COMPARISON OF REGIONAL WALL MOTION PARAMETERS BETWEEN ANGIOGRAPHIC AND ECHOCARDIOGRAPHIC IMAGES

T. Allan Pryor, Dennis L. Parker, J. Douglas Ridges

LDS Hospital and University of Utah
325 Eighth Avenue
Salt Lake City, Utah 84143

Comparison of regional wall motion on 14 patients was studied using left ventricular contours derived from angiographic and echocardiographic images. To insure accuracy of contour determination from the echocardiographic images, time motion data was used together with the two dimensional image in defining the ventricular borders. Percent shortening was measured using three separate reference systems. The reference systems included hemi diameters, radial diameters and an elliptical coordinate system. For all reference systems the echocardiographic measurements underestimated percent shortening for the septal wall and overestimated percent shortening for the posterior wall.

Angiographic measurements of left ventricular function is an important method of cardiac evaluation. Using automated or semi-automated techniques, measurements of volume, ejection fraction and regional wall motion have been developed. Previous attempts in the use of time motion echocardiography have been less than satisfactory in overall functional evaluation of patients with cardiac disease.[1,2] However, the development of two-dimensional ultrasonic imaging of the left ventricle has made possible the potential for extraction of parameters, similar to those used in left ventricular angiography, for the evaluation of ventricular function. The differences in the type of image produced from two-dimensional echocardiographic images as compared to angiographic images makes the ideal "gold standard" difficult to obtain for the purposes of comparison. Also, the differences in patient status in non-simultaneous data collection lead to increased variability between the methods being compared. It is the purpose of this paper to describe a method for objective comparison of regional wall motion measurements made using borders drawn from two-dimensional echocardiographic images and single-plane angiographic images of the left ventricle. Determination of echocardiographic borders is assisted by use of time motion data extracted from the two-dimensional image. Angiographic images were obtained from axial left anterior oblique angiograms to more closely approximate the echo image. The results provide an indication of the correspondence obtainable in measurements using echocardiographic images and also indicate areas where accuracy may be improved.

Methods

Patients

Patients undergoing routine left heart catheterization for evaluation of heart disease were selected for the study. The study group included 14 patients, 5 males and 9 females. The ages ranged from 25 to 73. Ten patients had moderate to severe mitral stenosis, three had moderate to severe aortic regurgitation and four had moderate to severe pulmonary hypertension. No patient had significant coronary artery disease.

Angiography

Left ventricular angiograms were obtained using standard angiographic techniques. Two angiograms were performed for purposes of comparison with echocardiographic images. A standard 30-degree right anterior oblique (RAO) angiogram was obtained. The second angiogram obtained was in the angulated axial left anterior oblique position (axial LAO). The axial LAO angiogram was obtained to give a more nearly comparative view of the left ventricle to that recorded by the echocardiographic image. Echocardiograms were performed within 24 hours of cardiac catheterization and the approximate plane of the echocardiographic image was used to select values for the axial LAO angles during angiography. Left ventricular angiograms were obtained injecting 45cc of contrast at a rate of

CH1391-2/78/0000-0063$00.75 © 1978 IEEE

15cc per second. All images were recorded on cine film and video tape at the rate of 60 fields per second. Angiographic images were excluded from comparison if a complete ventricular image could not be adequately visualized for determination of the ventricular border and if images of normally conducted (non extra systolic) beats were not recorded.

Borders were obtained from the angiographic images through use of a semi-automated system for border detection at LDS Hospital.[3] This system which is interfaced to a computer automatically determines the ventricular function parameters from either computer determined or hand drawn borders.

