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.

Single Isocenter Multiple Target SRS

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AAPM Spring Clinical Meeting
April 2, 2019

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

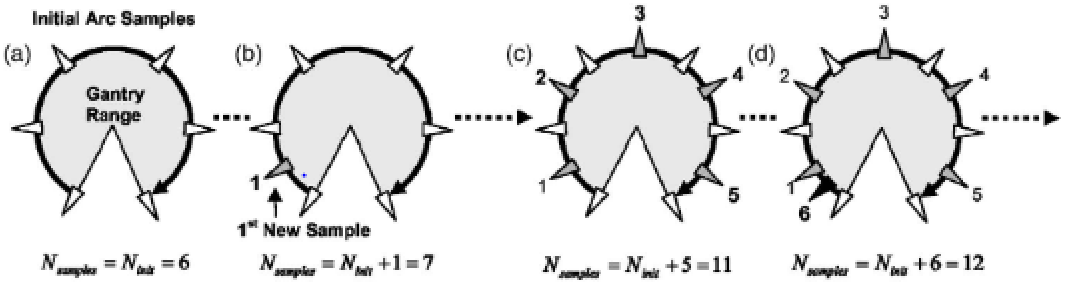
Linskey et al. Journal of Neuro-Oncology January 2010, Volume 96, Issue 1, pp 45–68

Challenges to SRS

- Labor intensive & lengthy treatments (esp multi targets)

VMAT – Efficient IMRT

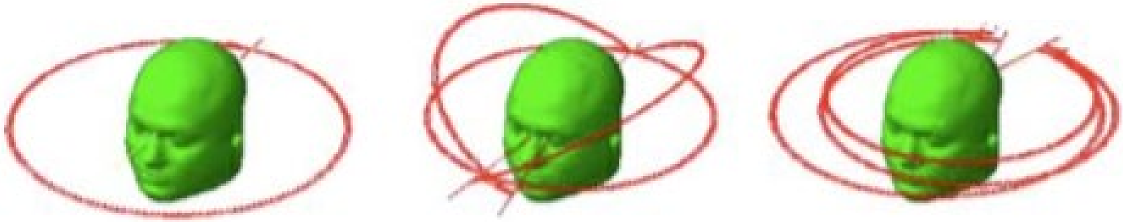
Volumetric modulated arc therapy: IMRT in a single gantry arc
K Otto - Medical physics, 2008 - Wiley Online Library



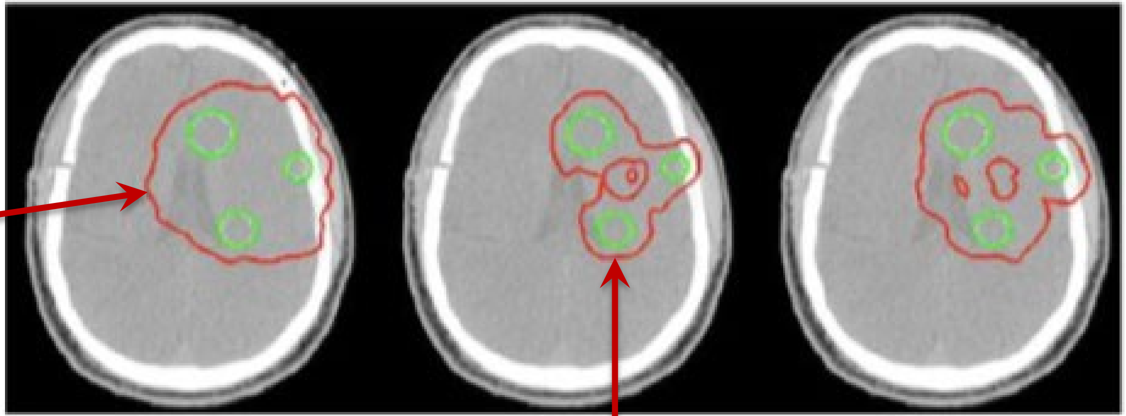
Cited 1571 times as of 3/29/2019

- 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

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Clark et al. Int J Radiat Oncol Biol Phys. 2010;76:296–302

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*

- <u>Normal brain dose</u>
- <u>Effects of setup errors</u>

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

Table 3. Rate of radionecrosis for V10 Gy and V12 Gy volumes

Volume (cm^3)	Radionecrosis (%)
V10 Gy	
<2.2	4.7
2.2–6.3	11.9
6.4–14.5	34.6
>14.5	68.8
V12 Gy	
<1.6	4.7
1.6–4.7	11.9
4.8–10.8	34.6
>10.8	68.8

Abbreviations: V10 Gy, V12 Gy = volume of brain receiving 10 Gy and 12 Gy, respectively.

Bionigen et al,
Int J Radiat Oncol Biol Phys.
(2010) 77:4 996–1001

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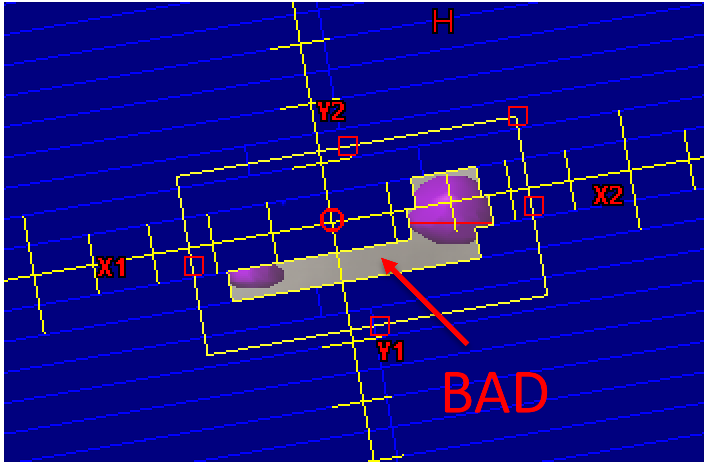
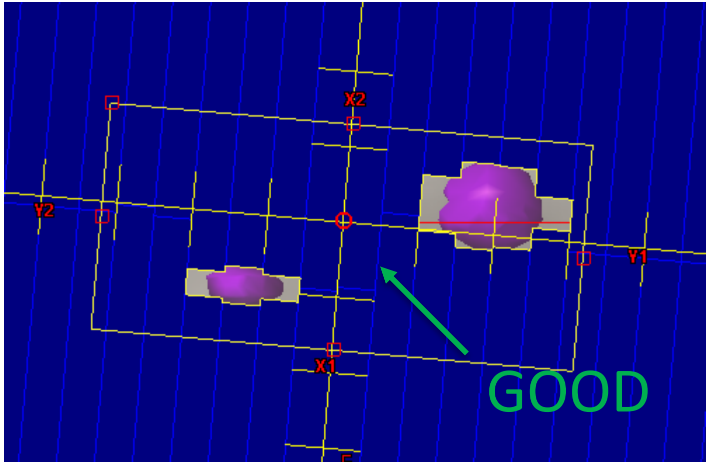
Minniti et al, Radiat Oncol. 2011; 6: 48.

