Comparative Study of Hypoxia and other non-invasive Stress Tests for Evaluation of Ischaemic Heart Disease

Sqn Ldr M Akhtar*, Lt Col BK Das†, Wg Cdr PC Chatterjee‡ and Lt Gen JC Chatterji§

Abstarct

167 cases subjected to Master double two step exercise under hypoxia are analysed and the electrocardiograms are compared with the records of their submaximal and maximal treadmill exercise. Though their electrocardiograms during the treadmill exercise and other non-invasive tests were normal, 6% cases showed positive findings at rest under hypoxia and 21.6% had positivity after exercise under hypoxia. A large number (11%), had non specific S-T changes under dual stress of hypoxia and exercise and require further follow up. 8% of ECG abnormality and 16.2% of vaso-regulatory abnormality so diagnosed by the various non-invasive stress tests were confirmed to have ischaemic heart disease by the combined stress of hypoxia and exercise. Thus the importance of hypoxia and indeed, a double stress of hypoxia and exercise is emphasized especially in relation to diagnosis and rehabilitation of cases of ischaemic heart disease in the Armed Forces.

Introduction

Evaluation of electrocardiographic abnormalities in the Armed Forces poses a special and serious problem ; the personnel evaluated 'fit' have to work under adverse conditions at high altitudes, during war and emergencies. The aircrew once cleared have to be in-charge of sophisticated modern aircraft where split-second decisions are required to avoid accidents. We therefore take great care to arrive at a decision, and to ensure that diagnosis and disposal are as far as possible correct and foolproof. We employ multiple stress tests like submaximal and maximal treadmill exercise, impedance cardiography, systolic time interval estimations and echocardiography.[1-7] In view of the peculiar requirement of the Armed Forces – the personnel having to work under chronic hypoxia at high altitudes – we subject our patients to the " hypoxic stress test."[11] The results of the hypoxic stress tests as compared to the other non-invasive stress tests are presented in this paper.

Materials and Methods

All cases of ischaemic heart disease with myocardial infarction and ECG abnormalities in the Armed Forces are referred to the Chief Consultant in Medicine for final evaluation and upgrading to category P1 or its equivalent. These cases are admitted to Army Hospital, Delhi Cantt. and are subjected to the following routine :

1. Recording of detailed case history.
2. Clinical examination including detailed evaluation of cardiovascular system done by a cardiologist.
3. Evaluation of biochemical parameters like blood urea, uric acid, cholesterol, free fatty acid, total fats and GTT.
4. Radiological evaluation of shape and size of heart by X-ray and screening heart.

* Classified Specialist in Medicine and DG AFMS Research Pool Officer, Army Hospital, New Delhi - 110 010.

† Classified Specialist in Medicine and Cardiology, Army Hospital, New Delhi - 110 010.

‡ Classified Specialist in Aviation Medicine and Officer in Charge Department of High Altitude Physiology, Institute of Aviation Medicine, Bangalore - 560 017.

§ Chief Consultant in Medicine, to the Indian Armed Forces, Office of the DG AFMS, New Delhi - 110 001.

5. Fourteen lead electrocardiographic recording, and comparison with the available past records.

6. Master double two step exercise[12] in those cases of ischaemic heart disease who are asymptomatic, free of complications and show stabilised resting electrocardiographic pattern. All cases of asymptomatic non-specific ECG abnormalities are subjected to Master double two step exercise.

7. All cases are subjected to graded multistage treadmill exercise. Those who show positive electrocardiographic changes during the treadmill exercise are not upgraded and are followed up further.

8. Those cases who show doubtful findings of ST, T wave during the treadmill exercise, are further evaluated with the following non-invasive techniques.

   (*a*) Study of Systolic Time Intervals (STI) before and after Master double two step exercise with the help of phonocardiography, electrocardiography (lead II), indirect carotid pulse tracing and apex cardiography recorded simultaneously in multichannel recorder.

   (*d*) Transthoracic Electrical Impedance (TEI) recordings before and after exercise to assess stroke volume, cardiac output, cardiac index and to evaluate the left ventricular function in response to exercise.[2]

   (*c*) Patient activated 24 hour ambulatory monitoring in doubtful cases of ECG abnormality to record continuous electrocardiogram during various periods of stress and strain in the day to day life.[6]

   (*d*) Echocardiographic studies to evaluate the left ventricular function, chamber size and valve competence in cases with systolic murmurs and borderline electrocardiographic changes.

