Exercise-Induced ST Changes in aVR, V5 and V1 in Differentiation between Single and Multi-Vessel Coronary Artery Disease

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ABSTRACT

Background: Angina occurs when there is regional myocardial ischemia caused by inadequate coronary perfusion and is usually but not always induced by increases in myocardial oxygen requirements.
Objective: The aim of this work was to study the significance of ST changes in aVR, V5, V1 during exercise ECG for diagnosis of single -or multi-vessel coronary artery disease.
Patients and methods: This study had been carried out in the cardiology department, Zagazig University and National Hear Institute during the period from January 2005 to January 2007. This study included 56 patients (40 male +16 female) with chronic stable angina. **Results:** Comparison was done among groups regarding demographic data, resting ECG data, echocardiographic findings and there were no statistical significant difference among groups. Single vessel disease: **LAD: -** the ability of the test to detect left anterior descending (LAD) lesion as a single vessel disease has high specificity 87.5%, high +ve predictive value 96%, but low sensitivity 50%. **Left circumflex (LCx):** the sensitivity of the test to detect LCx lesion as a single vessel disease was 53.4%, specificity 60%, but with low +ve predictive value 44%. **RCA:** as regard RCA lesion the test has low sensitivity, specificity positive and negative predictive values.
Conclusion: The concomitant appearance of exercise-induced ST-segment elevation in lead V1 and in lead aVR with simultaneous ST-segment depression in lead V5, or the isolated appearance of ST-segment elevation in lead V1 mostly detects single-vessel disease and correlates strongly with significant narrowing of the LAD coronary artery as single-vessel disease, or with significant stenosis of the LAD and LCx coronary arteries as double-vessel disease.
Keywords: Coronary Artery Disease, ST changes, aVR, V5 and V1, Single - and Multi-Vessel.

INTRODUCTION

Exercise testing is an important diagnostic and prognostic procedure in the assessment of patient with ischemic heart disease. The test is now most frequently used to estimate prognosis and to determine functional capacity, extent of coronary artery disease and the effect of therapy [(1)]. It is known that exercise-induced ST segment elevation in lead V1 detects left anterior descending (LAD) stenosis. It is also postulated that ST elevation in aVR and simultaneous ST depression in V5 is a marker of ischemia due to significant stenosis of LAD in patients with single vessel disease [(2)].

The study of **Michaelides *et al.*** [(2)] aimed to investigate the concomitant appearance of ST segment elevation in V1 and the simultaneous ST depression and ST elevation in aVR and each of them alone during exercise ECG to detect either LAD stenosis as a single–vessel coronary artery disease or multi-vessel coronary artery disease involvement. The concomitant appearance of exercise-induced ST segment elevation in Lead V1, ST elevation in lead aVR and ST depression in lead V5, as well as the isolated appearance of ST elevation in lead V1 detect significant LAD stenosis as a single vessel disease, or significant stenosis of LAD and left circumflex (LCx) arteries in patient with double vessel disease. Whereas, the appearance of ST segment elevation in aVR and ST depression in V5 but without ST elevation in V1 correlates strongly with significant LAD and right circumflex artery (RCA) stenosis and usually indicate double-vessel disease [(2)]. The aim of this work was to study the significance of ST changes in aVR, V5, V1 during exercise ECG for diagnosis of single- or multi-vessel coronary artery disease (ST segment elevation in V1 and simultaneous ST depression in V5 and ST elevation in aVR "aVR–E +V5-D" and each of them alone during exercise to detect either LAD stenosis as a single-vessel coronary artery disease or multi-vessel coronary artery disease involving LAD.

PATIENTS AND METHODS

This study was carried out in the Cardiology Department, Zagazig University and National Heart Institute during the period from January 2005 to January 2007. The study included 56 patients with chronic stable angina who presented to Outpatient Clinic, Stress ECG Lab, and Coronary Catheterization Laboratory, Zagazig University Hospital and National Heart Institute.

