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Medical Evaluation of Cosmonauts : Biochemical Investigations

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Biochemical investigations are done to ensure that the cosmonaut will be fit enough to undergo rigid preparation schedule for space flight and also to detect any latent pathology, which may either cause a postponement of the flight or inflight problems. The investigations are done in three phases, with special emphasis on cardiovascular fitness and liver function tests. The individuals are assessed in totality, without rigidness on a single biochemical parameter. The paper also elucidates areas of special interest and further research in biochemical investigations viz-a-viz space flight.

Introduction

The success of professional activity of the crew of Spacecrafts significantly depends upon the quality of medical selection. The basic requirments for physical fitness of cosmonauts entails a sound health and high functional potentialities. Though there is wealth of literature on various cardio-vascular, vestibular and other test standards, the biochemical parameters defined for such individuals have been fairly vague and non-specific. This is partly due to the fact that normal variations in different individuals embrace a fairly wide range of normal values and most of the average adults fit into these patterns.

Aims of Biochemical investigations

This apparently simple Situation gets complicated when we include another facet of biochemical values viz., effect of Space Flight factors on human organism. Thus, biochemical investigations of cosmonauts distinctly fall into two broad groups :-

(a) For evaluation of physical fitness and functional potentialities of the candidate for special training and participation in space flights, and

(b) Effect of Space Flight factors on such biochemical parameters.

Biochemical Investigations for Selection of Cosmonauts

There is a large battery of biochemical tests which is recommended during various stages of

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selection. First stage of selection is more or less like an initial assessment of fitness at outpatient/ poly clinic level. At this stage only routine blood, urine and stool tests are done like Haemoglobin, total red and white cell counts, ESR, differential white cells, urine analysis and general exam. of faeces. No. other biochemical test is recommended at this stage.

At the second stage of selection, which is known as "Hospital Stage" the main aim is to detect the latent pathology and initial stage of any disease. Though this paper primarily deals with biochemical investigations only, for the sake of totality, we have included most of the investigations which are recommended to be done at Pathology Laboratory during this hospital stage. These investigations are grouped as follows :-

(a) *Haematological Investigations* :-

(i) Haemoglobin

(ii) Total and Differential leucocyte count

(iii) Total Red Blood cell count

(iv) ESR

(v) Haematocrit values

(vi) Thrombocyte count

(vii) Absolute Eosinophil count

(viii) Reticulocyte count

(ix) Clotting time

(x) Bleeding time

(xi) Study of peripheral blood smear for abnormal size/shape of RBCs

(xii) Blood group and Rh factor

(b) *Serological Investigations*

(i) Wasserman Reaction

(ii) Rheumatoid factor

(iii) 'C' reactive protein

(iv) Anti-streptolysin 'O' titre

(v) Anti hyaluronidase

(c) *Biochemical Tests (Glucose/Nitrogen)*

(i) Blood Glucose and GTT

(ii) Galactose tolerance test (if required)

(iii) Blood urea

(iv) Uric Acid

(v) Creatine

(vi) Creatinine

(d) *Liver function tests*

(i) Serum bilirubin

(ii) Prothrombin proteins

(iii) Albumin/Globulin ratio

(iv) Thymol veronal test

(e) *Blood lipids*

(i) Cholesterol

(ii) Lipo-proteins

(iii) Lipo-protein lipases

(iv) Lecithin

(f) *Muco proteins*

(i) Sialic Acid (N-acetyl-neuraminic acid)

(ii) Seromucoid

(g) *Enzymes*

(i) Transaminases

(ii) Aldolase

(iii) Alkaline phosphatase

(iv) Amylase

(h) *Fractional Test Meal*

— Gastric analysis

(j) *Investigations on Urine*

(i) General analysis eg. pH, Sp. gr, protein, cells, casts, glucose, blood, acetone etc.