9. Those cases who have no complaints, no complications and who show normal biochemical, radiological parameters and have no abnormality in any of the non-invasive stress tests are considered suitable for upgrading to category P1 after a follow up for approximately two years.

The hypoxic chamber test is carried out in the decompression chamber at Institute of Aviation Medicine, Bangalore. The subjects are explained the procedure and shown around the chamber to allay anxiety and apprehension. Electrode—application is done according to the Mason-Liker system — taking care to make adequate contact with proper cleaning. A resting electrocardiogram is recorded at ground level. The subject is accompanied in the chamber by a trained technician for electrocardiographic lead adjustments and other requirements. The subject is then taken to a simulated height of 15,000 ft at the rate of 3,000 ft per minute. He is kept at 15,000 ft for 45 minutes without any additional oxygen. Resting ECG (14 lead) is recorded at 15,000 ft and then the subject is given Master[12] double two step exercise; and electrocardiograms in the usual order are recorded, immediately after, 5, 10 and 15 minutes after the exercise. The subject is then brought down to ground level at the rate of 2,000 ft per minute. He is examined by the Aviation Medicine Specialist as well as the physician to rule out any untoward effect of exposure to decompression.

Cases with the diagnosis of Vasoregulatory abnormality are subjected to repeat test after administration of propranolol 10 mg *tid* for three days.

The electrocardiograms are analysed and compared with the ground level records.

The diagnostic criteria for the stress tests followed are as follows[4]:

1. Absolute diagnostic criteria for ischaemic heart disease.

   (*a*) For Master double two step exercise both at ground level and under hypoxia.
   ST segment depression of 0.5 mm or more, sagging or horizontal in nature for at least 0.08 seconds after the 'J' point.

   (*b*) For treadmill stress tests.

   The ST segment displacement during treadmill exercise is read by the ST segment computer at a point 0.06 seconds after the end of preceeding 'R' wave. The diagnostic criteria are as follows:

   (*i*) Horizontal or downsloping ST depression of 1.0 mm or more.

(ii) Slow upsloping ST depression of 1.5 mm or more.

(iii) ST elevation of 1.0 mm or more.

2. Relatively doubtful criteria which require further evaluation and follow up before excluding ischaemic heart disease.

(a) 'J' point ST segment depression.

(b) Post exercise 'T' wave inversion.

(c) supraventricular or ventricular extra systoles coming in multiple numbers or bigeminy.

(d) Vague precordial discomfort during the test without associated electrocardiographic changes.

(e) Significant fall of blood pressure during exercise.

Results

During the period of six years from 1973 to 1978, 2174 stress tests have been done consisting of 1714 treadmill and 460 bicycle ergometer studies. Total Armed Forces personnel studied so far are 522, consisting of 301 Army, 24 Navy and 197 Air Force subjects. 356 cases have been diagnosed to have ischaemic heart disease, 74 cases vasoregulatory abnormality, 14 cases Wolff Parkinson White syndrome and 78 cases of non-specific ECG abnormality.

167 of these patients have been evaluated with hypoxia stress test during this period. All were males. Their age varied between 24 years to 52 years, mean age being 41.2 years and majority lying between 4th and 5th decades (Table I). 106 cases were from Army, 7 from Navy, 51 from Air Force, and 3 cases were civil pilots. Among the Armed Forces personnel 106 were officers and 58 were JCOs and other ranks (Table 2).

