ORIGINAL ARTICLE

Stress Testing and Coronary Artery Disease: Study of 140 Cases on Tread Mill

MM SINGH, KVS MANI, S KRISHNAMURTI

Stress testing in the detection of coronary artery disease is being done more often at present in all important medical evaluation centres. The results of 170 consecutive submaximal and maximal tread mill exercises done in 140 patients during a two year period are reported. The details of technique and procedure have been described. 37% cases showed abnormalities with ST segment depression, ventricular premature beats, incomplete RBBB and T wave changes. Interpretations and pathogenesis of various abnormalities are briefly discussed. It is concluded that submaximal tread mill stress is a fairly reliable non-invasive test in the diagnosis and assessment of coronary artery disease. Attention has also been drawn to the advantages and pitfalls of this technique.

THE natural history of coronary artery disease (CAD) demands early diagnosis to attempt secondary prevention for reducing morbidity and mortality. The early observations of ST-T changes that accompanied exercise and spontaneous episodes of angina provided impetus for applying a cardiovascular stress test and ECG recording[7]. During the last decade or so diagnosis of CAD by graded exercise testing has generated wide spread interest and practice. The electrocardiographic manifestations of exercise-induced myocardial ischaemia have been fairly well defined and generally accepted by now. The safety of stress tests has been greatly enhanced in recent years by standardised protocols and monitoring techniques. Several investigators have studied and monitored stress tests routinely in the presence of abnormal basal resting ECGs [1-4, 6-8, 11, 16-20] and in the course of early convalescent period following myocardial infarction (MI)[9].

Detection of CAD in the Armed Forces has assumed great importance. It concerns the Air Force much more so where proper evaluation of aircrew with CAD or ECG abnormality vis-a-vis flying duties and rehabilitation/follow up is of paramount significance. It has been stated that in over 20 aircraft accidents or incidents directly or indirectly attributable to the pilot, the pilot was suffering from CAD[1]. This paper presents the experience in tread mill testing done in the Institute of Aviation Medicine, IAF over a period of two years.

Material and Methods

Between February, 1978 and February, 1980, a total of 170 tread mill tests were performed on 140 referral patients. The subjects were all male, 17 to 55 years in age and from the Armed Forces. They

were grouped as in Table I in terms of reasons for tread mill evaluation :

TABLE I

Groups	No. of cases
A. ECG Abnormality	93
T wave changes	65
VPBs	5
Incomplete RBBB	5
SVPBs	5
Tachycardia (VRA)	3
Bradycardia	3
Miscellaneous (WPW syndrome, coronary sinus rhythm, low amplitude T, R more than S in V_1)	7
B. CAD (Stabilised resting and DMT ECG)	35
Symptomatic	31
Asymptomatic	4
C. Pain Chest (Atypical) Investigation	12
Total	140

All subjects were examined for any clinically detectable cardiovascular and other systemic abnormality. Routine haemogram, urinalysis and metabolic parameters including blood sugar, uric acid and cholesterol levels were determined in all cases. A chest PA skiagram of each and screening chest selectively were also carried out. All were subjected to ECG at rest and after Master's double two-step test (DMT)[14]. As and when indicated, ECG on standing, after fasting and before, during and after Valsalva manoeuvre, hyperventilation and following beta blockade were carried out. After informed consent, they were taken up on Venkey's tread mill for gradient exercise testing.

The Mason-Liker[13] system of electrode placement was followed. Continuous monitoring on oscilloscope with facility for simultaneous ECG recording was available. Prior to test, the subjects were fully briefed regarding the procedure and asked to indicate promptly any symptoms such as chest pain, dyspnoea, fatigue or profuse sweating if and as they occurred. The tread mill protocols employed in this series were the General Purpose Protocol[1] for the known CAD group and the Bruce Protocol[4] for the rest.