According to the result of exercise stress ECG, Patients included in this study were divided into three groups according to the ST changes in aVR, V1, and V5 as follow;

Group A: 25 patients with ST elevation in aVR, V1 and, ST depression in V5.
Group B: 19 patients with ST elevation in aVR and ST depression in V5).
Group C: 12 patients with ST elevation in V1.

Exclusion criteria:

All patients with ECG liable for ST and T wave changes like: Previous MI, bundle branch block (B.B.B.), electrolyte imbalance, patients receiving digitalis, ventricular pre-excitation, left ventricular hypertrophy,

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valvular heart disease and patients with previous history of CABG or PCI.

All patients were subjected to the following:

1) Full history taking: giving particular attention to risk factors for ischemic heart disease such as smoking, hypertension, D.M., obesity or positive family history of ischemic heart disease, age, sex, occupation, patient's complaint, and characters of chest pain as well as Past history of medical treatment, MI, CABG or PCI.

2) Thorough clinical examination.

3) Twelve leads surface resting ECG: Standard resting 12 leads ECG was done for every patient to exclude patients with BBB, pathological Q, and LVH.

4) Echo Doppler: All subjects were examined in supine and left positions and the standard views were obtained according to recommendations of American Society of Echocardiography 1996. Linear measurements such as wall thickness, internal chambers dimensions, and derived parameters such as fractional shortening and ejection fraction had been obtained from M-mode echocardiography [(3)].

5) Laboratory investigation: Laboratory investigations were done to detect risk factors as blood sugar level and lipid profile as well as investigation before coronary angiography (serum creatinine, hepatitis markers coagulation profile, and C.B.C.).

6) Coronary angiography: Coronary angiography was performed for all patients within 3 to 6 months of exercise ECG. Coronary angiography was done utilizing the retrograde, percutaneous transfemoral technique (Judkin's technique). The study was carried out with PHILLIPPS imaging system and was stored using a DICOM digital system. Multiple angulated views of each coronary artery were obtained. Coronary stenosis was evaluated qualitatively by experienced observer, unaware of the other results. A coronary stenosis was considered significant when the vessel diameter was narrowed 50% for the left main coronary artery and by 70% for other major coronary vessels. (A) Equipments: for monitoring, resuscitation, cineangiographic equipment, and equipments for coronary arteriography. (B) Patient preparation: Informed consent, pre-catheterization assessment, and Instructions were given to stop metformin and oral anticoagulants (INR less than 1.8), and ionic contrast dye was used.

7) Exercise stress testing: Treadmill exercise ECG was performed for all patients in the study according to ACC guidelines [(4)].

A) Equipments: treadmill as a method for exercise that allow the examiner to estimate workload, continuous 12 lead ECG monitoring and recording, sphygmomanometer for blood pressure assessment at the beginning of the test and before every stage change, computer and software for data storage and analysis, printer, and resuscitation equipments (defibrillator and intubation trays).

B) Patient preparation: Assessment: including full history, clinical examination, and ECG to detect if there is contra-indication for exercise test, also weight and height of the patients were measured, as well as calculation of the BMI using the equation (BMI; calculated as weight in kilograms divided by the square of height in meters). Instructions: Patient should stop ingestion of food, alcohol, or using tobacco product within 3 hours of the testing, patient should rest and avoid significant exertion on the day of assessment and wear clothing that allows freedom of movements. Medications: patients should discontinue prescribed cardiovascular medication, patients taking moderate or high dose of BB should taper their medication over 2 to 4 days period to minimize hyper-adrenergic withdrawal response.

C) Exercise protocol: **modified Bruce protocol** was used with gradual increase in workload and exercise duration up to 12 minutes.

Target heart rate, maximal sinus ST depression ≥ 3 mm, development of severe angina, incapacitating fatigue, dyspnea, and severe ventricular arrhythmia were the end points of exercise testing. An exercise test was considered positive if there was an horizontal or down-sloping ST depression 1mm at least 60 msec after the J point or an up-sloping ST segment depression ≥1.5 mm at 80 msec after the J point or an ST segment elevation of at least 1 mm.

