Optimal Interpretation of the Supine Exercise Electrocardiogram in Patients with Right Bundle Branch Block*

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A detailed analysis of the exercise ECG was performed in 82 patients with right bundle branch block who underwent supine exercise equilibrium radionuclide angiography. The sensitivity and specificity of each individual electrocardiographic lead for the detection of a positive radionuclide angiogram was determined. Leads V₁ and V₅ had a sensitivity of 58 percent and a specificity of 89 percent. The limb leads and lead V₅ had a lower sensitivity, but an equivalent specificity. Leads V₁ and V₅ each had a clearly lower specificity that ranged from 56 to 67 percent. Receiver operating characteristic curve analysis demonstrated that the optimal interpretation of the exercise ECG included the limb leads and V₅, but not V₁. The results of coronary angiography in the subset of 16 patients who underwent this procedure confirmed these findings. (Chest 1990; 98:1379-82)

The value of the exercise ECG for the detection of coronary artery disease in patients with complete right bundle branch block has not been completely delineated. Standard textbooks1,4 make statements based on a small number of references that give meager data. Prior studies, which are scarce, have been hampered by small numbers,3-5 the use of XYZ leads only6 or the inclusion of patients on digoxin5 and with prior myocardial infarction.4,6 No previous study has examined the incremental value of each ECG lead. This study was designed to use equilibrium radionuclide angiography to perform a detailed analysis of the supine exercise ECG for the detection of ischemia in patients with complete right bundle branch block.

METHODS

Study Patients

The study group consisted of a consecutive series of patients with right bundle branch block on their resting ECG who underwent supine rest and exercise equilibrium radionuclide angiography for the evaluation of chest pain. Right bundle branch block was defined as a QRS duration equal to or greater than 120 ms in lead V₁ or V₅, and S waves in lead 1 and either V₁ or V₅. The following were grounds for exclusion: (1) previous coronary revascularization by either angioplasty or surgery; (2) valvular heart disease; (3) left ventricular hypertrophy on the resting ECG; (4) digoxin use; (5) technically unsatisfactory study; (6) history of myocardial infarction or evidence of previous myocardial infarction on the resting ECG; and (7) maximal exercise heart rate less than 100. A total of 82 patients were included in the study group—63 men and 19 women.

Exercise Protocol

The patients were exercised in the supine position. Three ECG leads were monitored continuously and a standard 12-lead ECG was performed every minute to monitor S-T segment changes. Blood pressure was measured in the right arm by cuff. Red blood cell labeling was performed with 30 mCi of technetium 99m using either the in iodo procedure7 or the modified in iodo procedure of Callahan et al.7 Acquisitions were gated to the R wave of the ECG and collected at 16 frames per cycle. After a radionuclide angiogram at rest, exercise was performed on a bicycle ergometer. The standard exercise protocol began at a work load of 300 kg-m/min and increased every three minutes in increments of 300 kg-m/min. The exercise protocol was modified occasionally at the discretion of the monitoring physician.

Exercise was terminated at one of the following end points: (1) moderate chest pain; (2) marked ECG changes (0.2 mV of downsloping or horizontal S-T segment depression); (3) serious arrhythmias; or (4) severe fatigue. Repeat radionuclide angiographic acquisitions were obtained during the last 2 min of each exercise stage.

Exercise Electrocardiogram

The magnitude of S-T segment depression 80 ms after the J point was assessed visually in each of the 12 ECG leads and graded in the following categories: <1 mm, 1 mm, 1.5 mm, 2.0 mm, 2.5 mm, and 3.0 mm. The configuration of the S-T segment was recorded as upsloping, horizontal or downsloping. Exercise ECG interpretation was done without knowledge of the results of the radionuclide angiogram. The exercise ECG was considered positive if there was at least 1.0 mV of horizontal or downsloping S-T-segment depression 80 ms after the J point. In the presence of S-T-segment depression at rest, 1.0 mV of additional horizontal or downsloping S-T-segment depression was required. The individual leads in which positive S-T-segment changes occurred were recorded.

