Brain and Spine Treatment Planning

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Acknowledgements

• Zeke Ramirez, CMD, M.S.
Disclosures

• I receive research funding from the Cancer Prevention and Research Institute of Texas.
Overview

• Cranial planning and delivery options
  – GammaKnife
  – CyberKnife
  – Linac

• Spine planning
Learning Objectives

• Identify the available delivery techniques for cranial and spine SRS/SRT/SBRT
• Understand the advantages and disadvantages of the various techniques
• Identify the best delivery technique to use for a given lesion
Options for Cranial Planning

• GammaKnife
• CyberKnife
• Linac
  – Circular collimators
  – Dynamic conformal arcs
  – Conformal beams
  – IMRT
Basics of GammaKnife Planning

• Small spherical lesions – straightforward
  – Pick collimator size that will cover target

• Larger or irregular targets – more complicated
  – May require several shots
  – Determine number, size, location and weight of shots
  – Typically prescribed to 50% isodose line
Pituitary Adenoma on GammaKnife

- 35 Gy at 50%
- 5 shots
- 4 mm collimator
Meningioma on GammaKnife

- 15 Gy at 50%
- 34 shots
- 4.8 mm collimators
Brain Mets on GammaKnife

- 18 Gy at 50%
- 15 shots
- 4,8,16 mm collimators
Multiple Brain Mets on Gamma Knife

- 16 mets
- 16 or 18 Gy at 50%
- 77 shots
- ~6.5 hrs
- 4, 8, 16 mm collimators
Acoustic Neuroma on Gamma Knife

- 13 Gy at 50%
- 10 shots
- 4, 8 mm collimators
Trigeminal Neuralgia on Gamma Knife

- 85 Gy at 100%
- 1 shot
- 4 mm collimator
Re-treatment (AVM) on GammaKnife

- AVM – 2011
- 18 Gy at 50%
- 15 shots
- 8 mm collimator
- Re-treat 2014
- 20 Gy at 50%
- 6 shots
- 4, 8 mm collimator
Basics of CyberKnife Planning

- Fixed cones, IRIS or InCise MLC
- Radiation delivered with linac at fixed points in space called nodes
- ~ 100 nodes per fraction
- Nodes arranged in spherical (cranial) or ellipsoidal (extra-cranial) patterns
- Forward or inverse planning
- Prescribed to 60 - 90% isodose line
SRT on CyberKnife

- Pituitary adenoma
- 45 Gy in 25 fx
Staged AVM on CyberKnife

- Large AVM
- Too big for single fx ablative dose
- ~ 30 cc
- 11 patients
- 3-8 stages, 16-20 Gy
- Inverse planning better
- Patients in follow-up

Ding et al. Radiotherapy and Oncology 109, p. 452.
Trigeminal Neuralgia on CyberKnife

- 66 Gy to 80%
- 7.5 mm collimator

Linac Cranial SRS Techniques

• Circular arcs
• Dynamic arc
• Conformal beams
• IMRT
• How do you decide which technique to use?
Linac Cranial SRS Techniques

• It depends on…
• Size of target
• Shape of target
• Location of target
• Do a comparison…
Linac Cranial SRS Techniques

• Plan with circular arcs, conformal beams and dynamic arcs

Case 1

Case 2

According to Solberg et al, which linac-based SRS technique produces the most heterogeneous dose in the tumor?

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>%</td>
<td>78%</td>
<td>7%</td>
<td>8%</td>
<td>3%</td>
<td>4%</td>
</tr>
</tbody>
</table>
1. Multi-iso circular arcs
Ref. - Solberg et al. IJROBP 49, No. 5, 2001
Trigeminal Neuralgia on Linac

- 70 – 90 Gy at 100%
- 30% IDL touches brainstem
- 5 or 7.5 mm cones
- Circular arc delivery

Figure from BrainLab clinical white paper

Cavernous Sinus Meningioma SRT on Linac

- ~10 conformal noncoplanar beams
- Median 5040 cGy at 180 cGy/fx to ~90%

IMRT for SRS/ SRT on Linac

Fig. 4. Case 3: Sphenoid wing meningioma. Transverse CT of dose distributions on a section through the planning target volume (PTV), comparing a plan with 15 fixed-gantry uniform-intensity fields (left) and the same fixed-field arrangement with intensity-modulation (right). All plans were normalized to deliver 10 Gy to 99% of the PTV. The lesion and brainstem are the dark contours, and the dose lines surrounding the lesion are 11, 10, 9, 8, and 5 Gy, respectively.

Linac Cranial SRS Techniques

- Circular arcs – best for small spherical lesions, TN
- Dynamic arc – most frequently used technique
- Conformal beams – avoid critical structures
- IMRT – necessary to avoid critical structures or for highly irregularly shaped lesions
Which linac-based SRS delivery technique is best for irregularly shaped lesions?

1%  1. Circular arcs
9%  2. Conformal arcs
89% 3. IMRT
0%  4. 2D planning
2%  5. Conformal beams
3. IMRT

Spine SBRT/SRS Treatment Planning

- MR used to delineate spinal cord
- Fuse MR and CT carefully
- Cord contoured 2.5 cm above and below PTV
- Cord constraints must be met!
- Typically 10 – 15 non-opposing coplanar beams
- Almost always IMRT
Image Fusion
Image Fusion
RTOG 0631 Spine SBRT Protocol

• Prescription
  – 16 or 18 Gy Spine SBRT in 1 fx
  – 8 Gy EBRT in 1 fx

• Target Coverage
  – 90% coverage of prescription dose for target

• Target volumes

No margin added to these volumes!
RTOG 0631 Spine SBRT Protocol

- **Cord constraints**
  - 10 Gy < 10% of the partial cord
  - 10 Gy < 0.35 cc of the conventional cord
  - 14 Gy < 0.03 cc of the conventional cord
According to RTOG 0631, the margin added to the target volume is