Ethical approval:

An approval of the study was obtained from Zagazig University academic and ethical committee. Every patient signed an informed written consent for acceptance of the operation.

Statistical analysis:

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 22 for Windows® (IBM SPSS Inc, Chicago, IL, USA). Data were tested for normal distribution using the Shapiro Walk test. Qualitative data were represented as frequencies and relative percentages. Chi square test ($\chi 2$) to calculate difference between two or more groups of qualitative variables. Quantitative data were expressed as mean ± SD (Standard deviation). Independent samples t-test was used to compare between two independent groups of normally distributed variables (parametric data). ***Sensitivity:*** Probability that the test results will be positive when the disease is present (true positive rate, expressed as a percentage). ***Specificity:*** Probability that the test results will be negative when the disease is present (true negative rate, expressed as a percentage). P value ≤ 0.05 was considered significant.

RESULTS

This study included 56 patients with chronic stable angina who presented to Outpatient Clinic, Stress ECG Lab, and Coronary Catheterization Laboratory at Zagazig University Hospital and National Heart Institute during the period from January 2005 to January 2007.

Demographic data among the studied groups:

As regards the demographic data of the studied groups, there was no significant difference among the studied groups.

Table (1): Demographic data among the studied groups

	Group A (25)	Group B (19)	Group C (12)	Total (56)	Test of significance	P
Age (years) Mean ± SD	55.5 ± 8.2	53.9 ± 9.6	50.6 ± 5	53.9 ± 8.3	1.4	0.25
Sex N (%)					χ^2	
Male	17 (68%)	13 (68.4%)	10 (83.3%)	40 (71.4%)	1.06	0.55
Female	8 (32%)	6 (31.6%)	2 (16.7%)	16 (28.5%)		

Stress ECG data of the studied patients:

a) ST segment changes in leads aVR, V1, and V5: (table 2)

Patients included in this study were divided into three groups according to the ST changes in aVR, V1, and V5 as follow; **group A** includes patients with (ST segment elevation in V1, and simultaneous ST depression in V5, and ST elevation in aVR), **group B** (ST elevation in aVR and ST depression in V5), and **group C** (ST elevation in V1).

*Group A: in this group, ST elevation in aVR was 2.86 ± 0.75 mV with the range from 2 to 4 mV, ST elevation in V1 was 1.66 ± 0.51 mV with the range from 1 to 3 mV and ST depression in V 5 was 2.74 ± 0.81 mv with the range from 2 to 5 mV.

*Group B: in this group, ST elevation in aVR was 2.55 ± 0.48 mv, with range from 2 to 3.4 mv and ST depression in V 5 was 2.4 ±0.33, and range from 2 to 3 mv.

*Group C: in this group, ST elevation in V1 was 2.21 ± 0.44 mV, with the range from 1.8 to 3 mV, ST elevation in aVR was 1.75 ± 0.46 mV and range from 1 to 2 mV and ST depression in V 5 was 2.5 ±0.577 with the range from 2 to 3 mV.

By comparison among the studied groups as regards the changes in aVR, V1 and V5, there was no significant difference regarding ST segment depression in V5 with P value of 0.233, but there was significant difference concerning ST segment elevation in aVR and V1 with P value of 0.00, and 0.03 respectively.

In case of ST segment elevation in aVR, significant p value was noted as regards P 2 = 0.004 (group A versus group C), and P 3 = 0.00 (group B versus group C). In case of ST segment elevation in V1, significant p value was noted as regards P1= 0.03 (group A versus group B), and P 3 = 0.02 (group B versus group C).