Table 1

Age distribution of hypoxia cases

Cases	21-30 yrs	31-40 yrs	41-50 yrs	51-60 yrs
Negative (131) (78.4%)	18	54	49	10
Postive (36) (21.6%)	2	7	18	9
Total	20	61	67	19

Table 2

Rank distribution of hypoxia cases

Cases		Army		Navy		Air Force		Civil Pilots
		Offrs	JCOs/OR	Offrs	JCOs/OR	Offrs	JCOs/OR	
Negative	131	45	41	5	2	31	6	1
Positive	36	15	5	—	—	10	4	2
Total	167	60	46	5	2	41	10	3
		106		7		51		

TABLE 3

Diagnosis of Hypoxia cases

Cases		Ischaemic Heart Disease			ECG Abnormality			
		Old myocardial infarction	Old coronary insufficiency	Unclassified IHD	Non specific	VRA	WPW	RBBB
Negative	131	13	8	62	25	18	3	2
Positive	36	10	3	18	2	3	—	—
TOTAL	167	23	11	80	27	21	3	2
			114			53		

None of these 167 cases had any complaints. Clinical examination in all was normal, there being no cardiovascular complications in any of the cases. Their biochemical and radiological parameters were normal. Electrocardiographic analysis and survey of old documents revealed the following diagnoses. 114 cases (68.2%) had ischaemic heart disease, comprising of 23 cases of old healed myocardial infarction, 11 cases of coronary insufficiency and 80 cases of ischaemic heart disease diagnosed electrocardiographically. 53 cases (31.8%) had non-specific ECG abnormality which included 21 cases of vasoregulatory abnormality and 2 cases of right bundle branch block (Table 3).

Master double two step exercise did not show any deterioration in the ST-T segments in post exercise records as compared to the resting graph. Treadmill exercises also were within normal limits in all of them.

During the hypoxia stress test none of the cases had any untoward side effects or complications.

Analysis of electrocardiograms at rest at ground level and at 15,000 ft after exposure to hypoxia for 45 minutes revealed the following:

1. Rate and Rhythm: 107 cases showed increase of heart rate by 10–30 beats per minute. 53 cases showed no change and 7 cases showed decrease in heart rate as compared to the ground level record. Multiple ventricular ectopics were seen in 3 cases (Figure 1) and supraventricular ectopics were seen in 9 cases (Figure 2).

2. QRS frontal axis: 24 cases (14.4%) showed shift of frontal axis of QRS to the right by 20° to 30°, none showing abnormal right axis devia-

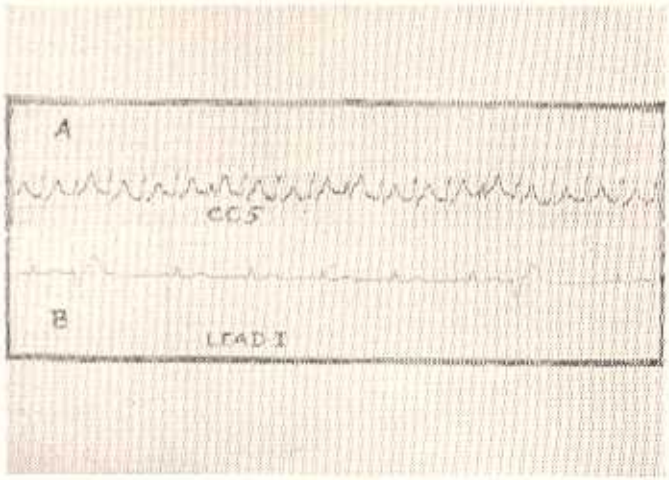

Fig. 1

The lead I recorded during hypoxia (B) of a case shows two unifocal ventricular extrasystoles. The CCS record (A) during treadmill of the same case did not show any arrhythmia.

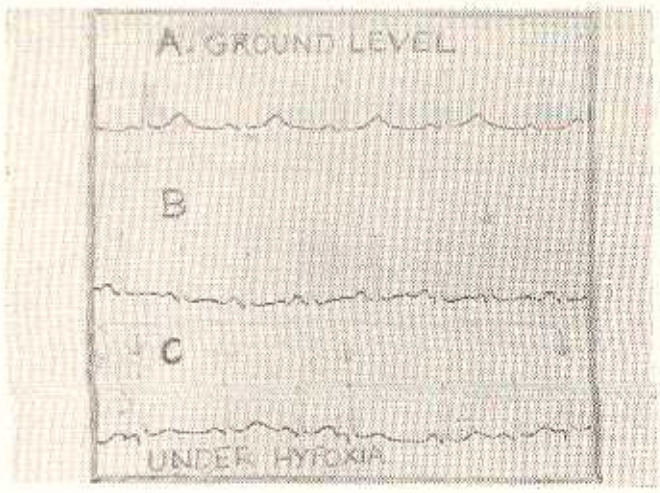

Fig. 2

ECG (Lead II) recorded at ground level (A) shows sinus rhythm but the graphs (B) and (C) recorded under hypoxia show multipule supraventricular ectopic beats.

