PhD Thesis title: 'Small animal radiotherapy: Dosimetry & Applications'

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ABSTRACT

Conformal **Sm**all **A**nimal **R**adio**T**herapy (S*m*ART) is a rapidly growing branch of pre-clinical radiation research through the introduction of dedicated commercial image-guided micro-irradiators (micro-IR) and bespoke ones. These devices make use of high-resolution CT imaging, beam sizes down to 1 mm and dose rates up to 4 Gy/min at energies ranging from 100 to 250 kVp. Machine-specific commissioning is required using the standard absolute dosimetry procedure for orthovoltage devices with only minor modifications and the use of radiochromic film for beam sizes smaller than 40x40 cm.

Monte Carlo modeling is required for accurate dose calculations at these energies and is fairly insensitive to the transport parameters used with the exception of the electron termination energy. Tissue assignment based on CT numbers or defined structures is however, a crucial step in treatment planning. The use of the machine-specific focal spot intensity distribution improves the agreement between Monte Carlo simulated dose distributions and experimental measurements. However, source-collimator alignment is rarely ideal and requires the use of correction factors for accurate dose predictions of the smallest beams. The use of 2-D portal dosimetry in pre-clinical micro-IR potentially can improve accurate radiotherapy e.g. assigning tissue correctly, or ensuring that the beam is in the correct position within the specimen position. The precise description of the beam at the exit of the collimator is contained within a phase-space file, which can be more rapidly created through the use of an analytical model using simplified geometries, a pinhole image of the source, and pre-calculated energy spectra.

A dedicated treatment planning system is essential to drive these image-guided micro-IR devices and software is presented and validated within this thesis. The software called SmART-Plan is designed in a modular fashion that novice users can segment, contour, plan, and calculate a treatment plan to a mouse within a matter of minutes for the majority of beam sizes often encountered. Through accurate and precise targeting and radiation delivery these image-guided micro-IR platforms can be used to address a number of hypothesis driven questions that could not ethically be performed in patients. One example provide in this thesis is in the study of radiation-induced lung fibrosis, which at high doses appears to be delayed and its severity diminished when using highly collimated beams supporting the volume effect in radiation induced lung damage.

References to author publications that relate specifically to the dissertation:

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2. **P.V. Granton**, P.E. Lindsay, A. Gaspararini, J. Sonke, F. Verhaegen, D.A. Jaffray. "Multi-institutional dosimetric and geometric commissioning of image-guided small animal irradiators." Med. Phys. 2014; Mar;41(3):031714, doi 10.1118/1.4866215

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5. **P.V. Granton**, M. Podesta, L. Guillaume, S. Nijsten, G. Bootsma, and F. Verhaegen. "A combined dose calculation and verification method for a small animal precision irradiator based on on-board imaging." Med Phys. 2012 Jul;39(7):4155-66

6. F. Verhaegen, **P.V. Granton**. E. Tryggastad Topical Review "Small animal imaging and irradiation devices" Physics in Medicine and Biology, **56** (2011) R55