Table (2): ST–segment changes during exercise stress ECG test in leads AVR, V1, and V5 in the studied groups

	Group A (25)	Group B (19)	Group C (12)	F	P
aVR elevation (Mean ± SD)	2.86 ± 0.759	2.552 ± 0.483	1.75 ± 0.462	9.381	0.000
range	2 -4	2 – 3	1 - 2		Sig*
V 5 depression (Mean ± SD)	2.744 ± 0.817	2.405 ± 0.334	2.5 ± 0.577	1.504	0.233
range	2 - 5	2 – 3	2 – 3		
V 1 elevation (Mean ± SD)	1.66 ± 0.509	--	2.216 ± 0.449	3.349	0.03
range	1 – 3	--	1.8 – 3		Sig**

*significant p value as regard P 2 = 0.004 (group A vs. group C), P 3 = 0.00 (group B vs. group C),** Significant p value as regard P1 (group A vs. group B), P3 (group B vs. group C).

b) Non ST, T wave changes during exercise stress test in the studied groups:

Arrhythmia: No arrhythmia in 39 patients, 11 patients had PVCs, 1 patient had PVCs and PACs, 1 patient had PVCs, SVT (supraventricular tachycardia (180/min) and non-sustained ventricular tachycardia, 2 patients had non-sustained ventricular tachycardia, 1 patient had SVT and non-sustained ventricular tachycardia and 1 patient had PVCs (bigeminy) and SVT. There was no statistical significant difference among groups as regards arrhythmia.

Blood pressure change: Fourteen patients had hypertensive response, four patients were in group A, six patients were in group B, and four were in group C with no significant difference among groups.

Percentage of age predicted maximum heart rate (APMHR %): In all studied group, patients reach APMHR % was 95.3 ± 13.04%, with the range from 68 % to 137 % with no significant difference among groups.

Duration of stress test: Mean of the duration of stress in all studied groups was 6.79 ± 2.22 minutes with range of 2 to 11 min with no significant difference among groups.

Causes of termination of stress test: In all studied groups, causes of stress test termination were reaching MAPHR, chest pain, fatigue, dyspnea, and tachyarrhythmia. Regarding tachyarrhythmia, it was present in three cases; one of them developed supraventricular tachycardia then non- sustained ventricular tachycardia. The other two cases had non sustained ventricular tachycardia. There was no significant difference among groups as regards the causes of termination of stress test.

Recovery period: In all the studied groups, recovery period was (4 ±2 min) with range from 1 to 9 min, there is no significant difference among groups.

Sensitivity, specificity, positive, and negative predictive values of the three electrocardiographic ischemic markers regarding the different types of coronary artery stenosis in group A (table 3):

Regarding single, double, three vessel diseases, sensitivity, specificity, positive, and negative predictive values are calculated less than 60% except the negative predictive value for three vessel diseases (93.5%).

1-Single vessel disease:

A) LAD: the ability of the test to detect LAD lesion as a single vessel disease had high **specificity 87.5%**, high **+ve predictive value 96%**, but low sensitivity 50%.

B) LCx: the sensitivity of the test to detect LCx lesion as a single vessel disease was 53.4%, **specificity 60%,** but with low +ve predictive value 44%.

C) RCA: as regards RCA lesion the test had low sensitivity, specificity positive and negative predictive values.

2- Double vessel disease:-

The highest sensitivity, specificity were noted as regards **LAD + LCx** with sensitivity 61.5% and specificity 60.5%, compared to 33.3% & 51.2%, and 50% & 55.6%) as regards LAD + RCA and LCX + RCA respectively.

Table (3): Sensitivity, specificity, positive, and negative predictive values of the three electrocardiographic ischemic markers regarding the different types of coronary artery stenosis in group A. **Group A (V1 ↑, AVR↑, V5 ↓)**

	Sensitivity	Specificity	Positive predictive value	Negative predictive values
Single VS %	40.9	52.9	36.0	58.1
Double VS %	46.7	57.7	56.0	48.4
Three VS %	50.0	55.8	8.0	93.5
LAD %	50.0	87.5	96.0	22.6
LCX %	52.4	60.0	44.0	67.7
RCA %	32.0	45.0	32.0	45.2
LAD, LCX %	61.5	60.5	32.0	83.9
LAD, RCA %	33.3	51.2	20.0	67.7
RCA, LCX %	50.0	55.6	4.0	96.8

Sensitivity, specificity, positive, and negative predictive values of the three electrocardiographic ischemic markers regarding the different types of coronary artery stenosis in group B (table 4):

Concerning single, double and three vessel disease**,** sensitivity, specificity, positive, and negative predictive values were calculated less than 60% except in case of double vessel disease with specificity of 74.1%, positive predictive value of 63.2%. The negative predictive value for three vessel diseases was 94.6%.

