

Title: Proton therapy range verification with gel and point detector array dosimetry

Rationale: Proton radiotherapy offers advantages over photon radiotherapy for the treatment of malignant diseases due to the characteristics of proton interactions with human tissue. The depth of the sharp distal dose gradient (Bragg peak) is a function of the incident proton beam energy, and modulation of beam energy and intensity during treatment allows for a dose distribution that is more conformal to the target. Proton therapy has garnered the attention of the radiation medicine community for the treatment of pediatric malignancies due to the potential reduction in the volume of healthy tissue irradiated to low dose as compared to modern photon radiotherapy techniques. Physical uncertainties in the treatment planning process currently limit the efficacy of proton therapy, most notably in determining the position of the Bragg peak (range uncertainty). Clinical methods for calculating Bragg peak position exhibit a 2.7 % uncertainty, and differences in tissue inhomogeneity between planning and delivery stages can result in an additional 2.5 % range uncertainty. Quantification of these uncertainties, known as range verification, is essential to the safe and effective use of proton therapy.

Research objectives: To achieve the objective of establishing clinical methods to reduce range uncertainty for proton therapy, we propose two complementary methods of range verification: (1) polymer gel dosimeters analyzed with optical computed tomography to evaluate the three-dimensional dose distribution of a therapeutic proton delivery prior to treatment, and (2) *in vivo* point detector measurements to perform adaptive beam energy adjustment for pediatric patients receiving craniospinal irradiation.

Experimental Approach: The project cultivates an interdisciplinary approach involving particle simulation, radiation dosimetry, imaging, clinical oncology, prototype design, and a multi-institutional collaboration to achieve the research objectives. Particle simulation studies using the Tool for Particle Simulation (TOPAS) platform will improve the calibration process and accuracy of the point detector technique and quantify range-mixing uncertainty. Design of a clinically compatible prototype will be achieved through consultation with a radiation oncologist and pediatric anesthesiologist. A fabrication protocol for the polymer gels will be established and validated in photon and electron beams at our institution using optical computed tomography (OCT) for imaging, and then tested on in a proton beam at the collaborating Francis H Burr Proton Therapy Center of the Massachusetts General Hospital (MGH) in Boston, Massachusetts.

Impact: The point detector array system aims to reduce range uncertainty for pediatric craniospinal irradiation cases by inserting the detector into the esophagus of the anesthetized patient immediately prior to treatment. A very low dose (on the order of 2 cGy) would allow for the characterized system to perform a final range verification measurement and potentially result in an adaptive adjustment of the beam energy to ensure target coverage while confirming adequate sparing of the esophagus, which may reduce the risk of acute esophagitis. For sites where an intracavitary measurement is impractical, a streamlined fabrication and imaging protocol for polymer gels could provide three-dimensional range verification for patient-specific quality assurance prior to treatment.