Prioritizing Patient-Specific Geometry: Beam Angle Optimization in Stereotactic Radiosurgery

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PURPOSE

To improve the plan quality of multi-metastatic **Stereotactic Radiosurgery (SRS)** treatments by implementing automated patient specific beam angle optimization

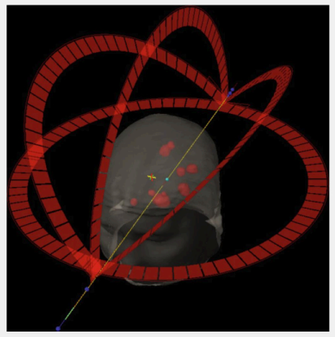


Fig 1. Example of a template-based plan with equally spaced treatment arcs.

Common to use a simplified template-based planning approach

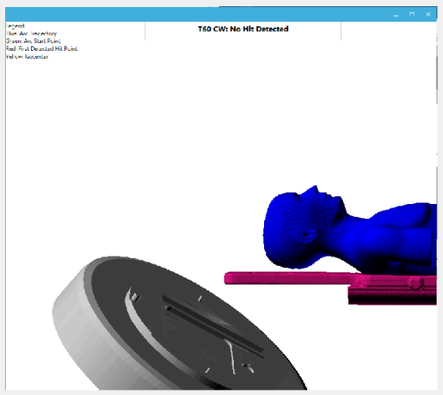
- Assigns beam angles based on general target location within brain
- Not specific to patient anatomy

Beam Angle Optimization (BAO) utilizes **patient specific geometry** to determine optimal beam angles

- Body Contour
- Organ at risk (OAR) locations
- Metastatic target locations

BACKGROUND

Beam Angle Optimization



- Expands on a Collision Prediction Application developed using Eclipse Scripting API (ESAPI)
- ESAPI allows direct access to patient plan data and integrates optimization into the planning workflow

Fig 2. Collision Prediction Application Display

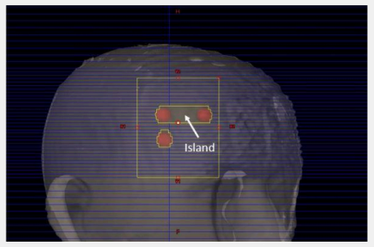
- Uses geometric heuristics instead of a fluence-based optimization
- Determines optimal treatment table and collimator angle combinations

METHODS

A. ESAPI Optimization Algorithm

Max trajectory for all treatment bed angles determined using collision prediction application.

a. MLC Area



b. OAR Overlap

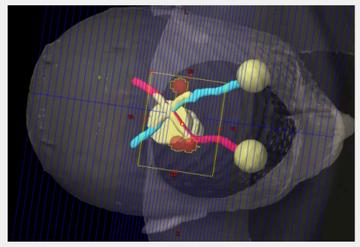


Fig 3. Beams eye view examples of optimization objectives

a. Summing of MLC open field area used to determine optimal collimator angles that minimize the "Island Blocking Problem" (Kang 2010, Wu 2016)

b. Organ at Risk overlap score used to determine optimal treatment table angles that prevent overlap with targets.

B. Retrospective Planning Study Design

Patient Selection:

- Multi-metastatic SRS patients treated within the last year, preferably with a single isocenter plan.

Planning Process:

- Same isocenter and number of arcs as clinical plan.
- Available treatment space maximized through collision prediction.
- Optimal treatment bed and collimator angles selected using MLC Area and OAR Overlap scores.
- Eclipse v13.6 photon optimizer used for VMAT optimization with same constraints as clinical plan.
- Target coverage normalized to be equal to or better than clinical plan coverage.

Plan Assessment:

- Organ at risk dose-volume metrics compared between clinical and beam angle optimized plans using Wilcoxon signed rank tests (a = 0.05).

RESULTS

A. ESAPI Optimization

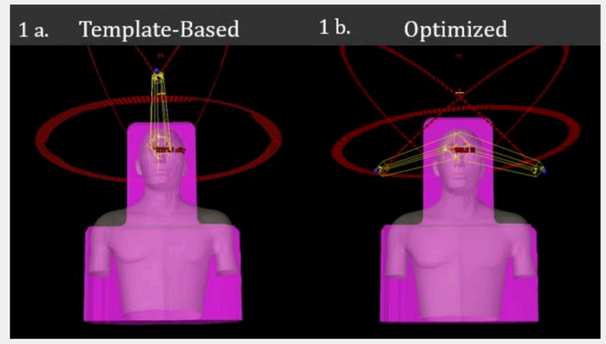


Fig 4. Example of the difference between optimized and template-based plans. Collision prediction allows non-coplanar 360° arcs and increased length on partial arc trajectories.

B. Study Results

36 multi-metastatic patient plans used for plan comparison. Patients had median 4 mets (range 2-13).

Organ At Risk	(N)	Parameter	Median (Range) Template-Based	BAO
Brain – PTV	(36)	V10Gy [cc]	**18.16** (1.92-137.88)	**20.50*** (2.39-190.86)
		V12Gy [cc]	**12.03** (1.11-83.26)	**12.88*** (1.25-84.32)
Brainstem	(36)	D0.03cc [Gy]	**3.71** (0.24-31.59)	**3.32*** (0.09-31.40)
Chiasm	(36)	D0.035cc [Gy]	**1.63** (0.07-7.35)	**1.20*** (0.05-7.14)
Cochlea Right	(15)	Mean [Gy])	**1.81** (0.13-6.95)	**1.67** (0.06-7.75)
Cochlea Left	(14)	Mean [Gy])	**1.50** (0.06-7.96)	**0.87** (0.03-5.56)
Eye Right	(36)	D0.1cc [Gy])	**0.66** (0.01-3.80)	**0.66** (0.04-5.23)
Eye Left	(36)	D0.1cc [Gy])	**0.83** (0.14-3.04)	**0.79** (0.02-3.41)
Optic Lens Right	(35)	D0.1cc [Gy])	**0.33** (0.00-2.04)	**0.27** (0.00-1.19)
Optic Lens Left	(35)	D0.1cc [Gy])	**0.30** (0.00-1.54)	**0.31** (0.00-1.33)
Optic Nerve Right	(36)	D0.035cc [Gy]	**1.00** (0.03-7.01)	**0.72*** (0.04-6.83)
Optic Nerve Left	(35)	D0.035cc [Gy]	**0.93** (0.06-7.59)	**1.24** (0.02-6.93)
Optic Tract Right	(23)	D0.035cc [Gy]	**0.91** (0.00-5.37)	**0.47*** (0.00-5.49)
Optic Tract Left	(23)	D0.035cc [Gy]	**0.71** (0.00-7.49)	**0.57*** (0.00-6.77)

Table 1. Planning study results. Statistically significant results are highlighted with an asterisk. Green shows improvement with BAO.

CONCLUSIONS

Statistically significant dose reductions were achieved for several OARs, while maintaining target coverage, with a slight increase in normal brain tissue volume irradiated.

References: Kang J. *et al*. A method for optimizing LINAC treatment geometry for volumetric modulated arc therapy of multiple brain metastases. *Med. Phys.* 2010; **37**(8)
Wu, Q. et al. Optimization of Treatment Geometry to Reduce Normal Brain Dose in Radiosurgery of Multiple Brain Metastases with Single-Isocenter Volumetric Modulated Arc Therapy. Sci. Rep. 6, 34511 (2016).

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