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Exercise under Hypoxia : A Stress Test for Evaluation of Cases with Ischaemic Heart Disease for Rehabilitation

M AKHTAR
PC CHATTERJEE

One hundred and eighty seven subjects with stabilised ischaemic heart disease and myocardial infarclion were subjected to exercise under hypoxic environment in their final phase of rehabilitation They had been asymptomatic, free of complications and had shown 'normal' response during Master double two step exercise and submaximal to maximal treadmill exercise. The hypoxic stress test consisting of Double Master Two Step exercise at a simulating altitude of 15,000 ft (4592 metre) showed positivity in 22.99% case. None had any untoward effect. Those who were cleared have been employed in strenuous duties including posting to mountainous terrains, followed up for 1 year to over 5 yrs. and have not shown deterioration. It can be postulated that 'Hypoxic Stress Test' used as a screening test prior to rehabilitation at high altitude is a safe. sensitive and reliable technique of investigation in addition to the currently available stress test and should be carried out in those likely to be employed at high altitude.

PATIENTS with stabilised ischaemic heart disease and myocardial infarction requiring ultimate rehabilitation at high altitude locales temporarily or permanently need assessment by tests simulating high altitude problems. Exposure to and exercise in air with diminished partial presence of oxygen inside decompression chambers have been variously used for this purpose [1,2,7,10]. We have employed this stress test for final evaluation of 187 patients with myocardial infarction before clearing them for duties in mountainous terrains and present our experiences here.

Material and Methods

Subjects for this study were selected from a large group of patients with ischaemic heart disease undergoing the rehabilitation schedule at our centre[1] These cases had suffered from electrocardiographically proved myocardial infarction at least 18 to 24 months back. They had been treated with

specific drugs, dietetic restriction, correction of risk factors and graded exertions, followed up at six monthly intervals, and were rendered asymptomatic and free of complications. Their resting electrocardiograms were stabilised and did not show any deterioration after Double Master two step exercise (DMT). Relevant biochemical and radiological investigations also had been normal. At the time of consideration for clearance to grade I state of rehabilitation and prior to subjecting to treadmill exercise and hypoxic stress test, all specific drugs were discontinued. None had hypertension or any other factors known to produce false positive results in stress tests.

Each patient was subjected to graded multistage submaximal to maximal treadmill exercise[3] with on-line computer analysis of ST displacement and heart rate. Bipolar lead system (CM5) was used for on-line electrocardiographic recording. A modified Balk Ware protocol was followed during treadmill exercise[3]. Horizontal or downsloping ST depression of 1 mm or more, slow upsloping ST depression of 1.5 mm or more and ST elevation of 1 mm or more, measured by the computer at a point 65 milliseconds after the end of preceding 'R' wave were considered positive during the treadmill exercise[1].

Patients showing no significant abnormality during or after the sub-maximal to maximal treadmill exercise (all the 187 subjects included in this study) were then evaluated by non-invasive techniques like transthoracic electrical impedance, systolic time interval studies, echocardiography and ambulatory monitoring whenever necessary and had shown no significant abnormality. They were, then subjected to the dual stress of hypoxia and Double Master two step exercise ("Hypoxic Stress Test"-DMTH). The DMTH was carried out in a decompression chamber (Institute of Aviation Medicine, Bangalore) at a simulated altitude of 15,000 ft (4592 metres)[1]. Written informed consent was taken from all subjects before the test. One or two subjects at a time were evaluated, a trained personnel accompanying them inside the chamber for recording respiration rate, blood pressure and electrocardiogram. A physician and a specialist in Aviation Medicine stood by or any emergency. The subjects were taken upto the simulated altitude of 15,000 ft at 3,000 ft per minute and kept there for 45 minutes without any additional oxygen ('hypoxic environment'). 12 lead ECG was repeated and then DMT exercise was given to the subjects. Conventional 45 lead application[11] during the exercise and post exercise ECG was recorded at, immediately after, 5 minutes and 10 minutes after exercise in the following order-V4, V5, V6, V1, V2, V3, aVL, aVF, aVR, I, II and III. The subjects were then brought down at 2,000 ft per minute and examined in detail to exclude any complications following exposure to decompression.

