A Comparison of Real-Time, Two-Dimensional Echocardiography and Cineangiography in Detecting Left Ventricular Asynergy

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SUMMARY Left ventricular wall motion was assessed in 105 consecutive patients both invasively, using biplane cineangiography, and noninvasively, by a real-time, phased-array, two-dimensional echocardiography system. Ventricular wall motion in five anatomic areas of the ventricle (anterolateral, posterolateral, apical, septal, and inferior) was analyzed by both methods in a double-blind manner. Two-dimensional echocardiographic images were deemed adequate for analysis in 82% of the regions (430 of 525). Fifty-five discrepancies were noted in the comparison of the remaining 430 regions. The reasons for discrepancies in interpretation between the two methods were established for 54 during retrospective review: 33 were due to echocardiography (inadequate target visualization, observer error, or tangential echo views). Fifteen were related to angiography (overlay of silhouettes or observer error), and six were due to other reasons including definition problems or spatial orientation difficulties.

Both real-time, two-dimensional echocardiography and cineangiography have advantages and disadvantages. The techniques used together could provide more complete information concerning ventricular wall motion than is now currently available.

REAL-TIME, TWO-DIMENSIONAL ECHOCARDIOGRAPHY is a relatively new approach to visualizing cardiac dynamics and its use in the detection of ventricular asynergy has not been studied. An early report of 25 patients by Teichholz et al.1 gave promise that ECG gated, compound B-scanning techniques could be used for this purpose. Weyman et al.2 recently used a mechanical sector scanning device for the detection of ventricular apical asynergy in 25 patients with angiographically-proven apical aneurysms. As Feigenbaum3 pointed out in a recent editorial, however, much more investigation into the advantages and limitations of real-time cross-sectional imaging methods is necessary before their clinical utility can be confirmed.

In the first two years of clinical use of this new imaging method, our initial attempts at defining abnormal areas of wall motion were frequently incorrect. Therefore, this prospective study was undertaken to define these sources of error. The results of the assessment of ventricular wall motion by two-dimensional echocardiography were compared to similar data obtained by biplane cineventriculography. Since both techniques have potential for error, we looked for areas of agreement and disagreement. When areas of disagreement occurred, we looked for explanations based on the capabilities and limitations of each method.

Methods

Patients

Left ventricular wall motion was studied by real-time, two-dimensional echocardiography and biplane cineventriculography in 105 consecutive patients undergoing diagnostic cardiac catheterization. Pertinent descriptive clinical data concerning the patients are listed in table 1.

Echocardiographic Imaging System

Two-dimensional echocardiograms were performed on all patients using a previously described4,5 real-time, phased-array imaging system. The system uses a hand-held, 24 element transducer array that measures 14 \times 24 \text{ mm} at the site of skin contact and relies upon phased-array principles to electronically steer and focus the sound beam through the structures under investigation. Real-time, cross-sectional images of cardiac structures are presented in a circular sector format, 50, 60, or 90 degrees in azimuth at a frame rate of 30 per second. Images are permanently recorded on videotape for later playback and analysis.

It is important to note that much detail is lost in the single frame scan images that constitute the illustrations in this paper. They were made from the videotape recordings by means of a 35 mm photograph of the sector arc in the stop-frame mode. As such, there is a loss of visual integration of motion that normally accompanies real-time playback. Moreover, there is a severe degradation in image quality caused by photographing a single frame image from the videotape recording because of the fact that an individual videotape frame represents the scan information collected in only 1/60th of a second. When operating in the 90 degree, 160 line format, therefore, each single frame video field shows only one-half (80 lines) of the information provided in the real-time scan.

Echocardiographic Technique

All two-dimensional echocardiograms were obtained on the day prior to cardiac catheterization. Ultrasonic examination of the heart was performed with the patients in the slight left lateral position. Figure 1 schematically demonstrates the two basic planes of view for examination of the left ventricle in both long and short axis. The five basic wall regions visualized (anterolateral, posterolateral, apical, septal, and inferior) are indicated on the schematic drawings of cross-sectional images of the left ventricle in long axis (Position I) and four serial short axis views (Positions IV, Va, Vb, and VI) shown in figure 2. The numerical identification of the various views corresponds to data previously published from this laboratory.6

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Position I was utilized to examine the long axis of the left ventricle as the scan plane intersected the aortic root, mitral valve leaflets, body of the left ventricle and ventricular apex. In those instances, when an adequate image of the apex was not obtained, the transducer was moved inferiorly into the next lowest interspace and angled slightly superiorly until echoes from the ventricular apex were identified. In short axis, a scan through Position IV revealed a cross-sectional image of the left ventricle at the level of the mitral leaflets. By progressively moving the transducer inferiorly on the chest wall, serial scans through the short axis of the left ventricle at the levels of the tips of the papillary muscles (Position Vа), the bodies of the papillary muscles (Position Vb) and the ventricular apex (Position VI) were obtained.

