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Radioprotectors

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This lecture topic is about the biological hazards associated with exposure to the types of radiation encountered by astronauts during space travel. The radiation environment encountered during space travel will expose astronauts to higher doses of radiation, and more varied types of radiation, than those encountered on earth. Two of the types of radiation which are encountered by astronauts during space travel, protons and highly energetic, heavy charged particles known as HZE particles, are not encountered by people on earth and are of particular concern for the health of astronauts. Very little is known about the biological effects of these types of radiation. We do, however, know a lot about the biologic effects of other types of radiation.

The types of radiation of most concern for the production of biological effects are called ionizing radiation. Ionizing radiation has the ability to penetrate deeply in our bodies and cause damage to critical biomolecules in our tissues that are needed to function properly. The deposition of energy from ionizing radiation results in the ejection of electrons from atoms within cells, which then results in the ionization of atoms in the cell. Such ionizations are only the first event in a chain of chemical reactions which lead to the known biologic effects of radiation – like the induction of cancer, birth defects and the production of alterations in the DNA of our germ cells which can lead to heritable genetic changes in our offspring. It is expected that the major biological effects of radiation are brought about by changes in the DNA of cells, which are the basic units of structure and function in biological systems, so measurements of DNA damage figure prominently in radiation biology research.

There are many different types of radiations encountered during space travel which could produce adverse biological effects in astronauts. Exposure to ionizing radiation during space travel poses some unique hazards, however– primarily due to the presence of relatively large numbers of heavy ions in space. Although we are not exposed to heavy ions on earth, we can study their biological effects at the NASA Space Radiation Laboratory, known as NSRL, which is a facility at the Brookhaven National Laboratory in Upton, New York. NSRL provides beam lines of the energetic heavy ions encountered during space travel which supports studies on the biologic effects of these types of radiations. Heavy ions contain different numbers of protons and neutrons (called nucleons) in the nucleus of atoms, and large numbers of them are found in outer-space. Iron (Fe) ions are frequently used as the HZE particles for radiation biology experiments. Iron ions, as well as other heavy ions, produce relatively large amounts of DNA damage, as their track width is considerably greater than the tracks which are produced by x- and gamma radiations.

A major question in space radiation research concerns how the expected biological effects of space radiations can be minimized. Theoretically, it would seem possible to eliminate the effects of heavy ions through shielding methods. Shielding for heavy ion exposure, however, is extremely difficult as it is complicated by nuclear fragmentation, in which the secondary fragments produced from heavy ion interactions can be equally or more hazardous to biologic tissues than the original heavy ion. Thus, the development of countermeasures for space radiation induced adverse biological effects has been more focused on the use of dietary supplements or pharmaceuticals to serve as countermeasures for the radiation risks.

Many space radiation projects are aimed at assessing risks of space radiation induced adverse effects, such as those leading to cancer, central nervous system effects and hematological/immunological parameters, and developing countermeasures for those adverse effects. It is recognized that ionizing radiation has major effects on the cells of the immune and blood-forming systems, with particularly profound effects leading to decreases in the numbers of circulating granulocytes, also called polymorphonuclear leukocytes, and lymphocytes – as can be observed in the slide showing the changes with time in numbers of circulating blood cells following exposure to a moderate dose of radiation.

As described earlier in this presentation, the important biological effects of many types of radiation are brought about by the ionization of atoms within cells, which in turn can lead to the production of free radicals. As approximately 80% of cells is water, oxygen-based free radicals, known as reactive oxygen species, are thought to be particularly important in the production of biologic effects from many types of radiation. Therefore, it seems reasonable to assume that antioxidants might be able to interact with the radiation-produced free radicals and eliminate or minimize the biological effects produced by radiation exposures. There are many different types of space radiation investigations that have involved evaluation of antioxidants as potential countermeasures for adverse biological effects.

It is now clear that many different classes of modifying agents for space radiation adverse biological effects exist; these modifying agents have different potential toxicities and side effects. The challenge for NASA researchers now is to determine the best possible modifying agents or countermeasures so that the potential biological effects from space radiations can be eliminated with the fewest possible toxicities and side effects of the pharmaceutical or nutritional supplement agents utilized.

References are given on the slides as appropriate, with the first author's name, and journal reference. A major reference for the general concepts described on the characteristics of radioprotective agents is the following textbook:

Hall, E.J. Chapter 9 - Radioprotectors. In: Radiobiology for the Radiologist. Lippincott Williams & Wilkins, pp. 136-143, Philadelphia, 2000.