Simulations of DSB yields and radiation-induced chromosomal aberrations in human cells based on the stochastic track structure induced by HZE particles

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The formation of double-strand breaks (DSBs) and chromosomal aberrations (CAs) is of great importance in radiation research and, specifically, in space applications. We are presenting a new particle track and DNA damage model, in which the particle stochastic track structure is combined with the random walk (RW) structure of chromosomes in a cell nucleus. The motivation for this effort stems from the fact that the model with the RW chromosomes, NASARTI (NASA radiation track image) previously relied on amorphous track structure, while the stochastic track structure model RITRACKS (Relativistic Ion Tracks) was focused on more microscopic targets than the entire genome. We have combined chromosomes simulated by RWs with stochastic track structure, which uses nanoscopic dose calculations performed with the Monte-Carlo simulation by RITRACKS in a voxelized space. The new simulations produce the number of DSBs as function of dose and particle fluence for high-energy particles, including iron, carbon and protons, using voxels of 20 nm dimension. The combined model also calculates yields of radiation-induced CAs and unrejoined chromosome breaks in normal and repair deficient cells. The joined computational model is calibrated using the relative frequencies and distributions of chromosomal aberrations reported in the literature. The model considers fractionated deposition of energy to approximate dose rates of the space flight environment. The joined model also predicts of the yields and sizes of translocations, dicentrics, rings, and more complex-type aberrations formed in the G0/G1 cell cycle phase during the first cell division after irradiation. We found that the main advantage of the joined model is our ability to simulate small doses: 0.05-0.5 Gy. At such low doses, the stochastic track structure proved to be indispensable, as the action of individual delta-rays becomes more important.