Segmental Wall-Motion Analysis in the Right Anterior Oblique Projection: Comparison of Exercise Equilibrium Radionuclide Ventriculography and Exercise Contrast Ventriculography

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Thirty-nine patients with known or suspected coronary artery disease were studied at rest and during supine bicycle exercise with radionuclide and contrast left ventriculography. Analysis of regional wall motion was made by visual evaluation of the five standard 30° right anterior oblique (RAO) wall segments in the contrast images and the corresponding 10° RAO radionuclide segments. The radionuclide studies were evaluated independently by three observers using a five-point grading system. The interobserver wall-motion grading agreed completely in more than 80% of segments at rest and exercise, and agreed within one wall-motion grade in more than 95% of segments. The comparison of wall-motion grades between radionuclide and contrast ventriculograms showed complete agreement in 86% of segments at rest and in 78% during exercise, and agreement within one wall-motion grade in 97% of rest and 96% of exercise segments.

Visual evaluation of 10° RAO rest and exercise radionuclide ventriculograms compares favorably with rest and exercise 30° RAO contrast ventriculograms and demonstrates satisfactory interobserver agreement.

J Nucl Med 21: 617–621, 1980

Abnormalities in regional myocardial wall motion at rest are seen in areas of prior myocardial infarction or damage, whereas exercise-induced defects are markers of ischemia. Previous studies by Sharma et al. (*1*) and Walton et al. (*2*) have shown that analysis of regional myocardial wall motion during exercise contrast ventriculography is a sensitive means of detecting patients with significant coronary artery disease (CAD). Borer et al. have shown that radionuclide ventriculography at rest and exercise is equally sensitive and has the advantage of being less invasive (*3,4*).

A diagnosis of CAD has serious clinical implications. If abnormalities in regional myocardial wall motion are used to diagnose patients with CAD, the analysis must be accurate at rest and during exercise. Investigators in many centers have demonstrated that resting wall-motion analysis compares favorably between radionuclide and contrast ventriculography (*5–7*). However, similar correlative studies during exercise have not been reported. The present study was undertaken to compare the regional myocardial wall motion at rest and during supine bicycle exercise using RAO radionuclide and contrast ventriculography.

MATERIALS AND METHODS

Radionuclide and contrast ventriculographic studies were obtained at rest and during exercise on 39 patients with known or suspected coronary artery disease. All studies were performed within 5 days of each other (average 1.5 days). There were 34 males and five females, with a mean age of 47 yr. Eleven patients had

Received Nov. 5, 1979; revision accepted Feb. 4, 1980.

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evidence of prior myocardial infarction, with Q waves present on resting electrocardiograms. Six patients were receiving propranolol and three were receiving nitrates at the time of both studies. There were no changes in medication or clinical status between procedures. Patients with valvular heart disease or prior myocarditis were excluded from the study. Informed consent was obtained for both procedures.

Radionuclide ventriculography. All patients underwent multiple gated-acquisition radionuclide left ventriculography at rest and during supine bicycle exercise as previously described (*8*). Each patient received 25 mCi of Tc-99m for in vivo labeling of red blood cells (*9*). Images were obtained with a standard-field gamma camera with a parallel-hole, low-energy, high-sensitivity collimator. Data collection was computer controlled in a multiple-acquisition format providing 14 synchronized frames per cardiac cycle based on the R wave of the ECG (*10*). Data collection was terminated when each of the 14 frames contained at least 150,000 counts. Each frame was digitized in a 64 × 64 matrix covering the camera's field of view. The acquisition times ranged from 90–130 sec at rest and 60–110 sec during exercise.

Two LAO resting studies were obtained and one in 10° RAO. Patients were then exercised in a supine position utilizing a bicylce ergometer. Data were acquired during exercise in the LAO position at progressive work loads (*8*). Thirty of 39 patients were limited by fatigue during maximal LAO exercise. With a workload decreased by 15 watts, these patients could easily complete the RAO exercise. This added an additional 60–110 sec to the overall study. Nine patients were limited by chest pain during the LAO exercise. These patients were rested until the pain subsided (range 30 sec–5 min) and then continued exercising in the RAO projection at a subanginal level. None of these patients had returned to baseline during the rest period.

Contrast ventriculography (CV). Single-plane left-ventricular contrast angiograms were obtained on all patients in the 30° RAO position. Thirty-five to 50 ml of sodium meglumine diatrizoate were power-injected at a rate of 15–20 ml per sec. Thirty-five millimeter filming was obtained at 60 frames per sec using a 9-in. image intensifier. After the resting study was performed and with the catheter residing in the left ventricle, patients were exercised in the supine position using a standard bicycle erogometer. The ergometer was in a similar although slightly higher position than in the radionuclide exercise laboratory but had identical workload settings. When angina or symptom-limiting fatigue developed, the exercise was stopped and a second contrast study was obtained within 10 sec. All patients subsequently had coronary angiography. There were 22 patients with greater than 70% stenosis of at least one major coronary artery. Seventeen patients had normal coronary arteries or less than 50% stenosis. There were no patients with a single lesion between 50 and 70% stenosis.

