5-31-56

A DOCTOR LOOKS INTO SPACE*

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Medical practice, in its earliest beginnings, was that of general medicine, treating illness and disease as an affliction of the body as a whole. As medical knowledge progressed, skills in more limited fields were developed, and various medical specialties were born, until now there are many specialties - some based upon methods of treatment, such as surgery, internal medicine and radiology; others based on anatomical structures, such as gynecology, urology, and cardiology; still others related to a specific occupation or environment, such as industrial medicine and tropical medicine. One of the most important types of environmental medicine is the specialty of aviation medicine, which had its beginnings some forty years ago and is now developed to a high degree. A recent outgrowth of this specialty is - Space Medicine. Because of the rapid progress in aeronautics and in rocket propulsion, in the years following World War II, Brig. General Harry G. Armstrong, in 1949, as Commandant of the School of Aviation Medicine, showing vision and foresight, founded the Department of Space Medicine. Medical Research has played an important part in the development of aviation and will continue to do so, to an even greater degree, in preparing man for the coming of global space flight.

But wait! Man is already flying in Space! And what is Space? Space may be defined as the absence of the atmospheric medium to which we are accustomed and upon which we are dependent for life-sustaining characteristics. The material limit of the atmosphere is at 600 miles. Beyond this is true Space.

*Given at Midland, Texas, 31 May 1956 to members of the Midland Rotary Club.

However, Space, insofar as man is concerned begins as low as 50,000 feet or about 10 miles. Let me explain!

There are various altitudes at which the life-sustaining characteristics of the atmosphere cease to function. These altitudes are called the functional borders of the atmosphere. For example, at 50,000 feet the barometric pressure is so low that we are no longer able to take into our lungs, and utilize what O_2 yet remains in the air. At 63,000 feet, the still lower barometric pressure no longer is able to keep body fluids in liquid state, which results in the so-called boiling of the blood. These are physiological functional borders of the atmosphere. There are also physical functional borders. Theses necessitate a completely sealed cabin, for the following reasons:

1. Thermodynamic reasons - Were it feasible to compress the air at these high altitudes, such compression would elevate the temperature of the cabin air to an intolerable level of $400^{\circ}F$, or more.

2. Toxicologic reasons - At 65,000 to 80,000 feet the air is rich in Ozone. If this air were compressed to a tolerable pressure, the Ozone concentration would be toxic to humans, and destructive to equipment, since Ozone is very active, chemically.

3. Technical reasons - at 80,000 feet the air density is only 1/30th of the air density at sea level. To compress this air to acceptable pressure levels would require equipment that would be prohibitive from the standpoint of size and weight.

4. In travel beyond the atmosphere, the ship will pass through the atmosphere with such speed that there will be very little time for the outside air to be used for cabin pressurization.

From these facts you can readily see that a completely sealed cabin will be absolutely necessary in all forms of space operations.

In addition to the life-sustaining properties, the atmosphere also exerts a protective function for human and animal life on the earth. Let us consider some of these extra-terrestrial factors found in the atmosphere, and which will be important to us in future space flight and travel. First, however, let me digress for a moment, and differentiate between space flight and space travel. Space flight is the movement of a craft from one point on the globe to another through the upper reaches of the atmosphere or, the orbital flight of a satellite within the atmosphere. Space travel is the movement of a manned vehicle from the earth, through interplanetary space, to another celestial body such as the Moon or Mars. We reserve the word "travel" for this future phase.

Now back to the extra-terrestrial factors of the atmosphere. The most important ones are solar radiation, cosmic rays and meteors. The upper absorption limit for cosmic rays is 120,000 feet. The sunburn-producing ultraviolet of solar radiation, in its full force, lies above the ozonosphere, or at 140,000 feet. The upper absorption limit for meteors is 400,000 feet. Above these limits, then, cosmic rays and ultraviolet radiation comprise another significant problem.

Above 400,000 feet the air molecules are so far apart that sound waves are no longer propagated, and also the air no longer has the capacity to scatter visible light. These phenomena result in the absolute silence of Space, and in the darkness of Space. The sky is completely black with the stars and sun visible visible, at the same time.

The last physical functional border of the atmosphere lies at 120 miles. At this point a moving craft ceases to obtain "lift" from the atmosphere, and there is no longer friction heat and heat transfer to the interior of the vehicle.

All these physical and physiological functional borders of the atmosphere have given rise to the concept of "Space Equivalence" within the atmosphere - a concept evolved by Dr. Hubertus Strughold, Chief of the Department of Space Medicine at the School of Aviation Medicine.

As you can see from these facts the conditions of Space are encountered, not all at once, but in a stepwise fashion, beginning as low as 50,000 feet, and ending at 120 miles. Beyond 120 miles, although still within the physical limits of the atmosphere, all these space-equivalent conditions continue. This concept of Space-equivalence explains the earlier statement that man is already flying in space. We are already in this phase of space flight, and have been for the past decade.

