AVIATION MEDICINE VOLUME 28 NUMBER 2 1984

Medical Evaluation of Cosmonauts : Cardio Vascular Assessment

VM ALURKAR

A high level of functional efficiency of the cardiovascular system is essential for space flight. The considerable increase in G forces during launching, the weightlessness during orbital flight and the physiological readjustments during re-entry are the main stresses affecting the cardiovascular system. Hence in its evaluation,special emphasis is laid on ruling out any underlying heart disease, by a thorough clinical, biochemical, radiological and electrocardiographic examination. ECG at rest and on stress testing are specially useful. Echocardiographic examination has been extremely useful in the diagnosis of IHSS, MVP and bicuspid aortic valve which could have been undetected earlier.

Introduction

Man's conquest of space, at one time considered an impossible dream, became a reality in 1961 when Yuri Gagarin became the first human in space. Less than a decade later in 1969, man first set foot on the Moon. This has been followed by spectacular achievements in space exploration during the last decade.

These exciting feats have been possible not only through tremendous technological advances, but they have also demonstrated man's inherent adaptability and his ability with adequate training to withstand prolonged exposure to adverse stresses such as encountered in space flight. This however demands careful pre-selection of candidates suitable for Space flight, as a high level of functional efficiency of various organ systems is required. The cardiovascular system is one of the vital organ systems whose integrity is paramount, and a healthy cardiovascular system is a pre-requisite for exposure to the type of stresses met within space flight.

The succeeding paragraphs will outline the evaluation and assessment of the cardiovascular system and the requirements for a successful candidate for Space flight.

Adverse stresses during Space flight

There are many problems related to the physi-

Wg Cdr VM Alurkar, MD, DM Classified Specialist (Medicine) and Cardiologist, Command Hospital Air Force Bangalore.

logy of the cardiovascular systems which have direct effects on the functioning of the circulatory system.

During launching

A considerable amount of anxiety is expected, which will augment the sympathetic phase of neurogenic control of the circulatory system. As the thrust is built up, a large G force is applied on the subject, with peaks as high as 8-10 G. Cardiac acceleration will be increased, with some impairment of respiration.

At the end of the first stage of flight, G force is markedly diminished for a short period, thus allowing a vagotonic rebound phenomenon and bradycardia to occur.

Prior to reaching orbital velocity, two more stages of exposure to relatively large G loads are expected.

During Space Flight

The environment in outer space is characterised by relative weightlessness owing to the relative absence of gravitational force. This causes redistribution of blood volume which, in susceptible individuals, may cause excessive stimulation of the carotid sinus with significant alteration in cardiovascular reflex mechanisms. This produces bradycardia which may be marked.

In extended space flight prolonged confinement and relative immobility are expected through deconditioning to adversely influence the cardivascular reflexes which protect against G stresses. Orthostatic tolerance is altered.

During Re-entry

The cardiovascular system has to readjust to gravitational forces from a weightless state. Other influences affecting the cardiovascular system and which have been tackled to a large extent include thermal variation and hypoxia.

Much experience has been gained from detailed medical post-flight evaluation of various space programmes such as the Apollo and Skylab missions. For example, stress tests conducted on Apollo astronauts on their return to earth showed reduced exercise tolerance characterised by pronounced tachycardia and decreased stroke volume. These effects were transitory. The Skylab astronauts demonstrated reduced cardiac output post-flight and the alterations lasted a longer time.

These findings re-emphasise the need for a detailed evaluation of candidates for cosmonaut training and rejection of individuals with cardiovascular problems.

Evaluation

Cardiovascular system evaluation for Space flight must include :-

(i) Detailed clinical examination
(ii) Biochemical tests/Hematological tests
(iii) Radiological examination
(iv) Electrocardiography
  (a) Resting
  (b) After Stress tests
(v) Tilt Table studies
(vi) Echocardiography

(i) Clinical examination

General examination is carried out with emphasis on blood pressure measurements, equality of pulses and weak or delayed pulses, abnormalities of the jugular venous pulse, abnormality of arterial pulses, presence of xanthoma/xanthelasma, premature corneal arcus.

