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Dosimetric Evaluation of a Novel Monte Carlo Dose Calculation Algorithm for Robotic Radiosurgery with MLC

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Abstract

Objectives: Since clinical introduction of the first MLC to be mounted on a robotic SRS/SBRT platform in 2015, dose calculation with a Finite-Sized Pencil Beam (FSPB) algorithm has been the only available option. Due to limitations of this calculation technique, use of the MLC in a heterogeneous situation such as lung SBRT was not appropriate. We now report on commissioning and pre-clinical dosimetric evaluation of an upcoming novel Monte Carlo (MC) calculation algorithm for robotic radiosurgery with MLC.

Methods: For commissioning, source parameters were iteratively adjusted to match water tank measurement data. Dosimetric verification was performed with radiochromic film (EBT 3) in phantoms with slabs of different density. The phantoms consisted of two layers of solid water (a=1 g/cc) enclosing one layer of lung-equivalent balsa wood (a=0.1…0.3 g/cc). Quadratic fields of different size (23.0 x 23.1 mm_ to 84.2x84.2 mm_) were delivered to the phantom. FSPB and MC calculated dose distributions were compared to film measurements using FilmQA (3cognition, Inc.). For single beams, gamma criteria of 5%/1 mm and 3%/1 mm (global gamma, limited to ROIs enclosing 1.5 times the beam size) were selected. For detailed local characterization, line scans were evaluated using ImageJ v1.51j (Rasband, W.S., USA).

Results: For beam commissioning, best correspondence between MC-calculated dose to water and diode measurements was achieved with a max beam energy setting of 6.3 MeV, a Gaussian source distribution with 1.8 mm FWHM and default settings for MLC transmission modelling. Film measurements in the variable density slab phantom corresponded much better with MC compared to FSPB calculations, with higher gamma pass rates of 95.4 +/- 1.2 % vs. 62.2 +/- 5.9 % (5%/1 mm) and 82.0 +/- 2.6 % vs 48.8 +/- 8.0 % (3%/1 mm). Contrary to FSPB, MC correctly predicts a decrease in dose upon entering low density tissue. Yet, non-negligible discrepancies at the transition from very low density material (<0.15 g/cc) to higher density material were identified, presumably due to different assumptions in the MC algorithm for particle transport below and above this density threshold, which affected calculated dose to film.

Conclusions: The novel MC dose algorithm improves calculation accuracy in heterogeneous tissue, potentially expanding the clinical use of robotic radiosurgery with MLC.

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