Planning Strategies to Minimize Normal Brain Dose

- Problem: Island blocking. Kang et al Med. Phys. 37, 4146–4154 (2010)
- Solution: Rotate the MLC so that multiple targets do not share the same leaf pair





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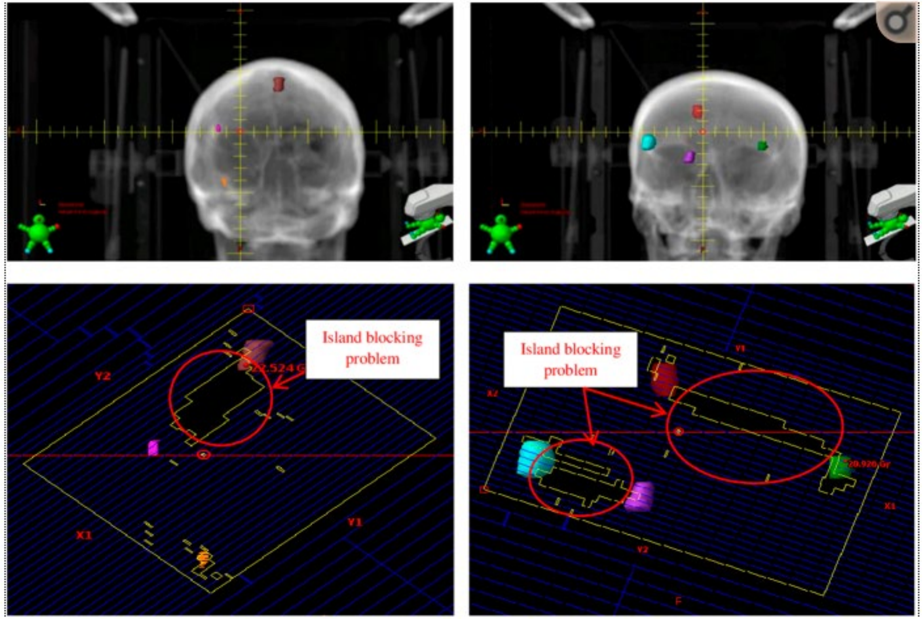
Planning Strategies to Minimize Normal Brain Dose

- Island blocking when there are many targets



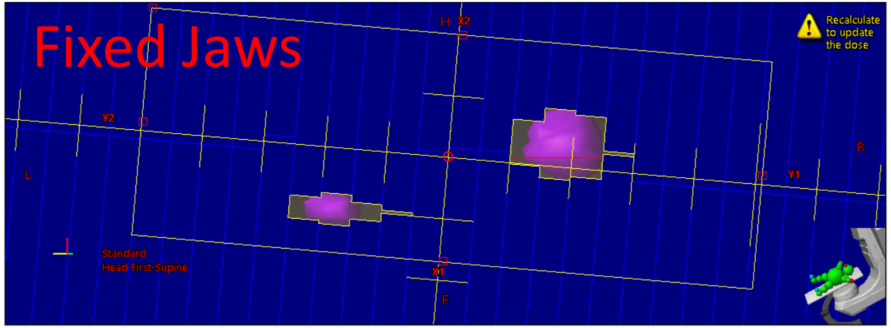
- More challenging to determine optimal rotations by visualization
- Wu et al. developed an algorithm that optimizes the collimator and couch angles by finding the least total unblocked area for an arc

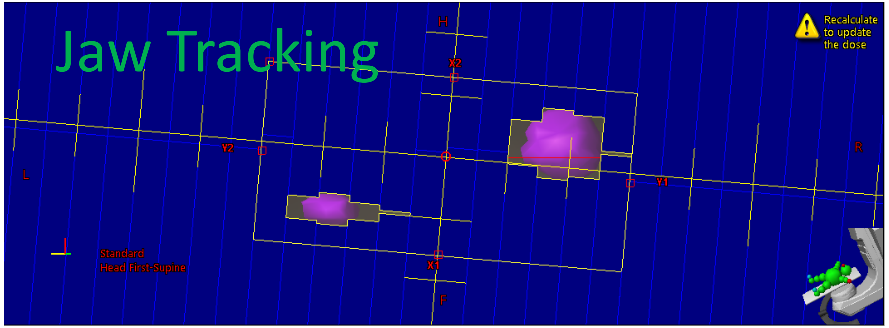
Wu et al. Sci Rep. 2016; 6: 34511.

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.

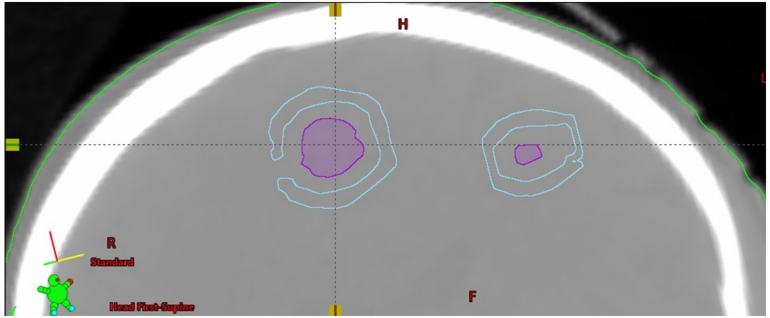




Planning Strategies to Minimize Normal Brain Dose

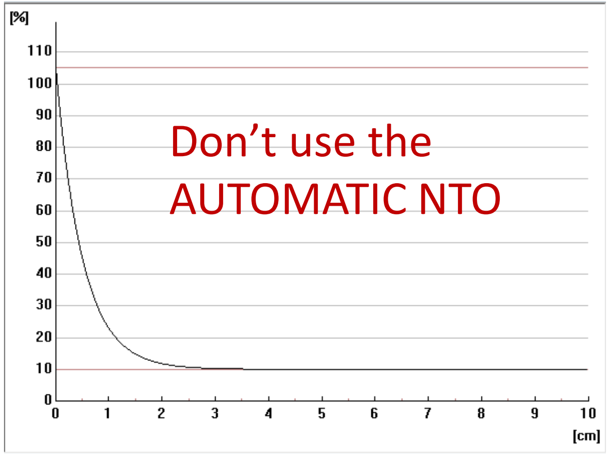
Penalize brain dose explicitly in the optimizer

