

Development of micro-radiotherapy within the design of integrated small animal imaging and therapy system: an open source medical devices initiative

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The open-source medical devices (OSMD) initiative was started in 2009, and the first OSMD Conference was organized in 2011, focusing on specifications of the development of small animal imaging and therapy system that included micro-CT, micro-PET and micro-RT systems. Then, the focus was placed on the design of a micro-RT system capable of intensity modulated RT (IMRT).

For IMRT dose delivery, multi-leaf collimators (MLCs) are required to modulate and shape an x-ray beam. Three different models of the binary micro-MLC (bmMLC) were designed for a 250 kVp x-ray beam which included 20, 0.5 mm width brass leaves, providing total collimation of 1 cm x 1 cm. The dosimetric properties including beam profiles for the latest design were investigated using Gafchromic[®] EBT3 films. Leaf motion was controlled by Arduino microcontroller, opening and closing in <1 sec. The leaf penumbra was <0.5 mm with average transmission <2%, and intraleaf leakage <1%. Each bmMLC leaves were resolved well when the back-end of the bmMLC assembly was positioned 10-20 cm from the water phantom placed 100 cm from source.

IMRT beam delivery also requires a treatment planning system (TPS). WiscPlan-kV is a TPS developed for kV x-ray beams which was updated from an in-house WiscPlan (used for MV beams) with high resolution, low energy EDKs and dose calculation code for the kV dose delivery set-up with flexible and user-friendly MATLAB[®] interface. Dose calculation from WiscPlan-kV was verified by comparing the percent depth dose (PDD) profile in both homogeneous and heterogeneous phantoms measured with EBT3 film for the UWMRRC 250 kVp x-ray beam and with the corresponding Monte Carlo simulations (EGS and MCNP5). The PDDs compared well, where the difference between measured, simulated and calculated dose was <5%. Equipped with a least square optimizer and a rotational dose delivery, it was demonstrated that WiscPlan-kV can target tumor <1 cm and deliver IMRT in small animals using the bmMLC assembly. Through this work, a portion of proof-of-principle micro-RT system was developed with IMRT capability which can significantly contribute to preclinical research. The bmMLC design and the WiscPlan-kV software are available for free via OSMD website.