Medical Aspects of Interdynamic Adaptation in Space Flight

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THE ASTRONAUT'S journey into space will require a series of adaptations to multiple sequential changes in environmental circumstances. These adaptations will involve an inter-relationship of more than one biological stress and more than one organ system. The success of the astronaut's flight into the cosmos may well hinge on his ability to make a series of interdynamic adaptations. Many of the biological stresses imposed by modern aircraft and proposed rocket type vehicles are acute in nature and may markedly influence the vital functions of the body, particularly the circulatory system.

The ability to make sequential adaptations to a variety of different biological stresses is greatly influenced by individual characteristics. Undesirable cardiovascular responses detected in apparently healthy persons indicate that many normal, healthy people are not suited for the journey into space. This report attempts to highlight some of the acute problems which must be considered on an individual basis in conjunction with a rocket flight.

The initial difficulties can begin at the time of rocket launching. With the subject placed in the supine position, being exposed to transverse G forces, his G tolerance is definitely increased. When from six to eight G are applied in a transverse manner, the pressure upon the thoracic cage is sufficiently great to make breathing difficult or impossible. With the force being applied from front to back, breathing may be completely arrested. This limits the time that forces of this magnitude can be applied.

The biological stress, apprehension and excitement all may be expected to induce a period of sympathetic discharge and an increase in cardiac rate. Gauer and Wieckert[2] clearly demonstrated such a period of increased cardiac rate in simple centrifuge experiments. This period of over stimulation may be followed in the recovery phase by marked cardiac slowing with bradycardia.

Prolonged breath-holding commonly results in tachycardia followed by bradycardia in the recovery period. Thus, the influence of G forces upon both the respiratory mechanics and the circulatory system tend to create a sympathetic response during launching.

Once the influence of increased G forces are removed, the recovery phase follows. In an individual prone to a marked vagotonic rebound, serious bradycardia might ensue. If the subject is exposed to a weightless state, redistribution of circulating blood volume to the head may well over stimulate carotid sinus receptors. The

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carotid sinus reflex may enhance a tendency toward an adverse cardio-inhibitory response.

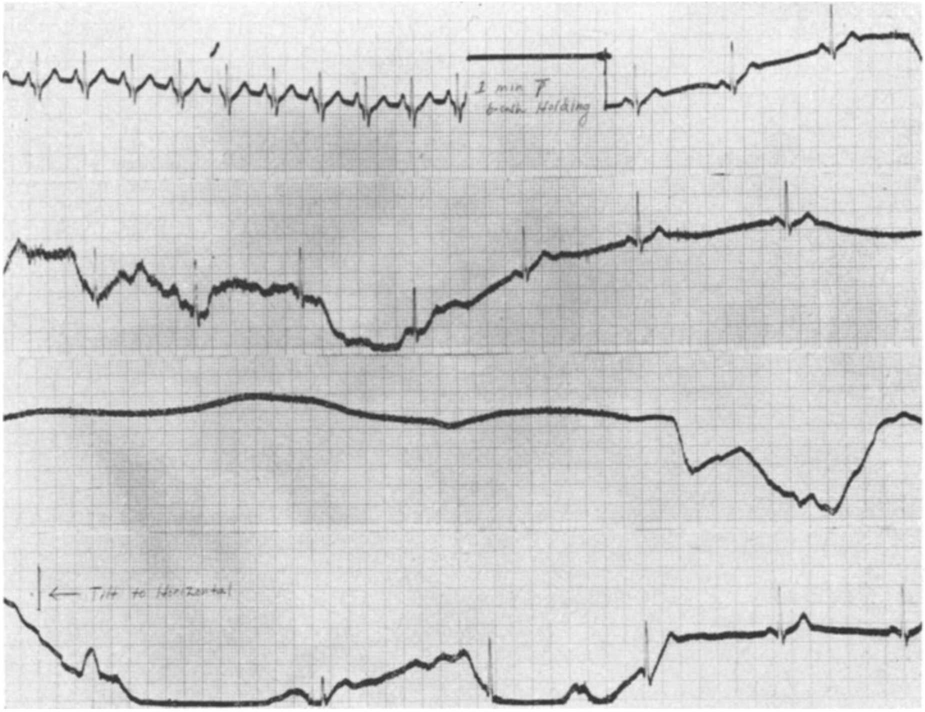

Fig. 1. Progressive passive rhythm with cardiac arrest following recovery phase, 1 minute after 45 seconds of breath holding. Note the ventricular escape beat terminating the period of arrest. These responses can be abolished by blocking vagal responses with atropine intravenously.