- One or more rings around each target



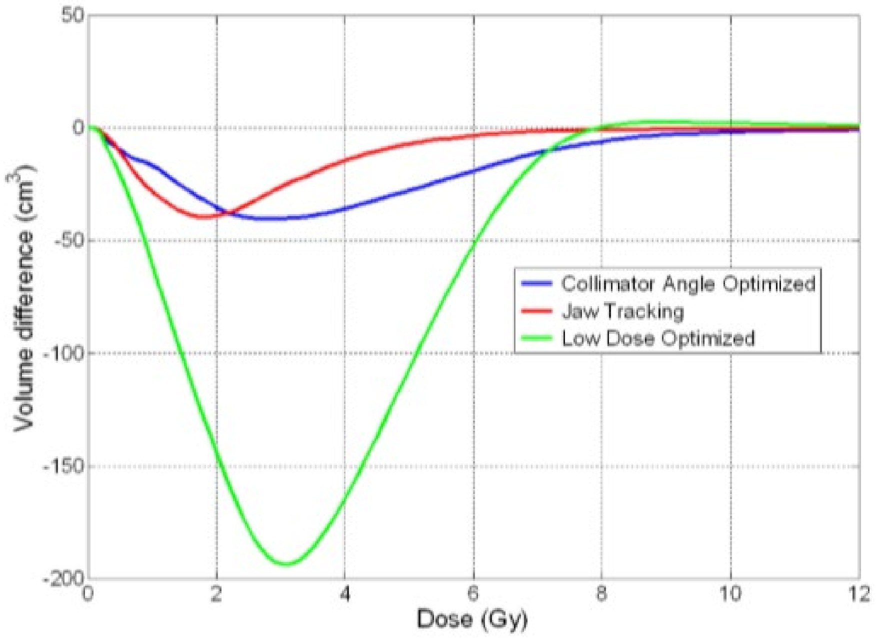
- Mean dose objective for normal brain

- Normal Tissue Objective



Bell et al, **Medical Dosimetry** Volume 43, Issue 4, Winter 2018, Pages 344-350

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

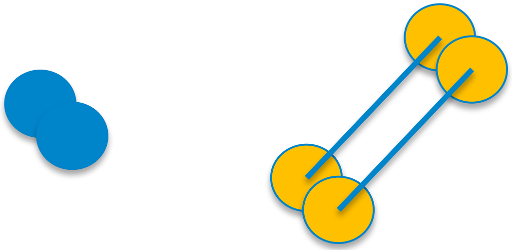
- Use non-coplanar geometries
- Rotate collimator to minimize MLC apertures
- Enable jaw tracking
- Penalize low dose, e.g. rings or custom NTO
- Consider both conformity index and gradient index

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

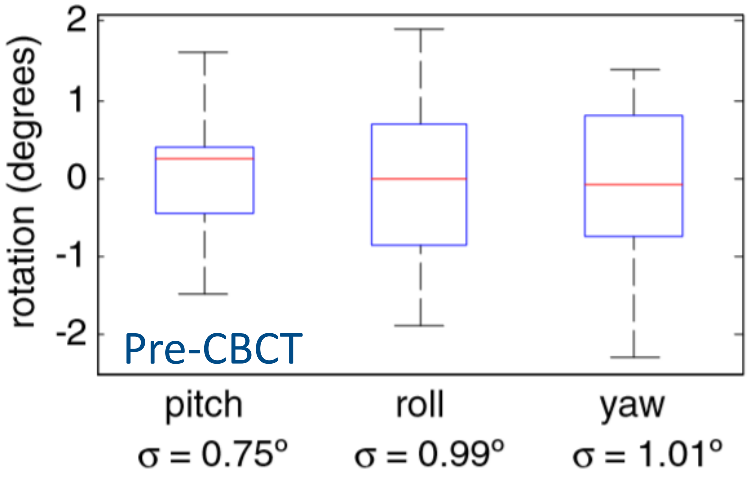
Translational errors: Same effect

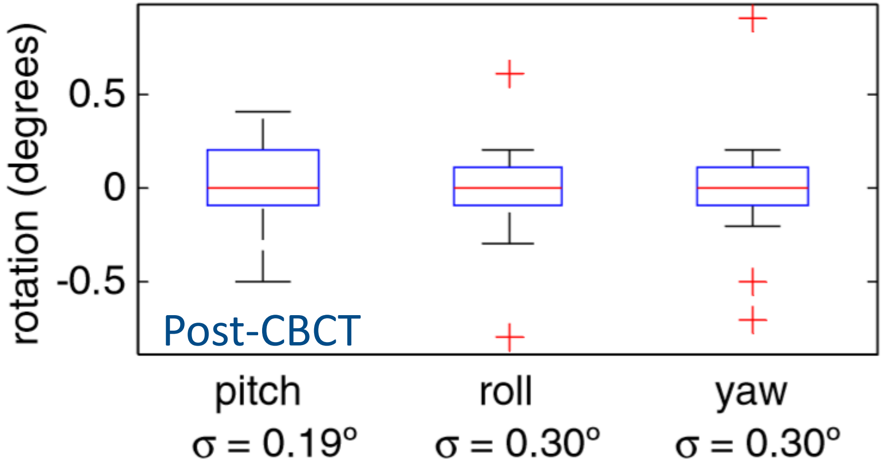


Rotational errors: Displacement varies with distance from point of rotation

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

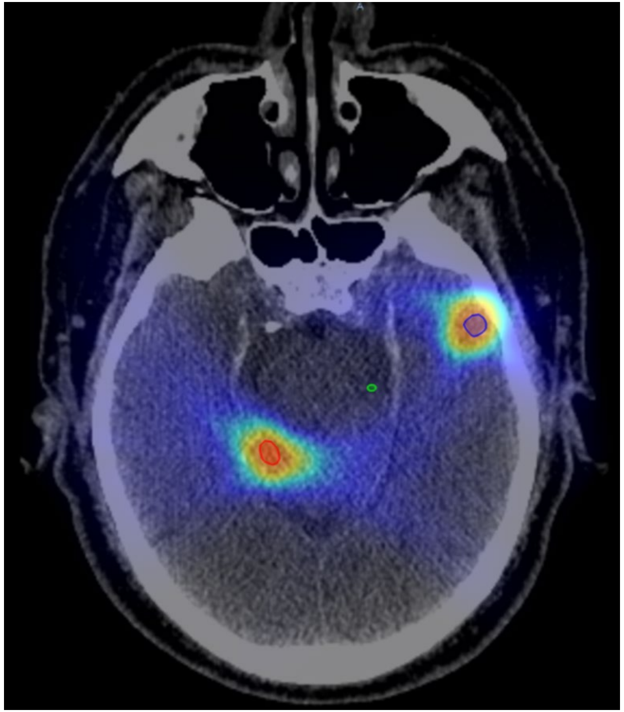
Intra-fractional errors were significantly correlated with the total treatment time with 0.7mm±0.5mm and 1.2mm±0.7mm for treatment times ≤23 minutes and >23 minutes ($p<0.01$)

