IMPLICATION OF REBOUND ST SEGMENT DEPRESSION FOR CORONARY COLLATERAL CIRCULATION

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Exercise testing is a well known accepted modality for diagnosis and prognostic prediction of coronary artery disease. Rebound phenomenon is characterized by ST segment depression at peak exercise which is normalized during early recovery phase, and later reapperance of ST segment depression. The aim of this study is to find out angiographic corresponding data of rebound phenomenon in terms of extension of disease along with grade of collateral circulation.

Thirty-one (31) patients with angina pectoris and normal resting electrocardiogram were included in this study. Standart Bruce protocol was performed and evaluated in a standart manner before coronary angiography was done to all patients. TIMI (Thrombolysis In Myocardial Infarction)classification was used for the determination of antegrade collateral flow. We described a scale for grading retrograde collateral flow. For grading the lesion severity, we used perfusion scoring which improved by Gensini et all.

We have found three vessel disease in 12 of 31 (32.25%), two vessel disease in 10 of 31 (38.70%) and one vessel disease in 8 of 31 (25.80%). Coronary angiography is considered normal in one patient. Coronary collateral circulation found in 9 of 12 patients with three vessel disease (75%), in 7 of 10 patients with two vessel disease (63.63%) and 7 of 8 patients with one vessel disease (87.80%). In this study group 74.20 % of patients had well-defined coronary collateral circulation and severe coronary artery stenosis.

As a conclusion, results of this preliminary study emphasis an importance of rebound phenomenon concerning of well-defined coronary collateral circulation in coronary artery disease.

Key words: exercise testing , rebound ST segment depression, coronary collateral circulation

ST Segment depression during exercise test is a sign of myocardial ischemia. The exercise test sensitivity is 68% (range 23-100), and specificity is 77% (range 23-100) for the diagnose of coronary artery disease. Early onset of ST

segment depression, profound ST segment displacement, ischemic changes in five or more electrocardiography (ECG) leads, persistence of the changes late in the recovery phase of exercise, exercise induced ST segment elevation, failure to increase systolic blood pressure over 120 mmHg, and evidence of angina pectoris during the exercise are associated with more severe myocardial ischemia, and increase the probability of more extensive disease. While the development of ≥0.10 mV (1 mm) of J point depression measured from the PQ junction, with a relatively flat ST segment slope (<1 mV/sec.), depressed ≥ 0.10 mV 60 to 80 msec. after the J point in three consecutive beats is considered to be an abnormal response, validity of recovery only ST segment depression is still controversial [1-7,18]. In this study we investigated angiographic equivalent of rebound ST segment depression.

METHODS

The study group was selected randomly from the patients admitted to the exercise test laboratory between 1995 to 1996. All of the study group patients had normal resting ECG's. There were 29 men (93.5%) and 2 women (6.5%), whose mean age was 57±7 yars (range 40 to 70). 7 of 31 patients (22.5%) had hypertension and 1 patient (3.2%) had hypercholesterolemia. There were no history and ECG findings indicating previous myocardial depression (Table 1). Standard Bruce protocol was applied to all patients and then we performed coronary angiography via femoral artery within 23 days (range 3-35 days). The angiographic results were analyzed by a single observer. We used the TIMI classification for the determination of antegrade collateral flow [8] (Table 2). For the grading of retrograde collateral flow we used the scale which is defined by our clinic (Table 3). Gensini perfusion scoring [21] system was performed to patients to determine the vessel disease extent by us.

Table 1: Clinical Characteristics of Study Group Patients.

Patients	
M/F(n)	29/2
mean age (yr)	57±7 (range 40-70)
Previous AMI (ECG)	0 (0%)
HT (n)	7 (22.58%)
DM (n)	0 (0%)
Hypercoll	1 (3.22%)
Per. art. dis.	0 (0%)

M=Males; F= Females; AMI= Acute Myocardial Infarction; ECG= Electrocardiography; HT= Hypertension; DM= Diabetes Mellitus; Hypercoll. Hypercholesterolemia.

Table 2. TIMI Classification for Antegrade Collateral Perfusion.

