Assessment of Left Ventricular Function in Severe Aortic Regurgitation

ALLEN D. JOHNSON, M.D., LCDR JOSEPH S. ALPERT, MC USNR,
LCDR GARY S. FRANCIS, MC USNR, CDR W. VICTOR R. VIEWEG, MC USN,
I. OCKENE, M.D., AND CAPT ARTHUR D. HAGAN, MC USN

SUMMARY Echocardiographic (echo) measurements of left ventricular ejection phase indices — ejection fraction, percent shortening of the minor diameter (%ΔD), and velocity of circumferential fiber shortening (Vcf) — are said to be accurate reflections of their angiographic (angio) counterparts. Most studies correlating echo and angio left ventricular function parameters have included relatively few patients with aortic regurgitation. Echo and angio measurements of left ventricular ejection phase indices thus might not correlate in these patients in whom left ventricular geometry may have been altered due to the volume overload.

IN RECENT YEARS, many investigators have suggested that echocardiography may provide reproducible measurements of a number of different parameters of left ventricular function heretofore only available from analysis of cineangiograms. Echocardiographic ejection fraction and fiber shortening rates (Vcf) are said to reflect accurately their angiographic counterparts.1,4 Most of these studies, however, have not concerned patients with significant volume overload of the left ventricle.

We recently noted discrepancies between echocardiographic and angiographic measurements of left ventricular ejection phase indices in patients with significant aortic regurgitation and the present study was designed to examine this observation in detail. In order to determine whether echocardiographic measurements of left ventricular function reflect their angiographic counterparts in patients with significant aortic regurgitation, we compared echocardiographic and angiographic measurements of left ventricular ejection phase indices in 20 patients with isolated severe aortic regurgitation who were being considered for aortic valve replacement.

Materials

Twenty patients with isolated severe aortic regurgitation demonstrated by cardiac catheterization comprised the study population. Coronary arteriography was performed in nine patients who were either older than 40 years or had complained of chest pain. In each case, the coronary arteriograms were normal. The remaining 11 patients were free of chest discomfort. Moreover, youth, female sex, and absence of risk factors made associated coronary artery disease highly unlikely. No patient had left bundle branch block by ECG.

The patients (7 males, 13 females) ranged in age from 18 to 63 (mean 40) years. Sixteen patients had chronic and four patients acute aortic regurgitation (table I). All patients manifested symptoms and signs of at least mild pulmonary congestion which prompted their admission to the hospital for catheterization. Four patients were in NYHA Class I, five, Class II, and eleven, Class III.

Fifteen patients eventually underwent aortic valve replacement shortly after their catheterization. Aortic valve replacement was advised for those patients who had clear-cut histories of symptomatic left ventricular failure supported by either hemodynamic and/or angiographic evidence of abnormal left ventricular pump or myocardial function.

Methods

Cardiac Catheterization

Routine hemodynamic measurements preceded left ventricular angiography in each case. Angiograms were performed in RAO and steep LAO projections injecting a total of 0.5 to 1.0 cc/kg of Renografin 76 through NIH or Cordis pigtail catheters during a 3 sec interval. The angiograms were exposed on 35 mm film using a Philips 6-inch or 9-inch image intensifier system. Single plane RAO left ventricular cineangiograms were obtained in 12 patients, and biplane studies were performed in eight patients. Ejection fraction was calculated using the method of Dodge,7 and the rate of circumferential fiber shortening (Vcf) was obtained using the method of Karliner et al.8 Care was taken to analyze only sinus beats, not following PVCs, early in the cineangiogram to avoid the depressant effects of radiopaque contrast material on left ventricular function.

In the eight patients who had biplane cineangiograms, the longitudinal axes from the apex to the midpoint of the aortic valve plane in the RAO projection, and from apex to the midpoint of the mitral valve ring in the LAO projection,
were quadrisectioned by three perpendicular chords (fig. 1). The six zonal radii thus provided for each projection were analyzed for percent shortening to evaluate segmental left ventricular wall motion.

**Echocardiography**

Echocardiograms were recorded on the day before or at the time of catheterization using a commercially available ultrasound continuous recording device (Picker Echoview 10...
interfaced with a Honeywell strip chart recorder) and a 2.25 megahertz transducer. Echocardiograms were obtained with the transducer positioned along the left sternal border and directed posteriorly. Recordings were made in the M-mode or "slow sweep" display. Airless contact between transducer and skin was achieved with a water soluble gel. Recording paper was calibrated for 1 cm anterior-posterior distance with 0.5 sec timing marks; paper speed was adjusted to provide optimum quality tracings appropriate to each patient's heart rate.

Left ventricular internal minor axis dimensions were obtained at a level just below the tip of the anterior mitral valve leaflet (fig. 2) where clear left septal and posterior wall endocardial echoes could be simultaneously recorded. Ejection fraction, percent shortening of the minor diameter (%AD), and mean circumferential fiber shortening rates (Vcf) were calculated from left ventricular dimensions employing the methods of Feigenbaum and Cooper et al.

Student's t-test was used for comparison of paired variables.