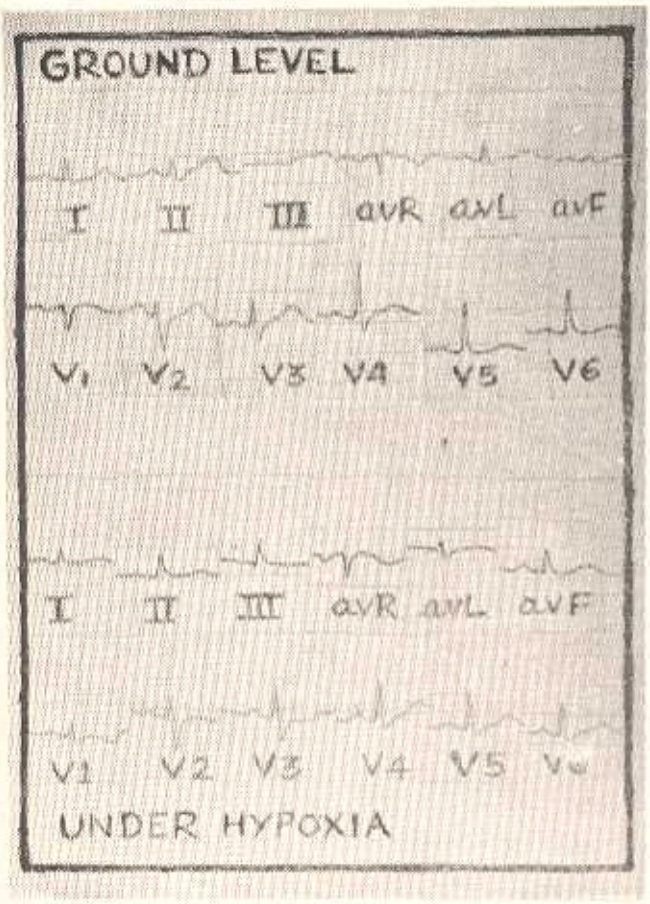

Fig. 3

The ground level record of a case is compared with the record under hypoxia. Note the configuration of V_1, V_2 and V_3 with prominent R waves and ST-T changes suggesting right ventricular strain pattern.

tion. 10 of these cases also showed clockwise rotation of the heart and tall 'R' in V1, with ST-T changes following exposure to hypoxia (Figure 3).

3. T Wave : T wave changes in the right ventricular leads were seen in 78 cases where the height of T wave was found to be decreased by more than 50%, 33 of these showing T inversions (Figure 3).

4. ST segment : ST segment depression in leads V4, V5, V6 were seen in 10 cases, four of which in addition had flattened/biphasic T waves (Figure 4).

Electrocardiographic analysis of the Master double two step exercise under hypoxia revealed ST-T abnormality of significance in 36 cases (21.6%) out of the total of 167. Twenty of these were from Army, 11 from Air Force and 2 were civil pilots. Their diagnosis was ischaemic heart disease in 31 and ECG abnormality in 5 cases. The abnormalities detected were ST segment depression (Figure 5) in 35 cases and ST elevation in one case. T wave inversion after exercise under hypoxia was recorded in 35 cases, 12 of these having ST depression in addition are included as abnormals in the total of 36. Of the remaining 23 cases, 18 showed isolated T inversion in one of the inferior leads II, III, aVF and 5 in the left ventricular leads I, aVL or V6, these cases have not been labelled as positive and are still under follow up and further evaluation. ST depression seen in 35 cases, consisted of 25 cases with horizontal or sagging depression of more than 0.5 mm and 11 cases with downsloping ST displacement alongwith T inversions. ST depression (J point) with normal shape of more than 1.0 mm was seen in additional 13 cases along with sinus tachy-