Echocardiography

Echocardiographic images were recorded using a computer-assisted non real time two-dimensional scanning system.[4] The images were generated at a frame rate of 60 frames per second. With this system echo scanlines were digitized at a 2mHz sampling rate of 60 times per second. With each sample set the associated electrocardiogram and respiration signal were also digitized and transmitted to the computer for processing. The transmitted sample sets were originally stored in chronological order on magnetic tape. Using this raw information 60 sequential frames through the heart cycle were subsequently created through sorting of the individual scanlines according to their position in the heart cycle. With the information sorted into a two-dimensional image format, additional computer processing was possible. This processing included image enhancement prior to determination of location of cardiac chambers. The computer, via a digital scan converter, recorded the images on a video disc for realtime playback or displayed the images directly on a TV monitor. The recorded data from this system was viewed on the TV monitor as a two-dimensional image or time motion data from each point in the image. For those patients included in the study, adequate visualization of 80 percent or more of the ventricle was required. The time motion display format was used to assist in the determination of the ventricular border on the two-dimensional image. By tracing the border on the displayed time motion data and displaying this information as brightened dots on the corresponding two-dimensional images, a more accurate determination of the two-dimensional border was obtained. This had the advantage of incorporating structure recognition from time motion data where more experience has been gained in the discrimination of echoes from various interfaces. To determine a ventricular border a series of scanlines was selected from the two-dimensional image which spanned the ventricle from the mitral valve region to the apex of the heart. The time motion data at the level of the scanlines was then displayed on the digital scan converter. Borders were traced using a sonic digitizer on the time motion data. These borders included the right and left ventricular septum, posterior wall endocardium and epicardium. The endocardial locations from the time motion tracing were then displayed on each frame of the two-dimensional image as brightened points. Any point which was an obvious outlier, was noted and corrected by retracing the time motion data for that position. These brightened points served also as visual aids in the final drawing of the left ventricular border on the two-dimensional image. The two-dimensional contour at end-diastole was drawn by tracing from the junction of the aortic and mitral valves across the aortic valve to the base of the left ventricular septum, down the left ventricular septum through the average of the time motion data enhanced points to the apex and, at the posterior wall, through the maximal distal endocardial border consistent with the time motion data and the two-dimensional image. From the posterior mitral valve, a straight line was drawn across the valve to the junction of posterior aorta and anterior mitral valve cusps. The border at end-systole was drawn in a similar fashion. The base was defined as the mid-point of the mitral valve orifice; the apex was then defined as that point most distal to the base. The long axis was measured from the starting point of the contour to the apex and was essentially equal to the length of the base to the apex.

This same procedure used for tracing the two-dimensional echocardiograms was used for tracing the LAO angiograms. The same programs for border tracing and motion analysis were used for both LAO angiographic and echocardiographic images.

A comparison of regional wall motion measurements was made between the sets of contours drawn on the echocardiographic images and those traced on the angulated axial LAO angiograms. Regional wall motion was computed using three separate coordinate systems. Two of these models, the hemi-diameter and the radial, have been described previously.[5] The elliptical coordinate system was developed as a part of this study. The coordinate system for each model is based upon a line from the base or mid-point of the mitral valve to the apex. A set of 72 lines is generated from the reference points to the contour. The percent change in length of each line represents motion of the outlined structure. Segment by segment comparisons can then be made between echocardiographic and angiographic motion measurements.

The three coordinate systems are illustrated in Figure 1. In each case the 72 lines are considered in order from the base around the septum to the apex and then up the posterior endocardium to the base again. In the hemi-diameter model the line from the base to the apex is divided into 36 equally spaced reference points. Line segments are then generated perpendicular to the long axis from each of these points to the contour. In the radial model, a single reference point is selected as the mid-point of the line between the base and the apex. A set of 72 line segments are then generated from the reference point to the contour at 5^{o} increments. The elliptical coordinate system assumes that the ventricle can be modeled as an ellipse and that contraction will be generally in the direction perpendicular to the ventricular outline. The two focii of an ellipse of the same area and long axis length as the ventricular outline are determined. The region between the two focii is divided to obtain 36 equally spaced reference points. Line segments are generated from each of the reference points to the contour. The direction of each segment is such that it would intersect normal to the circumference of the hypothetical ellipse with the same area and major axis length as the ventricular outline.

Figure 2 illustrates measurements made using each of the three reference systems on contours drawn on a normally contracting ventricle. The different orientations and lengths of the line segments in each of the three models results in the three separate graphs of percent shortening values. The relatively smooth distribution of percent shortening values is broken in the aortic root region of the radial and elliptical models and in the apical region of the hemi-diameter model. Figure 3 is an example of the output of the three models for an abnormally contracting heart. This patient has an aneurysm on the posterior wall near the apex. In each of the three models, the percent shortening and the absolute shortening become negative in the region of the aneurysm allowing an estimate of the size of the affected region to be made.

Wall Motion Comparison

Regional percent shortening was computed for each of the sets of LAO angiographic and echocardiographic contours using the three models previously described. Table I gives the qualitative results of this analysis. This table has broken the ventricle into four major regions - that consisting of the aortic mitral valve region, the left ventricular septal wall, the apical region and the left ventricle posterior wall. For each model and each area within the heart the table reports the percent of segments in that area where the motion measured as percent shortening of the segments from the angiographic images and echocardiographic images are in the same direction. As seen in these tables for all models the direction of motion measured in the posterior wall was identical for both modalities of images. Agreement for the septal wall ranged from 92% to 98% with the elliptical model exhibiting the poorest agreement. The range of agreement for the aortic mitral valve and apical regions were respectively 94% to 88% and 99% to 81% with the hemi-diameter model resulting in the most disagreement in both regions.