The end-point of the test was aimed to achieve maximal heart rate or submaximal heart rate as determined by protocol in the CAD and non-CAD group respectively. During the graded stress test each stage was punctuated by recording standing ECG from a pre-determined lead and simultaneous blood pressure measurement. Standard 12 lead ECG as well as rhythm strips were obtained as indicated. Any ectopic rhythm evident was continuously followed on oscilloscope. The stress testing was also terminated prematurely in case of (a) the subject developing symptoms of chest pain, fatigue, profuse sweating or cramps ; (b) untoward fall in systolic or rise in diastolic blood pressure ; (c) runs or salvos of ventricular premature beats (VPBs) and (d) marked and unequivocal ECG patterns of MI[1]. After cessation of the test, immediate standing and supine ECGs, in that order, and 3 min., 5 min. and 10 min. post-exercise records along with blood pressure recording every three minutes were obtained. In some instances, the evolution of the observed ST-T changes were followed up to 30 minutes. Restoration of basal heart rate, blood pressure and ECG pattern were ensured prior to returning the subject.

The following criteria were used to diagnose CAD based on tread mill stress test [1, 6, 7, 16, 17] :

a) Horizontal ST depression of 1·5 mm or more lasting for 0·06 sec or more, either during or after exercise.

b) Sloping ST depression with concave slope of more than 2 mm and progressive.

c) Inversion of U or T waves.

d) Multiple ventricular premature beats (VPBs).

e) 'J' depression of 2 mm or more.

f) Appearance of aberrant intraventricular conduction.

g) Fall of systolic blood pressure by 15 mm of Hg or increase in diastolic blood pressure by 10 mm of Hg.

Results

In 15 of the 140 subjects (10%), tread mill exercise was terminated prior to achieving maximal/ submaximal heart rate. The chief indications for abolishing the stress test were diagnostic ST depression (40%), appearance of symptoms (26·5%), fall in systolic blood pressure (13%), rise in diastolic pressure (6·5%), runs of VPBs (6·5%) and bradycardia (6·5%).

All the subjects were normotensive and free from any detectable abnormality on physical examination of the cardiovascular system except one who had a cardiac murmur. None manifested hyperglycaemia, hypercholesterolaemia or hyperuricaemia. No subject was on any cardio-active drugs at the time of the test. Aircrew formed 55% of the subjects. The age distribution is shown in Table II.

TABLE II

Age Group (years)	No. of cases
17-20	9
21-25	10
26-30	18
31-35	22
36-40	28
41-45	32
46-50	11
51-55	10
Total	140

Maximum incidence of ECG abnormalities (specific and non-specific) were observed in the age group 26 to 45 years (51%) but the majority in the CAD group belonged to the age group 30 to 55 years (25%).

Of the three major groups of cases, ECG abnormalities formed 66.5%, CAD 25% and atypical chest pain 8·5%. Fifty two cases showed abnormalities compatible with CAD when subjected to tread mill evaluation. Of these, besides the CAD group of 35 personnel, 17 subjects belonged to the other two groups presenting with ECG abnormalities or atypical chest pain. Table III consolidates the ECG changes observed during and after tread mill exercise on the total 140 cases.

TABLE III

	Stage I—VII	Post - exercise (min) 0-3	5-10	15
ST depression	12	22	17	—
VPBs	10	8	6	4
SVEB	3	3	3	2
T inversion becoming upright	2	3	3	1
T inversion	—	10	10	6
Incomplete RBBB	—	3	3	3
Increased PR interval	—	—	2	2
Tall T wave	—	3	2	1

Discussion

Various non-invasive techniques towards the diagnosis of CAD have assumed importance during the last decade. Their correlation with invasive procedures is well established. Cardiovascular stress testing is pre-eminent among them by virtue of its ease, safety, patient acceptability and wide practical applicability especially in the wake of refinement and standardisation of procedure since the early pioneering works of Gold Hammer and Scherf and later Master. When confronted with large number of cases presenting with ECG abnormalities or atypical chest pain, such a non-invasive test is warranted to identify those with ischaemic heart disease (IHD).

DMT gives few false positive results but fails to detect about 20% of patients with IHD[3]. The advantages of tread mill over this are that (a) it is a standard procedure, (b) good ECG record is obtainable during exercise, (c) the work load is designed to achieve a steady state at each level, (d) an initial warming up period leads to gradient exercise stress, (e) it is almost independent of patient's motivation and (f) it is safe for screening a large number of subjects[1]. When maximal stress and 12 lead deployment are utilised, a higher true positive results are yielded and can become a predictable index of the severity of CAD and localisation of the areas of ischaemia[3].