Electrocardiograms were analysed and compared with the DMT graphs recorded at ground level. Horizontal or downsloping ST depression of 0.5 mm or more for at least 80 millisecond after the 'J' point was considered positive following Double Master two step exercise at ground level and under hypoxia[4]. Patients who had no abnormality following the DMTH test were cleared to the highest grade of rehabilitation and often posted to high altitude terrains. They have been followed up regularly at yearly intervals to exclude deterioration of clinical and electrocardiographic status.

Observations

187 male service personnel with mean age of 44.32 ± 6.85 years were included in this study. None of the subjects had any clinical abnormality or complication. Relevant biochemical parameters were normal in all. Resting ECG's showed stabilised old myocardial infarction/insufficiency patterns. None had any abnormality during Double Master two step exercise at ground level. Treadmill exercise could be completed upto 100% (maximal) heart rate in 65 subjects, upto 95% heart rate in 47 subjects, 90% heart rate in 33 subjects and 85% (submaximal) in 42 subjects (Table I). Out of the 122 subjects who could not reach upto maximal heart rate, 84 subjects had extreme fatigue, 31 subjects had cramps in the calf muscles, 4 subjects had giddiness requiring termination of the test and in 3 electrical disturbances at the peak resulted in dis-

Table - I

Observations during Treadmill Exercise

(at ground level)

Grade of exercise	Number of cases	Mean basal heart rate/ min	Mean peak heart rate per min	Mean ST depre- ssion (mm)	Mean duration of exercise (min)	Cause of termination of test			
						Extreme fatigue	Leg cramps	Giddiness	Others
100%	65	68.14 ±4.25	189.23 ±4.14	—0.56 ±0.21	17.36 ± 2.13	—	—	—	—
95%	47	66.21 ±3.28	174.18 ±5.23	—0.81 ±0.16	15.31 ±3.26	28	17	1	1
90%	33	70.04 ±2.16	168.39 ±6.84	—0.71 ±0.22	14.18 ±2.88	24	5	2	2
85%	42	69.84 ±3.56	159.11 ±4.23	—0.79 ±0.13	12.32 ±1.86	32	9	1	—

Table - II

Comparative study of various parameters before and after DMT at ground level and under hypoxia

Parameters	Mean value with SEM ground level	Mean value with SEM under hypoxia	Significance (P value)
1. Resting heart rate/min	68 42 ± 6.84	85.52 ± 3.79	>0.001
2. Resting Resp rate/min	16.14 ± 1.80	17.64 ± 1.33	<0.05
3. Resting systolic Blood Pressure	136.46 ± 6.85	139.32 ± 5.21	<0.05
4. Resting diastolic Blood Pressure	84.13 ± 3.81	83.49 ± 2.86	<0.05
5. Peak heart rate/min after DMT.	98.14 ± 4.31	118.32 ± 6.45	>0.001

continuation of the exercise. None showed abnormal ST segement depression or significant arrhythmia. None had any complaints during exposure to hypoxia under hypoxic environment. Their mean respiratory and exercise rate and mean blood pressure did not show any significant change under hypoxia as compared to therespective mean values recorded at ground level Table (II).

Analysis of resting ECG at ground level and under hypoxia :

The mean heart rates at ground level and under hypoxia were 68.42 ± 6.84 per minute and 86.52 ± 3.79 per minute respectively, the increase being statistically significant (P = < 0.001). 15 subjects (8.02%) showed multiple supraventricular ectopics and 5 subjects (2.67%) showed multiple unifocal ventricular ectopics during exposure to hypaxia whereas none had any at ground level. The mean QRS axis in the forntal plane was 54.8 ± 8.25° at ground level and 65.2 ± 5.84° under hypoxia-an approximate mean shift of 10.4° to the right. Increase in the height of 'r' in v1 by more than 50% was recorded in 35 cases (18.71%). Upright T waves in V1 seen in 84 cases at ground level were found to be inverted in 23(27.38%) whereas inverted T waves in V1 seen in 103 cases werefound to further deepen by more than 50% in 47 cases (45.83%) under hypoxia. T waves in V5,V6 were flattened in 11 cases (5.88%) and inverted in 5 cases (2.67%) under hypoxia. There was no significant ST depression recorded under resting hypoxia.