Grade 0: Complete occlusion (absence of contrast flow distal to the infarct related occlusion site)

Grade 1: Minimal perfusion (contrast penetrates around the site of obstruction but minimal distal perfusion is present)

Grade 2: Partial perfusion (reduced rate of entry and clearance of contrast into and from the distal coronary bed)

Grade 3: Complete perfusion (normal entry and clearance rates of contrast to and from the distal coronary bed)

Table 3. The Scale of Retrograd Collateral Perfusion

Grade 0: Absence of retrograde contrast perfusion

Grade 1: Late and insignificant retrograd contrast perfusion except terminal branches.

Grade 2: Late and insignificant retrograd contrast perfusion with terminal branches.

Grade 3: Complete retrograde coronary bed perfusion.

STATISTICAL ANALYSIS

Statistical significance was calculated with the Student paired t-test for difference of exercise test rest and rebound time values. We used ANOVA and Tukeys-b test for calculating difference between vessel perfusion scoring. ANOVA was used for lesion extent and collateral perfusion relation.

RESULTS

The patients mean heart rate and also double product value at the rebound time was significantly higher than rest ($p<0.05$) (95±12 beats/min vs. 86±14 beats/min; 16.48±3.9 mmHg*beats/min*10^{-3} vs. 13.96±3.4 mmHg* beats/min* 10^{-3} respectively) (Table 4) (Fig 1-2). There was no statistically significance between the rest and rebound systolic and diastolic blood pressure (160±23 mm Hg vs 165±26 mmHg; 89±14 mmHg vs. 86±14 mmHg respectively) (Table 4) (Fig 3-4). During the exercise test, three patients had complained of angina and these patients coronary angiography showed serious coronary artery disease with well-defined

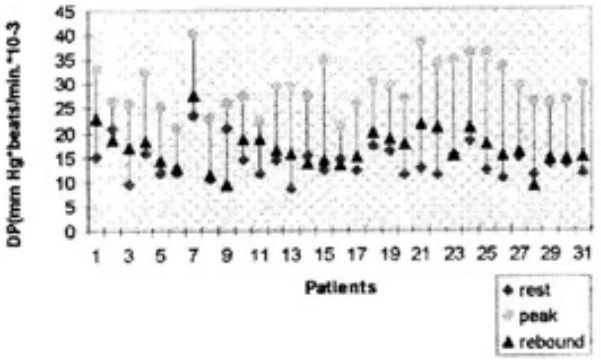

Figure 1. Double product of the patients during exercise test.

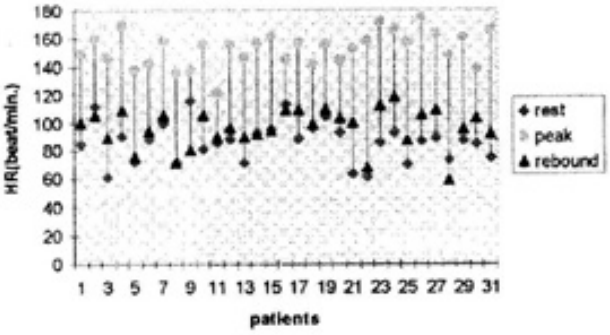

Figure 2. Heart rate responses during the exercise test

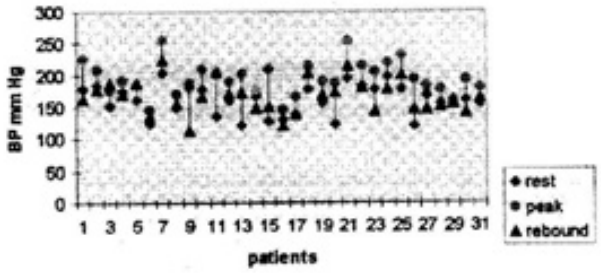

Figure 3. Systolic blood pressure of the patinets during the test.

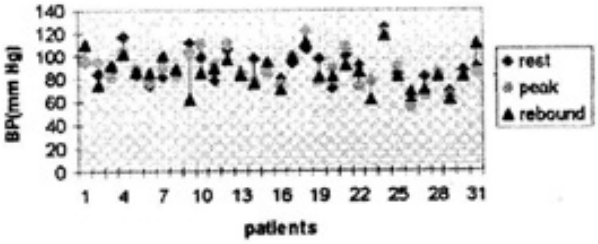

Figure 4. Diastolic blood pressure of the patinets during the exercise test.