In an attempt to closely approximate the true short axis of the left ventricle, the transducer was placed perpendicular to the chest wall and the ventricle was scanned until the image of the left ventricle appeared most circular in configuration. Particular care was taken to avoid extreme transducer angulation as it distorted the appearance of the ventricular circumference (oval rather than circular) and made the interpretation of ventricular geometry and asynergy unreliable.

**Catheterization Methods**

All patients underwent complete left and right heart catheterization from the right groin using the Seldinger technique. Biplane left ventricular cineangiograms were obtained in the orthogonal left and right anterior oblique projections using a mixture of 66% meglumine diatrizoate and 10% sodium diatrizoate (Renografin 76). Proper torso positioning for ventriculography varied slightly between patients depending on cardiac chamber size and body habitus. Cineangiograms were recorded on 35 mm film at a speed of 60 frames per second. Localization of the five wall regions on the angiographic views is illustrated in figure 3.

**Data Analysis**

As previously described, five left ventricular wall regions were identified from the echocardiographic and angiographic images (figs. 2, 3). The anterior wall was considered to extend over the anterior surface of the ventricle from the anterior interventricular sulcus around the free ventricular wall to the origin of the anterior papillary muscle. The posterolateral region was considered to extend posteriorly between the papillary muscles. The inferior region extended from the posterior papillary muscle to the junction with the septum at the posterior interventricular sulcus. The septal region included the septum while the apical region included the very tip of the ventricular cavity and apex.
Ventricular wall motion was classified as either normal or abnormal in each of the echocardiographically and angiographically determined wall regions. Abnormal systolic wall motion was defined according to the terminology of Herman et al.6

The echocardiograms and cineventriculograms were analyzed by two independent groups of investigators, neither having knowledge of the other's conclusions until the time of data correlation. To serve as a basis for comparison, the echocardiographic results were utilized to predict the appearance of the biplane cineventriculogram in each patient. The echocardiogram was then judged as correct or incorrect in identifying the ventricular wall motion characteristics as determined by angiography. In this way, a total of 525 potential wall regions were examined in each method. After initial correlation, both echocardiograms and angiograms were reviewed by the combined investigative teams to determine the reasons for agreement or disagreement.

Results

Correlative Examples

Figure 4 shows stop-frame systolic images through Positions I, Va, and VI from a patient with mild mitral prolapse and a normally contracting left ventricle. When the ventricle was normal in size, adequate visualization of the ventricular apex was often difficult due to intervening lung tissue. Figure 5 demonstrates the advantage of the 90° sector arc.

Figure 3. Schematic diagram showing the localization of the five wall regions by angiography examined in this study. RAO = right anterior oblique projection; LAO = left anterior oblique projection.

FIGURE 3. Schematic diagram showing the localization of the five wall regions by angiography examined in this study. RAO = right anterior oblique projection; LAO = left anterior oblique projection.

FIGURE 4. Stop-frame systolic images and schematic drawings through Position I (panels A and B), Position Va (panels C and D), and Position VI (panels E and F) from a patient with a normally contracting left ventricle and mild mitral prolapse. Scans in panels A and C are in the 50° sector arc while the scan in panel E is in the 90° sector arc. Note that the left ventricle is normally circular in configuration when viewed in short axis (C and D). Several endocardial trabeculations can also be seen in panel C. AoR = aortic root; LA = left atrium; AML = anterior mitral leaflet; EP = epicardium; PM = papillary muscle; P = pericardium; LVC = left ventricular cavity; IVS = interventricular septum; T = trabeculation.
arc since this wide field of view occasionally allowed for visualization of the entire left ventricle in long axis (Position I).

Figure 6 shows a systolic stop-frame image through the short axis (Position Va) of the left ventricle in a patient with pulmonary hypertension (panels A and B). The relationships of the angiographic planes of view are indicated on the echocardiographic image. This patient illustrates the usefulness of two-dimensional echocardiography for describing the abnormal geometry of the left ventricle.

The two-dimensional echo and angiographic findings of a patient with a ventricular aneurysm are shown in figures 7 and 8. While the two-dimensional echo demonstrated normal wall motion of the posterior region of the heart, this was difficult to appreciate in the ventriculogram due to superimposition of the large opacified aneurysm on the remainder of the ventricle.

Echocardiographic-Angiographic Correlations

The results of double blind correlation are summarized in the left hand panel of figure 9. In all 105 patients, biplane ventriculograms were considered adequate for the analysis of wall motion. Eighteen percent (95 of 525) of wall regions, however, could not be visualized by two-dimensional echocardiography. It should be noted that, in the 430 regions visualized by echocardiography, wall motion characteristics were correctly identified in 87% (375 of 430). Discrepancies between the echocardiographic and angiographic findings occurred in 13% (55 of 430).