ST Segment Changes : A large number of ECG changes following stress manoeuvres have been described in patients with IHD but only changes in the ST segment have shown sensitivity for the disease without loss of specificity. The most sensitive and specific indicator of myocardial ischaemia has been the horizontal or down-sloping ST segment. ST depression of 1.5 mm or more reduces the chances of false positive cases to a considerable degree[12]. J point depression more than 2 mm for more than 0.08 sec is being accepted as yet another indicator of significant CAD [7].

Among the various ECG abnormalities observed in this series, ST segment depression of more than 1.5 mm was observed in the maximum number of cases. During exercise, ST segment abnormalities formed 42% of all abnormal observations; ST-T abnormalities formed 61%, 58% and 31% of all observations in the immediate, 5—10 min and 15 min post exercise periods respectively (Fig. 1). The crucial period to observe and record ST segment changes (with or without T changes) is during exercise and up to 10 min post exercise period. It is noteworthy that no case in this series showed ST segment changes 15 min after exercise whereas T wave changes were still observable after 15 min post exercise and constituted 42% of all the abnormalities in this period.

A positive stress test without prior MI increases the likelihood of CAD with multi-vessel involvement. A negative test is also helpful in excluding multi-vessel disease in patients with atypical chest pain. In patients with prior MI, positive tread mill test is indicative of multi-vessel disease [13, 19, 20].

In the present series, none showed ST segment elevation on tread mill. ST segment elevation above the isoelectric line occasionally occurs during stress test. This kind of response is usually seen in patients with severe angina and also can be expected in cases manifesting variant angina. The lead location of ST elevation correlates well with near total or total occlusive lesions of the vessel supplying the region of the myocardium involved. It may be the manifestation of more severe myocardial disease reflecting transmural rather than subendocardial ischaemia. The prognosis in such cases, therefore, may be worse as compared to those with ST depression[9].

Heart Rate Response : One case in this series showed an abnormal heart rate response in the form of a drop from 120/min to 90/min at the end of Stage III (Fig. 2). Generally, cases of CAD attained the desired heart rate at lower load of exercise compared to these cases with non-specific ECG abnormality.

The heart rate response is part of the physiological integrated cardiovascular response to exercise towards augmenting cardiac output. Initially, rapidly rising heart rate contributes to augmentation of cardiac output but at near maximal levels, the quantum of rise in heart rate decreases. The heart rate response is probably mediated through autonomic nervous system such as increase in catecholamine levels and decrease in parasympathetic activity. Mechanical factors such as distension of right atrium with increased venous return (Bainbridge reflex) may also operate. Patients with impaired cardiac function have limited ability to increase stroke volume with exercise and in fact the volume may decrease. In such situations, increment in cardiac output depends largely and heavily on rise in heart rate. Patients with significant heart disease manifest a higher heart rate to a given work load than normals. A poor prognostic

index is subnormal increase in heart rate with exercise among patients of CAD [9, 10].

Blood Pressure Response : Three cases showed abnormal blood pressure response in this series. Fall of more than 15 mm of Hg in systolic pressure was observed in two cases and a rise of over 10 mm

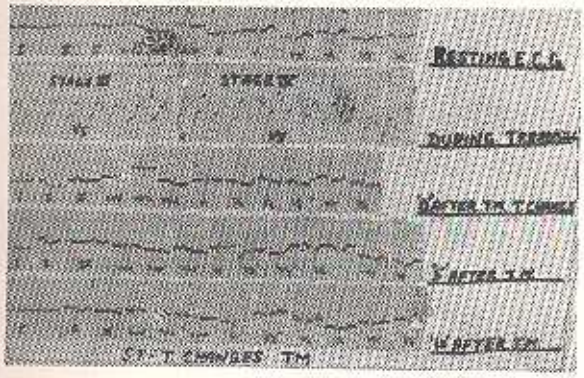

Fig. 1 — ST — T changes during tread mill exercise

Hg diastolic in one case. All three belonged to the CAD group.