1-Single vessel disease:

A) LAD: the ability of the test to detect LAD lesion as a single vessel disease had low sensitivity and specificity (29.2% and 37.5% respectively) but with **high +ve predictive value (74.7 %)**.

B) LCx: the sensitivity of the test to detect LCx lesion as a single vessel disease was 38.1% and specificity was 68.6%, but with low +ve predictive value (42.1%).

C) RCA: - the sensitivity of the test to detect RCA lesion as a single vessel disease was 52%, specificity was 80.6% and +ve predictive value was 68.4%

2- Double vessel disease:

The highest sensitivity, specificity were noted as regards LAD + RCA with sensitivity of 53.3% and specificity of 73.2%, compared to 23.1% & 62.8%, and 50% & 66.7%) as regards LAD + LCX and LCX + RCA respectively.

Table (4): Sensitivity, specificity, positive, and negative predictive values of the three electrocardiographic ischemic markers regarding the different types of coronary artery stenosis in group B. **Group B (AVR↑, V5 ↓)**

	Sensitivty	Specificity	Positive peridective value	Negative peridective values
Single VS %	22.7	58.8	26.3	54.1
Double VS %	40.0	74.1	63.2	51.4
Three VS %	50.0	67.3	10.5	94.6
LAD %	29.2	37.5	74.7	8.1
LCX %	38.1	68.6	42.1	64.9
RCA %	52.0	80.6	68.4	67.6
LAD, LCX %	23.1	62.8	15.8	73.0
LAD, RCA %	53.3	73.2	42.1	81.1
RCA, LCX %	50.0	66.7	5.3	97.3

Table (5): Sensitivity, specificity, positive, and negative predictive values of the three electrocardiographic ischemic markers regarding the different types of coronary artery stenosis in group C. **Group C (V1 ↓)**

	Sensitivity	Specificity	Positive peridective value	Negative peridective values
Single VS %	**36.4**	**88.2**	**66.7**	**68.2**
Double VS %	**13.3**	**69.2**	**33.3**	**40.9**
Three VS %	**---**	**76.9**	**---**	**90.9**
LAD %	**20.8**	**75.0**	**83.3**	**13.6**
LCX %	**9.5**	**71.4**	**16.7**	**56.8**
RCA %	**16.0**	**74.2**	**33.3**	**52.3**
LAD, LCX %	**15.4**	**76.7**	**16.7**	**75.0**
LAD, RCA %	**13.3**	**75.6**	**16.7**	**70.0**
RCA, LCX %	**---**	**77.8**	**---**	**95.5**

Sensitivity, specificity, positive, and negative predictive values of the three electrocardiographic ischemic markers regarding the different types of coronary artery stenosis in group C (table 5):

The ability of the test to diagnose single, double, three vessel diseases had low sensitivity but with high specificity 88.2%, 69.2% and 76.9% for single, double and three vessel disease respectively. The highest positive predictive value was in case of single vessel disease (66.7%).

1-Single vessel disease:-

A) LAD: the ability of the test to detect LAD lesion as a single vessel disease had low sensitivity (20.8%) and high specificity (75%) and high +ve predictive value of 83.3 %.

B) LCx: the ability of the test to detect LCx lesion as a single vessel disease had low sensitivity and low +ve predictive value but high specificity of 71.4 %.

C) RCA: the ability of the test to detect RCA lesion as a single vessel disease had low sensitivity and low +ve predictive value but high specificity of 74.2 %.

2- Double vessel disease: the sensitivity and +ve predictive value were low but as regards the specificity was 76.7% for (LAD + LCX) and 75.6% for LAD + RCA, and 77.8% for RCA + LCX.