What, then, are the medical problems to be solved in the evolution of space flight? Rocket-powered planes have already gone above the maximum limit of 80,000 feet for mere pressurized cabins, but for only 2 or 3 minutes. Manned balloons have gone to the same altitudes for longer periods of time, but these gondolas were sealed. Rockets have reached a height of 250 miles. How long will it be before a rocket ship is built with a sealed cabin to accommodate a man, or two men? Will man be able to withstand the flight? We must have the answers to these questions before that time comes, and come it shall, because the pioneering nature of man will not be held to this earth!

Let us consider, now, the factors involved in a typical rocket flight, in the order that they will be encountered by the crew.

The first factor will be the acceleration force produced at takeoff. This force, expressed in G's, will depend upon the type of fuel used in the rocket motor. Liquid fuels, at present produce accelerations of 4 or 5 G's for about one minute. Solid propellants, on the other hand, produce more severe accelerations - up to about 15 G's - for several seconds. This might be tolerable, but for only a few seconds. Eight to 10 G's is considered the upper limit for periods of several minutes. These forces are made more acceptable if the crew is in a semi-reclining position with the long axis of the body perpendicular to the direction of acceleration. Much research has been done in this field by both the Navy and the Air Force at their respective research centers, in large human centrifuges.

Our second factor is noise and vibration during takeoff, and at other times when the motors are functioning. This may be a problem because of the pitch and intensity of the sounds. The duration of these sounds will be such a short time, however, that an acceptable protection can be provided. Once the craft is beyond the atmosphere and after engine cutoff, the silence of space will prevail. Naturally, inside the cabin there will be only the noises caused by equipment, radio, and conversation among the crew members.

The climatization of this sealed cabin will be the next problem under consideration. This involves oxygen supply, absorption of the CO_2 in the air, humidity, odor, and temperature control, and regulation of barometric pressure. Under normal activity, one man will use approximately .7 kg of O_2 per day. Oxygen supply will not be a problem on flights of short duration, because sufficient amount can be carried in high-pressure gas containors, or in the liquid state. However, when the era of the manned satellite and space travel does arrive, an oxygen-carbon dioxide exchange system may be necessary. Such a system is the photosynthesis in green plants. Plants, in the presence of sufficient light of the proper wave length, absorb CO_2 from the air, and give off O_2 to the air. Basic research in this area is now being carried out at the University of Texas by Dr. Jack Myers. So far, Dr. Myers has found that 5 pounds of a certain common alga is sufficient to balance the respiratory cycle of one man. The enormous power requirement renders this method impractical for immediate use, but without a doubt there will be a practical application for such a method in the future. Believe it or not, algae are closely related to the green plant growth commonly found in swimming pools and in ponds. One research group in this country, and another in Japan, have been working for several years, on the utilization of such plant life as food supplements. Only recently, they served a banquet, to members of their society, in which all the courses of the meal were made up of algae.

The cabin, as has been stated, will be sealed at ground level. However, the barometric pressure at ground level would be difficult to maintain as the craft ascends. Therefore, a cabin pressure corresponding to altitudes of 10,000 to 18,000 feet will be considerably easier for the engineers, both from the standpoint of weight of equipment and of structural weight.

Temperature, humidity and odor control can be maintained by the use of conventional, or modified air-conditioning systems, and heating elements. Power requirements for these items may be considerable, but when solar power becomes available in space craft, the power source will be unlimited. The chief factors, then, would be the weight and size of the conversion equipment. If feasible, the same equipment can be used for all power requirements on the craft, such as the light source for the algae exchange system, compressors, motors, and so on.

Odor filters or oxidation devices for the destruction of odors, can be incorporated into the air conditioning system. Water vapor can be condensed from the air in the cabin by this unit, purified, and returned to storage tanks for use, over and over again. Theoretically, there would be no loss of moisture from such a sealed system.

One temperature problem already encountered in the latest research planes, is that of friction heating and heat transfer. In high supersonic speeds, at altitudes up to 120 miles, heat is produced by the movement of the vehicle through the air molecules. This heat can produce skin temperatures of the craft up to 700°F, and poses the additional problem of preventing transference of this heat to the interior of the cabin.

This problem is not so pronounced on takeoff and in movement through the atmosphere into Space, but will be quite severe on re-entry into the atmosphere from Space at hypersonic speeds. In general, we classify speeds into three categories; subsonic - less than the speed of sound, or Mach 1; supersonic - more than Mach 1 and less than Mach 10; and hypersonic - Mach 10 or more. A few years ago, the sound barrier was a most important problem. The sound barrier has been conquered and the next one, the heat barrier, is now being attacked. This is thought to be encountered at speeds of Mach 3 or 4, with regard to space-equivalent flight.

Visual perception in Space will be quite different from that on Earth. As previously mentioned, the sky will be black. The Earth will be seen from Space, as a lighted body in a black sky. Some confusion may exist until adaptation to these visual characteristics occurs. The eye will be exposed, in looking toward the sun, to the full intensity of solar radiation, without the protective property of our atmosphere. Thus, one must use a protective glass with very high absorptive properties, while looking toward the sun, in order to prevent retinal damage.