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



Roper et al. (2015) Int J Rad Bio Phys 93(3), 540-546

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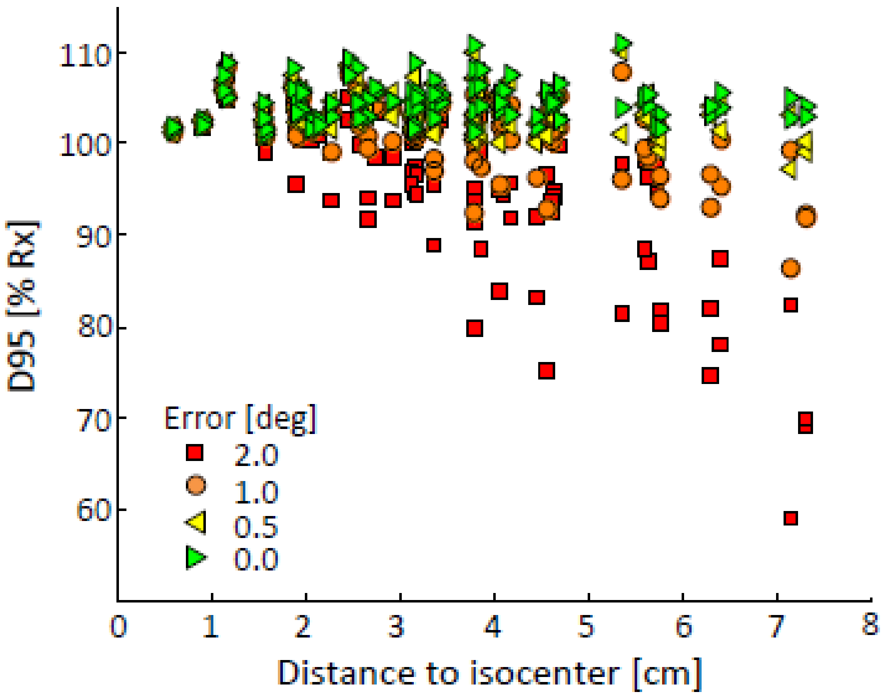
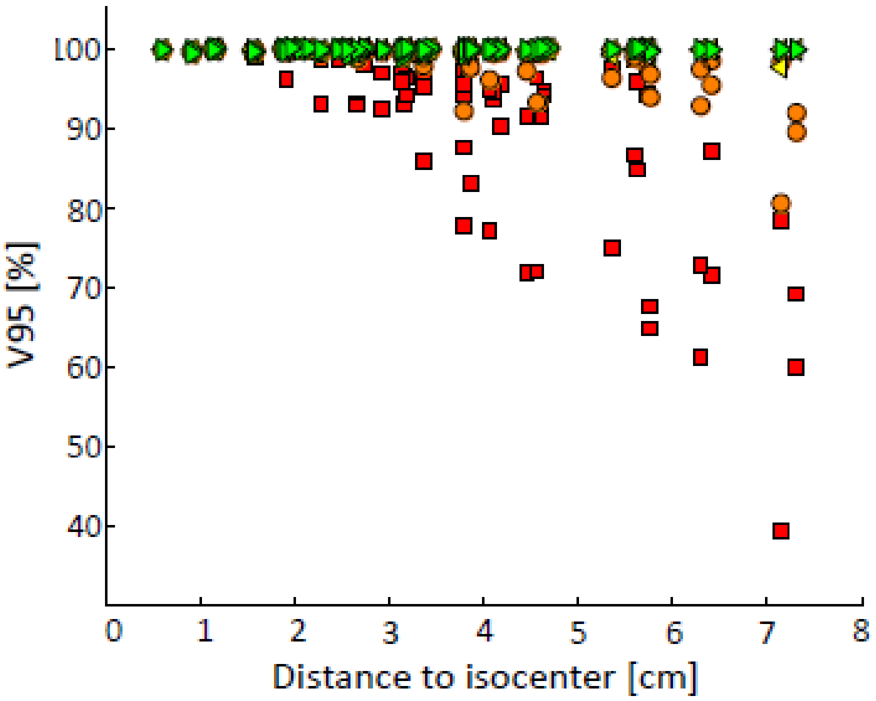
SINGLE ISOCENTER MULTIPLE TARGET SRS



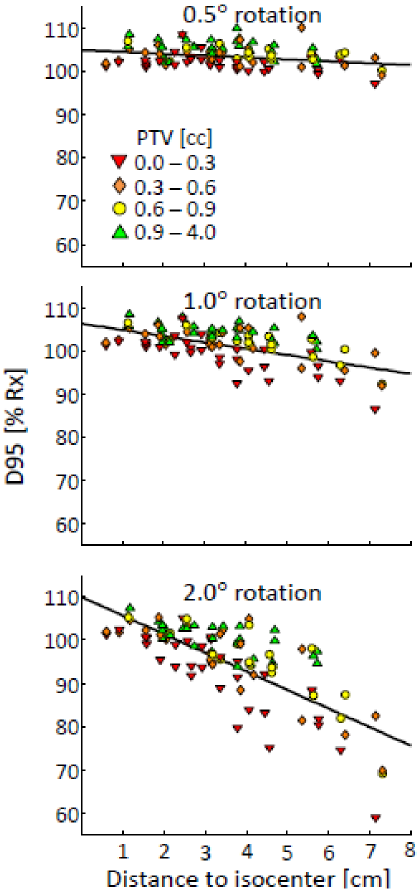


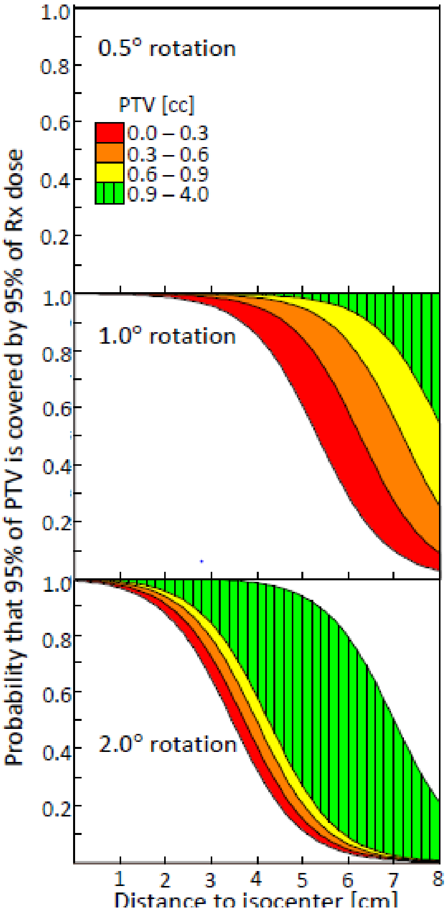
Roper et al. (2015) Int J Rad Bio Phys 93(3), 540-546