DISCUSSION

The age of the patients ranged from 33 to 72 years with a mean of 53.9 ± 8.3 years, forty patients were males (71.42%) and sixteen patients were females (28.58%) with male: female ratio of 10: 4. This means that chronic stable angina was predominant in male more than female and this is concordant with study of other investigators as **Michaelides *et al.*** [(2)]**.** As regards the demographic data of the studied groups there were no significant difference among the studied groups and this agrees with other investigators such as **Michaelides *et al.*** [(2)] who performed their study upon 880 patients with known or suspected coronary artery disease.

Regarding single, double and three vessel diseases, sensitivity, specificity, positive, and negative predictive values were calculated less than 60% except the negative predictive value for three vessel diseases (93.5%). These results are not in agreement with the result of **Michaelides *et al.*** [(2)] as they concluded higher sensitivity, specificity, positive, and negative predictive values in case of single vessel disease (79%, 78.5%, 67.55, and 87% respectively). But, our results are concordant with results of **Michaelides *et al.*** [(2)] regarding double and triple vessel disease.

1-Single vessel disease:

A) LAD: the ability of the test to detect LAD lesion as a single vessel disease had high specificity 87.5%, high +ve predictive value 96%, but low sensitivity 50%.

B) LCx: the sensitivity of the test to detect LCx lesion as a single vessel disease was 53.4%, specificity 60%, but with low +ve predictive value 44%.

C) RCA: as regard RCA lesion, the test had low sensitivity, specificity positive and negative predictive values. These are concordant with results of **Michaelides *et al.* [(2)].**

2- Double vessel disease:-

The highest sensitivity, specificity were noted as regards LAD + LCX with sensitivity of 61.5% and specificity of 60.5%, compared to 33.3% & 51.2%), and 50% & 55.6%. Regarding LAD + RCA and LCX + RCA respectively, which also are concordant with results **of Michaelides *et al.* [(2)].**

As regards single, double and three vessel disease, sensitivity, specificity, positive, and negative predictive values were calculated less than 60% except in case of double vessel disease with specificity of 74.1% and positive predictive value of 63.2%. The negative predictive value for three vessel diseases 94.6%, which also is concordant with results of **Michaelides *et al.* [(2)]** as they concluded 74.5% sensitivity and 67% specificity regarding double vessel disease.

1-Single vessel disease:-

A) LAD: the ability of the test to detect LAD lesion as a single vessel disease had low sensitivity and specificity (29.2% & 37.5% respectively but with high +ve predictive value 74.7 %**. Michaelides *et al.* [(2)]** also concluded low sensitivity, and positive predictive value but with specificity of 63.5%.

B) LCx: the sensitivity of the test to detect LCX lesion as a single vessel disease was 38.1%, specificity was 68.6%, but with low +ve predictive value of 42.1%, which were concordant with the results of **Michaelides *et al.* [(2)].**

C) RCA: - the sensitivity of the test to detect RCA lesion as a single vessel disease was 52%, specificity of 80.6% and +ve predictive value of 68.4%, which are concordant with the results of **Michaelides *et al.* [(2)].**

The ability of the test to diagnose single, double and three vessel diseases had low sensitivity but with high specificity of 88.2%, 69.2% and 76.9% for single, double and three vessel disease respectively. The highest positive predictive value was in case of single vessel disease (66.7%). These are concordant with the result of **Michaelides *et al.* [(2)]** but with higher specificity (93%, 90%, and 91%) for single, double and three vessel disease respectively and the highest positive predictive value was in case of single vessel disease (50%).

1-Single vessel disease:

A) LAD: the ability of the test to detect LAD lesion as a single vessel disease had low sensitivity (20.8%), high specificity (75%) and high +ve predictive value (83.3 %). These are in agreement with the results of **Michaelides *et al.* [(2)]** who reported sensitivity of 8%, high specificity of 73% and high +ve predictive value (62.5 %).

