People who live with cancer - those who work to prevent it, fight it, and survive it - are at the heart of every decision we make.
Outline

• Stereotactic Radiosurgery – Single Isocenter for Multiple Targets (SIMT) Technique
• Treatment Planning Tips
• Impact of Rotational Errors & Compensation Strategies
• Other Considerations for SIMT
Stereotactic Radiosurgery

- High dose per fraction
- Limited number of fractions
- Conformal prescription dose
- Sharp dose gradient
- Target at linac isocenter, at least historically
Motivation for SRS supported by clinical trial data

- SRS+WBRT has survival advantage over WBRT for patients with single brain met & KPS > 70
- SRS+WBRT has better local control and maintenance of functional status compared with WBRT for patients with 1-4 brain mets & KPS > 70
- 40% of cancer patients go on to develop brain mets


Challenges to SRS

- Labor intensive & lengthy treatments (esp multi targets)
VMAT – Efficient IMRT

Volumetric modulated arc therapy: IMRT in a single gantry arc
K. Otto - Medical physics, 2008 - Wiley Online Library

- Rotational IMRT with variable gantry speed
- Variable dose rate
- MLC motion while gantry rotates
- Single arc (or perhaps ≥2 arcs)
SINGLE ISOCENTER MULTIPLE TARGET SRS

Coplanar
50% Rx

Non-coplanar
50% Rx

My conversations with physics and physician colleagues regarding SIMT VMAT SRS went something like this...

Is high dose conformity acceptable? Yes

Is the treatment more efficient? Yes

Are there concerns? Yes

- Normal brain dose
- Effects of setup errors
SINGLE ISOCENTER MULTIPLE TARGET SRS

Normal Brain Dose

- SRS poses risk of radionecrosis – up to 50% of treated lesions (Minniti et al)
- Symptomatic radionecrosis can impair speech, decrease cognition, cause seizures and even lead to death
- Radionecrosis is correlated with single fraction doses ≥ 10 Gy to normal brain
- SIMT SRS may result in greater dose to normal brain due to larger jaw settings and less conformal MLC apertures


SINGLE ISOCENTER MULTIPLE TARGET SRS

Planning Strategies to Minimize Normal Brain Dose

- Solution: Rotate the MLC so that multiple targets do not share the same leaf pair.
Planning Strategies to Minimize Normal Brain Dose

• Island blocking when there are many targets

• More challenging to determine optimal rotations by visualization

• Wu et al. developed an algorithm that optimizes the collimator and couch angles by finding the least total unblocked area for an arc

Planning Strategies to Minimize Normal Brain Dose: Jaw Tracking

- Problem: For VMAT optimization, jaws must be set large enough to adequately cover targets throughout an arc. Optimizer does not open jaws. However, this jaw setting may be overly large at many angles.

- Solution: Enable jaw tracking to minimize the transmission dose through the MLC.
SINGLE ISOCENTER MULTIPLE TARGET SRS

Planning Strategies to Minimize Normal Brain Dose

Penalize brain dose explicitly in the optimizer

- One or more rings around each target
- Mean dose objective for normal brain

Normal Tissue Objective

Don’t use the AUTOMATIC NTO

Effects of island blocking, jaw tracking and low dose optimization on normal brain dose – the UAB experience

Fiveash and Popple. (2019) UAB Stereotactic Training Course
# SIMT SRS Planning Tips

**Do**
- Use non-coplanar geometries
- Rotate collimator to minimize MLC apertures
- Enable jaw tracking
- Penalize low dose, e.g. rings or custom NTO
- Consider both conformity index and gradient index

**Don’t**
- Use default jaw settings
- Attempt to achieve a homogeneous PTV dose
- Select Automatic NTO
- Forget important OARs
- Use collision prone geometries
Positioning errors: single vs multi target

Translational errors: Same effect

Rotational errors: Displacement varies with distance from point of rotation
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Rotational Errors at Initial Setup

Duke Experience: Frameless SRS with U Frame thermoplastic mask

Stanhope et al. (2016) PRO, 6, pp. 207-213
Rotational Positioning Errors

Patients move more the longer they are on the table.

Intra-fractional errors were significantly correlated with the total treatment time with 0.7mm±0.5mm and 1.2mm±0.7mm for treatment times ≤23 minutes and >23 minutes (p<0.01)

Guckenberger *Radiation Oncology* 2012 7:63
Target coverage studied as function of

- Rotational error
- Distance from point of rotation
- PTV size

50 prior cases
Simulated rotations of 0.5°, 1°, & 2°
Quantified target coverage

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Data stratified by PTV volume

Smaller targets are affected more by rotational errors
Discussion:

- Rotations seen clinically can compromise coverage
- 6 DoF corrections recommended
- Initial 6 DoF corrections may not be enough as a patient may move during treatment – monitoring is also recommended

What can be done to compensate for rotations?
Compensation strategies: Group proximal targets

- Characterize uncertainty in patient positioning
- Identify target size
- Select acceptable probability of target coverage
- Group targets within set distance for single isocenter SRS
- Added benefit of using the central more narrow MLC leaves
Compensation strategies: Optimized target grouping

k-means algorithm used to determine the number and position of isocenters

Compensation strategies: Add margin to avoid geometric miss but be aware of the consequences

Intracranial lesion 1 cm diameter = 0.5 cc

Add 1 mm margin $\rightarrow$ 0.9 cc  (1.73 x volume)

Add 3 mm margin $\rightarrow$ 2.1 cc  (4.01 x volume)
Compensation strategies: Margin 1 mm vs 3 mm

- Similar local control
- Greater radionecrosis

1 mm: 1/34
3 mm: 5/32

Compensation strategies: Custom Margins

Compensation strategies: 6 DoF Corrections

In house

Dhabaan et al. (2012)
JACMP, V13(6), pp. 215-225

Commercial

Elekta HexaPOD
Compensation strategies: Monitoring

Room mounted x-ray imaging

Optical surface imaging

Linac mounted x-ray imaging
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Compensation strategies: Monitoring

Optical surface imaging similar to room mounted x-ray

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Other considerations: Quality assurance

Tolerance limits and methodologies for IMRT measurement-based verification QA: *Recommendations of AAPM Task Group No. 218*

Moyed Milten, Arthur Oich, Dimitris Mihailidis, Jean Moran, Todd Pawlicki, Andrea Molineu, Harold Li, Krishni Wijesooriya, Jie Shi, Ping Xia, Nikos Papanikolaou, Daniel A. Low

- **True Composite:** 1\(^{st}\) choice, caveat angular response
- **Perpendicular Field by Field:** 2\(^{nd}\) choice and to investigate TC discrepancies
- **Perpendicular Composite (Portal Dosimetry):** Should NOT be used for IMRT QA
Other considerations: Quality assurance

Historically ion chamber and film

Many commercial devices are inadequate

Vendor solutions are improving
Other considerations: Quality assurance

SNC SRS MapCHECK

- Absolute dose comparison possible
- Measure multiple planes with the 77 mm x 77 mm array of >1000 diodes
- Vertex fields in near future
Frontiers of Quality Assurance

- 3D polymer gel
- Radiation changes both optical and mass density
- In room CT/CBCT can be used to evaluate spatial accuracy

Other considerations: Alternative planning solutions

BrainLab Elements

HyperARC

RayStation
UAB Experience

- Non-coplanar single isocenter VMAT to treat multiple targets
- Zero margin: GTV = PTV
- CBCT for initial positioning
- Optical surface monitoring

Clinical Result = No correlation between local recurrence and distance to isocenter
Thank you