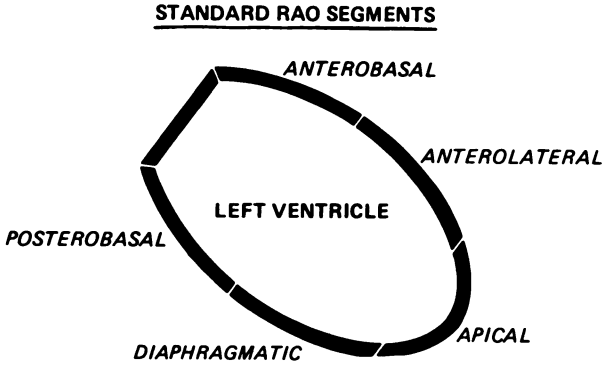

FIG. 1. Illustration of a 30° RAO contrast ventriculogram with the five standard segments.

Data analysis. The radionuclide studies were evaluated independently by three nuclear medicine staff physicians. Evaluations consisted of visual observation of rest and exercise studies in a cinematic closed-loop display. Wall motion was graded on a five-point scale: 3+ = normal, 2+ = mild hypokinesis, 1+ = marked hypokinesis, 0 = akinesis, −1 = dyskinesis. The observers were unaware of the patient's history, results of the contrast ventriculography, or the radionuclide ejection-fraction response to exercise.

The contrast studies were evaluated by two cardiologists. Rest and exercise cineangiographic ventriculograms were visually evaluated using the same five-point grading scale. A single sinus beat at least two cycles removed from the last ectopic beat was selected for analysis in each patient.

The five standard segments from 30° RAO contrast ventriculograms were analyzed (Fig. 1), and corresponding segments in the 10° RAO radionuclide study were selected. The anterobasal, anterolateral, and apical segments were visualized in all radionuclide studies (Fig. 2A). Due to the overlying right-ventricular activity, the diaphragmatic segment was visualized in only 75% of the RAO studies (Fig. 2B), and the posterobasal segment was visualized in only 23% of studies (Fig. 2C). Only

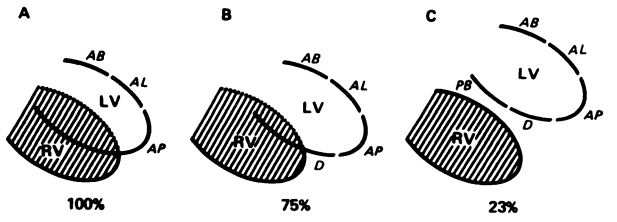

FIG. 2. (A) 10° RAO radionuclude left ventriculogram with overlying right-ventricular activity obscuring diaphragmatic and posterobasal segments. Anterobasal (AB), anterolateral (AL), and apical (AP) segments were visualized in all studies. (B) Diaphragmatic (D) segment was visualized in 75% of studies. (C) Posterobasal (PB) segment was visualized in only 23% of studies.

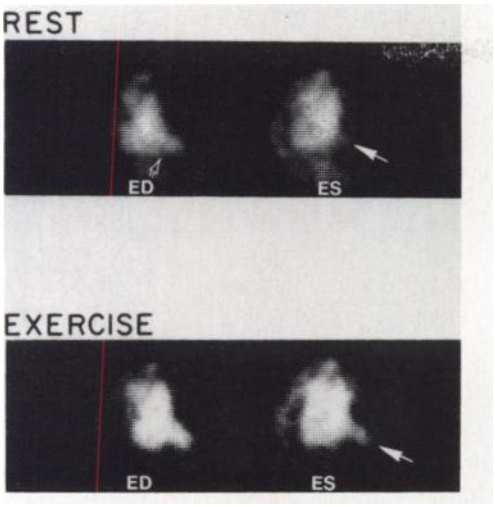

FIG. 3. Rest and exercise 10° RAO radionuclide ventriculogram. Resting study (top) shows normal left-ventricular contraction in end-systolic (ES) image. (Black arrow denotes apex of right ventricle.) Exercise study (bottom) demonstrates marked hypokinesis in several wall segments (white arrow).

those segments visualized by both methods were used for comparison.