A typical ground level response to the combined stress of breath holding and the upright posture imposing a stress of 1 G in a healthy young pilot is depicted in Figure 1. This person held his breath only 45 seconds. During this period the cardiac rate became rapid. One minute following release of breath holding, while breathing normally and strapped to a tilt-table in the upright position, bradycardia with cardiac arrest occurred. The postural influence might be eliminated during space flight, but the additional influence of stimulation of other vagal receptors during the weightless state could pose the same problem in the individual inclined to vagotonic rebound.

The total response noted clinically in a person about to lose consciousness includes nausea, palor, sweating, and disturbance in the circulation (cardio-inhibitory and vaso-depressor responses). These are chiefly brought about by vagal stimulation and represent a total response of the organism. For this reason, the term "vagotonic storm" is advocated to define the response. Of course, the adverse cardiovascular response is particularly important as it is a vital function. Perhaps as many as 40 per cent of the population is susceptable to such a rebound response after a sympathetic phase.

Animal experiments reported by Russian scientists indicate a marked variation in dogs used for rocket type experiments.[4] Depression of cardiac rate (vagotonic response) was noted in a number of dogs. Animals with normally rapid pulse rates may not be the best choice for investigation of these problems. The monkey in particular has a normal rapid heart rate far in excess of normal human heart rates. One can hardly expect comparable results.

The increased weight of organs during increased G forces may cause pain at ligamentous attachments. Pain may induce vagal reflexes and arrhythmias. In the event relatively low G forces are utilized for long periods of time in launching a rocket type aircraft, one must consider the possibility of responses similar to those obtained from prolonged standing (1 G). With restricted movement, many healthy persons develop marked bradycardia and cardiac arrest in less than three minutes' time. Prolonged exposure to smaller G forces may not be wholly innocuous.

The prolonged increased weight of the circulating blood may also adversely affect the circulation between the vascular compartment and the extravascular compartment. The return of fluid to the venous portion of the capillary may not be possible. In a space ship, once the weightless state has been achieved, the circulatory problems are not over. Hypoxia within the sealed environment may be sufficient to induce cardio-inhibitory responses. Although the myocardium is highly resistant to hypoxia, adverse reflexes may occur.[5] These are cardioinhibitory in nature induced by the vagus nerve.

Pressure breathing, should it be incorporated, may stimulate stretch receptors within the lung which can cause cardio-inhibitory responses.

If a G-suit is used one can expect major changes in the pulmonary circulation. Inflation of a G-suit to 75 mm. Hg. has been shown to raise the pulmonary artery wedge pressure by 25 mm. Hg. in normal subjects.[3] The engorgement of the pulmonary vascular bed increases the work of breathing by decreasing the lungs elasticity.[1] Adverse reflex responses initiated from the lung may in fact be augmented by distention of the pulmonary vascular bed.

Naturally there are long term effects of confinement and restriction of movement which must be considered for the long journey, including electrolyte and mineral problems, the loss of normal postural adaptation mechanisms and arteriolar tone. Should the journey be short, one of the immediate problems is to be certain that the subject is not exposed to negative G forces with stimulation of carotid sinus receptors. It is well-known that small negative G forces are poorly tolerated. Impact and blast also may produce adverse cardio-inhibitory responses.

It seems apparent that much needs to be done to understand the individual responses that can result from biological stresses of the type associated with rocket type aircraft. Some of the problems posed may not be important, or at least may be unimportant, in the properly selected person. Other problems may be prevented when recognized and proper measures instituted. In any case, it is clear that a thorough understanding of the hopeful astronaut's capability to accomplish vital interdynamic adaptations is a sensible and necessary prelude to his conquest of space.

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The Perils of Isolation

The isolation of man from his accustomed environment has profound impact on the functions of his mind. Many circumstances in real life entail such isolation. Their effects have many names, from "nostalgia" to "desert madness," and range from mild feelings of anxiety and depression to hallucinations, delusions, and even death by suicide. . . . Extension of flight range has increased the significance of isolation in aviation medicine. Crews on prolonged missions are exposed to a restricted, monotonous sensory field. It has been suggested that this type of isolation might be a contributory factor to "pilot disorientation," which not infrequently is cited in aircraft accident reports. Pilots flying at high altitudes may also report what has been called "the break-off phenomenon" or high altitude dissociation. Furthermore, space crews will be subjected to an artificial environment that will be isolating in many ways.—Edwin Z. Levy, George E. Ruff, and Victor H. Thaler: Studies in Human Isolation. *Journal of the American Medical Association,* January 17, 1959.