

First-In-Man Frameless and Coneless Linear Accelerator Delivery of Functional Stereotactic Radiosurgery Deliveries

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Abstract

Objectives: Stereotactic radiosurgery (SRS) has been used with success to manage a variety of neurological conditions. Because of the high doses, small target sizes, and degree of precision required, Gamma Knife has been the traditional modality chosen for delivery. Our objective was to develop and deploy an equally safe, effective, and precise alternative on the linear accelerator. We present here the first deployments of this new approach for an trigeminal rhizotomy and thalamotomy for essential tremor.

Methods: A previously described multi-leaf collimator (MLC) based treatment plan dubbed Virtual Cone was designed to mimic the dosimetric profile of a single 4-mm Gamma Knife collimator shot. The plan utilizes ten non-coplanar arcs and static multi-leaf collimator (MLC) positioning and mitigates the necessity of employing cones for small target treatments. Extensive film dosimetry was performed to confirm close agreement between calculated and delivered dosimetry. The plan utilizes thirteen arcs, twelve of which are non-coplanar with an axial arc, and the two central MLC-leaves open at 2.5mm throughout the duration of the delivery. The modulation pattern is not-patient specific, which will eventually render moot the necessity of patient-specific QA.

Results: We secured IRB approval to prospectively study the safety and efficacy of the new approach in comparison to traditional GK delivery for both trigeminal rhizotomy and thalamotomy. The patient receiving the trigeminal rhizotomy was prescribed a plan for delivery of Dmax = 80Gy to the dorsal root entry zone of the trigeminal nerve. The patient receiving thalamotomy for essential tremor was prescribed a Dmax = 130Gy to the ventral intermediate nucleus (VIM), which was targeted using stereotactic coordinates optimized to keep dose spill away from the internal capsule. Both plans were delivered on an Edge platform (Varian Medical Systems) with 10MV, flattening filter free beam configuration at a dose rate of 2400 MU/s. Both patients were immobilized using a QFix Encompass mask onto a 6 degree of freedom (DOF) Perfect Pitch couch. The Align-RT optical surface monitoring system (OSMS) was used to monitor the patients' positions in real-time. Deviation beyond 1 mm prompted cessation of treatment and return to couch angle = 0° for CBCT. Dosimetric discrepancy between the Eclipse v13 treatment planning system (TPS) and EBT2 GafChromic film was less than 3% for both plans. (Figures 2 & 3) Both treatments were delivered successfully without incident. Three additional intra-treatment CBCT's were performed during the thalamotomy for instantaneous

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magnitudinal patient positioning deviations beyond 1mm as registered by OSMS. Each time repeat CBCT confirmed patient positioning within original acceptable parameters. We eventually determined the OSMS camera inadvertently conflates longitudinal artifact at certain camera angles.

Conclusions: To the authors' knowledge, this is the first published description of MLC-based, frameless functional SRS treatments on a linear accelerator. Further work and additional treatments are necessary to demonstrate equivalent outcomes in each patient population for this new mode of treatment; however, excellent dosimetric agreement between the technique described here and previously described Gamma Knife treatments should antecede similar outcomes between the two delivery modalities.