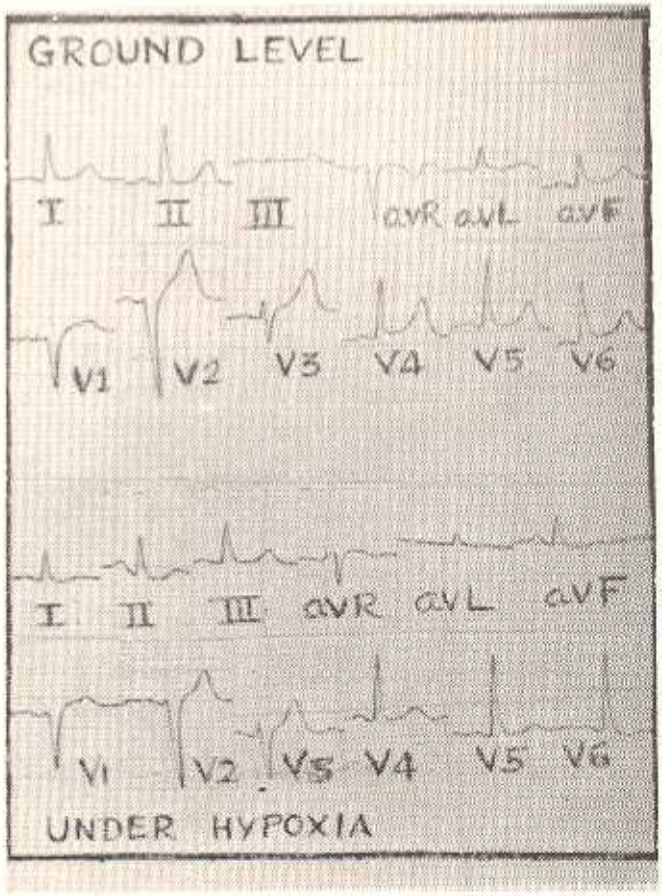

Fig. 4

The electrocardiogram under hypoxia of a case shows significant ST-T changes in V_4, V_5, V_6 as compared to the ground level record.

cardia. These cases are also under follow up and further disposal.

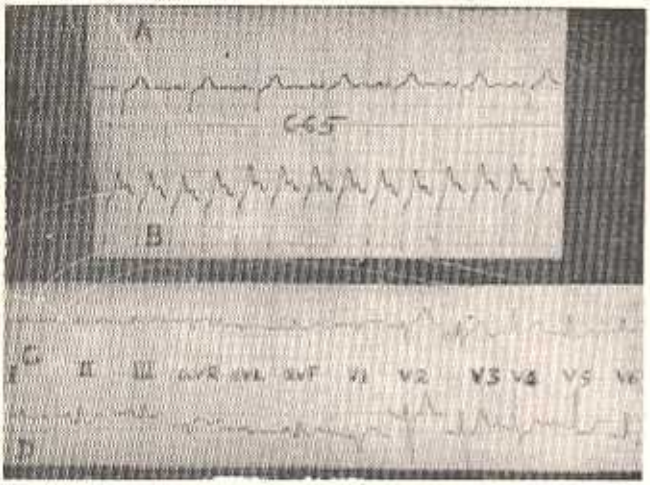

Fig. 5

The CC5 recording during treadmill exercise (strips A and B) show a heart rate of 80/mt at rest and 168/mt with ST depression of −0.3 mm at the peak of exercise. The treadmill exercise is within normal limits. However the same subject when subjected to DMT under hypoxia showed marked "Ischaemic" ST depressions in V_4, V_5, V_6 (record D). Record C is the ground level 12 lead ECG record prior to exposure to Hypoxia and is inserted for comparison.