Results

Hemodynamic measurements in our 20 patients with isolated severe aortic insufficiency were abnormal in most cases (table 1). Angiographic left ventricular volume determinations, available in 13 patients, revealed increased end-diastolic volumes (table 1).

Eight patients had biplane left ventriculograms performed. As noted in figure 3 and in table 2, LAO and biplane determinations of Vcf, %AD, and ejection fraction were significantly higher than measurements obtained from the RAO projection. Values for ejection fraction using the LAO projection only were significantly higher than biplane values (table 2, fig. 3).

Echocardiographic Vcf, %AD, and ejection fraction were normal in most patients. Septal and posterior wall endocardial echoes often demonstrated increased ranges of excursion in these patients, a finding which has been noted previously (fig. 2). In patients studied with biplane cineangiography, echocardiographic measurements of %AD, Vcf, and ejection fraction were not significantly different from those obtained from the LAO cineangiogram.

A comparison of RAO angiographic and standard echocardiographic ejection phase indices (fig. 4 and table 1) demonstrated larger echocardiographic Vcf, %AD, and ejec-

![Figure 2](http://circ.ahajournals.org/)

**Figure 2.** Septal (S) and posterior wall endocardial (PWE) echoes in a patient with severe aortic insufficiency. Dd and Ds are the internal left ventricular end-diastolic and end-systolic dimensions.
tion fraction in every patient, and the mean values of each parameter were significantly different.

Four patients (2, 6, 7, 8) who had biplane cineangiograms demonstrated reduction of each of the ejection phase indices in the RAO projection. Analysis of these four angiograms demonstrated that the radii corresponding to the anterolateral segments of the left ventricular free wall in the RAO projection showed decreased extent of shortening during systole, compared to the remainder of the zonal radii in the RAO and LAO projections (fig. 1). In the four patients with normal ejection fractions in both RAO and LAO projections, no segmental contraction abnormalities were apparent; instead, less shortening occurred in each zone of the RAO projection as compared to the LAO projection.

Discussion

The data presented here demonstrate that in patients with clinical and hemodynamic evidence of severe aortic regurgitation, RAO cineangiographic measurements of ejection fraction, percent decrease in minor diameter, and Vcf are consistently lower than the same parameters determined from LAO and biplane cineangiographic analysis.

In our study, echocardiographic measurements of ejection fraction, %AD, and Vcf corresponded to values derived from the LAO cineangiogram but in every case gave higher values for the ejection phase indices obtained from the RAO cineangiogram (figs. 3, 4). In two papers by Quinones et al.,11, 12 examination of the data from six patients with aortic regurgitation who had both echocardiographic and cineangiographic ejection phase indices calculated reveals values similar to those obtained in the present work: in each case ejection fraction and/or Vcf is larger by echo than by angiography.

Usual echocardiographic measurements of left ventricular ejection fraction, %AD, and Vcf are based on the analysis of motion of a single chord of the left ventricle. This diameter corresponds closely to the LAO view of the ventricle in the cineangiogram. Segmental contraction patterns of only the septal and posterior walls can be seen in this view.13, 14 Patients with coronary artery disease can have localized anterior wall movement disorders, abnormal ejection frac-

![Figure 3](http://circ.ahajournals.org/content/54/6/758/F3.large.jpg)

**Figure 3.** Biplane cineangiographic ejection phase indices compared to those obtained by echocardiography in patients with aortic regurgitation. Abbreviations as in figure 1.

![Figure 4](http://circ.ahajournals.org/content/54/6/758/F4.large.jpg)

**Figure 4.** Comparison of ejection phase indices obtained from the RAO cineangiogram with those obtained by echocardiography in 20 patients with aortic regurgitation.6, 18 Abbreviations as in figure 1.
tion, \(%\Delta D\), and \(V_{cf}\) as measured by left ventricular cineangiography despite normal measurements of these parameters by echocardiography. In normal subjects, without evidence of heart disease by cardiac catheterization and angiography, ejection fraction and measurements of minor diameter shortening in both RAO and LAO projections are the same.\(^{15}\)

Abnormal apex to base shortening, changes in the left ventricular cavity toward a more spherical shape, and abnormalities in wall stress have all been documented in patients with aortic regurgitation.\(^{16}-^{18}\) We noted anterolateral hypokinesis in some of our patients. Furthermore, Feigenbaum’s group has recently reported segmental anterior wall motion disorders by echo in two patients with aortic insufficiency.\(^{19}\)

We conclude that patients with severe aortic insufficiency seem to have a nonuniform left ventricular contraction pattern, often with hypokinesis of the anterolateral segments of the left ventricle. Septal and posterior wall motion can remain normal or appear exaggerated in these patients. These characteristics taken together can produce differing ejection phase indices, depending on whether an RAO or LAO cineangiogram is used for the calculations. Since the echocardiographic view of the left ventricle essentially corresponds to an LAO projection, ejection phase indices derived by echo may be normal despite abnormal measurements of \(V_{cf}\), \(%\Delta D\), and ejection fraction obtained from the RAO cineangiogram. Biplane cineangiographically determined ejection fractions, because they include input from the RAO angiogram, produce the same inconsistency.

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