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Different Protocols Generate Variations in Systolic Blood Pressure Response After Exercise in Patients With Coronary Artery Disease

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Abstract

Some patients with coronary artery disease (CAD) and exercise-induced myocardial ischemia demonstrate no change or a paradoxical increase in systolic blood pressure (SBP) during recovery following exercise. Previous studies have investigated the significance and clinical usefulness of analysis of recovery SBP response in detecting CAD, but conflicting data have been reported. Different protocols were used for the time of SBP recording and either bicycle or treadmill testing. We studied the exercise response in 64 male patients investigated for CAD who underwent symptom-limited treadmill stress testing during electrocardiographic monitoring and serial recording of blood pressure. Forty-three patients showed one or more stenoses of at least 70% at angiography (CAD). Twenty-one patients with normal coronary tree or slight lesions served as controls. The sensitivity (true positive/all CAD patients), specificity (true negative/all CAD-free patients), and the correct classification rate (correct diagnoses/all subjects) were assessed by standard ST segment analysis and two recovery SBP ratios calculated by dividing the first minute recovery SBP by the immediate postexercise value (RR/R) or by the true peak exercise value (RR/P). ST segment analysis achieved 53% sensitivity, 57% specificity, and 54% correct classification, the RR/R ratio achieved 73%, 23%, and 60%, and the RR/P ratio 53%, 71%, and 59%, respectively. There were significant differences in results using these ratios. Time of SBP recording generated discrepancies in recovery SBP ratios. Therefore, differences in the timing of SBP measurement may generate conflicting clinical indications.

Key Words
blood pressure, exercise test, coronary artery disease, ischemia (myocardial)

INTRODUCTION

Systolic blood pressure (SBP) in some patients with coronary artery disease (CAD) does not decrease or paradoxically increases during recovery following treadmill exercise in contrast to normal individuals[1]. The SBP recovery ratio calculated by dividing the first and third minutes recovery SBP values by the immediate post-peak exercise values has a high predictive accuracy for detecting CAD[1]. However, studies have demonstrated different results introducing uncertainty about the clinical usefulness of SBP recovery ratio for clinical use[2–9]. We recently suggested that the timing of SBP recording

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might be a possible source of the variation in reported results[8]. We demonstrated different clinical indications of two ratios (calculated using early postexercise or peak exercise values) after upright bicycle exercise testing[8].

To confirm this hypothesis, we investigated the timing of SBP evaluation (peak exercise or immediately postexercise) using the treadmill test in patients with suspected CAD. The two evaluated SBP recovery ratios were compared to standard ST segment analysis.

METHODS

Study population

We evaluated 64 patients with chest pain syndrome. Twenty of them had suffered a previous myocardial infarction. Forty-three showed one or more major coronary stenoses of at least 70% at angiography. Twenty-one showed a normal coronary tree or minimal irregularities. None of them had received any drug treatment for at least one week at time of study.

Treadmill stress testing

The patients underwent symptom limited treadmill stress testing with a modified Bruce protocol. Exercise was interrupted if at least 2 mm ST depression with or without angina, exhaustion or an SBP fall (at least 20 mmHg) occurred. After exercise subjects walked at 1.6 mph and 0° grade during 2 minutes and then were seated under continuous electrocardiographic monitoring. Blood pressure was measured by a fully trained cardiologist according to a standard protocol[4,5]. Blood pressure was measured without connection of the arm with the treadmill to minimize noise. Auscultatory measurements were performed using a mercury sphygmomanometer at rest, every minute during exercise, and every thirty seconds during strenuous exercise in all patients just before stopping, immediately after exercise, and every minute during recovery. We used the Borg scale[10] for estimation of exercise perceived exertion to assess the intensity of exercise. The test was performed according to the recommendations of Ellestad[2] to improve the accuracy of electrocardiography (ECG) and blood pressure monitoring.