RESULTS

High-quality 10° RAO radionuclide and 30° RAO contrast ventriculograms were obtained from all patients. Figure 3 is an example of RAO radionuclide ventriculograms obtained at rest and during exercise. The top row contains the end-diastolic (ED) and end-systolic (ES) images, which show normal contraction of all wall segments. The bottom row contains the exercise ED and ES images, which now show marked hypokinesis in several wall segments. Figure 4 illustrates the rest and exercise contrast ventriculograms from the same patient. The top row contains the resting ED and ES frames with normal wall motion. The bottom row contains the exercise ED and ES frames that now show marked hypokinesis in the same wall segments. The patient developed chest pain during both exercise studies.

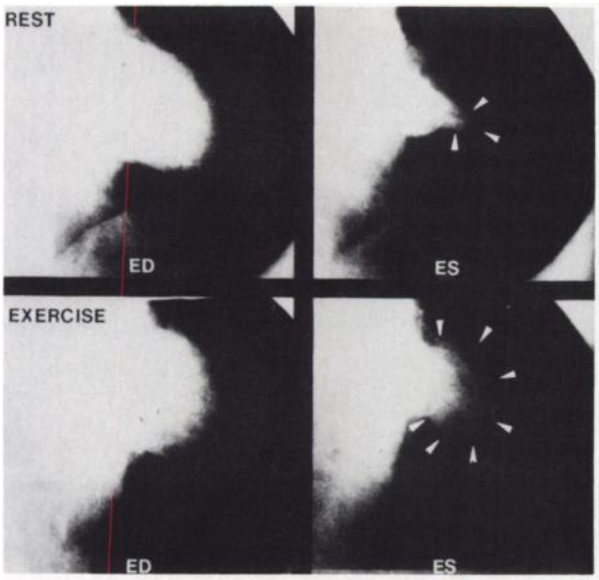

FIG. 4. Rest and exercise 30° RAO contrast ventriculograms in same patient as in Fig. 3. Resting study (top) shows normal left-ventricular motion. Exercise study (bottom) demonstrates marked hypokinesis in same segments (white arrows).

Of the 39 patients studied, there were 161 rest and 164 exercise segments available for evaluation by both techniques. Table 1 compares the data from the rest segments. There was complete agreement in 139 of 161 segments (86%). Agreement within one wall-motion grade was present in 97% of segments. In only four segments did the studies disagree by more than one wall-motion grade.

The data for the segments studied during exercise are presented in Table 2. There was complete agreement in 128 of 164 segments (78%). Agreement within one wall-motion grade was present in 96% of segments. In only seven segments was there disagreement by more than one wall-motion grade. Comparing only the data from the 22 patients with significant coronary artery disease, we find fewer segments that agreed completely (rest, 78%; exercise, 65%), but agreement within one wall-motion grade was essentially unchanged (rest, 95%, exercise, 91%). In the 17 normal patients, only two segments at rest and one during exercise disagreed between studies.

Table 3 summarizes the sensitivity of the radionuclide wall-motion analysis in detecting abnormal segments seen by contrast ventriculography. For contrast segments graded as showing marked hypokinesis, akinesis, or dyskinesis, the radionuclide wall-motion analysis was abnormal in 30 of 31 segments, for a sensitivity of 97%. In segments graded as mildly hypokinetic (2+) by contrast ventriculography, the radionuclide wall-motion analysis was abnormal in 20 of 44 segments, for a sen-

TABLE 1. COMPARISON OF 161 REST RAO WALL-MOTION SEGMENTS BETWEEN RADIONUCLIDE (RV) AND CONTRAST (CV) VENTRICULOGRAMS*

	C.V.				
	3+	2+	1+	0	−1
3+	120	11	—		
2+	1	3	—	—	
R.V. 1+	3	3	4	2	—
0		1	—	3	1
−1			—	—	1

* Complete agreement (139 of 161) = 86%. Agreement within 1 W.M. grade (157 of 161) = 97%.

TABLE 2. COMPARISON OF 164 EXERCISE RAO WALL-MOTION SEGMENTS BETWEEN RADIONUCLIDE (RV) AND CONTRAST (CV) VENTRICULOGRAPHY*

	C.V.				
	3+	2+	1+	0	−1
3+	111	14	1		
2+	3	8	2	2	
R.V. 1+	3	4	3	3	—
0		1	2	5	1
−1			—	—	1

* Complete agreement (128 of 164) = 78%. Agreement within 1 W.M. grade (157 of 164) = 96%.

sitivity of only 45%.

The interobserver grading of RAO radionuclide wall motion is summarized in Table 4. Between any two observers there was complete agreement in wall-motion grading in more than 80% of rest and exercise segments, and agreement within one wall-motion grade in more than 95% of segments. When the data from all three observers were compared, there was complete agreement in 80% of rest and 79% of exercise segments. Agreement within one wall-motion grade was present in 95% of rest and 93% of exercise segments. In determining whether a study was normal or abnormal, there was diagnostic agreement among observers in 35 of 39 studies (90%).

