Modeling the Complexity of DNA Damage and Cell Survival Following the Exposure of Ionizing Radiations with Different Characteristics

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Research on the biological effects of ionising radiation is an actively developing field of interdisciplinary research having applications in many fields including radiation protection, nuclear medicine, and deep space exploration. In this report a review of biophysical models hierarchy to study early radiation effects in DNA and cells that are not available experimentally, and study on the problem of relative biological effectiveness of different types of ionizing radiation is presented.

In recent years a hierarchy of biophysical models incorporating physical, chemical, and biological events in a cell has been actively developed [1]. The key element of this hierarchy is the description of initial physical interaction with biological materials at the molecular level. Many dedicated track structure Monte Carlo simulation codes [2] have been developed for this purpose by simulating the transport of particles and the subsequent physical/chemical reactions with biological components of the cell that result in DNA damage. Finally, a set of biochemical reactions need to be simulated in order to study DNA repair and cell survival [3] that can be directly measured in the radiobiological experiments.

Presented model approach is based on recent version of Geant4-DNA simulation toolkit for computation of various types of DNA lesions, including single and clustered double strand breaks of different complexity. The model incorporates various structures of chromatin and reaction-diffusion events with damaging radyolityc species. Next stages of hierarchy incorporate the overall kinetics of DNA repair and its fidelity, to predict a range of biological endpoints including residual DNA damage, chromosome aberrations, and cell death. An extended example is given on the problem of radiation-induced effects in the central nervous system, where complex geometry of cells and heterogeneity of cell population increase the computational difficulty [4]. As a final endpoint of this partucular case the dose-dependence of sensitive cell survival was calculated in specific area of brain (hyppocampus) and projected on long-term effect of impaired neurogenesis [5].

References

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