Data analysis

Data shown are mean ± standard deviation (SD). Comparison between patients was performed by the *t*-test for unpaired samples. ST segment analysis was performed according to standard methods[2]. The RR/R ratio was calculated as the first minute recovery SBP divided by the immediate postexercise value. The RR/P ratio was calculated by dividing the first minute recovery SBP by the peak exercise value. The abnormal response was defined as unchanged or paradoxically increased SBP recovery value compared to exercise (postexercise or peak exercise value)[1]. A value of one or more for both RR/R and RR/P ratios was an abnormal result. The sensitivity (true CAD patients with positive test/all CAD patients), specificity (true CAD-free subjects with negative test/all CAD-free subjects) and correct classification rate (CCR) (correct diagnoses/study population) were calculated for ST segment analysis and both RR/R and RR/P ratios.

RESULTS

Estimated METS during exercise were 8.9±1.1 in controls and 4.9±1.1 in CAD patients ($p<0.05$). Peak exercise heart rate was 149±16 bpm in controls and 122±20 bpm in CAD patients ($p<0.01$). SBP at peak exercise was 181±27 mmHg in controls and 172±25 mmHg in CAD (not significant). Immediate postexercise SBP was 170±20 mmHg in controls and 172±21 mmHg in CAD (not significant). After the first minute during recovery SBP was 165±30 mmHg in controls and 167±27 mmHg in CAD (not significant) (**Fig. 1**).

ST standard analysis identified CAD in 23/43 (53%) and a false positive response was observed in 9/21 (42%) controls. Sensitivity was 53% and specificity was 57% (**Fig. 2**). An abnormal RR/R ratio was observed in 34/43 CAD patients (79%) and in 16/21 controls (76%). Sensitivity was 73% and specificity was 23%. The RR/P ratio was abnormal in 23/43 CAD patients (53%) and in 6/21 controls (28%). Sensitivity was 53% and specificity was 71% (**Fig. 2**).

DISCUSSION

Evaluation of blood pressure response may be useful to identify a flat or hypotensive exercise response in patients with cardiac dysfunction or severe CAD. Amon *et al*[1] observed no change or a paradoxical rise of SBP postexercise in some patients with CAD. They suggested an abnormal SBP ratio was a highly useful clinical tool for detecting

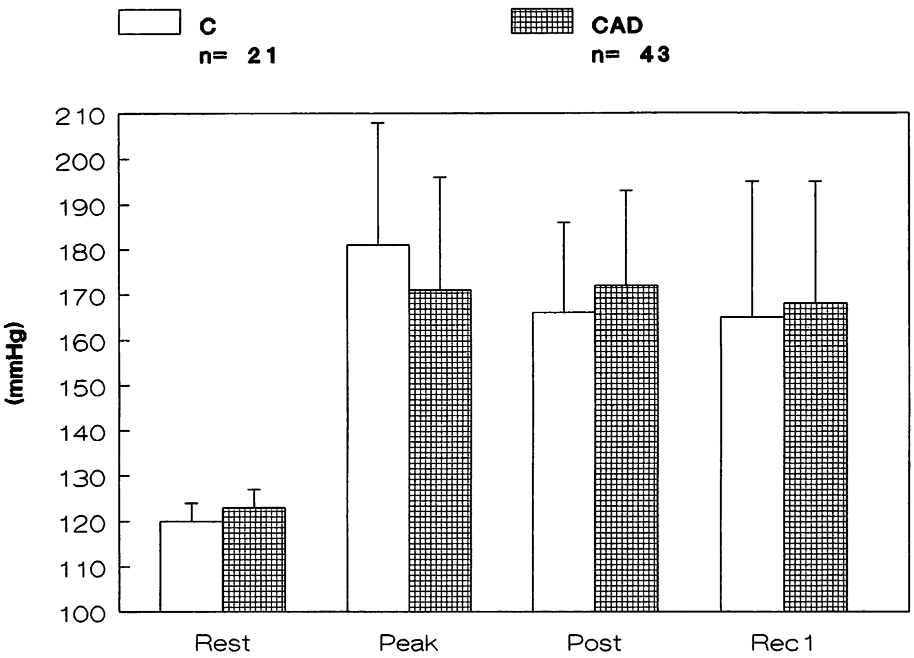

Fig. 1 Systolic blood pressure at rest (Rest), at peak exercise (Peak), immediately post exercise (Post) and after first minute of recovery (Rec 1) in controls (*open columns*) and patients with coronary artery disease (*hatched columns*) Mean ± standard deviation.

