Exercise testing remains one of the most useful noninvasive diagnostic tests for identification of the patient with coronary artery disease. Significant ST segment depression,1 chronotropic incompetence,2 hypotensive systolic blood pressure response,3 and angina at low workload4 have all been shown to be of diagnostic and prognostic value in patients with severe coronary artery disease. However, the sensitivity of these criteria varies considerably, and their diagnostic value can be further limited in the presence of LVH,5 electrocardiographic conduction abnormalities such as LBBB,6 arrhythmia such as atrial fibrillation,7 and in patients receiving medical therapy such as digitalis8 or beta adrenergic blockers.9 Thus, limitations of exercise ECGs in identifying patients with severe coronary artery disease has prompted research into newer and more sensitive criteria such as the ST/heart rate ratio and evaluation of the systolic blood pressure response during the recovery period.

Recently, the systolic blood pressure recovery ratio (SBP-RR), the ratio of the postexercise systolic blood pressure to peak exercise systolic blood pressure, has been shown to be of diagnostic value in patients with coronary artery disease.10 We have observed that a SBP-RR which is >1.0, 0.9, or 0.8 at respectively 1, 2, or 3 minutes in the recovery period and further increases from either minutes 1 to 2 or 2 to 3 of the recovery period (↑ SBP-RR) is highly predictive and more sensitive than diagnostic ST segment depression or angina in the diagnosis of multivessel coronary artery disease.11 In this case report, we describe the usefulness of an ↑ SBP-RR in the identification of a patient with angiographically proven three-vessel coronary artery disease undergoing exercise thallium 201 scintigraphy.

**CASE REPORT**

The patient is a 60-year-old white man with a history of insulin-dependent diabetes mellitus, hypertension, and two prior non-q-wave myocardial infarctions. The patient also has exertional angina usually relieved by rest and sublingual nitroglycerin. Cardiac catheterization had revealed significant three-vessel coronary artery disease; mid-left circumflex artery lesion (80 percent), proximal right coronary artery lesion (75 percent), and a 60 percent lesion in the diagonal branch of the left anterior descending artery (Fig 1). The left ventriculogram revealed an ejection fraction of 79 percent with normal systolic function. Despite a progressive increase in

![Figure 1](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21592/)
medical therapy, his anginal symptoms continued, and exercise thallium 201 scintigraphy was performed to evaluate the extent and severity of ischemia. At the time of investigation, the patient was receiving diltiazem, 240 mg daily; Nitrobid, 36 mg daily; prazosin, 15 mg daily; and aspirin, 300 mg daily. The patient was exercised on a standard Bruce protocol, and the test was terminated secondary to leg fatigue at 4 minutes and 46 seconds. He had no chest pain or shortness of breath during or after the test. Also, no diagnostic ST segment depression was achieved either during exercise or the recovery period (Fig 2). The patient achieved a peak heart rate of 108 beats per minute (65 percent of maximum predicted) and a peak blood pressure of 154/74 mm Hg giving a double product of 196. At one minute prior to termination, the patient received an intravenous injection of 1.92 mCi of thallium 201 radioisotope. The 1, 2, and 3 minute recovery period blood pressure measurements were respectively 138/52, 145/54, and 156/56 mm Hg giving rise to 1, 2, and 3 minute systolic blood pressure recovery ratios of 0.90, 0.96, and 1.02, respectively.

The heart was tomographically imaged under an orbitor gamma scintillation camera within 10 minutes after exercise and three hours later to obtain the redistribution images. The thallium 201 scintigrams revealed reversible filling defects indicative of ischemia in the anterior, inferior, and septal regions of the heart (Fig 3).

**Discussion**

This case demonstrates the usefulness of a new exercise parameter, SBP-RR, in the diagnosis of severe coronary artery disease. The patient did not have any of the previously described exercise criteria for significant multivessel or left main coronary artery disease including exertional hypotension, angina at low level of exercise, ST-segment depression, or exercise limited to stage 1 of Bruce protocol. However, he did have an abnormal recovery period, blood pressure response (△SBP-RR) with the ratios increasing from minutes 1 to 2 and 2 to 3 in the recovery period. The presence of significant reversible thallium 201 defects confirms the presence of myocardial ischemia.