Table 4. Comparison of Rest, Peak and Rebound mean Blood Pressure, Heart Rate and Double Product of Study Patients.

	HR (beats/min)	Systolic BP (mmHg)	Diastolic BP(mmHg)	DP (mmHg*beats/min*10-3)
Rest	86 ± 1	160±23	89±14	13.962±3.408
Peak	152±11	195±26	88±15	30.250±8.040
Rebound	95 ±13	165±26	86±14	16.487±3.909
P value	0.001	NS	NS	0.002

BP=Blood Pressure; HR= Heart Rate; NS= Not Significant

coronary collateral circulation. Mean exercise time was 5.8±1.7 min, and mean METS (metabolic equivalent) were 7.5±1.8. Rebound ST segment depression was seen at 3.2±0.9 min, and return to the baseline at 5.8±0.5 min in the recovery period (Table 5). We have found three vessel disease in 12 of 31 (38.70%), two vessel disease in 10 of 31 (32.25%), and one vessel disease 8 of 31 (25.80%). Coronary angiography was considered normal in one patient. Thus 30 patients with rebound ST segment depression had been found to have severe coronary artery disease (Table 6). The mean perfusion scores of LAD, Cx and RCA were 33.42±20.55, 20.33±18.76 and 20.35±12.41 respectively. The LAD perfusion score was significantly higher than Cx and RCA ($p<0.05$). We found that mean stenosis score was 52.79±30.03 (Table 7). Coronary collateral circulation was found in 9 of 12 patients with three vessel disease (%75), 7 of 10 patients with two vessel disease (63.63%), and 7 of 8 patients with single vessel disease (87.80%) (Table 8). There was 5 LAD, 2 RCA and 1 Cx lesions in the single vessel disease group. 3 of 5 LAD lesions had grade 3, and 1 of had grade 2 collateral perfusion. Two patients who had only RCA stenosis had grade 3 collateral perfusion. There was no collateral in patient who had a Cx lesion (Table 9). In two vessel disease group; three patients had grade 0 (30%), one patient had grade 1 (10%), one patient had grade 2 (10%) and 5 patiens had grade 3 (50%) collateral circulation (Table 10). There were 3 patients with grade 0 (25%), 3 patients with grade 1 (25%), 0 patients with grade 2 (0%) and 6 patients with grade 3 (50%) collateral perfusion in the three vessel disease group (Table 11). In the whole study group, 14 patients had grade 3 (45.18%), 5 patients had grade 2 (16.12%) and 4 patients had grade 1 (12.90%) collateral perfusion

Table 5: Exercise Test Parameters of Patients.

	Patients
MET	7.5±1.5
ET	5.8±1.7 min
RT	3.2±0.9 min
RTend	5±0.5 min
Angina (%)	3 (9.7%)

METS= Metabolic equivalent; ET=Exercise time; RT= Rebound time; RTend= End of Rebound ST Depression.

Table 6. Angiographic Results of Patients

vessel	no of pts (n)	%
normal	1	3.2
single vessel	8	25.8
double vessel	10	32.3
triple vessel	12	38.7
TOTAL	31	100

Table 7. Perfusion Scoring of The Patients

	LAD	CX	RCA	Total	p value
Total	869	366	346	1531	<0.05
Mean	33.42	20.33	20.35	52.79	
Std dev	20.55	18.76	12.41	30.03	

LAD: Left Anterior Descending Artery; CX: Circumflex Artery; RCA: Right Coronary Artery, Std. dev.: Standart Deviation.

Table 8. Coronary Collateral Circulation in Patients

	Collateral (n) (%)	Collateral absent (n) (%)	Total (n) (%)
one vessel	7 (87.80%)	1 (12.20%)	8 (100%)
two vessel	7 (63.63%)	3 (36.37%)	10 (100%)
three vessel	9 (75.00%)	3 (25.00%)	12 (100%)

Table 9. Collateral Grading of Single Vessel Disease

	Patients (%)
Grade 0	1 (12.50)
Grade 1	0 (0 %)
Grade 2	2 (25 %)
Grade 3	5 (67.50 %)

Table 10. Collateral Grading of Two Vessel Disease

	Patients (%)
Grade 0	3 (30 %)
Grade 1	1 (10 %)
Grade 2	1 (10 %)
Grade 3	5 (50 %)