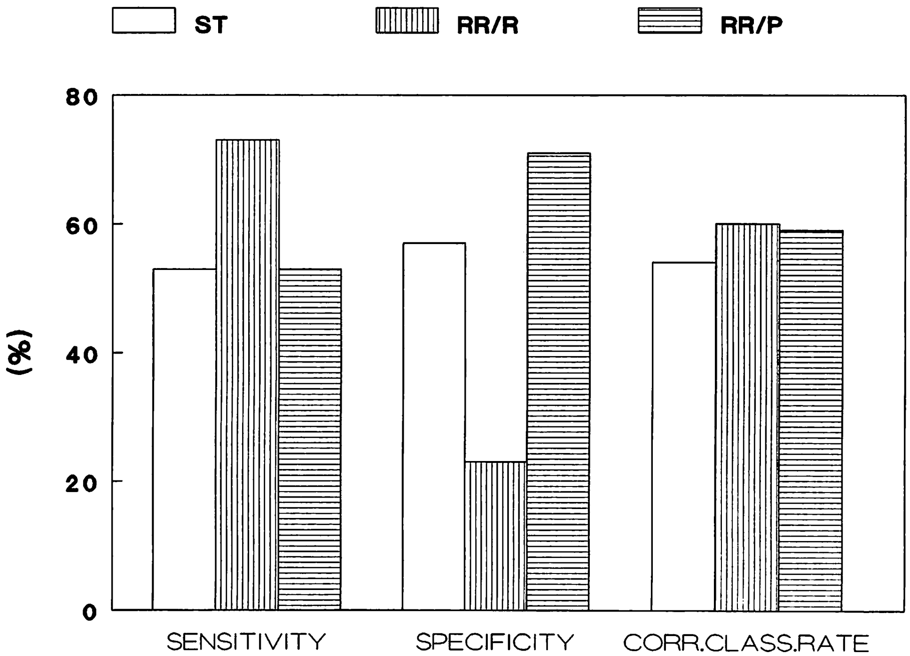

Fig. 2 Sensitivity, specificity and correct classification rate of ST segment analysis (ST), RR/R ratio, and RR/P ratio

CAD[1]. However, Ellestad[2], using a treadmill, did not confirm these results. Acanfora *et al*[3] and Romano *et al*[4,7,8], using bicycle exercise with different timing of SBP recordings, found the clinical usefulness was less than that of standard ST. In 1988 we[4] found that SBP response detected CAD with low sensitivity and high specificity, suggesting a supporting role to ST analysis. We focused on different protocols to explain the discrepancies in the literature, and demonstrated that SBP response was characterized by high SBP ratio in patients with hypertension[4] (affecting the clinical usefulness), in women vs men[7], and in controls with exercise-induced ST segment depression without CAD[7].

Using the treadmill, we confirmed the doubts of Ellestad[2] about a significant difference between the mean value of SBP ratios in CAD patients vs controls[5]. We suggested that the use of true peak exercise SBP or the value recorded immediately after stopping exercise as the peak SBP value may generate a reliable difference in results using upright bicycle exercise[8]. In contrast, Miyahara *et al*[6] using supine bicycle exercise confirmed the results by Amon *et al*[1]. Tsuda *et al*[10] using the treadmill and an artificial cut off point for analysis claimed that postexercise SBP ratio could reliably detect CAD in patients with hypertension.

The present study used a treadmill and recovery walking time. Peak exercise SBP was investigated using different timing of recording as previously proposed[8]. In this study, however, we did not use different standards for each approach for evaluating the standard 2SD criteria. Our basis was the clinical observation of Amon *et al*[1], so no change or a paradoxical rise was considered as an abnormal response. Despite the different results, we agree about the clinical usefulness of analyzing this phenomenon, related probably to blunted SBP rise during test[6] and restored myocardial function after exercise[11] almost only in multivessel CAD[4,7].

