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SIMULATED RADIATION DAMAGE TO TUMOR CELLS ACCUMULATED BORON NITRIDE QUANTUM DOTS

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Boron neutron capture therapy (BNCT) is a promising non-surgical radiotherapy method for the treatment of invasive malignant tumors (primary brain tumors, recurrent head, and neck cancer, cutaneous and extracutaneous melanomas), which includes two stages: (i) a drug, containing the non-radioactive isotope boron-10 (^{10}B), is injected to the patient, where it localizes in the tumor, (ii) the patient is irradiated with epithermal neutrons. The absorption of neutrons by boron-10 causes the formation of alpha particles, nucleus of ^{7}Li and high-energy gamma quant. The effectiveness of BNCT depends mainly on the concentration of boron (approximately 10^9 atoms of ^{10}B per cell should be selectively delivered [1]) and its selective accumulation and distribution in tumor target cells. In the present study, a theoretical evaluation of the effectiveness of BNCT based on the use of boron nitride quantum dots (BNQDs) is carried out.

Simulation of the interaction of formed pairs of ions (Li, α-particle) with the cell components was performed by the Monte Carlo method implemented in the 'Stopping and Range of Ion in Matter' (SRIM) [2]. Several models of tumor cells with different nucleoplasmic ratios (a unified cell model, lymphoma, melanoma, squamous cell carcinoma) were considered. The focus of the study was the dependence of radiation damage to cells on the specific localization of BNQDs in different compartments: intercellular space, membrane, cytoplasm, nucleus.

As a result of modeling, the optimal localization of BNQD in tumor cells depending on the type of tumor was determined. Cell nuclei are the main target for BNCT as they are the storage of DNA. It was revealed that the most effective damage to the nucleus of a unified cell (Fig.1a) occurs in the case of localization of the BNQD in the cytoplasm of cells due to the energy release (Fig.1b-c). The same results were obtained for other cell types with small variations.

The obtained results indicate that the increased effectiveness of BNCT can be achieved by using BNQDs specifically functionalized to be accumulated in the cell cytoplasm, thus, providing the possibility to reduce the time of BNCT and radiation dose as well as improve the prognosis for recovery.

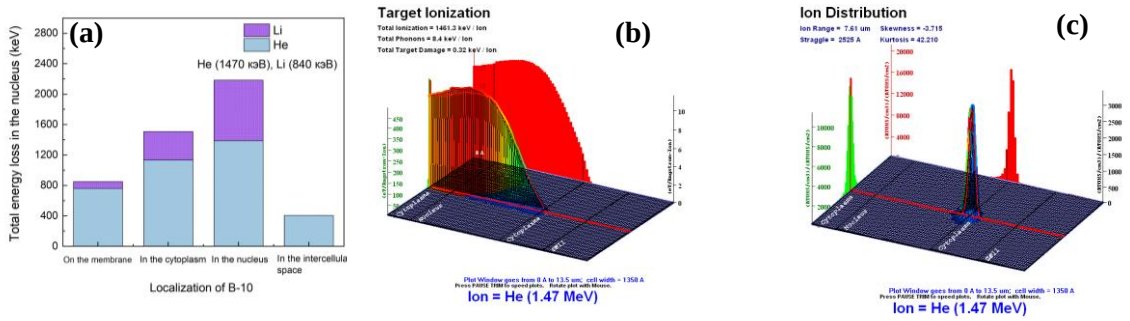

Fig. 1. Simulated radiation damage to tumor cells. **(a)** – the total energy loss on the ionization of the nucleus (violet and blue colors correspond to energy loss by Li ions and α-particles, respectively), **(b, c)** – Interaction of α-particles (1470 keV) with the cell during BNCT when BNQDs were localized in the cell cytoplasm: **(b)** – ionization of the target itself during the propagation of α-particles, **(c)** – final distribution of α-particles in the target.

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