Previously, we have demonstrated both in a retrospective as well as a prospective manner that an △SBP-RR is highly predictive (100 percent) of an abnormal exercise thallium 201 scintigram. In the prospective study, an △SBP-RR was also found to be more sensitive than diagnostic ST segment depression ≥ 0.1 millivolts (38 percent vs 15 percent) or angina (38 percent vs 26 percent) in identifying patients with multivessel coronary artery disease receiving antianginal medications. Also, the △SBP-RR was more predictive than ST depression (86 percent vs 57 percent) but similar to angina (86 percent vs 88 percent) in identifying patients with scintigraphic evidence of multivessel coronary artery disease in this study. Although hypertension is known to falsely elevate the SBP-RR, we recently described that a history of hypertension does not alter the diagnostic value of an △SBP-RR. Crawford et al demonstrated that an abnormal SBP-RR (defined as a SBP-RR >1.0, >0.9, >0.8 at respectively 1, 2, and 3 minutes in the recovery period) is equal in sensitivity to exercise thallium 201 scintigraphy in detecting single vessel disease. Finally, Mohan and Wasir observed that after coronary artery bypass surgery, the SBP-RR returned back toward normal. The diagnostic utility of this new exercise parameter is particularly important in view of the known limitations in interpretation of ST segment changes along with reduced functional capacity in patients receiving antianginal drugs such as beta blockers.

The exact mechanism of progressive increase in the recovery period systolic blood pressure is unknown; however, the available data suggest that in the postexercise period when ischemia is relieved and left ventric-
ular function returns toward normal, there may be augmentation of contractility possibly under the influence of elevated catecholamines. This course of events has been suggested by Pfisterer et al\textsuperscript{16} who observed that in patients with documented coronary artery disease undergoing supine bicycle exercise, the LV ejection fraction progressively increases in the recovery period predominantly in patients demonstrating a decline in the exercise ejection fraction. Similarly, Crawford et al\textsuperscript{17} observed that abnormal SBP-RR is associated with an abnormally elevated stroke volume measured with exercise echocardiography during the recovery period. We have prospectively observed\textsuperscript{18} that the SBP-RR is related to exercise hemodynamic parameters. The peak systolic blood pressure and heart rate were 196 mm Hg and 132 beats per minute in the normal group compared to 146 mm Hg and 119 beats per minute in patients with an ↑SBP-RR, respectively. Thus, the underlying mechanism of an ↑SBP-RR may be related to excessive catecholamine response occurring as a result of exercise induced ischemia and related left ventricular dysfunction. Recently, it has been shown\textsuperscript{19} that exercise induced increase in catecholamine levels is greater in patients with three-vessel disease than in those with one- or two-vessel coronary disease. This excessive catecholamine response could result in improvement in left ventricular contractility after relief of ischemia. Horn et al\textsuperscript{20} demonstrated augmentation of left ventricular contraction induced by a constant infusion of epinephrine in 16 patients with coronary artery disease. In 11 of these 16 patients, improved contraction in previously asynergic areas was observed. Thus, an improvement in contractility resulting in a greater stroke volume could be responsible for the abnormally elevated systolic blood pressures in the recovery period.

The case we have described here illustrates the clinical usefulness of ↑SBP-RR in the diagnosis of severe coronary artery disease in patients receiving antianginal therapy. As shown in Figure 2, the patient's

\textbf{FIGURE 3.} Thallium 201 scintigraphic findings immediately postexercise (exercise) and three hours posttesting (rest) to evaluate for redistribution. Reversible filling defects due to myocardial ischemia are seen in the anterior, apical and inferior regions of the heart.
12-lead electrocardiographic recordings during peak exercise and recovery period failed to reveal diagnostic ST segment changes, and the patient did not experience exercise-induced angina. However, he had an abnormal SBP-RR which correlated with presence of ischemia on thallium-201 scintigraphy as well as demonstration of three-vessel coronary artery disease on coronary angiography.

The limitation of traditional exercise parameters in the diagnosis of multivessel coronary artery disease in our case is not unique; “equivocal” or “inconclusive” test results occur frequently in patients undergoing exercise treadmill testing.21-23 In the study by Iskandrian and Segal,21 71 of 194 patients undergoing selective coronary arteriography and exercise thallium 201 scintigraphy had an inconclusive exercise ECG predominantly due to an achieved peak heart rate of less than 85 percent of the maximum predicted by age and to the presence of baseline ST segment abnormalities. In their study, 26 and 33 of the 71 patients with inconclusive treadmill exercise tests had abnormal thallium 201 scintigrams and significant coronary artery disease (≥70 percent luminal narrowing) respectively. The patient in the case reported here only achieved 65 percent of the maximum predicted heart rate and had baseline ST segment abnormalities which failed to reach diagnostic criteria at peak exercise. However, the recovery blood pressure response was abnormal and correlated with angiographic and scintigraphic findings diagnostic of multivessel coronary artery disease. In summary, this case illustrates the importance of the ↑ SBP-RR even in the absence of well accepted hemodynamic and electrocardiographic criteria for the diagnosis of significant multivessel coronary artery disease. This new exercise criterion should improve the diagnostic utility of exercise treadmill testing in patients with limited exercise capacity and baseline electrocardiographic abnormalities.

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