The Boice Report #27

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Men and Women on Mars

I just spent a stellar week in Houston discussing radiation protection issues of traveling in space with National Aeronautics and Space Admininistration (NASA) personnel, including four astronauts. The focus was on long-term voyages for space exploration and possible radiation effects on mental function. Earlier this year I wrote the column "NASA – The Final Frontier in Radiation Protection" where I mentioned having lunch with Neil Armstrong. This time lunch was with Mike Barratt, MD, a real-life Dr. McCoy (think "Bones" in *Star Trek*) and former chief medical officer of the International Space Station (ISS). An earlier photo of National Council on Radiation Protection and Measurements (NCRP) Scientific Committee (SC) 1-24 on *Radiation Exposure in Space and Potential of Central Nervous System (CNS) Effects* is below and includes Rudy Tanzi (a neuroscientist "rock star" who moonlights with Aerosmith guitarist Joe Petty and with guitarist Francis Collins, who is head of the National Institutes of Health). Also in the photo is yours truly (a "wannabee" folk singer)—another example of the connection between science and music. But I digress.

Synopsis of Meeting. The meeting, held in the ISS Conference Center, began with four comprehensive presentations by NASA personnel: "The Space Radiation Program Element" (J. Uri), "Research Overview: Risk of Acute and Late Central Nervous System Risks From Space Radiation Exposure" (J. Huff), "Space Radiation Analysis Group (SRAG)" (E. Sermones), and "Behavioral Health and Performance Element" (L. Leveton).

A panel of four astronauts (M. Barrett, T. Marshburn, D. Pettit, S. Walker) shared their views and questions on cognitive and behavioral effects that may be related to flight stressors (e.g., sleep deprivation, sleep disorders, fatigue, microgravity), including radiation impinging on the CNS. Each astronaut had participated in one or more missions of six months' duration to the ISS. There are fewer than 400 U.S. astronauts so SC 1-24 greatly appreciated this opportunity to speak, at length, with so many.

What are the unique radiation exposures in space? Traveling beyond the Earth's protective atmosphere and magnetic shield increases exposure to cosmic rays (sort of a uniform and continuous bathing in protons) and galactic cosmic rays (the high-energy ions coming from exploded supernovas). The latter are high-charge (Z) and high-energy (E) particles (HZE particles) zinging through space like cosmic bullets.

What are the effects of HZE particles? No one is sure and thus the need for continued research and for NCRP SC 1-24. HZE particle effects were "seen" early when astronauts reported seeing stars and light flashes when their eyes were closed. These responses were attributed to HZE particles hitting the optic nerve (possibly related to Cherenkov radiation). They produced an array of visual effects: dots, streaks, and blobs in various colors. Light was seen when there was no light to be seen! These transient light flash effects, while of uncertain functional significance, indicate that these tiny iron bullets (or other heavy ions from space) interact with brain tissue and might affect cognitive function such that a mission might be impaired and the future risk of dementia and Alzheimer's disease might be increased (NCRP Report No. 153).

If CNS effects are a concern, how can they be studied? With great difficulty it seems. Humans are not usually exposed to HZE particles, so biological effects might, in principal, be extrapolated

from human exposures to lower linear-energy-transfer radiations as has been done for cancer and has been considered for heart disease. But there are many possible CNS effects, they are not all well-defined, and they are challenging to measure. Further, except at very high doses seen in cancer therapy, there is little human evidence for CNS effects.

Of mice and Mars. Animal experiments are clearly important. But how to extrapolate to humans is also challenging. A unique mouse study, for example, indicated that HZE particles could advance the onset of genetically determined Alzheimer's disease. The mouse was genetically engineered to have two genes that predispose it to Alzheimer's disease, and this double dose of genes predestines it to Alzheimer's disease even in the absence of radiation. This may not be easily generalized to astronauts in space. Consideration of nonhuman primate and other animal evaluations might be helpful to advance understanding.

CNS damage assessment and prediction. The approaches used to predict CNS risks are challenging and the approaches used for cancer risk assessment may not be easily applied to predicting CNS effects. CNS effects may occur in the short term (cognitive dysfunction, memory loss, etc.) as well as the long term (dementia), and the mechanisms for inducing cancer and CNS damage differ. Cancer is thought to be related to DNA damage, but CNS effects may involve protein or membrane effects outside the nucleus or other interactions with neural pathways that are not clearly defined. The dosimetry for HZE particles is challenging. The possible interaction of HZE exposure and other flight stressors is unknown. A long-term (longitudinal) follow-up of astronauts for CNS as well as other health issues might be especially helpful in understanding CNS effects.

Way forward. Within the year, SC 1-24 will summarize the potential short- and long-term consequences of space radiation on the CNS, describe existing human and experimental data, outline research needs, and provide the groundwork for a comprehensive subsequent report to more fully describe the risk of CNS effects following radiation exposure in space and to provide guidance for risk management and radiation protection. May the force be with us!

NCRP SC 1-24: Radiation Exposures in Space and the Potential of Central Nervous System Effects. Standing, left to right: Cochair Richard Nowakowski (Florida State University), James Root (Memorial Sloan Kettering Cancer Center), Marvin Rosenstein (NCRP), Cochair Les Braby (Texas A&M University), Greg Nelson (Loma Linda University), and Julian Preston (Environmental Protection Agency, retired); sitting, left to right: John Boice (NCRP), Rudy Tanzi (Harvard, Massachusetts General Hospital), Lee Goldstein (Boston University), Walter Schimmerling (NASA, retired), and Greg Armstrong (St. Jude Children's Research Hospital); insert: Kathy Held (Harvard, Massachusetts General Hospital)