PhD Thesis title: Monte Carlo treatment planning with modulated electron radiotherapy: framework development and application
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ABSTRACT: Within the field of medical physics, Monte Carlo radiation transport simulations are considered to be the most accurate method for the determination of dose distributions in patients. The McGill Monte Carlo treatment planning system (MMCTP), provides a flexible software environment to integrate Monte Carlo simulations with current and new treatment modalities. A developing treatment modality called energy and intensity modulated electron radiotherapy (MERT) is a promising modality, which has the fundamental capabilities to enhance the dosimetry of superficial targets. An objective of this work is to advance the research and development of MERT with the end goal of clinical use. To this end, we present the MMCTP system with an integrated toolkit for MERT planning and delivery of MERT fields. Delivery is achieved using an automated ``few leaf electron collimator'' (FLEC) and a controller. Aside from the MERT planning toolkit, the MMCTP system required numerous add-ons to perform the complex task of large-scale autonomous Monte Carlo simulations. The first was a DICOM import filter, followed by the implementation of DOSXYZnrc as a dose calculation engine and by logic methods for submitting and updating the status of Monte Carlo simulations. Within this work we validated the MMCTP system with a head and neck Monte Carlo recalculation study performed by a medical dosimetrist. The impact of MMCTP lies in the fact that it allows for systematic and platform independent large-scale Monte Carlo dose calculations for different treatment sites and treatment modalities. In addition to the MERT planning tools, various optimization algorithms were created external to MMCTP. The algorithms produced MERT treatment plans based on dose volume constraints that employ Monte Carlo pre-generated patient-specific kernels. The Monte Carlo kernels are generated from patient-specific Monte Carlo dose distributions within MMCTP. The structure of the MERT planning toolkit software and optimization algorithms are demonstrated. We investigated the clinical significance of MERT on spinal irradiation, breast boost irradiation, and a head and neck sarcoma cancer site using several parameters to analyze the treatment plans. Finally, we investigated the idea of mixed beam photon and electron treatment planning. Photon optimization treatment planning tools were included within the MERT planning toolkit for the purpose of mixed beam optimization. In conclusion, this thesis work has resulted in the development of an advanced framework for photon and electron Monte Carlo treatment planning studies and the development of an inverse planning system for photon, electron or mixed beam radiotherapy (MBRT). The justification and validation of this work is found within the results of the

planning studies, which have demonstrated dosimetric advantages to using MERT or MBRT in comparison to clinical treatment alternatives.

References to author publications that relate specifically to the dissertation:

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