PhD Thesis Title: Development of a Remote Dosimetric Audit Framework for Carbon Therapy

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Carbon ion therapy is available at over a dozen institutions around the world and is being employed for treatment of cancer. The increased biological effect of carbon compared to conventional photon-based radiotherapy holds promise for the therapeutic benefit in historically radioresistant tumors. While ion chamber dosimetry has been used for day-to-day clinical measurements of absorbed dose, there are few options for remote dosimetry. The availability of such tools would support the development of a robust remote audit program for carbon therapy.

The Imaging and Radiation Oncology Core (IROC) conducts remote audits of photon and proton therapy. These audits are used to ensure comparability and consistency among radiotherapy clinics and are an important peer-review tool to ensure accurate dose delivery. To address the gaps in the tools available for peer review audits for carbon ion therapy, the following aims were developed:

Aim 1: Characterize passive dosimeters for absolute dosimetry of carbon radiotherapy. We will evaluate the LET and ion species dependence of TLD-100, OSLD nanoDots, and EBT3 GafChromic film. We will characterize dose correction factors to validate the dose response, with a goal of 2.5% uncertainty (1σ).

Aim 2: Evaluate tissue-equivalent phantom materials for use in carbon radiotherapy dosimetry. This will be done by measuring the Hounsfield units, relative linear stopping powers, and relative dose of each material and comparing to a human tissue conversion curve, with a goal of 2.5% uncertainty (1σ).

Aim 3: Develop an end-to-end measurement-based audit of carbon therapy. A simple geometric and an anthropomorphic phantom will be designed, built, and irradiated in clinical carbon therapy beams at several carbon facilities. The overall accuracy of the end-to-end tests will be quantified.

The absorbed dose corrections factors for TLD and OSLD were characterized in a therapeutic carbon beam, as well as variety of plastics typically used in phantom dose measurements. An anthropomorphic phantom, mimicking pancreatic cancer, was designed, and field-tested at a clinical carbon facility. A realistic carbon ion treatment plan was created for the pancreas phantom and delivered using a therapeutic carbon beam at the Centro Nazionale di Adroterapia Oncologica (CNAO) in Pavia, Italy. The phantom dosimetry was measured using film and TLD characterized by this project and compared to the treatment planning system (TPS) calculations, demonstrating good agreement with the TPS.

This work laid the foundation for remote audits of carbon therapy centers. This was an important step in developing a framework for clinical trial credentialing for carbon therapy randomized trials. These tools will help ensure that carbon therapy treatment around the world is accurate and consistent.

References to author publications that relate specifically to the dissertation:

1. **Taylor PA**, Mirandola A, Ciocca M, Hartzell S, Vai A, Alvarez P, Howell RM, Koay EJ, Peeler CR, Peterson CB, Kry SF. Technical note: Radiological clinical equivalence for phantom materials in carbon ion therapy. Med Phys. 2024 Jul;51(7):5154-5158. doi: 10.1002/mp.17056. Epub 2024 Apr 10. PMID: 38598230; PMCID: PMC11233228.
2. **Taylor PA**, Hartzell S, Mirandola A, Ciocca M, Magro G, Alvarez P, Peterson CB, Peeler CR, Koay EJ, Howell RM, Kry SF. OSLD nanoDot characterization for carbon radiotherapy dosimetry. Phys Med Biol. 2024 May 14;69(11). doi: 10.1088/1361-6560/ad43ac. PMID: 38663410.
3. **Taylor PA**, Mirandola A, Ciocca M, Hartzell S, Magro G, Alvarez P, Peterson CB, Peeler CR, Koay EJ, Howell RM, Kry SF. Characterization of LiF TLD-100 in carbon ion beams for remote audits. Med Phys. 2025 Mar;52(3):1858-1866. doi: 10.1002/mp.17605. Epub 2024 Dec 24. PMID: 39718203.