

Purpose: The purpose of this work is to develop and evaluate an inverse planning approach for automatic generation of treatment plans for Gamma Knife Perfexion using intelligent isocenter placement and penalty-based optimization for beam-weights.

Methods: The optimization is a two-step process. First, a grassfire and sphere-packing hybrid algorithm determines the desired number of isocentre locations based on the shape and size of the target structures. Next, the selected isocentres are used in a penalty-based optimization model to minimize the deviation of the dose delivered to each structure from its objective dose. For fast computation time and solution optimality, a constraint generation algorithm is used. This model was tested on four clinical cases: two acoustic neuromas impinging upon the brainstem, and two large brain metastases. Two sets of treatment plans were created for each case: radiosurgery (target conformality optimized) and radiotherapy (additional planning target volume, plus dose homogeneity is emphasized).

Results: The mean optimization time for 30 isocentres was 15min. Multiple plans were generated for each target, with varying emphasis on minimizing beam-on time versus maximizing target coverage and conformality. In radiosurgery (12Gy prescription dose), with a beam-on time of 62min, 100% of the target received 98% of the prescription ($V_{100}=98\%$) with a maximum brainstem dose of 14.0Gy. Increasing beam-on time up to 147min, resulted in $V_{100}=100\%$ with a maximum brainstem dose of 13.2Gy. Similar tradeoffs were observed in radiotherapy with 50Gy prescription dose in 25 fractions. For the PTV, $V_{100}=78\%$ and $V_{100}=85\%$ for 17min and 46 min beam-on time per-fraction, respectively, while the max brainstem dose was kept at 52.5Gy.

Conclusions: Our approach is capable of fast, efficient treatment plan design. Our results indicate a tradeoff between beam-on time and dose objectives, the balance of which can ultimately be chosen by the radiation oncologist for any particular case.