Table 11. Collateral Grading of Three Vessel Disease

	Patients (%)
Grade 0	3 (25 %)
Grade 1	3 (25 %)
Grade 2	0 (0 %)
Grade 3	6 (50 %)

Table 12. Collateral Grading of Study Patients

	Patients (%)
Grade 3	14 (45.18 %)
Grade 2	5 (16.12 %)
Grade 1	4 (12.90 %)
Grade 0	8 (25.80 %)

Table 13. Left Ventriculographic Evaluation of Patients in Study Group

	Coll. positive	Coll. negative (n)	Total (n)
Normal	18 (58.08 %) (78.26 %)*	5 (16.12 %) (62.50 %)*	23 (74.20 %)
Segment dysfunction	5 (16.12) (21.74 %)*	3 (9.68) (37.50 %)*	8 (25.80 %)
Total	23 (74.20 %)	8 (25.80 %)	31 (100 %)

Coll. =Collateral; * = In the Own Group

(Table 12). The patients who had single vessel disease had significantly higher collateral circulation than two and three vessel disease ($p<0.05$). We have found normal left ventricular function in 23 of 31 (74.20%), and wall motion abnormalities 8 of 31 patients (25.80%). While 18 of 23 (78.26%) patients with normal left ventriculography had collateral circulation, 5 of 8 (62.50%) patients with wall motion abnormalities had collateral circulation (Table 13).

DISCUSSION

Review of the literature revealed that there has not sufficent and reliable data published on rebound ST segment depression. Nevertheless, it has been suggested that the ST segment depression seen only at the recovery period is related to catecholamin levels that continue to increase in the post exersize period. Thus, increasing catecholamine levels could increase myocardial contractility and increase the myocardial oxygen demand. Another explanation; postural change from upright to supine during recovery may be responsible for the development of subendocardial ischemia. Post exercise supine posture immediately after erect exercise, augmenting the preload by abruptly increasing the venous return. The resultant expansion in left ventricular volume will increase wall stress and myocardial oxygen compsuption. Increased preload will also increase left ventricular diastolic pressure which will reduce the perfusion pressure gradient responsible for subendocardial flow [2-5,7,16]. In the study by Shinmura et all. ST segment depression during the recovery period is related to an abnormal response to imbalances in the cardiovascular sympathetic system in the post exercise period, rather than ischemia. Another study by Fabbiocchi et all. claimed that recovery positive positon exercise test patients with atrial pacing had arterial narrowing about 3 min of recovery [17]. In our study, all the patients have sitting positive after exercise test. There were no differences between rest and recovery systolic and diastolic blood pressure, but heart rate and consequently the double product was higher in recovery. Thus rebound ST segment depression may be related to this higher double product and ischemia. Like study by Fabbbiocchi et all. rebound ST segment depression in our study was seen in 3±0.9 min in recovery. Thus active arterial vasoconstiction may be also responsible from rebound ST segment depression too. Coronary collaterals are present in normal human hearts and become functionally relevant, and angiographically visible in the presence of hemodynamically significant atherosclerotic obstructions [9-14]. In the sutdy by Bonetti et all. it was clarified that effect of coronary collaterals on exercise test recovery period was reducing duration of ischemia [15]. Another study by Bonetti et all. showed that more severe disease and angiographically visible collateral patients had more rapid ST segment return to the baseline in the recovery, than patients who had less severe disease and non visible collaterals [19]. The results of this study suggests that in patients with a well developed collateral circulation, even in severe coronary artery disease the electrocardiographic pattern returns back to the baseline in early recovery period. The same thing could not be said for the rebound ST segment depression in the late recovery period.

Perini et all. showed that blood norepinephrine levels were high at 2-5 minute, and related to high heart rate in the recovery period [20]. The mechanism of late recovery ischemia may be a result of increased blood norepinephrine concentration and high heart rate.

We also think that patients with angiographically visible collaterals had good left ventricular function (in our study 78.26%). Additionaly in patients with rebound ST segment depression, the LAD perfusion score was much more higher. Moreover we must determine that 30 of 31 rebound ST segment depression patients had been revascularised in the following days. In conclusion; existance of rebound ST segment depression in exercise test is indicative of serious coronary artery disease with angiographically visible collateral circulation, and this finding can be considered a reliable sign of by-passable coronary arteries.

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