SIMULATION OF THE ENERGY DEPOSITION IN GLUN1A/GLUN2B NMDA SYNAPTIC RECEPTOR UNDER EXPOSURE TO HZE PARTICLES

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The initial physical structure of high-energy heavy-charged (HZE) particle tracks plays an important role in understanding the basic mechanism of radiation actions on biological tissues. The Monte-Carlo based simulations provide detailed information on properties of the interactions such as spatial distribution of energy depositions, interaction types (ionization, excitation, etc.) and radical species produced. Some recent challenges referred, for example, to preparation of deep-space exploratory missions and to ongoing expansion of the radiation therapy for brain cancer treatment require prediction of radiation risk for the central nervous system (CNS) [1]. In this regard, development of new simulation techniques aimed at estimation of radiation injury to CNS is of great importance.

In our work, we suggest a model approach designed for prediction of radiation-induced impairments in synaptic receptors of hippocampal neurons. The model is based on combination of the particle track structures produced by the Geant4 Monte-Carlo toolkit [2] with voxel models of receptors. The abilities of the suggested simulation technique are demonstrated with the use of ^{1}H, ^{4}He, ^{12}C, ^{28}Si, and ^{56}Fe particles as a damaging factor and the GluN1a/GluN2B NMDA receptor as a target for radiation. With our model we simulated the stochastic energy deposition in the receptor under exposure to the different HZE particles with various dose and linear energy transfer (LET). Our results suggest that large energy deposition in small volumes likely enables HZE nuclei to induce violations in the synaptic active zone and, in particular, cause damage of synaptic receptors. Although the precise mechanism of radiation effects on synapses is unknown, our study may contribute to better understanding of the early stages of damage, starting from the primary interaction of a charged particle with the biological matter.

References

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