Discrepancy Analysis

In order to fully appreciate the interrelationships between two-dimensional echocardiography and angiography, the data was then retrospectively reviewed. Suspected reasons for 54 of the 55 discrepancies were identified and classified (fig. 9).

Reasons for the various discrepancies are summarized in table 2. Of the 34 discrepancies attributable to echocardiography, ten were due to observer error and 19 were due to inadequately visualized echo targets that were previously judged as adequate. Despite the care taken to properly position the transducer on the chest wall, four errors were caused by tangential angulation of the transducer through the short axis of the ventricular cavity resulting in distortion of wall movement. These latter errors were detected in two patients by repeat studies. In two others, careful review of the videotape record showed previously unnoticed brief scan sequences through the true short axis of the ventricle.

The majority of the 15 discrepancies due to angiography resulted from the superimposition of abnormally contracting wall regions over the normally contracting portions of the ventricle (fig. 8). For example, when severe anterior wall asynery was present, the abnormally contracting anterior wall was superimposed over the interventricular septum in the LAO angiographic view, thus obscuring true septal wall motion.

The six discrepancies termed indeterminant were so classified because they could not readily be attributed to either imaging technique. This category includes unresolved disagreements between the echocardiographic and angiographic interpretations. The indeterminant discrepancies included only mild abnormalities and in two instances, the asynery noted in a specific region by echocardiography was seen in an adjacent wall region by angiography.

The frequency of the various discrepancies as they related to specific wall regions are tabulated in table 3. Discrepancies due to observer error and inadequate target visualization by echo were most frequently encountered in the interpretation of apical wall motion while problems experienced with the ventricular silhouette on angiography were encountered most frequently in interpreting septal wall motion.

Adequacy of Echo Targets

Since the double-blind analysis revealed that inadequate endocardial echo targets accounted for the most frequent error by echocardiography, the echocardiograms were carefully reviewed in an effort to establish minimal criteria
FIGURE 6. A) Systolic stop-frame image through the short axis (Position Va) of the left ventricle in a patient with pulmonary hypertension. The ventricle is somewhat flattened in comparison to the normal seen in figure 4C. B) Schematic diagram of the scan image showing the orientation of the radiographic planes of view. Because the ventricle is flattened, it appears slightly dilated and poorly contractile in the RAO angiographic projection (C and D) while it is narrow and well contractile in the LAO projection (E and F). Both angiographic frames are in systole.
for assessing the adequacy of an echo image. Upon review, it was clear that at least 50% of the endocardium in any one wall region must be visualized throughout the cardiac cycle in order to reliably predict the presence or absence of asynergy.

The number of wall regions visualized per patient, both double-blind and after discrepancy analysis, is shown in Table 4. Visualization of all regions of the left ventricle by two-dimensional echocardiography was possible in 60% of these patients while failure to visualize any of the regions occurred in 11%.

Table 5 relates the frequency of inadequately visualized targets to specific wall regions. The most readily visualized regions were the septal and posterior walls; the most difficult region to visualize, the ventricular apex.

Reliability of Echo in Visualizing Abnormal Motion

Table 6 presents the data illustrated in Figure 9. Line A indicates that most discrepancies occurred in abnormally contracting wall segments (75% or 41 of 55). Inadequate target visualization initially appeared to be equal between the normal and abnormal regions (18% or 74 of 413 and 21 of 112 respectively). The data in lines B and C describe intermediate stages of the retrospective review when angio-

**Figure 8.** Sequential diastolic (A and D) and systolic (B and E) angiographic frames from the same patient pictured in Figure 7. The RAO view is pictured on the top row while the LAO view is on the bottom. Note the large ventricular aneurysm and contracting base in panel C. The arrows in panel E point to the contracting base that is poorly visualized through the silhouette of the aneurysm in the LAO view (panel F). These findings were similar to those predicted by two-dimensional echocardiography. For reference as to location of wall regions, see Figure 3.

**Figure 7.** Sequential diastolic (A) and systolic (C) stop-frame scan images in the 90° sector arc through the long axis of the left ventricle (Position 1) of a patient with coronary artery disease and a huge ventricular aneurysm. The corresponding schematic diagrams (B and D) have been added to help locate structures since these images are typical of the somewhat degraded images seen in patients with ventricular asynergy. Panel E demonstrates diffuse asynergy with relative preservation of motion along the posterior wall region at the base of the heart. LVA = left ventricular aneurysm. Remainder of abbreviations are the same as in Figure 4. For reference as to location of wall regions, see Figure 2.
graphic and indeterminate discrepancies were eliminated (Line B) and when discrepancies due to inadequate target visualization were eliminated. Upon complete data review, it was seen that abnormally contracting regions were much more difficult to visualize (Line D) than normally contracting segments since 19% of the normally moving regions were not visualized (78 of 413) as opposed to 32% of the abnormally moving segments (35 of 112). Thus, the greatest problems in the detection of adequate echo targets were seen in patients with abnormal wall motion patterns.