<table>
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<th>Percentage</th>
<th>Margin (mm)</th>
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<tr>
<td>81%</td>
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<tr>
<td>8%</td>
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<tr>
<td>7%</td>
<td>3</td>
</tr>
<tr>
<td>3%</td>
<td>5</td>
</tr>
<tr>
<td>0%</td>
<td>10</td>
</tr>
</tbody>
</table>
The target as defined above will not be enlarged (i.e., no "margin" for presumed microscopic extension). This target volume ultimately becomes the radiosurgery planning target volume. The radiosurgery does not assume set-up errors. However, depending on the radiosurgery system, a beam aperture margin of 2-3 mm beyond the target volume is allowed to meet the adequate dose coverage of the target. This margin can be reduced to 0-1 mm at the area of spinal cord to meet the spinal cord dose constraints. The treatment plan is acceptable as long as ≈ 90% of the target volume receives the prescribed radiosurgery dose.
UTSW Spine SBRT Protocol

- **Prescription**
  - CTV 14Gy and GTV 20Gy X 1 fraction
  - Patients with prior radiation receive 5 fraction regimen.

- **Target Coverage**
  - 95% coverage of prescription dose for CTV.
  - 90% coverage of prescription dose for GTV.

- **Spinal Cord Dose Constraints:**

<table>
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<tr>
<th>Volume (cc)</th>
<th>Dose (Gy)</th>
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<tbody>
<tr>
<td>&lt;.035 cc</td>
<td>14 Gy</td>
</tr>
<tr>
<td>&lt;.25 cc</td>
<td>10 Gy</td>
</tr>
<tr>
<td>&lt;.5 cc</td>
<td>7 Gy</td>
</tr>
</tbody>
</table>
UTSW Spine SBRT Protocol Re-irradiation

- Same total dose, but in 4 fractions
- 2.8 Gy/fx to CTV, 4 Gy/fx to GTV
- Cord constraints same as single fraction

<table>
<thead>
<tr>
<th>Volume (cc)</th>
<th>Gy</th>
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<tbody>
<tr>
<td>&lt;.035</td>
<td>14</td>
</tr>
<tr>
<td>&lt;.25</td>
<td>10</td>
</tr>
<tr>
<td>&lt;.5</td>
<td>7</td>
</tr>
</tbody>
</table>
Spine Treatment Planning

- GTV - defines lesion.
- CTV - expansion to include contiguous bone marrow adjacent to tumor.
- No expansion for PTV.
- Target does not overlap cord
Multiple Lesions
• Several options are available for cranial and spine SRS/SBRT
• Cranial plans and delivery techniques are determined by the target size, shape and location
• Spine SRS/SBRT is almost always IMRT
Radiation Oncology at UT SW
SRS/ SBRT at UTSW

- GammaKnife – cranial SRS, tumors < 4 cm
- CyberKnife – cranial SRT, some SBRT (breast)
- Linac – All other SBRT
IROC SRS Head Phantom

- CT or MR imaging
- Target delineation
- TLDs and film
IROC Spine Phantom

Date of Report: September 12, 2013
Institution: UTSW Med Ctr-Moncrief
Physicist: Brian Hryciuk
Radiation Machine: Elekta, Agility S (1245) – 10 MV
IMRT Technique: Segmented (step and shoot) MLC
Treatment Planning System: Philips, Pinnacle (3D/IMRT) – CCC
Date of Irradiation: July 29, 2013

Description of procedure:
An anthropomorphic thorax phantom incorporating a dosimetry system, lung-equivalent structures, and a spine structure was placed in the supine position in a CT scanner and imaged. The spine structure contained a target simulating a spine metastasis. TLD capsules located near the center of the target provided point dose information. Sheets of radiochromic film provided dose distributions in the axial and sagittal planes in the spine. The phantom included a heart structure containing one TLD capsule. A treatment plan with correction for errors heterogeneity was performed. The phantom with the inserts was irradiated to approximately 6 Gy using an IMRT technique.

The dosimetric precision of the TLD is 3%, and the spatial precision of the film and densitometer system is 1 mm.

Summary Results:

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<th>Location</th>
<th>RPC vs. Inst</th>
<th>Criteria</th>
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<tbody>
<tr>
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<td>0.93 – 1.07</td>
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<tr>
<td>PTV_TLD_inf_ant</td>
<td>1.00</td>
<td>0.93 – 1.07</td>
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<td>PTV_TLD_sup_post</td>
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<tr>
<td>PTV_TLD_inf_post</td>
<td>1.03</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
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</table>

<table>
<thead>
<tr>
<th>Film Plane</th>
<th>Gamma Index*</th>
<th>Criteria</th>
<th>Acceptable</th>
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</thead>
<tbody>
<tr>
<td>Axial</td>
<td>99%</td>
<td>≥95%</td>
<td>Yes</td>
</tr>
<tr>
<td>Sagittal</td>
<td>95%</td>
<td>≥95%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Percentage of points meeting gamma-index criteria of 5% and 3 mm.

Your plan does meet the protocol criteria.

The phantom irradiation results above do meet the criteria established by the RPC in collaboration with the cooperative study groups. Therefore, your institution has satisfied the phantom irradiation component of the credentialing process for spine radiosurgery protocols.

TLD and Film Analysis by: Nadia Hernandez and Andrea Molineu, M.S.

Report Checked by: David S. Followill, Ph.D.
Director, Radiological Physics Center
Dynamic Arc
Circular Cones

http://www.aktina.com/product/small-field-circular-cones-system-for-siemens/