Optimized orthovoltage stereotactic radiosurgery

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Because of its ability to treat intracranial targets effectively and noninvasively, stereotactic radiosurgery (SRS) is a prevalent treatment modality in modern radiation therapy. This work focused on SRS delivering rectangular function dose distributions, which are desirable for some targets such as those with functional tissue included within the target volume. In order to achieve such distributions, this work used fluence modulation and energies lower than those utilized in conventional SRS.

In this work, the relationship between prescription isodose and dose gradients was examined for standard, unmodulated orthovoltage SRS dose distributions. Monte Carlo-generated energy deposition kernels were used to calculate 4π, isocentric dose distributions for a polyenergetic orthovoltage spectrum, as well as monoenergetic orthovoltage beams. The relationship between dose gradients and prescription isodose was found to be field size and energy dependent, and values were found for prescription isodose that optimize dose gradients.

Next, a pencil-beam model was used with a Genetic Algorithm search heuristic to optimize the spatial distribution of added tungsten filtration within apertures of cone collimators in a moderately filtered 250 kVp beam. Four cone sizes at three depths were examined with a Monte Carlo model to determine the effects of the optimized energy fluence modulation compared to open cones, and the simulations found that the optimized cones were able to achieve both improved penumbra and flatness statistics at depth compared to the open cones.

Prototypes of the filter designs calculated using mathematical optimization techniques and Monte Carlo simulations were then manufactured and inserted into custom built orthovoltage SRS cone collimators. A positioning system built in-house was used to place the collimator and filter assemblies temporarily in the 250 kVp beam line. Measurements were performed in water using radiochromic film scanned with both a standard white light flatbed scanner as well as an in-house laser densitometry system. Measured beam profiles showed that the modulated beams could more closely approach rectangular function dose profiles compared to the open cones.

A methodology has been described and implemented to achieve optimized SRS delivery, including the development of working prototypes. Future work may include the construction of a full treatment platform.