B) LCx: the ability of the test to detect LCx lesion as a single vessel disease had low sensitivity and low +ve predictive value but high specificity 71.4 %. These are in agreement with the results of other investigators **Michaelides *et al.* [(2)]** who concluded low sensitivity and low +ve predictive value but higher specificity 90.5 %

C) RCA: the ability of the test to detect RCA lesion as a single vessel disease had low sensitivity, low +ve predictive value, but high specificity 74.2 %, which are concordant with the result of **Michaelides *et al.* [(2)]** who showed low sensitivity, low +ve predictive value but higher specificity (89.5 %).

2- **Double vessel disease:** the sensitivity and the +ve predictive value were low but the specificity was 76.7% for LAD + LCx, 75.6% for LAD + RCA, and 77.8% for RCA + LCX, which are concordant with the result of **Michaelides *et al.* [(2)]** who recorded low sensitivity and low +ve predictive value but higher specificity 98 % for LAD + LCX, 88.5% for LAD +RCA, and 94.5% for RCA+LCX.

Other investigators performed studies to detect the importance of ST segment elevation in aVR during stress test regardless the changes in other leads as V1, V5, for example **Neill *et al.* [(5)]** who studied the significance of ST elevation (STE) in lead aVR during exercise. They aimed to assess the diagnostic value of STE in aVR during exercise prior to Tc^{99}-sestamibi scanning and its predictive value in identifying ischemic territory and angiographic findings. Consecutive patients for Tc^{99}-sestamibi perfusion imaging between April and August 2004 were enrolled. Their peak exercise ECGs were coded by 2 blinded investigators. STE $\geq$ 0.05 mV in lead aVR was significant. Gated perfusion imaging and angiographic findings were assessed. STE in lead aVR occurred in 25% (138/557) of patients. More patients with STE in aVR had reversible defects on imaging compared to those that had no STE in aVR (41% 56/138 vs 27% 114/419, p = 0.003). Defects indicating a left anterior descending artery (LAD) culprit lesion were more common in the STE aVR group (20% 27/138 vs 9% 39/419, p=0.001). There was a trend towards coronary artery stenosis (>70%) in a double vessel distribution involving the LAD in

those patients who had STE in aVR compared to those who did not (22% 8/37 vs 5% 4/76, p=0.06)

Logistic regression demonstrated that STE in aVR (OR 1.36 p=0.233) is not an independent predictor of inducible abnormality when adjusted for STD > 0.1mV (OR 1.7 p=0.03). However, using anterior wall defect as an endpoint STE in aVR (OR 2.77 p=0.008) remained a predictor after adjustment for STD (OR 1.4 p=0.281). They concluded that STE in aVR during exercise does not diagnose significantly more inducible abnormalities than STD alone. However, unlike STD, which is not predictive of a territory of ischemia, STE in aVR is associated with an anterior wall reversible defect. Also, they mentioned in their study that although ST segment elevation in frontal lead aVR is commonly observed during exercise, its uncertain significance means that it is usually selectively ignored [(5)].

Michaelides *et al.* [(6)] investigated the correlation of exercise induced ST segment changes in lead V1 regardless the changes in V5, or aVR with the detection of significantly narrowed vessel that induced ischemia during exercise in myocardial area supplied by this vessel. They studied 198 patients who underwent exercise testing, thalium-201 scintigraphy, and coronary angiography. The patients were divided into three groups; in group 1 (ST segment elevation in lead V1), 84% had LAD coronary artery disease ($p < 0.001$). In group 2 (ST segment depression in V1), 76% had RCA disease ($p < 0.001$). In group 3 (no ST changes in V1), there were no significant difference concerning the narrowed vessel. Thallium scintigraphy data confirmed the existence of the reversible perfusion defect(s) in an area(s) of myocardium supplied by the respective coronary artery ($p < 0.001$). Also, they concluded that exercise–induced ST segment elevation or depression in V1 may identify the obstructed vessel in patients with single–vessel disease without prior myocardial infarction. Hence, our study is in good agreement with **Michaelides *et al.*** [(7)] regarding ST elevation in V1, as in our study 75% of patients with single vessel disease who had only ST segment elevation in V1 (group C) had LAD lesion. Moreover, LAD lesions were found whether as single or multi-vessel disease in 83.9% in (group C). Also, in group A (ST elevation in aVR and ST depression in V5 + ST elevation in V1). LAD lesion was found in 100% of patients with single vessel disease, and in 96% of all cases in group A whether as single or multi-vessel disease.

