AbstractID: 12968 Title: Relative biological effectiveness of proton – an empirical model prediction

Purpose: To propose a simple Relative Biological Effective (RBE) model for proton that describes the RBE as a function of proton depth, dose, and the linear energy transfer (LET).

Methods and Materials: Radiobiological parameters α and β were obtained by fitting the published experimental proton cell survival data where the surviving fraction (*SF*) as a function of dose (*D*) is given by $SF(D) = \exp(-\alpha D - \beta D^2)$. The RBE defined as the ratio of photon dose over proton dose (D_x / D_p) for the same *SF*, is given in the present model by,

$$RBE = \frac{\sqrt{\alpha_x^2 - 4\beta_x LnSF} - \alpha_x}{\sqrt{\alpha_p^2 - 4\beta_p LnSF} - \alpha_p} \times \frac{\beta_p}{\beta_x}$$

where

$$\alpha_p = \alpha_0 + \frac{1 - e^{-\lambda_1 * LET^2}}{\lambda_2 * LET}$$ and $\beta_p = \beta_x$.

A software program gnuplot with the Levenberg-Marquardt algorithm was used to fit the experimental data with the empirical formula mentioned above by minimizing χ^2 with the selection of suitable parameters (λ_1, λ_2, α_0). The dose average LET values were calculated for 250 MeV proton in water using GEANT4 (version 4.9.3) Monte Carlo simulation code. The model was then used to calculate the RBE values as a function of depths that includes the Bragg peak depths of 250 MeV protons, where the increasing RBE with depths causes an extended biological effective dose in the distal falloff range.

Results: The best fit parameters obtained were α_0=0.1 Gy^{-1}, λ_1=0.0013 (keV/μm)$^{-2}$ and λ_2=0.045 (keV/μm)$^{-1}$·Gy. The model was found to be able to reproduce the measured RBE values as a function of LET and dose. The biological effective dose (physical dose multiplied by RBE) as a function of depths for 250 MeV incident proton shows that the shift in the depth of distal edge at 90% level of physical dose is 1 mm.

Conclusions: The new model is providing an improved understanding of the RBE as a function of depth, dose and LET for proton beam.