SINGLE ISOCENTER MULTIPLE TARGET SRS

Data stratified by PTV volume

Smaller targets are affected more by rotational errors





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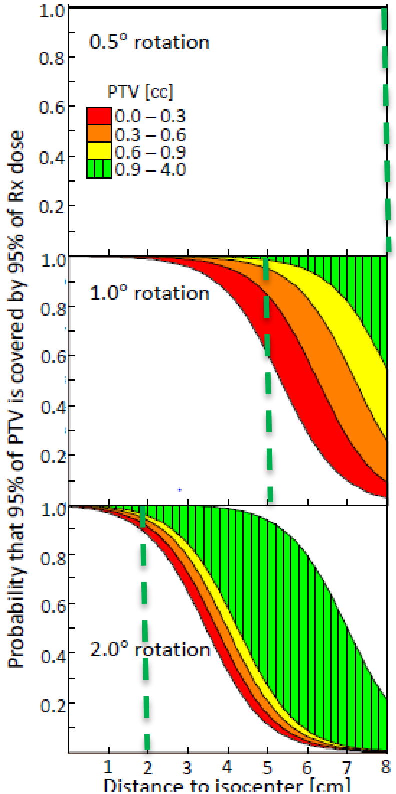
Discussion:

- 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



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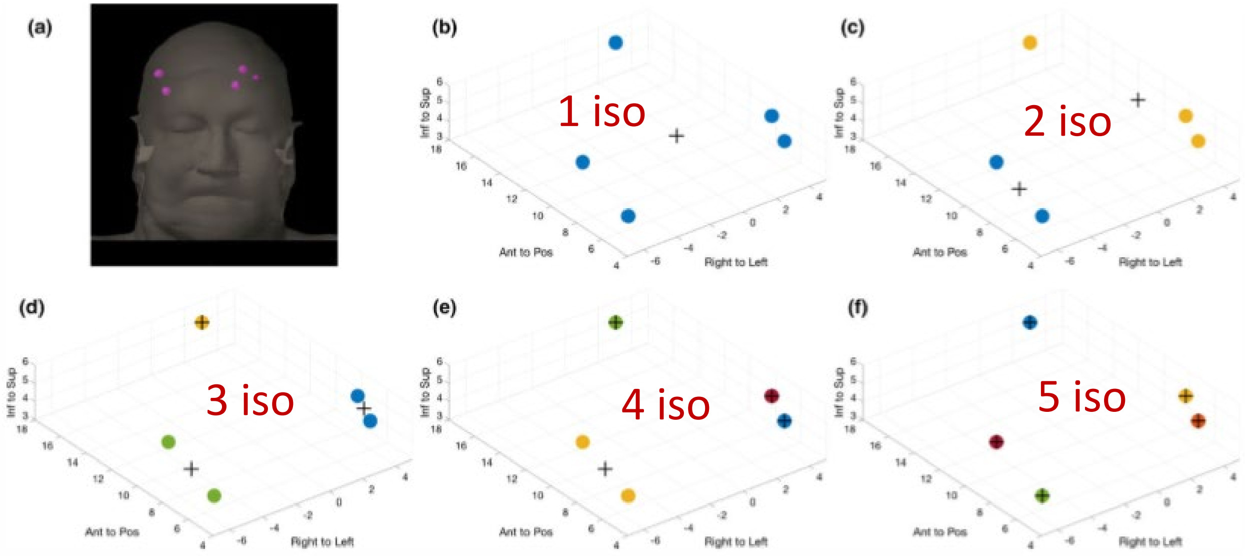
Compensation strategies: Optimized target grouping

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



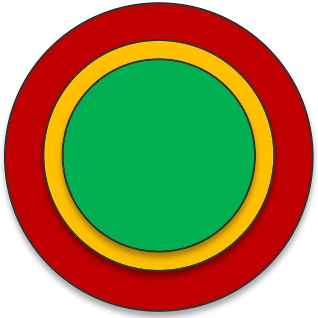
Yock and Kim (2017) J Appl Clin Med Phys 18:5, pp. 351-357

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 → 0.9 cc (1.73 x volume)

Add 3 mm margin → 2.1 cc (4.01 x volume)



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Compensation strategies: Margin 1 mm vs 3 mm

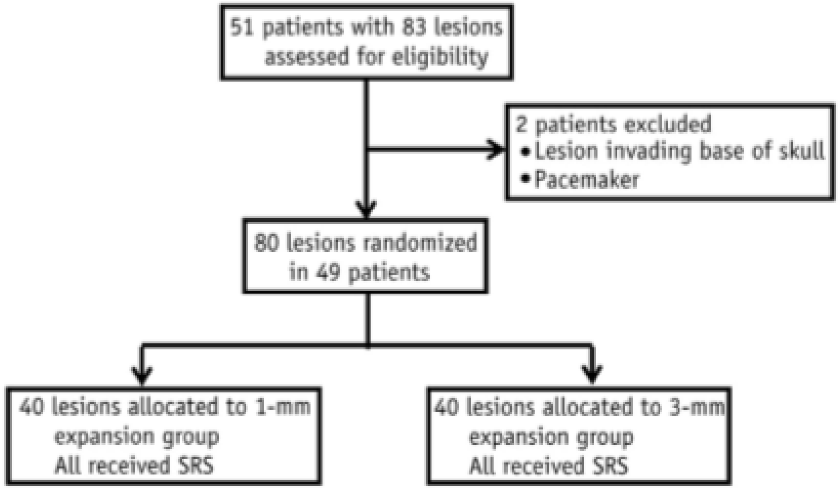

Fig. 1. Trial profile.