Radionuclide Processing

Radionuclide data were processed using a commercially available computer system (Medical Data System) and previously reported techniques.8,9 A second derivative technique was employed to identify the left ventricular region of interest in each frame. A background region was chosen 5 pixels lateral to the left ventricular region of interest in the systolic frame. The ejection fraction was calculated in standard fashion from the curve depicting the back-ground-corrected left ventricular counts vs time. Wall motion was assessed subjectively as the consensus of two experienced observers. Each of the four segments of the left ventricle was scored on a six-point system (1 = normal; 2 = mild hypokinesia; 3 = moderate hypokinesia; 4 = severe hypokinesia; 5 = akinesia; and 6 = dyskinesia).
The wall motion score was the average of the scores for the four segments. A new wall motion abnormality with exercise was defined as a worsening in any segment of at least one grade with exercise.

**Coronary Angiography**

Sixteen patients underwent coronary angiography within six months of the exercise radionuclide angiogram. Coronary angiography was performed using a standard percutaneous femoral or brachial cut-down approach. Multiple selective contrast injections were performed in the left and right coronary arteries. Caudal and cranial angulation were routinely employed. The degree of coronary artery stenosis was assessed visually in each of 23 different segments by two observers who were unaware of the radionuclide results. Significant coronary artery disease was established using the definitions of the Coronary Artery Surgery Study; i.e., greater than or equal to 50 percent stenosis of the left main coronary artery and greater than or equal to 70 percent stenosis of the remaining coronary vessels were considered significant.

**Data Analysis**

A radionuclide angiogram was considered positive for ischemia if there was (1) a decrease in left ventricular ejection fraction with exercise, or (2) the development of a new wall motion abnormality with exercise. Sensitivity and specificity were defined as follows: sensitivity = number of patients with positive exercise ECGs and positive radionuclide angiograms/total number of patients with positive radionuclide angiograms; specificity = number of patients with negative exercise ECGs and negative radionuclide angiograms/total number of patients with negative radionuclide angiograms. The sensitivity and specificity were computed individually for the limb leads, V, V, V, V, V, and V, and for the exercise ECG beginning with leads V and V and then adding the limb leads, V, V, V, V, V, and V. A receiver-operator curve was constructed by plotting sensitivity on the Y axis and 1-specificity on the X axis.

**RESULTS**

Forty-six of the 82 patients in this study had a radionuclide angiogram that was positive for ischemia. Thirty-one of these (67 percent) had a corresponding exercise ECG that was positive for ischemia in at least one of the 12 ECG leads.

**Sensitivity and Specificity of the 12-Lead Exercise ECG**

As can be seen in Figure 1, the sensitivity was 48 percent for V/V and increased with the addition of the limb leads. However, there was a concomitant decrease in specificity. When all 12 ECG leads were included, the resultant sensitivity was 67 percent, but the specificity was only 39 percent. The best results (sensitivity = 59 percent, specificity = 80 percent) were obtained using leads V, V, V, and the limb leads (Fig 1). The results were essentially identical if either criterion for an abnormal radionuclide angiogram (decrease in ejection fraction or new regional wall motion abnormality) was considered separately.

**Sensitivity and Specificity of Individual ECG Leads**

The combination of leads V and V had the highest sensitivity (48 percent) and specificity (89 percent), for a positive predictive value of 66 percent (Fig 2). Lead V had a slightly lower sensitivity (29 percent), but an equal specificity (89 percent). The limb leads had a still lower sensitivity (24 percent), but a good specificity (86 percent). The right precordial leads (V to V) had a clearly lower specificity of 56, 56 and 67 percent, respectively.

**Comparison with Coronary Angiography**

Sixteen of the 82 patients, 14 men and 2 women, included in this study had coronary angiography within 6 months of the index exercise test. Thirteen of the 16 patients had at least one major coronary artery with significant stenosis (Table 1). Of the three patients with normal coronary arteries, one had a false-positive radionuclide angiogram and one had a false-positive exercise ECG, with S-T segment changes in V only. Thus, utilizing only the limb leads and V to V, the sensitivity and specificity of the exercise ECG for the detection of significant disease were 92 and 100 percent, respectively, in the subset of patients who underwent coronary angiography. The addition of the right precordial leads was not beneficial.