Individuals with coarctation of aorta will have been eliminated at preliminary medical examination.

An important cause of inequality of pulse and bruits heard over vessels is aorto—arteritis. The condition is progressive and may be missed in early stages.

Candidates with persistently elevated basal blood pressure, even if controlled with treatment, are unsuitable for astronaut training owing to their inability to cope adequately with changes in G forces and posture.

Individuals with irregular pulse should be evaluated in conjunction with electrocardiographic findings.

The presence of xanthoma/premature corneal arcus should lead to a search for other coronary risk factors like abnormal lipid profile, diabetes mellitus etc.

Examination of the heart

The heart should not be enlarged. S_1 and S_2 should be normal. An S_3 may be physiological in a younger subject but the presence of S_3 or S_4 in older individuals should lead to a search for possible organic heart disease.

Structural congenital abnormalities of the heart such as Atrial Septal defect, Ventricular Septal defect are rejected.

Short, soft pulmonary systolic murmurs when unaccompanied by clicks or any alterations in second sound, and with normal ECG and chest X-Ray are likely to be innocent and hemodynamically insignificant. Apical systolic murmurs are invariably organic, as also are all diastolic murmurs.

Special mention must be made of three conditions which are a cause for rejection and can be picked up during careful auscultation of the heart but may have been missed during initial medical examination. These are :-

Hypertropic cardiomyopathy or I.H.S.S.

This is suspected when the pulse is brisk, apex forceful and there is a systolic murmur at the left sternal border which may vary in intensity, become prominent on standing, and inaudible on isometric hand-grip. These individuals are prone to syncope and sudden death may occur.

Congenital Bicuspid Aortic valve

This abnormality is present in about 2% of the general population. Its presence is suspected by an Apical ejection click and a basal systolic murmur. When the Aortic stenosis is insignificant, the clinical findings may be missed on a casual examination. However these individuals are prone to infective endocarditis and to progressive aortic stenosis.

Mitral Valve prolapse

This condition is being increasingly recognised in recent years and is commoner than was thought earlier.

These individuals are prone to various complications including arrhythmias, infective endocarditis, mitral regurgitation, transient cerebral ischemic episodes and even sudden death is reported. The clinical findings of a non-ejection systolic click and murmur at the apex may be over looked by the unwary examiner and may be detected only on standing. Echocardiography provides an excellent means for accurate diagnosis.

(ii) Hematological/Biochemical tests

In as much as they pertain to the cardiovascular system, the following tests are important :-

Lipid profile—The abnormal elevation of cholesterol and triglycerides in the blood constitutes an important coronary risk factor.

Hyperuricemia—Besides being a risk factor, sudden incapacitation can occur during flight due to acute gouty arthritis.

Anaemia—This should be investigated and corrected before acceptance.

Diabetes Mellitus/Abnormal Glucose Tolerance—This is a well known risk factor for IHD and is a cause for rejection in its own right.

Raised ASO titre—This is an indicator of recent streptococcal infection, and a persistant rise should alert one about the possibility of rheumatic activity, particularly when anti-hyaluronidase titre (AHT) and ADN ase B titres are also elevated. Values upto 333 units (Todd) for ASO titre may be considered normal for our population.

(iii) Radiological examination

The following aspects should be looked into:-

Cardio-thoracic ratio—Cardiac enlargement should lead to the suspicion of chamber enlargement or hypertrophy, hypertensive heart disease, pericardial disease or myocarditis. The latter may follow mild or inapparent viral infections of the respiratory tract.

Enlargement of pulmonary artery shadow—This may result from pulmonary hypertension or pul-

monary stenosis or a left to right shunt.

Pulmonary venous hypertension which may result from mitral stenosis and which may have been missed on cardiac auscultation.

