Abstract

A Study of Methods to Reduce Uncertainty in External Beam Radiotherapy

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The Tomotherapy Hi-Art machine is a highly advanced radiotherapy treatment modality that uses a megavoltage (MV) linear accelerator (linac) mounted on a CT ring gantry to rotationally deliver intensity modulated fan-beams of radiation to a patient as they are translated through the machine on a treatment couch. Patient delivery outcomes are predicted by the Hi-Art's integrated treatment planning system (TPS) using sophisticated beams models and knowledge of the machine's nominal dose rate output. For delivered patient dose distributions to match those predicted by the TPS, it is vital that the beam models and nominal output value used by the Hi-Art's TPS are accurate. Amongst other things, beam models within the TPS must account for the effects of using the machine's collimators to shape the fields of radiation produced by the linac. The aim of this work is to reduce the uncertainties in the treatment delivery process induced by variations in the Hi-Art's nominal dose rate output and limitations in the accuracy of measurements made on small radiation fields produced by narrow collimator settings.

Unlike most conventional radiotherapy modalities, the TomoTherapy Hi-Art does not use a dose-rate servo (DRS) system to regulate the dose rate output of its linac. In chapter 2, we investigate the feasibility of implementing a DRS system on a TomoTherapy machine to improve the stability of its dose rate. The designed DRS circuit monitors the instantaneous dose

rate of a linac and adjusts its pulsing to maintain a constant output. The circuit is initially tested and found to be effective in regulating the dose rates of a Varian Clinac 600 and a Siemens bench top linac. The DRS circuit is then tested on a Hi-Art machine and found to improve the overall stability of its dose rate output.

In chapter 3, one-dimensional detector-scanning techniques are developed and investigated as a means to accurately measure small TomoTherapy fields. In the study, common clinical detectors such as ion chambers and radiographic film are longitudinally scanned through static rectangular fields produced by the Hi-Art. This allows detectors to make measurements under conditions of improved lateral electronic equilibrium and virtually eliminates detector volume averaging effects. Detector scanning also allows accurate small-field measurements to be made with relatively large detectors that would traditionally be considered inappropriate for use in small-field dosimetry. A quantity termed “the integral scanned dose to slice width ratio”, or (D/SW), is introduced and found to be a sensitive metric of the photon-source occlusion effect for small TomoTherapy fields. The (D/SW) quantity proved to be highly sensitive to the modeled electron source spot size in the Monte Carlo (MC) code TomoPen, making it a valuable tool for evaluating the accuracy of photon source models used in analytical/MC dose calculation algorithms.

In chapter 4, we expand on the detector-scanning methodologies presented in chapter 3 and develop two-dimensional detector-scanning techniques for the measurement of stereotactic radiosurgery (SRS) fields. Due to their extremely small dimensions, SRS fields are difficult to measure reliably. Often, SRS fields are measured with multiple different detectors (some of which can be laborious to calibrate and readout) and results compared. Ideally, accurate measurements of SRS fields could be made using a single non-specialized detector. In this study, SRS field measurements are made by scanning a standard ion chamber in a two-dimensional “raster” like pattern. The integral dose measured during each scan is divided by the area of the scanned field to obtain what is termed the “integral scanned dose to field area ratio”, or (D/FA). The measured (D/FA) ratios for the SRS fields were consistent with the expected effects of source occlusion.