardiac magnetic resonance imaging(28-32). (See 'Cardiovascular magnetic resonance imaging' below.)

3D echocardiography has also been investigated as a tool to quantify LV dyssynchrony in patients being considered for cardiac resynchronization therapy (biventricular pacing).