(ii) Diastase

(k) *Faecal examination*

(i) General examination

(ii) Occult blood

(iii) Repeated exams to rule our helminthiasis

Having undergone these tests and subject to passing other fitness tests, cosmonauts enter into the third stage of selection which is also termed as "Final examination". Some more biochemical tests are added at this stage which are mentioned below :

(a) *Blood Lipids*

(i) Free cholesterol (76-116 mg%)

(ii) Cholesterol esters (77-131 mg%)

(iii) Esterification co-efficient (0.47-0.52)

(iv) β Lipo-proteins (350-600 mg%)

(v) Cholesterol in β lipo proteins (upto 130 mg%)

(vi) Triglycerides (40-165 mg%)

(vi) Phospholipids (150-275 mg%)

(b) *Electrolytes/trace elements*

(i) Serum Potassium (4.0 to 5.0 meq/l)

(ii) Serum calcium (4.25 to 6.0 meq/l)

(iii) Chlorides (98-107 meq/l)

(c) *Proteins*

(i) Albumin (4-5 g%)

(ii) Alpha 1 Globulin (0.3 g%)

(iii) Alpha 2 Globulin (0.5 g%)

(iv) Beta Globulin (0.8 g%)

(v) Gamma Globulin (1.4 g%)

(vi) Fibrinogen (200-400 mg%)

Yardsticks of fitness

A limited mention has been made in this article about the normal values of various haematological and biochemical parameters. It is due to the fact that the normal range allowed is extremely wide and no rigid standards are laid down to pass the biochemical tests as far as these values are concerned. To quote example—a fasting blood glucose value of 60 to 100 mg/100 ml is considered normal and blood urea range is 15 to 50 mg%. At the same time-as is evident from the spectrum of investigations, the individuals are assessed in totality without rigidness on a single biochemical value.

While discussing this matter with the scientists of a friendly country it was obvious that there are two aspects of this investigation viz.,

(a) Biochemical parameters should denote that the individual will be fit enough to undergo rigid preparation schedule for space flight, and

(b) There should be no such latent pathology, however minor, which may cause a postponement of the flight.

Most of the fundamental Biochemical tests are devoted to the first aspect while investigations like C reactive protein, ASO titre, anti hyaluronidase, absolute eosinophil count, ESR etc., have a dual application.

A lot of emphasis is laid on the cardiovascular fitness and therefore the blood lipid estimations are quite detailed. Infact they embrace a total lipid spectrum which is possible to determine. This may be due to the reason that more abnormalities are encountered in this sphere in the population of these countries where these standards are formulated. Probably due to the same reason and taking into consideration the high alcohol intake in those countries, a lot of stress is laid on liver function tests.

In the lipid spectrum, phospholipids and lecithin (which is about 50% of total phospholipids) are determined as a routine. Phospholipids increase in those conditions in which there is an increase in cholesterol though to a smaller degree. This applies to liver and biliary tract diseases, diabetes mellitus and myxoedema. An electrophoretic pattern of proteins is insisted to rule out presence of abnormal globulins and also to assess the albumin levels as a part of liver function test. Aldolase activity is assessed because it is increased in infectious hepatitis, progressive muscular dystrophy, myocardial infarction, pancreatitis and haemolytic conditions.

Another parameter which we usually do not ascertain in our country is determination of seromucoid and sialic acid (N-acetyl neuraminic acid). These come under protein-carbohydrate complexes. Compounds present in these include hexoses (galactose and mannose), the hexosamines (galactosamine and glucosamine), the methyl pentose fucose, and sialic acid. They have been named as mucoproteins and glycoproteins and also called mucopolysaccharides by some. An increase in seromucoid is found in patients with cancer, infections, rheumatoid arthritis and ankylosing spondilytis. In infectious hepatitis and cirrhosis the levels are usually reduced, while in biliary obstruction normal/slightly raised values may be obtained.

Areas of special interest and Research

It is again emphasised that though biochemical parameters for selection of cosmonauts appear to be very simple and easy, the things are going to be more difficult in future. Use of long duration orbital stations, ground base simulation studies and actual space flights have shown that man can withstand space stress for a long time. But "how long ?" is the question. What is applicable for a few months space flight may not hold good when stresses like weightlessness persist for a couple of years. To understand this problem we will have to briefly consider some haematological and biochemical changes which have been encountered during space flights :-

(a) *Haematological changes*

During first hours of completion of short term VOSTOK, VOSKHOD and SOYUZ flights, cosmonauts showed increse in haemoglobin, Red and white cell counts with increase in neutrophils and decrease in eosinophils. There was increase in haematocrit and decrease in plasma volume. A few days later there was tendency towards decreased haemoglobin, red cells and reticulocytes.