**DISCUSSION**

The current study is the first systematic investigation of the S-T segment response to exercise in individual leads of a standard 12-lead ECG in a large number of patients with right bundle branch block and suspected coronary artery disease. It demonstrates that the optimal interpretation of the exercise ECG in right bundle branch block includes the limb leads and V to V, but not V to V.

One of the earliest attempts to study the S-T segment response to exercise in patients with right bundle branch block was that of Feil and Brofman in
1953. They found a very low sensitivity and specificity. However, their results are questionable, since coronary angiography was not available to establish or disprove the existence of coronary artery disease.

Whinnery et al. studied 40 asymptomatic young aircrewmen who had developed right bundle branch block on serial annual ECGs. None of their subjects had a positive exercise ECG on maximal treadmill testing using leads X, Y and Z; all underwent subsequent coronary angiography. Eight aircrewmen were found to have significant coronary artery disease, predominantly single-vessel type and involving the right coronary artery in six. Our study population, which consists of middle-aged patients referred because of symptoms suggestive of coronary artery disease, should be more representative of the usual patient with right bundle branch block who is referred for exercise testing. In addition, we examined all standard 12 ECG leads.

Tanaka et al. reported a retrospective study of 30 patients with right bundle branch block who had coronary angiography following a 12-lead ECG exercise treadmill test. All had symptoms suggestive of coronary artery disease and were predominantly male and middle-aged. Several had had a prior myocardial infarction. They found a sensitivity and specificity of 61 and 50 percent, respectively, using all 12 ECG leads. If leads V1 to V3 were excluded, the specificity was 100 percent, but the sensitivity fell to 44 percent. Although our patient population and methods differ from theirs, our results are similar.

Susmano and Teran examined the S-T segment response to maximal treadmill testing in patients with bundle branch block, including 12 patients with right bundle branch block. All 12 patients had been referred for the evaluation of chest pain; one patient was receiving digoxin; two patients had had a prior myocardial infarction. Only leads 1, 2, 3, V4, V5 and V6 were monitored, and no specifics were given as to the S-T segment response of any individual ECG lead. They reported a sensitivity and specificity of 87 and 67 percent, respectively. In contrast, when only the limb leads and V4 to V6 were considered in the current study, we found a somewhat lower sensitivity (59 percent) but a higher specificity (80 percent). These differences may reflect differences in the end points used as well as in patient population. We excluded patients taking digoxin and those with prior myocardial infarction. Digoxin is well recognized as a cause of false-positive ECGs. The diagnosis of coronary artery disease is already well established in the presence of a prior myocardial infarction. The lower

![Figure 2: Sensitivity and specificity for individual electrocardiographic leads. The right precordial leads (V1, V2 and V3) have a lower specificity.](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21622/)
specificity in the study by Susmano and Teran may reflect the effects of workup or post-test referral bias.

The current study differs from any previous study in that we used supine rather than upright exercise. The physiologic response to exercise differs with the subject in the supine position where there is less of an increase in heart rate and more of an increase in blood pressure. Compared to upright exercise, there is an increase in venous return and a larger stroke volume, which should increase left ventricular wall tension. Despite the lower exercise heart rates achieved in this position, supine exercise has been shown to increase exercise-induced myocardial ischemia. Further studies are needed to determine whether our findings also apply to upright treadmill exercise.

Most importantly, our study used an exercise radionuclide angiogram as the standard rather than a coronary angiogram in order to avoid the effects of post-test referral bias. The results, therefore, are more appropriately viewed as the sensitivity and specificity of a supine exercise ECG in predicting an abnormal or normal exercise radionuclide angiogram. Although the specificity of exercise radionuclide angiography is sometimes viewed as suboptimal, the criteria used in this study have been reported to have a specificity of >80 percent in patients with a low likelihood of coronary artery disease. The use of a radionuclide angiographic end point may influence the absolute magnitude of sensitivity and specificity, but it is unlikely to account for the decreased specificity of the right chest leads.

Despite these limitations, our results demonstrate that in patients with right bundle branch block, the optimal interpretation of the supine exercise ECG requires consideration of the limb leads and V4 to V6 but not V1 to V3.

References