Michaelides *et al.* [(6)] performed another study, their study was undertaken to investigate the ability of the exercise-induced ST depression in lead V5 and concomitant ST elevation in lead aVR for the identification of the significantly narrowed coronary artery in patients with single vessel disease. They studied 229 consecutive patients who developed the exercise-induced electrocardiographic changes. All underwent Thallium-201 scintigraphy and coronary arteriography. Patients were divided into three groups. In group A, 58 patients with ST depression in V5 and ST elevation in aVR, in group B 149 patients with ST depression in V5 without ST elevation in aVR, and in group C 22 patients with ST elevation in aVR without ST depression in V5 induced with exercise. In group A, 81% of the patients while in group B, 29% and in group C only 18% of the patients had left anterior descending artery disease. According to Thallium-201 scintigraphy, 80% of the group A, 27% of the group B and 12% of the group C patients developed myocardial ischemia in areas supplied by the left anterior descending artery. Thus, exercise-induced ST depression in V5 and concomitant ST elevation in aVR, may detect left anterior descending artery significant stenosis in patients with single vessel disease. So the results of our study are in good agreement with this study as in our study (ST elevation aVR, ST depression were found in group A & B). So, LAD was found in (group A+ B) as a single vessel disease in a percentage of 71.4%.

Indeed, the main finding of this study is that the combination of (1) exercise-induced ST-segment elevation in lead V1, and (2) the concomitant ST-segment elevation in lead aVR and ST-segment depression in lead V5, is useful as a stronger marker of ischemia in the myocardial area supplied by a significantly narrowed LAD coronary artery in comparison with each ischemic marker independently. Furthermore, the importance of this finding was investigated in patients with double-vessel disease. This inquiry revealed that patients with double-vessel disease and exercise-induced ST-segment elevation in leads V1 and aVR, as well as ST-segment depression in lead V5, are more likely to suffer from significant stenosis of the LAD and the LCx coronary arteries.

The exclusive appearance of exercise-induced ST-segment elevation in lead V1 in patients with double-vessel disease seems to be also a useful ischemic marker that correlates with LAD and LCx stenosis, although no definite conclusions can be drawn from this study because of the small patient's sample of this particular group.

It is interesting that those patients with double-vessel disease and exercise-induced concomitant ST-segment elevation in lead aVR and ST-segment depression in lead V5 without ST-segment elevation in lead V1 exhibited mostly significant LAD and RCA stenosis. This could be explained by that exercise-induced ST-depression in lead V5 in patients with RCA stenosis, which might compensate the tendency for the ST segment to elevate because of the LAD stenosis. Furthermore, the ECG finding in B (aVR-E + V5 -D) seems to be a better predictor of

double- and triple-vessel disease (63 vs. 56%, and 10 vs. 8%, respectively) than ECG finding in A (V -E + aVR-E + V -D), which could be explained by the same compensative mechanism.

CONCLUSION

(1) The concomitant appearance of exercise-induced ST-segment elevation in lead V1 and in lead aVR with simultaneous ST-segment depression in lead V5, or the isolated appearance of ST-segment elevation in lead V1 mostly detect single-vessel disease and correlate strongly with significant narrowing of the LAD coronary artery as single-vessel disease, or with significant stenosis of the LAD and LCx coronary arteries as double-vessel disease.

(2) The appearance of ST-segment elevation in lead aVR and ST-segment depression in lead V5 at the same time but without ST-segment elevation in lead V1 usually indicates double-vessel disease (LAD and RCA) and mostly detects multi-vessel disease.

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