Now - to one of the most completely different phenomena of space flight - that of weightlessness. Weightlessness is characterized by the absence of the usual gravitational force which keeps us on the earth. One is subnormal in weight or weightless for only a moment when an express elevator begins its descent. One is also weightless for a moment in passing the crest of a rise during a ride on a roller coaster. You have all experienced this sensation. At first the feeling is more or less pleasant, but how would one feel if this state should continue for an indefinite period of time? Could one adapt to it, or would one become disoriented, nauseated, and unable to function properly? At present, we have only partial answers to these questions. The chief reason for the paucity of information in this area, is the difficulty in maintaining a gravity-free state for a sufficient length of time, for the subject to evaluate his reactions.

We are currently studying the effects of gravity-free states on test subjects while flying a curve in the shape of a parabola, in jet aircraft. The gravity-free state can be maintained for a period of 30-35 seconds in the current two-seated jet planes. This is a relatively short time and not too much information can be obtained as yet. However, test subjects fall into three general groups - those who have little or no ill effects, those who become somewhat nauseated, and those who become disoriented and nauseated and find the state quite disagreeable. Two factors are most important in producing these reactions - visual orientation, and the effect upon the equilibrium mechanism of the ear, the semi-circular canals. The part played by each of these factors varies considerably in different individuals. Longer periods of the gravity-free state can be obtained during a rocket flight. Monkeys and mice have been sent up in rockets to heights of 40 miles or more, and have been weightless for two to two and a half minutes. As observed by the motion picture camera, the mice seemed to experience some disorientation, except one mouse whose equilibrium mechanism of the ear had been destroyed. This mouse had little or no disorientation, having adjusted himself to this situation some time before when that part of his anatomy had been destroyed. Now, we must determine whether disorientation is the result of weightlessness in itself, or the change from ~~xxxgxkkxxx~~

weightiness to weightlessness and back again. I, myself, am of the opinion that the change from one state to the other contributes most to such disorientation. At least, I have drawn this conclusion from my own reactions during such flights. The final answer to this question will have to wait until longer periods of weightlessneas can be obtained, either during longer rocket flights or during flight in orbital pathways.

As you know, all life processes occur in cycles or rhythms. The most significant of these is the physiological day-night cycle, which is characterized by rhythmic changes in bodily processes such as respiration, digestion, circulation and body temperature. These changes are closely related to the physical manifestations of day and night caused by the rotation of the earth. You all know of the adjustment which an individual must make, in changing from a day to a night shift in a hospital, in factories, or on board ships, and to a lesser degree, even the change from one time zone to an adjacent one. The problem of adjustment is just as acute in travel, by fast plane, across large areas of the globe. In some instances, the adjustment difference may be as much as twelve hours. Thus, after such a journey, an individual may arrive in time for an important conference in the afternoon, when his physiological processes are at low ebb, and indicate that it time for sleep and not for alert mental activity. The period required for natural adjustment in such cases may be as long as a week for some individuals. Others make very rapid adjustments. Dr. Kleitmann, of the University of Chicago, in his research on this subject, found that the body can adapt itself, within certain limitations, to time changes of this nature. He and his associates remained for two months in Mammouth Cave, in Kentudky, without seeing the light of day. During this time, their cycle of work or activity, and rest, recreation and sleep, was varied from less than 16 hours to more than 32 hours. They found that the cyclic rhythm can be maintained in periods as short as 18 hours and as long as 28 hours without significant alteration. Beyond these points, the body will re-establish a rhythm corresponding to that of a more or less normal day. This information becomes extremely important when planning for the crew of a manned satellite. Will it be necessary to plan for three crews for a 24 hour period, or can two crews operate efficiently on a shift of nine hours each? The difference in weight alone between three crews and two crews would be a significant factor.

The physical day-night period in a satellite orbit would be quite different from that on the earth. For instance, Werhner von Braun, noted German rocket scientist, now in this country, has proposed a manned satellite circling the earth in an orbit at 1,000 miles. The time required for one revolution of the earth would be approximately two hours at a speed of about 16,000 mph. Twelve times in 24 hours, the satellite would pass through day and night. The night would ~~be~~ occur during the movement of the vehicle through the shadow of the earth. The "night" of the satellite orbit, then, would be only 30-40 minutes in duration. This is assuming that the satellite is travelling around the earth in the same direction as the sun's rays. Were the satellite circling in a plane perpendicular to the sun's rays, there would be no night at all. Thus, it becomes necessary to create an artificial day-night cycle which would correspond rather closely to that of our metabolic clock, if satellite operations are to be efficiently maintained.

Here, then, is the charted course for us, in the field of Space Medicine! Here are our problems: acceleration factors, effects of noise and vibration, climatization of the sealed cabin, visual perception in Space, weightlessness, cosmic rays and ultraviolet radiation, regulation of the day-night cycle, and last, but certainly not least, the unique psychological stresses which will be associated with conquering these problems. We do not see these as obstacles, but as challenges to the ingenuity and imagination of man!

This outline is necessarily only a very brief glimpse into the future, but I hope that I have given you some idea of the problems and challenges that confront us in Space Medicine and in future Space Operations.

JGGaume/mbn

4 June 1956