A fast method to calculate RBE weighted dose distribution

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Purpose/Objective: It is well known that proton RBE is not a constant, but depends on several factors such as dose per fraction, biological endpoint, tissue type and local energy spectrum. However at the moment, commercial options for applying variable RBE in clinical applications are limited, due to the fact that calculation of the effect of local energy spectrum is time consuming. In this study, we present a fast method to calculate 3-D RBE weighted proton dose distribution.

Materials/Methods: A phenomenological model that describes proton RBE in the framework of the linear-quadratic model was proposed. In the model, effect of local energy spectrum is characterized by the dose-averaged-local-linear-energy-transfer (DALLET). The calculation of DALLET is usually a time consuming task, and therefore not well suited to clinical application. In this study, we are developing a method that can calculate the RBE within a clinically acceptable time frame. We first developed and validated a Monte Carlo (MC) program in Geant4 to model our institution-specific proton pencil-beam-scanning (PBS) system. Then the MC program is employed to generate DALLET data for selected human tissues. These DALLET data depends on tissue type, initial energy, and the actual energy at the point where the proton interacts with tissue. The chemical composition and material density of all selected human tissues are taken from ICRP pub. 23 (1975). The DALLET data are then incorporated into an in-house developed computer code to calculate variable RBE-weighted dose distribution within the patient represented by CT. Since the DALLET data are pre-calculated and bundled as a look-up-table, the RBE computation time is reduced substantially.

Results: The MC validation result is first presented, which includes (1) transverse profile in air at 5 different locations along the beam central axis for 5 selected energies, (2) the nozzle water-equivalent-thickness, and (3) all 107 proton PBS beam characteristics (range, peak width and peak-to-entrance ratio) in water. The DALLET data, generated by the validated MC program, is then presented. After incorporating the pre-calculated DALLET data, the in-house computer code is employed to calculate variable RBE weighted dose distributions. As the application of the fast method, a couple of clinical cases are chosen to be recalculated, and the focus is on the distal end region of PBS beam. The comparison between fixed RBE and variable RBE dose distributions are presented, with an emphasis on field-specific range.

Conclusion: We are developing a fast method to calculate 3-D RBE distribution for proton treatment. The method is expected to perform the proton’s RBE calculation with the accuracy and computation time accepted in a busy clinical setting.

1 Jan J. Wilkens and Uwe Oelfke, “Optimization of radiobiological effects in intensity modulated proton therapy”, Medical Physics 32, 455 (2005);