Reduction of circulating red cell mass of 14% to 7% has been encountered and average value of loss of RBCs is 232 ml. Quantum of this loss is not related to duration of flight (weightlessness). After 28 days mission of sky lab, the loss was more than what was encountered after longer (84 days) mission. There appears to be some adaptation factor operating. Atmosphere of Skylab had 70% oxygen and 30% Nitrogen at 258 mm Hg pressure. Reduction of RBCs was attributed to haemolysis of cells by peroxidation of their membrane. Plasmic iron content measured immediately after mission was normal. Reticulocyte count was lower at the end of mission as compared to pre-mission values indicating inhibition in production or increased loss. Life of RBC was not shortened either during or after the flight. Intravascular haemorrhages and haemolysis have been ruled out.

Only explanation is decrease in erythropoiesis which automatically gets checked after a particular stage, the mechanism of which is not known. What relation this has got to loss of muscle mass is also not understood. Factor of hypersplenism in the early stage of increased blood volume is only partly understood which is linked with increase in portal pressure with choking of portal circulatory system resulting in to nausea and loss of appetite in first few days.

Mechanism of inhibition of bone marrow is considered to be due to :-

(i) Tissues sensitive to modifications of the peripheral haematocrit do not acknowledge reduction of RBCs.

(ii) Hyperphosphatemia, always present during flight, would cause setting a big quantity of oxygen free at the cost of oxy-haemoglobin. Renal tissue sensitive to oxygen would react by reducing production of erythropoietin. Reduction of red cell mass can not be followed by a compensatory increase of erythropoietin-until an increase in the plasma volume is taken up again. Without erythropoietin increase bone marrow cannot respond and appears inhibited till a new balance is struck.

Exact nature of depressed erythropoiesis is not known and if explanation found, it will help in laying down criteria for selection of cosmonauts.

(b) *Loss of bone and muscular substance*

Calcium : There is continuous loss of calcium under weightlessness. This has been confirmed by reduction in bone calcium density which is reduced by monthly rate of 1 to 2%. This loss pattern is remarkably same as encountered by immobilisation. With duration of flight, this loss continues to aggravate and in prolonged flights of 1 or 2 years possibility of fractures and renal stones has to be considered. Oral intake of calcium does not fully compensate this loss and phosphorus balance is also negative.

Nitrogen : Urinary elimination of Nitrogen is also present which reaches its maximum between 7th and 9th day and then appears to be stablised at a constant rate of loss. Average daily deficit of 4.4 gm is observed.

Potassium : Potassium balance is also negative. The above mentioned losses are associated with that of loss of muscle mass. Exercises and dietary supplements do not help much. Study on hormonal system regulating osteoblastic and osteoclastic activities are under progress which may either differentiate between more or less prone individuals or offer a remedy to this.

(c) *Muscular atrophy*

An individual incurs a loss of 3-4 kg weight starting as early as first day of weightlessness. 60% of this is due to quick loss of body fluids, 30% due to insufficient ingestion and 10% due to muscular atrophy. Negative nitrogen balance and decrease in muscle power are noted. Intensive practical and regular exercises, electric stimulation of muscles or intervention in "trophic system of innervation" are being tried. Pharmacological, biochemical and enzyme aspects of atrophy are under study which may throw further light on this matter.

(d) *Metabolism*

Study on effect of weightlessness on metabolic process are being done. 7 days space flights showed activity in insular apparatus of pancreas, intensification of glucose corticoidal function of adrenal cortex, increased activity of hormonic element of the sympatho-adrenal system, excess of prostaglandins and increase in cyclic nucleotides and transaminases.

Effects on metabolism of lipids, trace elements and immunological process are under study by a joint Soviet-Hungarian exercise known as "Metabolism". This will help in selections of better candidates and recommend measures on prophylaxis and rehabilitation.

(e) *Interferon*

One of the facets understudy by joint Soviet-Hungary mission is on interferon. This heterogenic class of proteins whose synthesis is genetically determined responds to various inductors in the field of immunology to produce immunological responses against viral infections. Experiments with human lymphocytes under flight conditions are in progress with the hope that immunological protection can be enhanced to cover a wider range of stresses. Are the lymphocytes of some individuals better in producing such responses? If this is so, selection procedures will include this investigation also so that a person with better interferon system will be a better subject for space flight.

Conclusion

It is thus summarised that though biochemical selection procedures appear to be easy and within reach of a fighting fit healthy adult, further research into endocrinal, haematological, biochemical and immunological aspects is likely to throw more light on the mechanism of body response to space stresses aspects especially weightlessness. On understanding these it will be possible to include more intricate biochemical tests for the cosmonaut candidates with the hope of finding persons who are better suited to space flights as compared to their other healthy counterparts.

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