Table II reports the average percent shortening for both the echocardiographic and angiographic images for each model. The third column under each model gives the difference in average percent shortening from each image. In this table the ventricle has been divided into twelve regions, with each region consisting of six consecutive segments. For all of the models regions 3, 4 and 5 correspond to the septal wall and regions 8 thru 11 correspond to the posterior wall. As noted in this table, regardless of the model, the echocardiographic average percent shortening in the septal wall underestimates the percent shortening measured from the angiograms and for the posterior wall overestimates the percent shortening as indicated by the angiographic measurements.

Several possible explanations for this difference have been considered. The first and most obvious is the possible difference in reference points from the angiographic image and the echocardiographic images. Even though an attempt was made to capture the same reference plane for analysis and the definition of the reference point for each model was identical, a slight difference in direction of the plane may have caused this discrepancy. A second explanation of this difference is the fact that the angiogram is a two-dimensional projection, whereas the echocardiogram is a direct measurement of a plane through the heart and may be more subject to translation and rotation movements of the heart. Another explanation could be in the definition of the border defined by the x-ray system and that defined by the echocardiographic system; that is, structures being identified as endocardial surface by either the density of the dye or presence of detectable echoes in the image may not be the same surface. This difference might be explained by the changes in endocardial morphology which occur during cardiac contraction and the way in which these changes affect the ultrasound images. Developing

