Relative Effectiveness of HZE ^{56}Fe Particles for the Induction of Cytogenetic Damage in Vivo

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Risk from prolonged manned space flight includes the radiation exposure from galactic cosmic rays containing high energy, heavy ions like ^{56}Fe. Studies were conducted at the Brookhaven National Laboratory by exposing Wistar rats to high mass, high-energy (HZE) particles using the Alternating Gradient Synchrotron (AGS). The biological effectiveness of ^{56}Fe ions (1000 GeV/AMU) relative to low-LET gamma rays and high LET alpha particles for the induction of chromosome damage and micronuclei was determined. The mitotic index and the frequency of chromosome aberrations were evaluated in the bone marrow and the frequency of micronuclei was measured in cells isolated from the trachea and the deep lung. A marked mitotic lag was induced in the bone marrow, which decreased as a function of time after the exposure. The frequency of chromatid aberrations and micronuclei increased as a linear function of radiation dose. Aberration frequency induced by HZE particles was about 3.2 times higher than that observed following exposure to ^{60}Co gamma rays. The frequency of micronuclei in rat lung fibroblast, lung epithelial cells and tracheal epithelial cells increases linearly with slopes of 7×10^{-4}, 12×10^{-4} and 11×10^{-4} micronuclei/binucleated cell/Gy, respectively. When genetic damage from ^{56}Fe was compared to that from exposure to ^{60}Co, ^{56}Fe was between 0.9 and 3.3 times as effective as ^{60}Co. However, the HZE exposures were less effective than radon (0.1 to 0.2) in producing micronuclei in either deep lung or tracheal epithelial cells. Studies using micro-dosimetric techniques estimated that there were about 60 cells hit by delta rays for each cell that was traversed by the primary HZE ^{56}Fe particle. These calculations and the observed, low relative effectiveness of the radiation exposure to HZE particles suggest that at least part of the cytogenetic damage measured was caused by the delta rays. Much of the energy deposited by the primary HZE particles may result in cell killing and therefore be "wasted" as far as production of detectable micronuclei is concerned. The role of "wasted" energy on cancer induction may be very important in risk estimates for HZE particles.

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