RADIATION EFFECTS IN THE CENTRAL NERVOUS SYSTEM: SIMULATION TECHNIQUE AND PRACTICAL APPLICATIONS

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In recent years, radiation damage to the central nervous system (CNS) has become an increasingly important field of research for two major reasons. First one is represented by the ongoing preparation of deep-space manned flights. For these missions, the prediction of the health risk from space radiation is one of the crucial tasks. The second reason is determined by the estimation of possible side effects of brain cancer therapy with hadron beams [1].

Neuronal cell injury initiated by ionizing energy deposition involves a cascade of physico-chemical and patho-physiological pathways that are poorly understood [2]. Typically, a neuron appear as very complex structural and of greatly variable-sized geometry, and consists of a soma which contains the cell nucleus, an axon which carries nerve signals away from the soma, and many dendrites which occur that signal receivers as a dendritic tree with thousands of dendritic spines. In our study, a computational model of the radiation-induced neuron morphologies has been developed. The model simulates the time-evaluation of particle`s tracks traversals to the detailed neuron structure (soma, dendrites, axons and dendritic spines). It was adapted for the Geant4 Monte Carlo simulation toolkit [3, 4]. The considered incident particles include protons, carbon and iron ions with different doses and linear energy transfers (LET) which are common in space radiation exposures. The pyramidal and granule neurons of various hippocampal regions are selected as a target for radiation exposure since the activity of the hippocampus is thought to be highly disturbed by irradiation with the mentioned heavy charged particles.

The computational model covers the stochastics of generation of energy deposition events, reaction and diffusion of the seven water radiolysis products (e^{-}_{aq}, $^{\bullet}OH$, H_3O^+, $H^{\bullet}$, OH^{-}, $H_2^{\bullet}$, $H_2O_2^{\bullet}$) after irradiation, delivery of particle beams and neuronal morphology. In order to benchmark our model, we estimated the deposited dose and radiolytic yields of each water radiolysis products at 1 microsecond as a function of the LET of mentioned particles.

References

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