The use of early postexercise SBP as the peak value (RR/R) gave data quite similar to the results by Ellestad[2]. We observed many controls with an abnormal SBP response. In contrast, the use of the true peak exercise SBP (RR/P) (affected by problems in detecting the value accurately) decreased the incidence of false positive responses in controls. As previously suggested[4,8], the SBP declines rapidly after exercise was discontinued, so that in controls early postexercise SBP was frequently similar to the first minute recovery value. In CAD patients the peak exercise vasodilation restores failing stroke volume, so that SBP may restore rapidly after exercise was discontinued. Therefore, in our opinion, the differences between controls and CAD patients may be discovered using true peak exercise SBP. Early postexercise SBP minimizes the differences between the two groups.

We have used both bicycle and treadmill procedures[4,5,7,8]. In both cases we aimed to avoid a change of posture after exercise as in other studies[1,2,10]. Changing the posture changes the firing of baroreceptors after exercise. Therefore, there are conflicting data, particularly in hypertensive patients, between our experience[4] and that of another laboratory[10].

The present study supports our previous data on upright bicycle exercise with variations related to different population, prevalence of CAD, and postexercise sitting position on the bicycle vs walking treadmill recovery. This study did not investigate strictly the clinical usefulness of SBP response but attempted to facilitate the interpretation of different data. Amon *et al*[1] used immediate postexercise SBP as the peak value and sitting recovery posture. Ellestad[2] probably used true peak SBP data and supine recovery position. Tsuda *et al*[10] did not clearly report their protocol, but possibly used supine for both immediate postexercise and recovery. In our opinion the timing of recording SBP at or after peak exercise and use of walking, sitting or supine position during recovery can generate important differences in clinical indications based on the SBP recovery ratios.

References

1) Amon KW, Richards KL, Crawford MH : Usefulness of the postexercise response of systolic blood pressure in the diagnosis of coronary artery disease. Circulation 1984; **70** : 951–956
2) Ellestad MH : Stress testing. *in* Principles and Practice, 3rd Ed. Park Davis, Philadelphia, 1986
3) Acanfora D, de Caprio L, Cuomo S, Papa M, Ferrara N, Leosco D, Abete P, Rengo F : Diagnostic value of the ratio of recovery systolic blood pressure to peak exercise systolic blood pressure for the detection of coronary artery disease. Circulation 1988; **77** : 1306–1310
4) Romano M, Caiazzo MR, Di Maro T, Carella G, Golia B, Chiariello M, Condorelli M : Increased recovery systolic blood pressure after upright bicycle exercise : Its incidence and usefulness for detecting coronary artery disease. Am J Noninvas Cardiol 1988; **2** : 259–263
5) Romano M, Caiazzo MR, Marchegiano R, Raponi M, Morra AMI, de Arcangelis E, Chiariello M, Condorelli M : Recovery systolic blood pressure response after treadmill exercise procedures : Evidence against its usefulness in detecting coronary artery disease. Ann It Med Int 1990; **5** : 13–17
6) Miyahara T, Yokota M, Iwase M, Watanabe M, Matsunami T, Koide M, Saito H, Takeuchi J : Mechanism of abnormal postexercise systolic blood pressure response and its diagnostic value in patients with coronary artery disease. Am Heart J 1990; **120** : 40–49
7) Romano M, Caiazzo MR, Di Maro T, de Arcangelis E, Carella G,

Golia B, Chiariello M, Condorelli M : Abnormal recovery systolic blood pressure response for detecting coronary artery disease in men and women investigated by upright bicycle exercise. Acta Cardiol 1991; **46** : 153–160

8) Romano M : Postexercise systolic blood pressure in coronary artery disease. Am Heart J 1991; **121** : 1847–1848

9) Borg GAV : Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982; **14** : 377–381

10) Tsuda M, Hatano K, Hayashi H, Yokota M, Hirai M, Saito H : Diagnostic value of postexercise systolic blood pressure response for detecting coronary artery disease in patients with or without hypertension. Am Heart J 1993; **125** : 718–725

11) Rozanski A, Elkayam U, Berman DS, Diamond GA, Prause J, Swan HJC : Improvement of resting myocardial asynergy with cessation of upright bicycle exercise. Circulation 1983; **67** : 529–535