An Absorbed Dose Model for Range-Modulated Proton Beams and Applications in Quality Assurance

The consistency of absolute proton dosimetry has been significantly improved (Vatnitsky, et al. Radiother Oncol, in press) with the adoption of standard methods for reference dosimetry, i.e., at single reference point in a phantom. However, the interpretation of proton dose distributions in depth is, in many cases, difficult due to structure in the peak and/or to limited experimental data. In order to overcome these problems, we developed a model for absorbed dose as a function of depth in a spread out Bragg peak (SOBP). This model accurately describes a wide variety of ideal and imperfect SOBPs. In a fitting procedure, several parameters in the model are allowed to vary simultaneously in order to obtain an optimal fit to the entire measured SOBP. The model parameters obtained from the fitting procedure provide clinically relevant information such as the proximal and distal depths of the SOBP, field flatness, distal falloff width, and skin dose. Measured depth dose data from the Northeast Proton Therapy Center were fitted to the model, including SOBPs that ranged from 4 to 31 cm in water equivalent depth, and with corresponding modulation widths ranging from 1 cm to full depth. Monte Carlo simulations revealed how proton scattering and non-elastic nuclear reactions influence the model parameters that predict dose at shallow depths. We propose standard methods for characterizing SOBPs in depth, with the aim of achieving consistency in spatial dosimetry of approximately 1% (1 standard deviation) at MGH and 3% (1 s. d.) with other proton therapy centers.