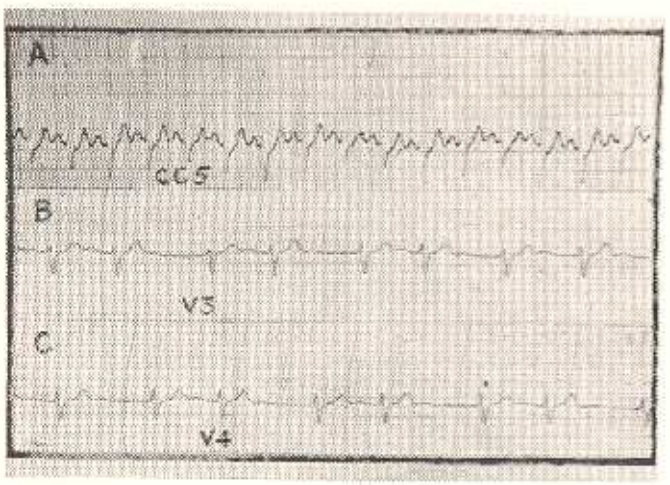

Fig. 6

Graph (A) of a case shows CC5 recording during peak treadmill exercise. The rhythm is regular and there is no significant ST depression. Graph (B) and (C) of the same subject under hypoxia shows the evidence of a 2nd degree A-V block (Wenchebach Phenemenon).

Arrhythmias recorded were (1) multiple supraventricular ectopics in 3 cases (2) multiple unifocal ventricular ectopics in one case and (3) 2nd degree heart block with Wenckebach's phenomenon (Figure 6) in one case. These cases are also under follow up and further evaluation.

Repeat hypoxia test with administration of Propranolol 40 mg *tid* for 3 days was done in 21 cases of vasoregulatory abnormality. 18 showed normalisation of the ST-T changes recorded prior to administration of the drug, and hence their original diagnoses were retained. Three cases who persisted with the positive ST-T findings even after administration of Propranolol were grouped among positive cases and their diagnosis was changed to ischaemic heart disease.

Among the ECG abnormality group, cases with WPW syndrome and right bundle branch block did not show any significant ST-T depression during the Master double two step exercise under hypoxia, excluding the possibility of ischaemic heart disease in them. However, these cases are still under follow up. Two cases from the non-specific ECG abnormality group showed significant ST depression and here were diagonsed as inchaemic heart disease.

Discussion

Chronic hypoxia is known to be beneficial to the ischaemic heart as it results in improvement of coronary circulation by various ways.[3,9] But the initial exposure to hypoxia — "Acute hypoxia" — is known for its catastrophic effect on cardiovascular system. Increase in heart rate, supraventricular ectopics, shift of QRS frontal axis to the right with clockwise rotation of heart, tall R in V1, V2 and ST-T changes in right ventricular precordial leads, suggesting acute right ventricular strain, are the main findings recorded prior to the cardiopulmonary problems [1,10] associated with high altitude pulmonary oedema. ST-T changes found in the left ventricular leads under exposure to hypoxia denote subclinical ischaemic heart disease.[1]

Exercise under hypoxia provides dual stress and is likely to bring out ischaemic changes than exercise alone.[8,11] In our experience of 167 cases of ischaemic heart disease who were found to have 'normal' treadmill test and then subjected to hypoxia, this observation has been amply confirmed. Analysis of resting electrocardiogram under hypoxia showed

shift of QRS axis to the right in 14.4% cases, acute right ventricular strain pattern in 6% cases and T wave changes in right ventricular leads in as much as 47% cases. Though only 6% showed ischaemic changes under the stress of hypoxia at rest, when Master double two step exercise was added to it, 21.6% cases were found to be positive. Thus hypoxia alone had brought out 6% positivity from among all who had normal treadmill stress test. When combined with exercise both these stresses have shown 21.6% positivity. This amply emphasizes the importance of this dual stress test in the evaluation of ischaemic heart disease.

It is worthwhile to impress that we have observed strict criteria of ST segment depression as accepted internationally for positive diagnosis. It would be seen that further to this, an additional 14% have shown non-specific ST-T changes under this combined stress.

16.2% cases of vasoregulatory abnormality, and 8% of non specific ECG abnormality – so diagnosed by the various non-invasive stress tests including maximal treadmill exercise – did show ischaemic pattern of ST-T changes, not corrected by propranolol administration, in the former group when subjected to exercise under hypoxia.

It will be seen that cases of ischaemic heart disease formed a majority (68.3%) of the cases subjected to hypoxia. This group was evaluated for rehabilitation. Thus in addition to the diagnostic value of hypoxia test, we in the Armed Forces make use of this for rehabilitation of ischaemic heart disease which of late has gained tremendous significance in the management of coronary artery disease.[5]

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