Blood pressure response to graded exercise stress has been described to be significant in the detection of CAD. The behaviour of both systolic and diastolic pressures are important in this context. Decrease in the peak systolic blood pressure of 15 mm Hg or more is considered by some as highly specific for

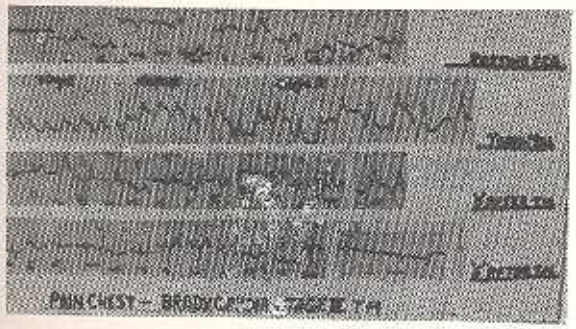

Fig. 2 — Bradycardia during stage III of tread mill test

multi-vessel coronary disease when significant valvular lesions and cardiomyopathy are absent [17]. Increase by 10 mm Hg or over of diastolic pressure on at least two determinations is considered an abnormal response to muscular isotonic exercise [16]. It may be a good indicator of CAD even in the absence of ST-T changes.

Arrhythmias : The commonest arrhythmia observed was VPBs (Fig. 3). In one case VPBs were fired in salvos and consequently tread mill stress was aborted. After 15 min post-exercise period, four out of the ten subjects still showed VPBs at a rate of 15-25 per min. Five of the ten cases were from the group of ECG abnormalities.

Fig. 3 — Ventricular and supraventricular ectopics during tread mill test

Exercise-induced ventricular ectopics occur more frequently in patients with CAD than in the normal subjects. Frequent multifocal VPBs and

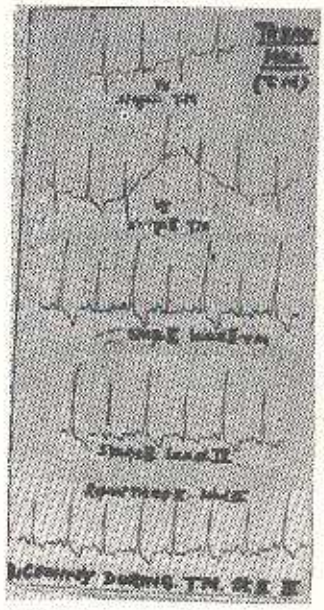

Fig. 4 — Bigeminy during stages II and III of tread mill test

ventricular tachycardia occur with greater frequency and at lower levels of work load and heart rate among patients with CAD. These do not seem to

be related either to the presence or extent of exercise-induced ST segment abnormal response. Supraventricular premature beats are induced less frequently by exercise as compared to VPBs [1,9].

Intraventricular Conduction Defects : Three cases showed incomplete RBBB in post-exercise ECG. Cases with initial diagnosis of incomplete RBBB showed no deviation or deterioration on tread mill.

Development of BBB/intraventricular conduction defect on stress testing is considered significant. They are responsible for the false negative results as they tend to mask the exercise-induced primary ST — T changes of myocardial ischaemia. RBBB, RVH and left anterior hemi-block have all in common deep S in precordial leads with T waves directed opposite. In these complexes, area of T wave is usually increased and ST segment tends to slope up steeply from the nadir of S to onset of T. These secondary ST — T changes tend to obscure or cancel the characteristic horizontal or downsloping ST segment response to stress - induced myocardial ischaemia [14].

Vasoregulatory Asthenia : Three cases manifesting tachycardia and borderline ST - T changes were also subjected to tread mill evaluation. It was seen that heart rate and ST — T changes were marked on standing whereas no significant deviation or deterioration occurred on stress testing; besides, ECG changes showed improvement following administration of propranolol.

These types of abnormalities are due to the syndrome of vasoregulatory asthenia. Propranolol usually partially or completely reverses the observed non-specific ST — T changes. This entity is an additional cause for giving rise to false positive result in stress testing [9].