- Similar local control
- Greater radionecrosis

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

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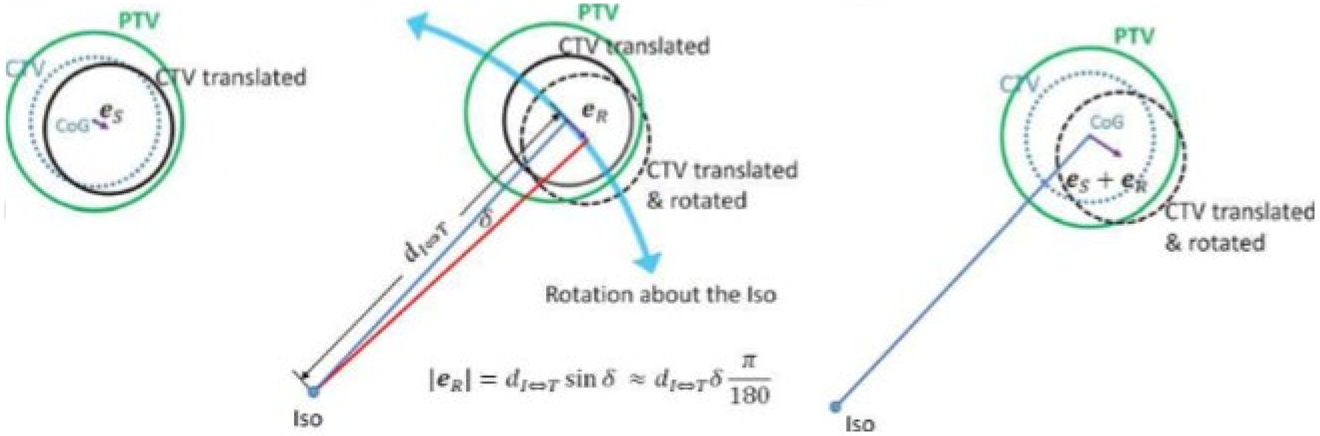
Kirkpatrick et al. (2015) Radiation Oncology Biology, 91(1), 100–108.

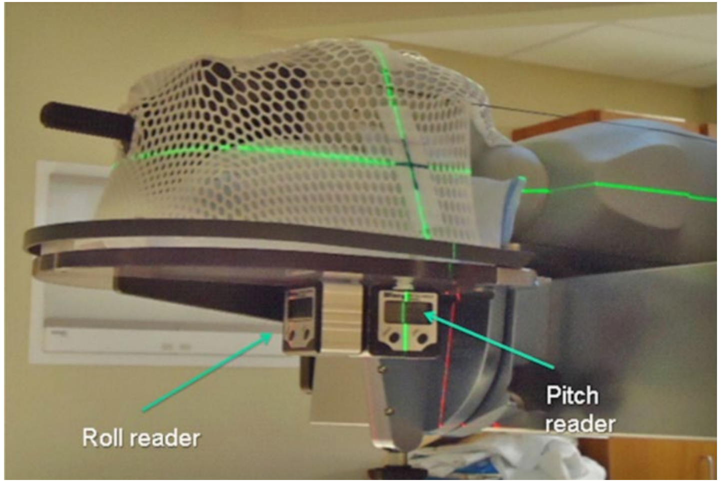
Compensation strategies: Custom Margins



Chang (2017) Med Phys, Vol 44(6), 2115-2123

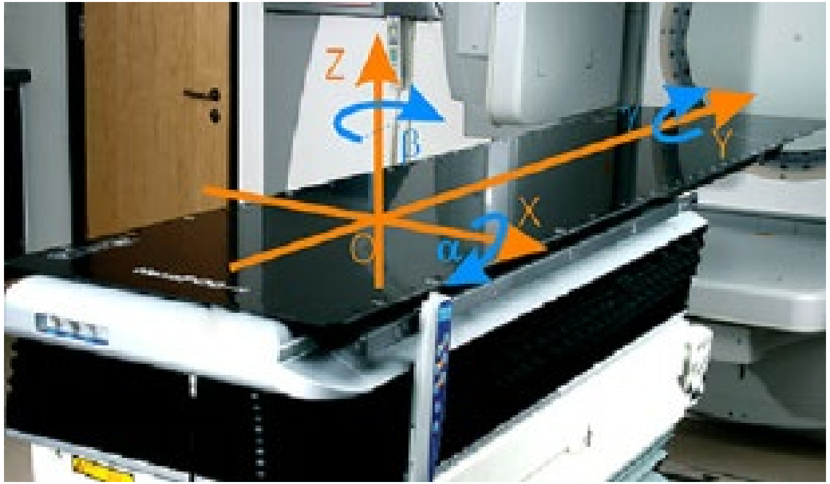
Compensation strategies: 6 DoF Corrections

In house



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

Commercial



Elekta HexaPOD

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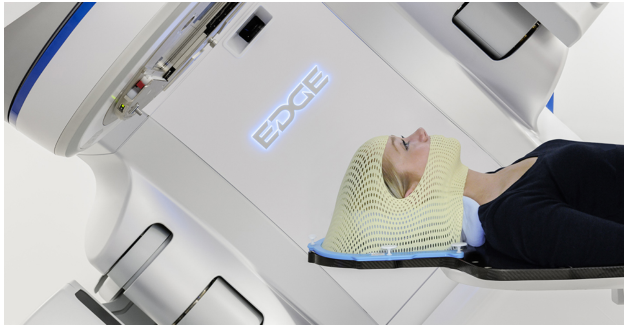
Compensation strategies: Monitoring

Optical surface imaging

Room mounted x-ray imaging

Linac mounted x-ray imaging



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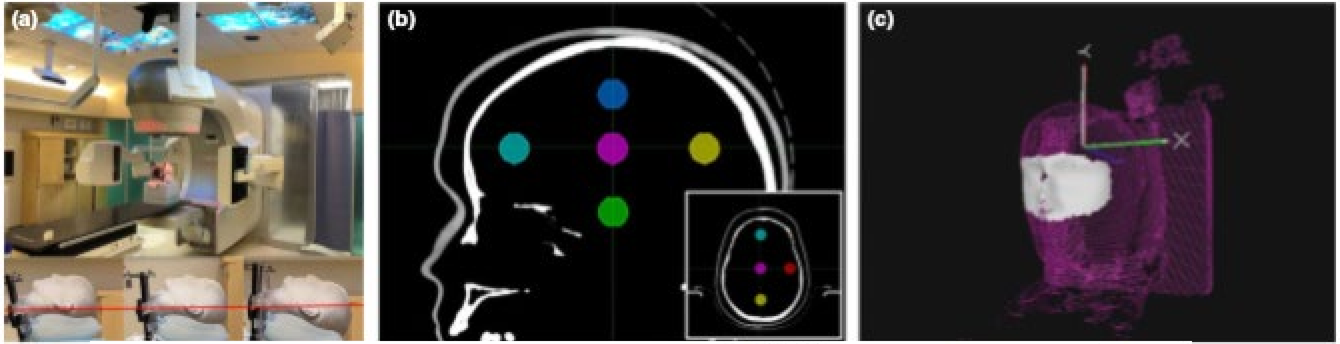
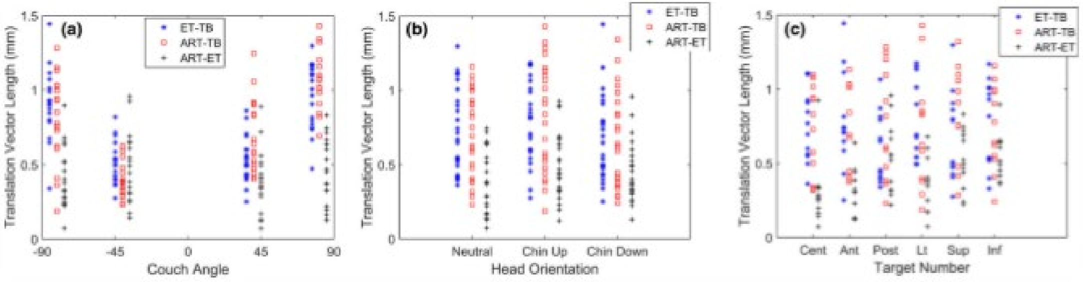
Compensation strategies: Monitoring