Analysis of ECG after Double Master two step exercise at ground level and under hypoxia :

The mean heart rates immediately after DMT exercise at ground level and under hypoxia were 98.14 ± 4.31 per minute and 118.32 ± 6.45 per minute respectively, the difference being statistically significant (P = > 0.001). (The mean peak heart rate and mean peak ST depression during treadmill exercise were 167.32 ± 4.81 per minute and 0.72 ± 0.14 mm respectively). 12 cases (6.41%) showed persistence of premature beats (9 supraventricular and 3 ventricular) during the DMTH test, whereas no arrhythmia was recorded during either DMT at ground level or sub-maximal to maximal treadmill exercise. Significant ST depression (more than 0.5 mm) was recorded in 43 cases (22.99%) 33 of them horizontal and 10 downsloping in nature—fo lowing DMT exercise under hypoxia in contrast to none recorded after DMT at ground level (Table III).

Patients who showed no significant abnormality after DMTH have been cleared to highest grade of rehabilitation (Table—IV) and followed up for 6 months to more than 5 years including tenures in mountainous terrains — none have shown any clinical or electrocardiographic deterioration.

Table - III

ST segment depression during stress tests

ST segment depression (mm)	DMT at ground level	Treadmill exercise	DMT under hypoxia
<0.5	187 (100%)	31 (16.57%)	144 (77.01%)
0.5—1	— —	107 (57.22%)	15 (8.32%)
> 1	— —	49* (26.21%)	28 (14.97)

*Slow upsloping ST depression (within normal limits).

Table - IV

Grades of Rehabilitation

Grades	Equivalent Medical Category			
	ARMY	NAVY	AIRFORCE	
			Ground duties	Pilots
I	P1	S1 A1	A4 G1 A4 G2	A1 G1 A2 G1 A2 G2
II	P2	S2 A2 S2 A1 S1 A2	A4 G3	A2 G3 A3 G1 A3 G2 A3 G3
III	P3	S3 A3 S3 A1 S3 A2	A4 G4 A4 G5	A4 G5

Discussion

A programme for rehabilitation of patients with Ischaemic heart disease and myocardial infarction should aim at returning the patients to their original duties as far as possible. The programme schedule, therefore may vary from centre to centre evaluating groups of subjects engaged in different types of jobs. The patients in the Armed Forces are evaluated by us with a view to achieving optimum cardio-vascular and physical fitness so as to be able to work under adverse conditions, in wars and emergencies and at high altitude. In addition to treatment with specific drugs, dietic restrictions, control of risk factors and graded exercises, these subjects are periodically evaluated with various non-invasive tests to assess the grade of proficiency achieved.[4] Finally, they are subjected to hypoxic stress test in vew of the specific service requirement—to serve under hypoxic environment in the mountainous terrains, and in case of aviators—to fly sophisticated aitcraft requiring split—second decision tor success and survival. Exercise under hypoxia has been shown to be a safe procedure.[3, 7, 7, 10] Acute exposure to hypoxia ("rapid induction") produces sinus tachycardia, shift of QRS frontal axis to the right and ST-T changes in the right ventricular leads suggestive of right ventricular preponderance (overload) pattern even in normal individuals; these observations have been variously explained as end result of hyperventilation, lower position of diaphragm and acute pulmonary congestion.[5, 8, 9, 11, 12] ST-T charges in the left ventricular leads under hypoxia on the otherhand are apparently due to latent ischaemic heart disease.[5, 6] The electrocardiographic evidences of right ventricular preponderance recorded in this study are similar to our earlier observations.[5] The interesting finding noted this time by us, however, is the ischaemic ST depression in left ventricular leads in 22.99% cases exercised (DMT) under hypoxia, all ot whom had earlier shown 'normal' response to Double Master two step exercise and submaximal to maximal treadmill exercise at ground level. This statistically significant percentage of positivity highlights the usefulness of hypoxia stress test as a reliable method for evaluation of ischaemic heart disease in addition to various other stress test techniques available in our country. Subjects cleared by this evaluation have

been working in various strenuous Armed Forces employments for periods ranging from one year to over five years including postings to mountainous terrains but none have so far any clinical or electrocardiographic deterioration. We, therefore, feel that evaluation by exercise under hypoxia is a safe, reliable and justifiable screening test for cases with stabilised ischaemic heart disease required to be rehabilitated at high altitude.

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