Variations in relative biological effectiveness of protons estimated using two computational models

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*Abstract*

Background: There has been growing interest in the use of proton-beam radiotherapy for cancer treatment. A key advantage of protons compared to conventional photon-beam radiotherapy is its better spatial dose distribution and greater biological effect. The latter can be quantified by the relative biological effectiveness (RBE) quantity, defined as a ratio of two absorbed doses delivered by one type of ionizing radiation to the reference beam with the same effect in a given biological system. A constant RBE of 1.1 is usually applied for proton beams, despite the fact that the RBE of protons has been suggested to vary depending on a number of factors. Therefore, it is important to develop computational tools which can model the variations in RBE and use their results in radiobiological modeling calculations of tumor control and normal-tissue complication probabilities.

Aim: The absorbed dose and the linear energy transfer (LET) are both depth-dependent along the path of a proton beam. The present study aimed to calculate the RBE variations at different depths for protons based on two different computational models.

Materials and Methods: First, dose deposition at different depths of a 2.5 cm diameter, 62 MeV proton beam depth-dose distribution was simulated in a water phantom using the MCNPX Monte Carlo radiation transport code. Then, theoretical calculations were used to compute the RBE values and their variations with depth. The RBE predictions of two models by Wilkens and Wedenberg were studied based on the linear quadratic (LQ) dose-response model as a function of dose and LET.

Results: The obtained results showed that the RBE of the incident 62 MeV proton beam changed from 0.92 (at the depth of 1 mm) to 1.05 (at the Bragg peak depth of 30 mm) for the Wilkens model. However the corresponding values for the Wedenberg model varied from 1.03 to 1.14.

Conclusions: These results provide further evidence of the large RBE variations with proton beams and that the RBE = 1.1 assumption can give rise to incorrect prediction of radiobiological dose-response. They also highlight differences in the predictions of the two models, which merit further investigation before clinical use.

Keywords—Proton therapy, Monte Carlo, Dose, RBE, LET

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