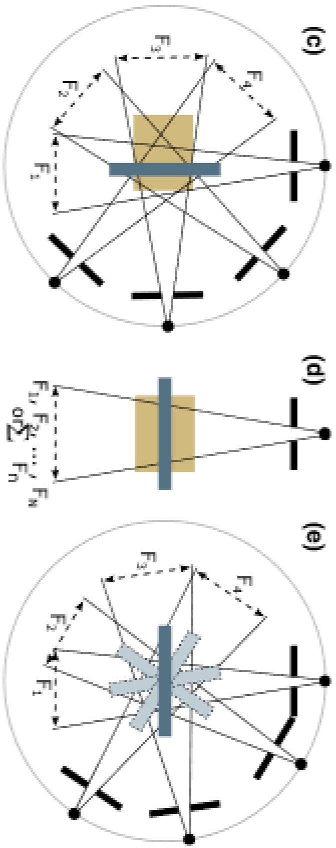
Optical surface imaging similar to room mounted x-ray

Wiant et al. (2019) J Appl Clin Med Phys 20:1, pp. 137-144

Other considerations: Quality assurance

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

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



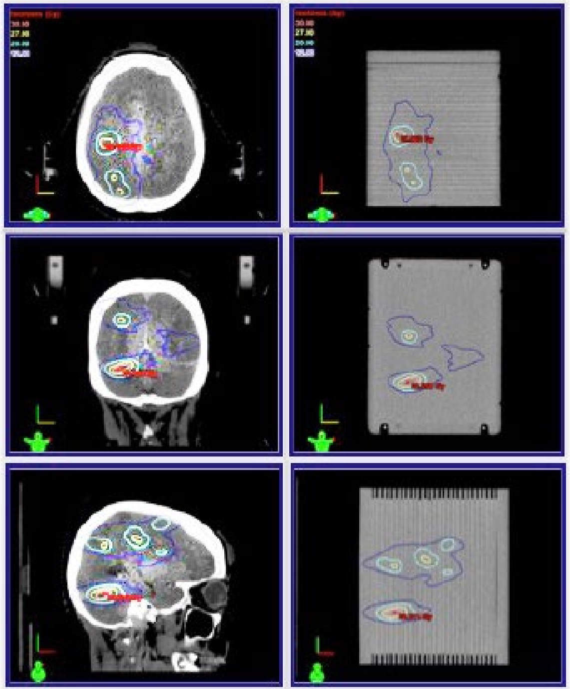
- True Composite: 1st choice, caveat angular response
- Perpendicular Field by Field: 2nd choice and to investigate TC discrepancies
- Perpendicular Composite (Portal Dosimetry): Should NOT be used for IMRT QA

Other considerations: Quality assurance

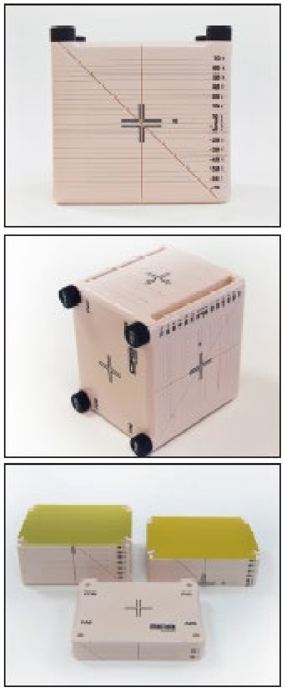
Historically ion chamber and film

Many commercial devices are inadequate

Vendor solutions are improving



Clinical Images of Multi-Lesion Brain QA Phantom for SRS



Set up photos of
Multi-Lesion Brain QA Phantom for SRS

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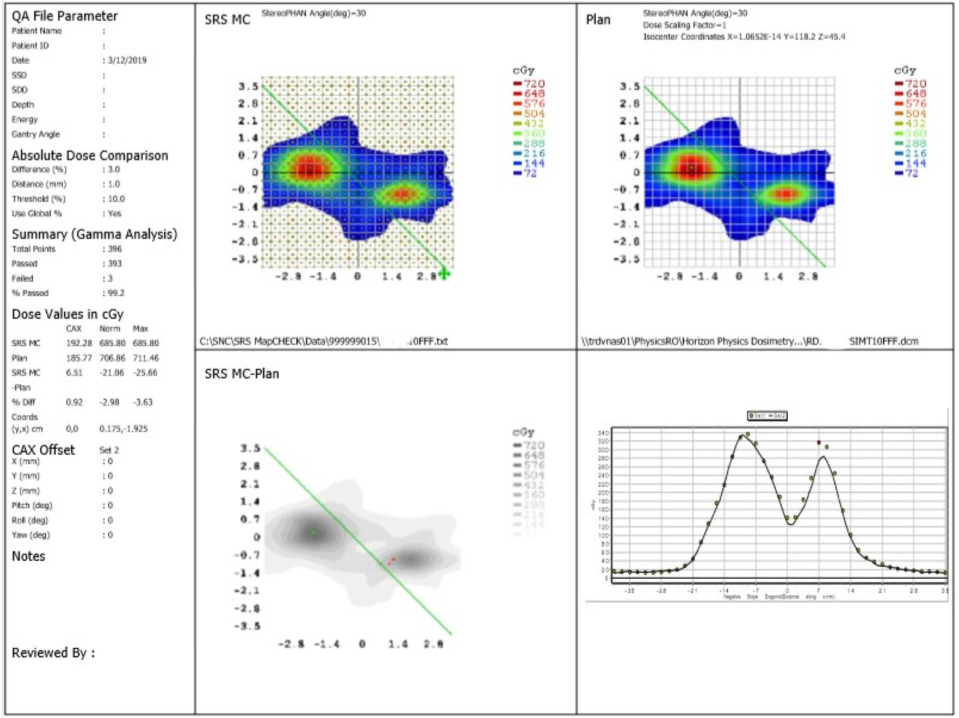
Other considerations: Quality assurance