(iv) Electrocardiography

Electrocardiography forms an important investigation in the assessment of the Cardiovascular system. While a normal electrocardiogram does not exclude organic heart disease, an individual with an abnormal record must be thoroughly investigated.

Unequivocal electrocardiographic evidence of coronary artery disease precludes fitness for astronaut duties. A stress test, either on multi stage treadmill or on bicycle ergometer is performed on all individuals and those with a positive test are considered unfit. Stress test can also be repeated after exposure to high altitude, simulated in a decompression chamber.

Individuals with obvious right or left ventricular hypertrophy are unfit.

Conduction disturbances—The following conduction disturbances should be considered as unfit for astronauts training :-

(a) Gross first degree, or 2nd and 3rd degree Atrio-ventricular block.

(b) Left bundle branch block

(c) Bifascicular or trifascicular block.

(d) Complete right bundle bracch block.

Individuals with incomplete RBBB or with "rsr" pattern in V_1, with normal QRS duration should be considered fit if there is no evidence of heart disease clinically and if stress tests are normal.

Mild degrees of PR prolongation (0.20 to 0.22 sec) with a normal stress test response and absence of heart disease are likewise fit.

(e) Preexcitation syndromes e g Wolff-Parkinson White syndrome (WPW) or Lown—Ganong—Levine Syndrome (LGL) are a disqualification for astronaut training since these individuals are prone to bursts of supraventricular tachy arrhythmias.

Cardiac arrhythmias—Analysis of the data obtained from monitoring of the Apollo astronauts during space flight reveals that, despite strict pre-flight evaluation, astronauts were prone to develop extra systoles including bigeminy and frequent ventricular ectopics. One of the astronauts had a heart rate of as low as 28 beats per minute during flight. As such, when arrhythmias are detected during initial evaluation, a detailed and critical assessment must be made.

Sinus arrhythmia is a normal finding and does not disqualify.

Persistent sinus tachycardia should be investigated further.

Individuals with marked bradycardia, escape beats, wandering pacemaker, sinus pauses, and sinus arrest are most likely candidates for "Sick Sinus Syndrome" and sinus node dysfunction, and should be rejected. Some of these subjects may have runs of tachy arrhythmia as well. (Tachy-Brady Syndrome.)

Occasional premature beats need not be a cause for rejection but where the ectopics are frequent, multifocal, parasystolic or occur in couplets, there is a serious danger of atrial flutter-fibrillation, or of ventricular tachycardia and fibrillation, and such applicants must be rejected. Individuals with documented supraventricular tachycardias should similarly be considered unfit.

Vector cardiography—may be required to elucidate certain ECG findings such as suspicious inferior wall infarction or bundle branch block.

(v) *Tilt table studies and response to G forces in human certrifuge*

These tests are an essential part of the evaluation of the cardiovascular system, since as already brought out, the astronaut is subjected to variable and severe G forces during flight, and to postural changes. Individuals with postural

intolerance are prone to developing syncope, and should be rejected. From the Apollo missions experience it has been seen that Orthostatic tolerance is found to be diminished during post flight examination even in apparently fit individuals.

(vi) Echocardiography

The availability of Echocardiography including 2-Dimensional real time Echo has added a new dimension to the non-invasive assessment of the cardiovascular system. This investigation is invaluable in the evaluation of chamber enlargements, pericardial disease, valvular disease and congenital intra cardiac shunts. It is particularly useful in the diagnosis of Hypertrophic Cardiomyopathy, Mitral Valve Prolapse, and Bicuspid Aortic valve with or without stenosis. More importantly, the fitness of some doubtful cases can be favourably decided upon after Echocardiography, without having to resort to invasive hemodynamic studies.

Conclusion

Forming as it does a vital link in the Aeromedical aspects of man's conquest of space, a detailed and careful evaluation of the cardiovascular system will go a long way in ensuring success of the Space mission.