DISCUSSION

The results of the present study demonstrate that RAO radionuclide wall-motion analysis compares favorably with the analysis of RAO contrast ventriculogram segments at rest and during exercise. The radionuclide analysis is sensitive in detecting myocardial segments that had severe wall-motion abnormalities (grades 1,0,−1) confirmed by contrast angiography. Sensitivity for detecting myocardial segments with mild hypokinesis (grade 2) was considerably lower. The superior resolution of contrast ventriculography in assessing regional myocardial wall motion is a major factor accounting for its greater sensitivity. Patient motion during exercise is another potential difficulty that may obscure mildly hypokinetic segments during accumulation of a radionuclide ventriculogram. The injection of hyperosmotic contrast media is known to cause mild ventricular dysfunction, and this may account for some of the mild hypokinesis seen in the exercise contrast studies (*18*) but not detected in the exercise radionuclide studies.

TABLE 3. SENSITIVITY OF RAO RADIONUCLIDE WALL-MOTION ANALYSIS IN DETECTING SEGMENTS FOUND ABNORMAL BY REST AND EXERCISE CONTRAST VENTRICULOGRAPHY

Grade	Abnormal C.V. segments	Abnormal R.V. segments	Sensitivity
2+	44	20	45%
1+	14	13	93%
0	13	13	100%
−1	4	4	100%

TABLE 4. INTEROBSERVER COMPARISON OF 161 REST AND 164 EXERCISE RAO RADIONUCLIDE WALL-MOTION SEGMENTS

Observers	% Complete agreement rest–exercise	% Agreement within 1 W.M. grade rest–exercise
A vs B	88–89	96–96
A vs C	86–82	98–98
B vs C	86–87	96–97
All 3	80–79	95–93

In the present study, ventricular wall motion was graded using visual interpretation. Although quantitative analysis of regional myocardial wall motion has been described by regional ejection fraction (*16*) and with functional images (*15*), experience is still limited. In a recent study evaluating quantitative regional wall-motion programs, Steckley et al. found no significant difference between visual assessment and computer analysis of regional myocardial wall motion (*17*).

The 30° RAO view is widely accepted as the best single projection for assessment of left-ventricular wall motion (*14*). However, with 30° RAO equilibrium radionuclide ventriculograms, a large portion of the left ventricle is often obscured by right-ventricular activity. In a 10° RAO projection it is possible to evaluate most of the left-ventricular circumference. In the present study, the anterior wall and apex were visualized in all cases. The inferior surface was more difficult to visualize, as reflected in Fig. 2. Although the radionuclide segments do not correspond exactly with the 30° RAO contrast segments, a comparison of these views should be more informative than studies comparing LAO radionuclide wall segments with RAO contrast segments (*15*).

Coronary angiography provides anatomical information regarding the presence of coronary obstruction. The functional significance of the coronary artery narrowing detected by coronary angiography depends upon several factors, including the number, length, and location of lesions and how these lesions affect ventricular performance at rest and during exercise. Sharma et al. (*1*) and Walton et al. (*2*) assessed the hemodynamic

significance of lesions seen angiographically using rest and exercise contrast ventriculography. With this technique the authors were able to identify exercise-induced regional abnormalities of wall motion and to correlate these with the locations and percent stenosis of coronary lesions. However, the additional radiation exposure and exercise load of contrast ventriculography are disadvantages that have limited the application of the technique.

Methods, including echocardiography and radionuclide ventriculography, are currently available allowing the noninvasive evaluation of ventricular wall motion, both at rest and during exercise. M-mode echocardiography has the advantage of single-beat analysis with no radiation exposure to the patient, but it suffers from limited sampling of the myocardium (*11*). Cross-sectional echo has improved sampling but is routinely unable to obtain data in exercise. First-pass radionuclide ventriculography can isolate the left ventricle at rest and during exercise, making possible a 30° RAO study (*12,13*). Multiple views of the left ventricle can be obtained, but require additional injections of radioactivity. The same problem of excessive radiation prohibits data collection during graded or submaximal exercise.

Equilibrium gated radionuclide ventriculography has the advantage that multiple studies of cardiac function can be obtained from a single dose of radiotracer at rest and during exercise. The calculation of ejection fraction requires separation of the right and left ventricles, which can be accomplished readily only in the LAO projection (*10*). However, ventricular wall motion can be assessed from multiple projections, including the RAO. In this projection the anterior and apical segments are seen particularly well, although the inability to visualize basal and inferior segments in some patients is a limitation of the RAO view, and must be borne in mind for equilibrium studies.

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