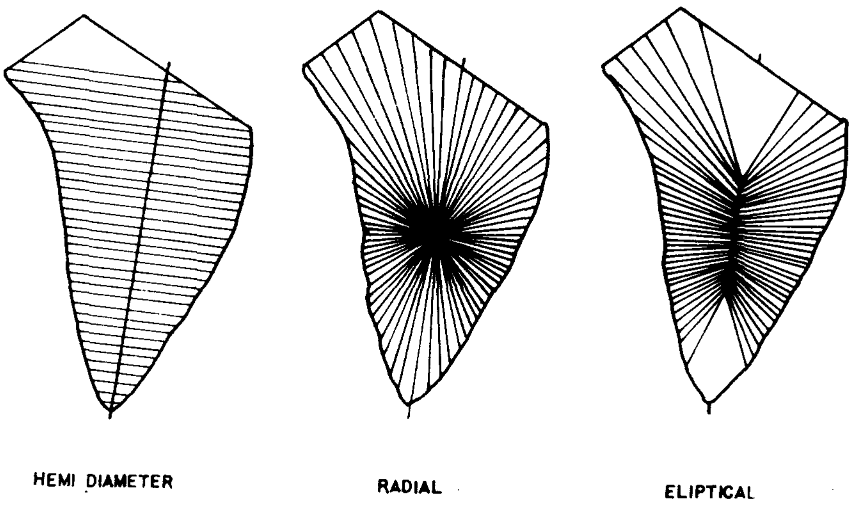

Figure 1

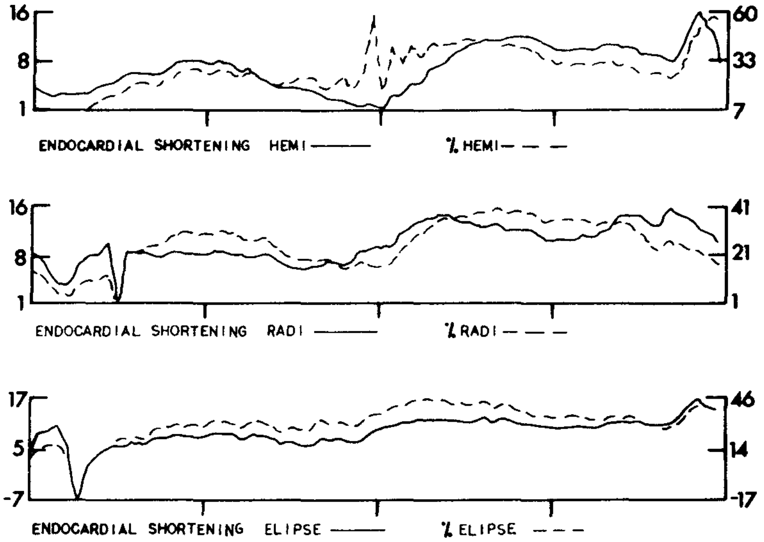

Figure 2

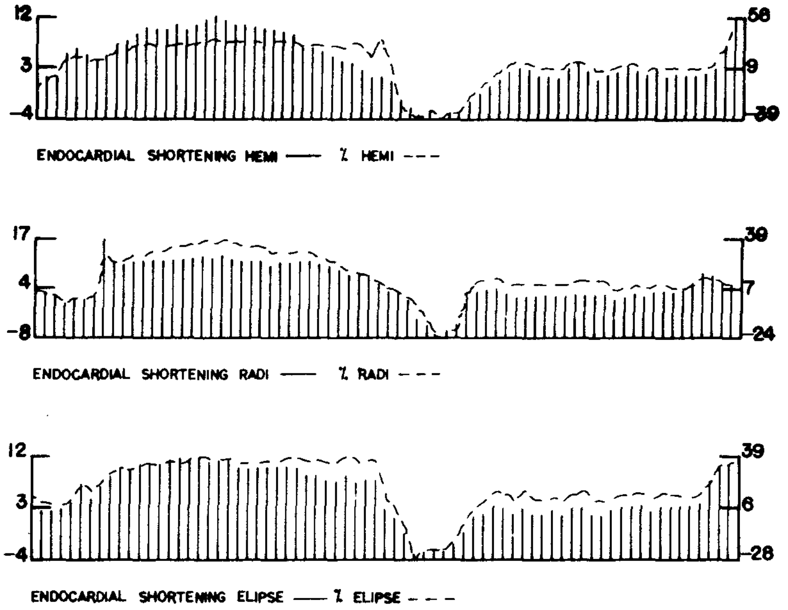

Figure 3

TABLE I

	A-M	Septal	Apex	Posterior
Hemi	88%	95%	81%	100%
Radial	92%	98%	94%	100%
Elliptical	94%	92%	96%	100%

a model of contraction it is assumed that the rough trabeculae openings of the endocardium are filled with blood at end diastole. In this instance the echoes would appear at the apex of the trabeculae, but the dye interface would be deep to that onset. On contraction in squeezing together these openings during systole most of the blood is removed from this area moving the muscle blood interface to the anterior portion of the posterior endocardium, causing the dye interface to be now at the anterior edge of the echo surface. Additional studies are required to further determine the correlation between these two modalities of wall motion measurement.

No attempt has been made in this study to define limits of percent shortening values but to show the feasibility of similar wall motion analysis from two-dimensional images as that currently employed with the angiographic images. No significant difference is seen in the three separate reference systems for analysis of percent shortening but should be and need to be further studied with real-time two-dimensional echocardiographic systems to better determine the angle of scan and accuracy of the information being recorded for wall motion analysis.

TABLE II

AREA

HEMI			RADIAL			ELLIPTICAL		
Echo	Angio	Dif	Echo	Angio	Dif	Echo	Angio	Dif
15.06	15.94	-.89	19.21	14.08	5.13	23.26	18.35	4.92
18.90	25.10	-6.19	16.50	20.19	-3.69	15.31	24.17	-8.86
24.85	31.39	-6.54	23.26	32.31	-9.04	24.31	31.47	-7.17
29.81	32.25	-2.44	27.29	32.17	-4.88	29.24	33.06	-3.82
28.07	32.61	-4.54	27.88	29.69	-1.82	32.53	33.58	-1.06
26.42	32.74	-6.32	24.65	23.58	1.07	34.78	38.38	-3.60
35.92	41.21	-5.29	26.49	27.58	-1.10	42.57	47.06	-4.49
42.25	43.86	-1.61	37.28	33.65	3.63	42.92	41.68	1.24
43.63	36.85	6.78	43.26	34.31	8.96	43.35	35.97	7.38
41.00	31.83	9.17	42.19	23.61	8.58	41.94	32.46	9.49
35.90	25.93	9.97	34.71	28.22	6.49	58.58	26.99	11.60
31.85	29.11	2.74	24.51	19.90	4.61	34.11	32.75	1.36

References

1. Teichholz, L.E., Kreulen, T., Herman, M.V., and Gorlin, R. Problems in echocardiographic volume determinations: echocardiographic-angiographic correlations in the presence or absence of asynergy. Am. J. Cardiol. 37:7, 1976.

2. Linhart, J.W., Mintz, G.S., Segal, B.L., Kawai, N., and Kotler, M.N. Left ventricular volume measurement by echocardiography: fact or fiction? Am. J. of Cardiol. 36:114, 1975.

3. Clayton, P.D., Harris, L.D., Rumel, S.R., and Warner, H.R. Left ventricular videometry. Comp. and Biomed. Res. 7:369, 1974.

4. Robison, E.P., Pryor, T.A., Wellard, S.J., Jones, D.S., and Ridges, J.D. Recognition of left ventricular borders using two-dimensional echocardiographic images. Comp. and Biomed. Res. 9:247, 1976.

5. Urie, P.M. The detection of abnormal segments of the human left ventricle by a quantitative measure of asynergy. Ph.D. Dissertation, University of Utah, 1975.