Clinical Implementation of a New a Single-Isocenter Multiple-Target Cranial Optimization Algorithm

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INTRODUCTION

- Single-isocenter multiple-target (SIMT) stereotactic radiosurgery has been used clinically to treat brain metastasis using a fixed MLC margin of up to 1mm around the target to optimize dose conformity.
- Advances in Brainlab's SIMT optimizer and calculation algorithm now include the following major changes:
  1) MLC margins can vary between -3mm to 3mm and change between arcs (previously a universal 1mm margin was used),
  2) Jaws can partially cover an MLC leaf (previously fixed to the leaf edge),
  3) Optimizer cost function focuses on dose falloff as well as conformity (previously only conformity).
  4) Addition of a secondary source function to improve the scattering model.

AIMS

- Calculate the new secondary source function.
- Determine the effect of the new SIMT optimization algorithm on cranial stereotactic radiosurgery plan metrics.
- Validate the delivery and dosimetric accuracy of clinical treatment plans generated with the new optimization algorithm on Elekta's Versa HD.

METHOD

- The co-dependent radial factors and source functions were iteratively calculated, starting with an assumed set of default values, until they converged on a local solution.
- Previously treated clinical SIMT plans were re-optimized using the proposed new algorithm for 9 patients with 41 targets ranging in size from 0.06cc to 19.41cc. All re-plans were normalized to at least 95% target coverage to match initial clinical objectives.
- Plan quality was evaluated using: inverse Paddick Conformity Index (ICI), Gradient Index (GI), minimum dose to the PTV (PTVmin), and volume of the whole brain receiving 12Gy (WBV12).
- A student t-test was used to compare plan quality metrics for the two optimizations.
- Finally, a subset of the plans were delivered to an SRSMapcheck and microDiamond in a StereoPHAN on a Versa HD to verify dose.

RESULTS

SECONDARY SOURCE FUNCTION

- The iterative recalculation of the source function and radial factors converged quickly to a local solution after 4 runs (Table 1).
- Additional efforts were made to manually adjust the parameters to achieve better dose modeling. However, the automatically calculated parameters were chosen for the final clinical values as they produced the most accurate dose calculation throughout the entire model.

PLAN METRICS

- The new optimization algorithm reduced GI by 0.40+/-0.65 [P < 0.01] (Figure 1a). Smaller targets tended to show larger improvements in GI.
- The new optimization algorithm reduced ICI by 0.05+/-0.10 [P < 0.01] (Figure 1b). There was no strong correlation between ICI improvement and target size.
- There was no significant changes to the PTVmin [P > 0.10].
- WBV12 was reduced by an average of 2.39cc [P < 0.01] (Figure 1c-d).
- Planning times increased from approximately 1 minutes per arc arrangement, to 3 minutes per arc arrangement which reflects the larger solution space due to the additional degrees of freedom in the optimization algorithm.

DOSIMETRIC ACCURACY

- Strict commissioning tolerances were used for gamma analysis (per-field γ > 95% using 2%/1mm/10% threshold) and point dose measurement (<%3 between planned and measured)
- Average SRSMapcheck pass rates were 98.7% [97.0% - 99.8%].
- Measured microDiamond dose was within 1.40% of calculated for all targets.

Run	SFC Used to Calculate Radial Factors	Source Function 1 Depth = 15mm Amp.	Source Function 1 Depth = 15mm Sigma	Source Function 1 Depth = 200mm Amp.	Source Function 1 Depth = 200mm Sigma	Source Function 2 Depth = 15mm Amp.	Source Function 2 Depth = 15mm Sigma	Source Function 2 Depth = 200mm Amp.	Source Function 2 Depth = 200mm Sigma
1	Default	4	7.4	0	1.6	3.5	27.7	3	21.5
2	Run 1	4.5	7	0	2.3	2.5	20.8	2.5	17.7
3	Run 2	4.5	6.9	0	1.7	2.5	21.1	3	21.2
4	Run 3	4.5	6.9	0	1.7	2.5	21.1	3	21.2

Table 1: Results of the auto modeling of the radial factors and source functions. The co-dependence of the two variables meant that initial source functions were assumed and the two variables were alternatively calculated until they converged on a steady-state solution.

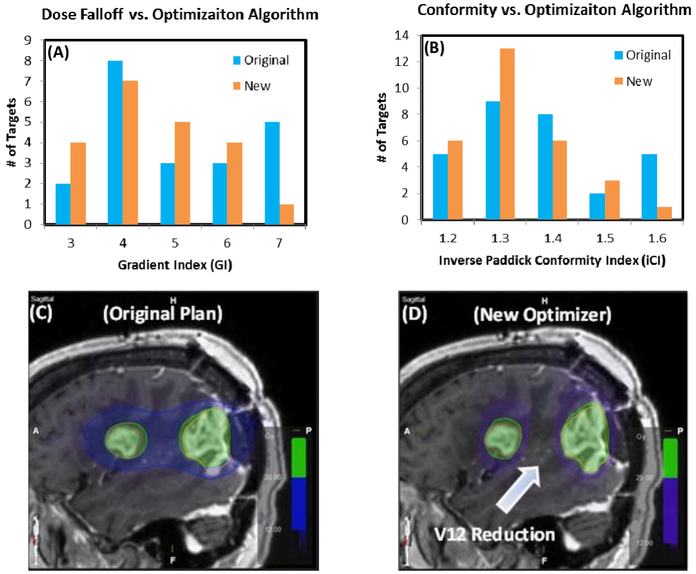

Figure 1: Plan comparisons between existing clinical and proposed new optimization. (A) Histogram distribution of target gradient indices, (B) histogram distribution of target conformity indices, (C) clinical case showing 12Gy dose-bridging between targets, (D) re-plan of clinical case with new optimizer showing removal of 12Gy dose-bridging.

PLANNING METRICS

$$ICI = \frac{(TV \times PIV)}{(TV_{PIV})^2}$$

$$GI = PIV_{half}/PIV$$

- *ICI* = Inverse Conformity Index
- *GI* = Gradient Index
- *TV* = Target Volume
- *PIV* = Isodose Volume for the prescription dose
- TV_{PIV} = Treatment volume covered by the prescription isodose volume
- *PIVhalf* = Isodose Volume for half of the prescription dose.

CONCLUSIONS

- The additional degrees of freedom in Brainlab's SIMT optimization algorithm have a positive effect in dose conformity and falloff, resulting in better OAR sparing for a similar target coverage.
- The added plan complexity from the increased solution space of the optimizer did not effect the deliverability of the plans on the Versa HD.
- All plans generated by the new SIMT algorithm passed the strict commissioning tolerances for planar and absolute doses measurement.
- Although the new SIMT algorithm increased optimization time from one to three minutes, the overall optimization time remains a small fraction of the pre-treatment planning and QA process.

CONTACT INFORMATION

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