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Environmental Health in Space

The human race has gradually extended its boundaries beyond the physical limitations of Earth to include the outer reaches of space. Over the past 40 years, beginning with the former Soviet astronaut Yuri Gagarin, we have been exploring this previously unknown and inaccessible realm. Although the number of people who have so far experienced the environment of space is limited (some 300 astronauts), the lay public is expected to join the ranks of these well-trained and well-educated space travelers.

This has already begun with the inclusion of Dennis Tito on board a Russian rocket to the international space station (ISS). In the near future, it is expected that the lay public will be able to travel and stay in space for extended periods. In any case, many medical capabilities are needed for those who travel and stay at a significant distance from Earth, such as an extended sojourn in the ISS or participation in interplanetary missions—a more distant probability. Environmental health in space may yet become a field of study in its own right.

One of the main avenues of research to be undertaken at the ISS will be the elucidation of biomedical risks and hazards relating to space habitation. Space medicine—the ability to deliver high quality health care in space—is in its earliest stages of development; it is hampered by limited flight opportunities, few clinical incidents, and competition for resources among various disciplines (*1*). As a result, few publications exist in this field as compared to other areas of medicine (*2*), and it is uncertain whether all potential problems that may arise from long-term space habitation have been anticipated and tabulated (*3*). Space medicine, therefore, will play an important role in biomedical research in space in the 21st century, as well as in the prevention and treatment of medical problems that will arise in a space environment. The space environment encompasses unique characteristics, forcing scientists to investigate a variety of subjects by using this interesting environment—an environment that is not easily reproduced on Earth.

From a cosmic point of view, we have to consider the prevention of space pollution produced by human activity, such as solid wastes and trace contaminants. This "space garbage" includes breakaway parts of rockets, spent satellites, paint flecks, and other hardware. These pieces of trash travel in orbit at high speed (~30,000 km/hr), posing a potential hazard to spacecraft and astronauts.

In space there are varying primary cosmic rays. These cosmic rays are continuously penetrating Earth's magnetosphere. However, we are usually protected from galactic cosmic radiation and solar particle radiation by a double radiation shielding, namely, the atmosphere and the magnetosphere. Therefore, the trapped particle radiation confined by the magnetosphere in the Van Allen belt is the major source of exposure in the low-Earth orbit where the ISS is located. This is especially the case in the South Atlantic Anomaly, where the Van Allen belt is shifted to a low-Earth orbit. The resulting increase in solar activity might lead to a 10–100-fold increase in radiation originating from solar flares (*4*). In addition, this increased solar activity influences the distribution and intensity of the geomagnetic field through an increase in plasma jet to the earth, causing a rise in galactic cosmic radiation and trapped particle radiation as well as solar particle radiation. We must consider periodic and accidental solar activities when contemplating cosmic radiation in a space environment.

In addition to existing cosmic rays, there is a possibility of the production of secondary rays, which could result from the interaction of primary cosmic rays and the structural materials of the spacecraft or space station. We also have to consider single-particle effects produced by heavy ions (high Z and energy particles), although there are several conflicting reports in this regard. [See Nelson et al. (*5*) for an affirmative view, and Krebs et al. (*6*) for one that disputes these effects.] Potentially, as well, there might be a synergistic action between radiation and microgravity (*7*). In any case, we must make every effort to reduce the strength and quantity of potentially hazardous radiation.

Other physiologic problems of weightlessness are motion sickness, a fluid shift to the upper part of the body due to a loss of hydrostatic pressure, and decreased physical fitness. A prolonged stay in space results in a decrease in blood volume and red blood cell mass, muscle atrophy, a loss of bone mass, and autonomic system disturbance causing orthostatic intolerance. These symptoms are not extremely severe in terms of being life threatening; however, they should be taken into account for the efficient and safe operation of the spacecraft or space station. Exposure to microgravity produces a number of physiologic changes of metabolic and environmental origins that increase the potential for renal stone formation.

Although we do not have adequate information as to the changes in immune function caused by being in space, there are reductions in the quantity and reactivity of T lymphocytes, the activity of helper cells and natural killer cells, and the synthetic activity of the principal lymphokines (*8*), and a decrease in interferon production. The pathogenicity of microorganisms is altered, and some microorganisms have shown a resistance to antibiotics after long flights (*8*). Immune suppression could impair both physical and mental performance by increasing susceptibility to opportunistic microorganisms. Appropriate onboard exercise is believed to be an effective countermeasure against a decrease in immune function (*8*).

In the 21st century, we expect members of pediatric, geriatric, and obstetric populations, as well as astronauts, to travel and stay under the challenging conditions of a space environment. These populations may prove to be more susceptible to the potential hazards of a space environment than those who are selected as astronauts, partly because of astronauts' greater capability in physical and mental fitness and because of their specialized training for occupational missions. In the long run, there is much territory to be covered toward achieving safe, comfortable travel and long-term habitation under the extreme conditions of space, but these are challenges that, when eventually surpassed, will potentially be of great benefit to the human race.

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