Space Radiation Cancer, Circulatory Disease and CNS Risks for Near Earth Asteroid and Mars Missions: Uncertainty Estimates for Never-Smokers

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Abstract:

The uncertainties in estimating the health risks from galactic cosmic rays (GCR) and solar particle events (SPE) are a major limitation to the length of space missions and the evaluation of potential risk mitigation approaches. NASA limits astronaut exposures to a 3% risk of exposure induced cancer death (REID), and protects against uncertainties in risks projections using an assessment of 95% confidence intervals after propagating the error from all model factors (environment and organ exposure, risk coefficients, dose-rate modifiers, and quality factors). Because there are potentially significant late mortality risks from diseases of the circulatory system and central nervous system (CNS) which are less well defined than cancer risks, the cancer REID limit is not necessarily conservative.

In this report, we discuss estimates of lifetime risks from space radiation and new estimates of model uncertainties are described. The key updates to the NASA risk projection model are:

1) Revised values for low LET risk coefficients for tissue specific cancer incidence, with incidence rates transported to an average U.S. population to estimate the probability of Risk of Exposure Induced Cancer (REIC) and REID.
2) An analysis of smoking attributable cancer risks for never-smokers that shows significantly reduced lung cancer risk as well as overall cancer risks from radiation compared to risk estimated for the average U.S. population.
3) Derivation of track structure based quality functions depends on particle fluence, charge number, Z and kinetic energy, E.
4) The assignment of a smaller maximum in quality function for leukemia than for solid cancers.
5) The use of the ICRP tissue weights is shown to over-estimate cancer risks from SPEs by a factor of 2 or more. Summing cancer risks for each tissue is recommended as a more accurate approach to estimate SPE cancer risks.
6) Additional considerations on circulatory and CNS disease risks.

Our analysis shows that an individual's history of smoking exposure has a larger impact on GCR risk estimates than amounts of radiation shielding or age at exposure (amongst adults). Risks for never-smokers compared to the average U.S. population are estimated to be reduced between 30% and 60% dependent on model assumptions. Lung cancer is the major contributor to the reduction for never-smokers, with additional contributions from circulatory diseases and cancers of the stomach, liver, bladder, oral cavity and esophagus, and leukemia. The relative contribution of CNS risks to the overall space radiation detriment is potentially increased for never-smokers such as most astronauts. Problems in estimating risks for former smokers and the influence of second-hand smoke are discussed. Compared to the LET approximation, the new track structure derived radiation quality functions lead to a reduced risk for relativistic energy particles and increased risks for intermediate energy particles. Revised estimates for the number of "safe days" in space at solar minimum for heavy shielding conditions are described for never-smokers and the average U.S. population. Results show that missions to near Earth asteroids (NEA) or Mars violate NASA's radiation safety standards with the current levels of uncertainties. Greater improvements in risk estimates for never-smokers are possible, and would be dependent on improved understanding of risk transfer models, and elucidating the role of space radiation on the various stages of disease formation (e.g. initiation, promotion, and progression).