Accelerator-based neutron source for boron neutron capture therapy: in vitro efficacy evaluation with in-sample dosimetry using gold nanoparticles

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In BNCT, the use of an accelerator to produce neutrons instead of a nuclear reactor makes it possible to place the treatment facility in medical institutions. We evaluated the efficacy of the accelerator-based neutron source for BNCT in experiments in vitro, using animal and human cell lines and a colony-forming assay. U251MG, T98G, CHO-K1, and V79 cells were incubated with BPA containing boron-10 or boric acid at different concentrations (0, 10, 20, 40 ppm). Additionally, glycylglycine-coated gold nanoparticles were used in T98G cells to evaluate the absorbed neutron dose in the samples.

The samples were placed in a phantom made of organic glass under the lithium target of the tandem accelerator with vacuum insulation. The irradiation was performed for 1 to 2 hours with the following accelerator settings: 2.0 to 2.3 MeV proton energy, 1 to 3 mA proton current, and 50 to 300 million events of epithermal neutron generation. The activation of gold in the samples was measured using a gamma spectrometer. The accumulation of gold in the samples was observed by electronic microscopy and measured by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Using gold nanoparticle activation data, the boron dose was estimated by Monte Carlo simulation. After irradiation, the cells were seeded into 6-cm round dishes for colony formation assessment. After 1 to 2 weeks, the colonies of ≥50 cells were counted for each sample and each irradiation dose. The results were compared with controls irradiated without boron.

The cell survival data confirm the efficacy of the tandem accelerator with the lithium target to produce a sufficient number of neutrons to initiate the boron neutron capture reaction within and close to tumor cells, leading to a decrease in colony formation. The new approach in dosimetry for BNCT that we tested in the current study may allow us to determine the absorbed neutron dose using combined boron compounds containing an additional high-Z element. This approach may open up a new perspective in boron compound distribution and treatment efficacy evaluation that may lead to modification of such methods as isotope scanning and positron emission tomography (PET). A more detailed description of the results will be provided at the 17th International Congress on Neutron Capture Therapy.