**Discussion**

Proper echocardiographic technique is most important in obtaining a true cross-sectional image of the left ventricle. Even though this difficulty was well recognized before this study was begun, 7% of the discrepancies noted on double-blind analysis were due to improper echo technique. The heart, as a constantly moving three-dimensional target, is rotating in and out of the interrogating plane during the cardiac cycle. An improperly directed transducer causes the scan plane to intersect the ventricular cavity tangentially and may result in distortion of normal ventricular configuration and wall motion. When the ventricle is viewed in long axis (Position I), this problem is most easily recognized when the normal elliptical configuration of the cavity appears circular, or cut-off, near the origins of the papillary muscles. When the ventricle is viewed in short axis (Positions IV, Va, Vb, and VI), this problem is recognized when the cavity appears oval, rather than circular, in shape.

Eighteen percent of the discrepancies noted were due to echocardiographic observer error caused by two problems that had not been recognized previously. First, as the heart contracts in systole, it rotates and moves in an inferior and anterior direction. In the short axis view of the left ventricle, this cardiac movement reduces the posterior systolic motion of the septum that can be seen echocardiographically. Second, several observer errors were made when the 50° sector scan format was used. Because in short axis the entire ventricular circumference is not included in the field of view, the motion of the various wall regions relative to one another was not fully appreciated and minor to moderate degrees of asynergy were missed. When the ventricle is dilated, a short axis scan in 50° sector arc may not include the entire ventricular wall. A wide field of view, therefore, should be employed when examining the left ventricle for asynergy.

Proper judgment concerning the adequacy of an echocardiographic image for interpretation of left ventricular asynergy is clearly most important. Thirty-five percent of the discrepancies noted were due to the inadequacy of the echocardiographic image. At the present time, it is not certain why this difficulty is more prevalent in the abnormally moving wall regions.

In retrospect, it appeared that assessment of wall motion characteristics of a specific wall region could be reliably attempted only when at least 50% of the endocardium in any one wall region is visualized throughout the cardiac cycle. All five heart wall regions could be visualized using this criteria in 60% of the patients examined (Table 4). It should be kept in mind, however, that the most difficult wall regions to visualize were the apical, inferior, and anterolateral (Table 5). Such findings are not surprising since target drop out (loss of targets due to tangential angulation of the echo beam) and/or interfering lung tissue are most often encountered when attempting to image these particular wall regions. As a general rule, when the ventricle was large, the lung tissue normally overlying the ventricular apex was displaced and further interfered with visualization of the apex.

Twenty-seven percent (15 of 55) of the discrepancies noted were attributable to errors in angiographic detection. Paramount among these is the superimposition of the silhouette of an abnormally contracting wall segment over one that is normal, occasionally making detection of the...
normal motion difficult or impossible. For similar reasons, most of the ventricular wall surfaces are inaccessible to radiographic contrast imaging techniques. The only wall motion detected by this method is seen along the borders of the ventricular silhouette. Biplane cineventriculography, of course, tends to reduce these sources of misinterpretation. Furthermore, since this technique is invasive, its application is limited to relatively small numbers of patients selected for cardiac catheterization.

When the data are adjusted for angiographic errors (table 6), the accuracy of two-dimensional echocardiography in detecting asynergy improved. When cases of errors in target visualization were removed, the method's sensitivity was further improved.

Nevertheless, biplane cineventriculography is still the most reliable method for visualizing the moving ventricular cavity. All 105 patients in this study had adequate images of the left ventricular structures as opposed to echo which failed to visualize any targets in 11%.

Since this study deals with the correlation of data from two distinctly different imaging techniques, it is not surprising that several discrepancies occurred that could not readily be attributed to either echocardiography or angiography.

Most of these resulted from the occasional disagreement between observers concerning the presence or absence of mild degrees of asynergy. It is most important to realize that the two techniques, working together, could potentially provide more complete information concerning ventricular wall movement than is now currently available.

These observations need to be tested on a large prospective series of patients. Such future study, however, must also deal with the fact that angiography is a somewhat compromised standard by which to determine the true efficacy of two-dimensional echocardiography in the assessment of ventricular wall motion characteristics. If echocardiography is to become a useful diagnostic tool, its reliability may have to be judged, in time, within the framework of continued clinical experience. In addition, the interpretive techniques utilized for the echograms were purely subjective and a method for the quantitative assessment of ventricular asynergy similar to that used in angiography is clearly needed.

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