Other Factors : While interpreting an abnormal ST segment response to a stress test, apart from CAD, other causes like false positivity, normal variance specially racial, cardiomyopathies, coronary artery spasm, myocarditis, cellular membrane defect, neurogenic imbalance, small vessel d and haemoglobin dysfunction are to be remem as possible causes in select situations [8]. evaluating abnormal ST segment response to testing, many other factors like maximal heart maximum systolic blood pressure, chest pa wave configuration, ST segment contour, ST changes with posture and hyperventilation and increase in the P wave negativity in V_1 are als be reckoned with [5, 15].

References

1. Balasubramaniam, V, Khanna, PK and Hoon, RS. On digital computer quantitated ST segment response to maximal tread mill exercise. J Assoc Phys Ind, 23 : 1, 1.

2. Balnave, K, Scott, ME, Marton, P and Murragh, JG. Reli production of coronary disease using tread mill exer testing. Brit Med J, 1 : 958, 1978.

3. Baron, DW, Poole, W and Ricksrgs, AF. 12 lead maxi exercise testing as a predictor of severe coronary art disease. Brit Heart J, 41 : 364, 1979.

4. Bruce, RA, and Hornston, TR. Exercise stress testing evaluation of patients with ischaemic heart disease. Pro in Cardiovasc Dis, 11 : 371, 1969.

5. Corruthers, M, et al. Electrocardiographic changes resemb ling myocardial ischaemia in asymptomatic men with norm coronary arteriograms. Brit Heart J, 41 : 214, 1979.

6. Ferlinz, J and Aronow, WS. Comprehensive approach to the diagnosis and evaluation of coronary artery disease. Appl Med, 3 : 717, 1977.

7. Forrain, NJ and Weiss, J. Exercise stress testing. Circula tion, 50 : 699, 1977.

8. Froelicher, VF. Use of the exercise electrocardiogram to identify latent coronary atherosclerotic heart disease. SAM Tr, 26 : 12, 1976.

9. Gandhi, MJ. Early post myocardial infarction tread mill exercise test. Ind Heart J, 31 : 253, 1979.

10. Holdin, W, McAnulty, Rahimtoola, SH. Characteristics of heart rate response to exercise in the sick sinus syndrome. Brit Heart J, 40 : 923, 1978.

11. Kurita, A, Chaitman, BR and Martial, GB. Significance of exercise induced functional ST depression in evaluation of coronary artery disease. Am J Cardiol, 40 : 492, 1977.

12. Martin, CM and McConsbuy, DR. Maximal tread mill exercise electrocardiography. Circulation, 46 : 986, 1972.

13. Mason, RE and Liker, I. A new system of multiple lead exercise electrocardiography. Am Heart J, 71 : 196, 1966.

14. Master, AM and Rosenfeltd. Criteria for the application of the "Two Step" exercise test. JAMA, 179 : 283, 1961.

15. Myrvin, H, Ellestad, S, David, B and James, T. False positive stress test. Am J Cardiol, 40 : 681, 1977.

16. Sheps, DS, Ernst, JC, Driese, FW and Myeberg, RJ. Exercise induced increase in diastolic pressure as indicator of severe coronary artery disease. Am J Cardiol, 43 : 708, 1979.

17. Stephen, N, Massis, J, Phillips, F, Jordan, JW and McHenry, PL. Incidence and significance of decrease in systolic blood pressure during graded tread mill exercise testing. Am J Cardiol, 44 : 221, 1978.

18. Surawicz, B and Saito, S. Exercise testing for detection of myocardial ischaemia in patients with abnormal electrocardiograms at rest. Am J Cardiol, 41 : 943, 1978.

19. Thomas, GB, Philip, JP and Bernard, LD. The reproducibility of profound ST segment depression to maximal exercise tread mill testing. Am J Cardiol, 39 : 288,1977.

20. Thomas, JR, Mary, JG, Kennedy, JW, Michael, S and Felix, T. Maximal exercise testing of coronary disease in 2617 males. Am J Cardiol, 41 : 736, 1978.