SNC SRS MapCHECK

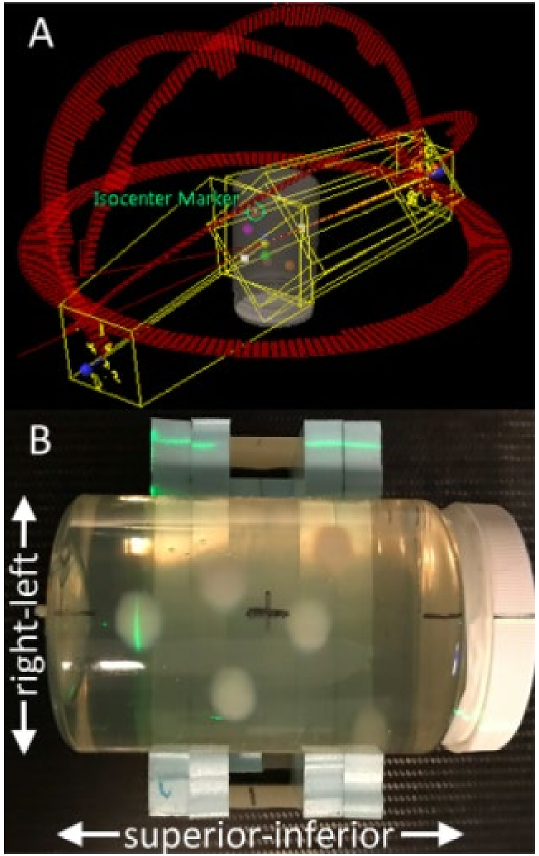


- Absolute dose comparison possible
- Measure multiple planes with the 77 mm x 77 mm array of >1000 diodes
- Vertex fields in near future

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

Adamson et al. (2019) Int J Rad Bio Phys 103(5), 1271-1279



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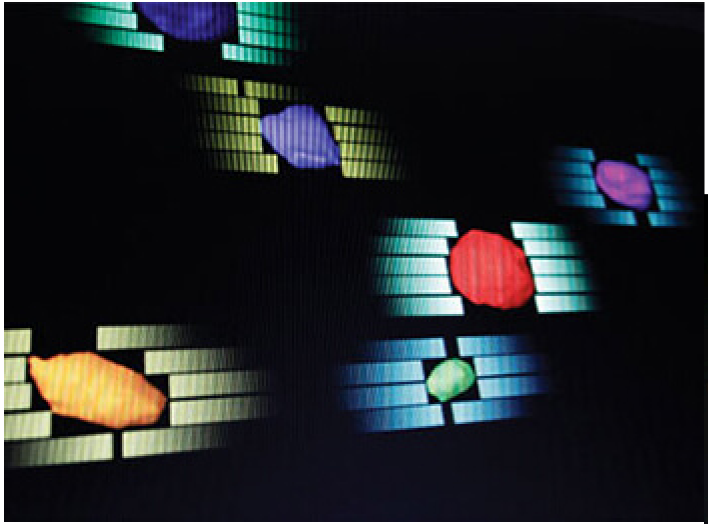
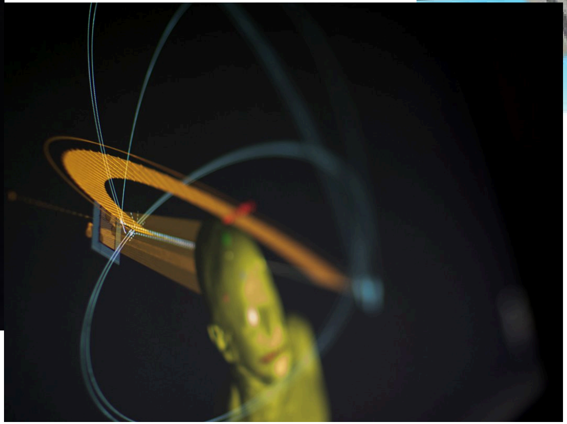
Other considerations: Alternative planning solutions

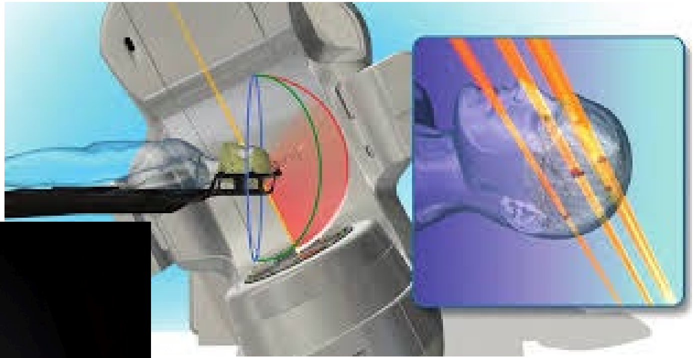
BrainLab Elements



RayStation



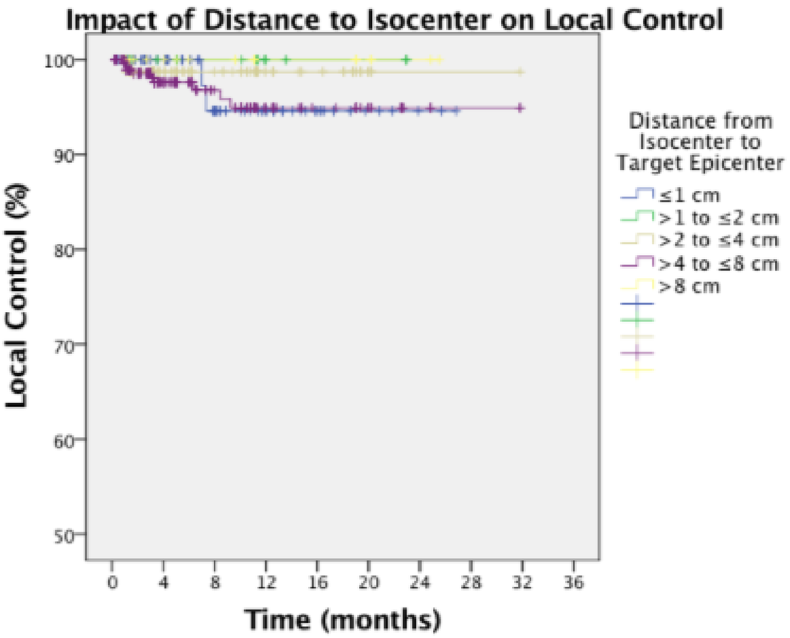
HyperARC



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



532 tumors single fraction SRS

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Marcrom et al, ASTRO 2018, abstract *MO_8_267*, Poster Q&A 2 Monday 1045-1215

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Thank you