RADIATION RISK PROJECTIONS FOR SPACE TRAVEL

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ABSTRACT:

Space travelers are exposed to solar and galactic cosmic rays comprised of protons and heavy ions moving with velocities close to the speed of light. Cosmic ray heavy ions are known to produce more severe types of biomolecular damage in comparison to terrestrial forms of radiation, however the relationship between such damage and disease has not been fully elucidated. On Earth, we are protected from cosmic rays by atmospheric and magnetic shielding, and only the remnants of cosmic rays in the form of ground level muons and other secondary radiations are present. Because human epidemiology data is lacking for cosmic rays, risk projection must rely on theoretical understanding and data from experimental models exposed to space radiation using charged particle accelerators to simulate space radiation. Although the risks of cancer and other late effects from cosmic rays are currently believed to present a severe challenge to space travel, this challenge is centered on our lack of confidence in risk projections methodologies. We review biophysics and radiobiology data on the effects of the cosmic ray heavy ions, and the current methods used to project radiation risks. Cancer risk projections are described as a product of many biological and physical factors, each of which has a differential range of uncertainty due to lack of data and knowledge. Risk projections for space travel are described using Monte-Carlo sampling from subjective error distributions that represent the lack of knowledge in each factor that contributes to the projection model in order to quantify the overall uncertainty in risk projections. This analysis is applied to space mission scenarios including lunar colony, deep space outpost, and a Mars mission. Results suggest that the number of days in space where cancer mortality risks can be assured at a 95% confidence level to be below the maximum acceptable risk for radiation workers on Earth or the International Space Station is only on the order of 100-200 days. Approaches to reduce these uncertainties and mitigate risks are described.