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Incorporation of multiple Coulomb scattering in the prediction of optimal focal lengths in magnetically focused proton radiosurgery

Steven J. Martinez, Grant A. McAuley, Jerry D. Slater, Andrew J. Wroe

Purpose:
Magnetic focusing of protons is a promising approach to improve patient radiation dose distribution in proton radiosurgery. The paths of individual protons are affected by multiple atomic deflections (multiple Coulomb scattering (MCS)) and affect overall beam characteristics in the patient. The purpose of this project is to account for the effects of MCS in the optimization of focal lengths in magnetically focused proton radiosurgery.

Methods:
Monte Carlo (MC) computer simulations were performed on magnetically focused proton beams wherein phase space data (i.e., individual particle angle and displacement from beam axis) were collected at the upstream surface of a water tank and at Bragg depth. Phase space data at Bragg depth was also calculated using a second method that incorporated a statistical model of MCS. The change in particle angle and displacement due to MCS was determined in multiple steps along the beam path from the water tank to Bragg depth using a Gaussian approximation and an inverse transform sampling method. Second order statistical moments of angle and displacement were then calculated to generate the so-called sigma matrix, which characterizes essential properties of the phase space data. The sigma matrix calculated at Bragg depth using the MCS model was compared to the sigma matrix determined from the MC simulations.

Results:
Preliminary results suggest that a simple Gaussian approximation of angle and displacement can reproduce the elements of the sigma matrix within an error of 15% compared to the original MC simulation. Refinements to the MCS model and data analysis are ongoing and the latest results will be presented.

Conclusions:
Optimization of magnetic focal lengths is important for future individualized radiosurgery treatment plans. Previous efforts in our lab to predict optimal focal lengths included the properties of focusing magnets but not the effects of MCS. The present research represents an effort to effectively model MCS and incorporate its effects in the prediction of the optimal focal lengths of a magnet focusing system.

From Loma Linda University School of Medicine (S.J.M.) and Loma Linda University Department of Radiation Medicine (G.A.M., J.D.S., A.J.W.)
Accepted for Publication: November 2018
The authors have no funding, financial relationships, or conflicts of interest to disclose.
Send correspondence to: sjmartinez@llu.edu

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