Evaluation of biological effectiveness of 65 MeV therapeutic proton beams using the GATE platform

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Introduction:

In order to optimize hadrontherapy treatments, it is needed to consider the biological effect on irradiated tumor cells. The biological dose can be evaluated through biophysical models, such as the Microdosimetric Kinetic Model (MKM)[1–5]. This model is implemented to take into account a corrected lineal energy spectrum obtained from Monte Carlo simulations and the model parameters of irradiated cells obtained from experiments. The purpose of this study is to validate the implementation of the MKM model into GATE through the simulation of the 65 MeV therapeutic proton beam (MediCyc) of Antoine Lacassagne centre for the estimation of the relative biological effectiveness (RBE).

Material and Methods:

First, the full MediCyc proton beam line has been modelled using the GATE Monte Carlo platform (version 8.1 using geant4.10.04.p01) to assess depth dose distributions of a monoenergetic and a 16 mm Spread Out Bragg Peak (SOBP). Melanoma cells (SkMel28 cell type) are irradiated with a 250 kVp X-ray beam (X-rad 320 X-ray system) and with the MediCyc line for 0 to 10 Gy dose range to obtain survival curves. The microdosimetric spectra of lineal energy are obtained for different depth in water for the monoenergetic and 16 mm SOBP. Then, the frequency mean lineal energy, the dose mean lineal energy and the saturation-corrected dose-mean specific energy are calculated in function of depth to obtain finally an estimation of the depth–RBE distribution.

Results:

Simulated depth dose profiles are in well agreement with measurements. The microdosimetric spectra of lineal energy obtained with the GATE "TEPC and the LET actors" are compared to measurements using a miniaturized TEPC from literature[6]. Cell survival curves are fitted using the linear quadratic model to recover the α and β parameters. The different lineal energies and depth-RBE distributions are then compared to those obtained with the FLUKA code[6].

Conclusions:

This work lead to the implementation and the validation of the MKM biophysical model on the GATE platform. The same validation methodology will be applied to the evaluation of biological dose treatment plans for the 235 MeV proton beam line (ProteusOne) of Antoine Lacassagne centre.

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