Robotic Brain and Spine
SRS/SBRT

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Genesis of Robotic Frameless SRS/SRT

Adler J R, Jr, Murphy M J, Chang S D and Hancock S L 1999
Image-guided robotic radiosurgery
Neurosurgery 44 1299-306; discussion 306-7

Integrated Stereo-imaging is the Key
Example: Large Met SRT (25 Gy/5 Fx)

Genesis of Spine SBRT

Spine Anatomy

SPINO Review: Lancet Oncol 2015  DOI: http://dx.doi.org/10.1016/S1470-2045(15)00366-7
Image-Guided Hypofractionated Spinal SRS/SBRT

• Imaging guidance key to precise set up and motion managements

• Hypofractionation to minimize spinal cord dose & vertebra body fracture risks

Robotic Beam-Tracking Platforms

Cyberknife (USA) vs Vero 4DRT (JPN)

Example: 2VB SBRT (20 Gy/1 Fx)

MLC based (M6) & Iris based (VSI) CyberKnife Treatment Delivery

Courtesy of Dr. Lei Wang Stanford University
### Key Features

<table>
<thead>
<tr>
<th>System</th>
<th>Characteristics</th>
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</table>
| CyberKnife  | • Active Feedback Beam Control  
• Cone, Iris, MLC  
• 2D Stereoscopic kV real-time imaging  
• 6D Robotic Couch |
| Vero 4DRT   | • 60 deg O-ring Gantry; Gimbaled Source  
• MLC only  
• 3D CBCT +/- 2D kV +/- Surface markers  
• 5D Robotic Couch |

### Effect of Residual Motion Uncertainty

**Simple Case**

![Graph showing dose distribution for Simple Case](image1.png)

**Complex Case**

![Graph showing dose distribution for Complex Case](image2.png)
Key Points For Practice

- Human spinal cord at this time should be considered as an organ functioned in series
- Dose to the point maximum PRV or thecal sac should be respected

Sagal, Lo, Ma and Sheehan: Image-Guided Hypofractionated SRS Ch 21.6, pg 330 (2016)

Spinal Cord PRV Dose Limits

<table>
<thead>
<tr>
<th>SBRT number of fractions</th>
<th>No prior radiotherapy</th>
<th>Prior radiotherapy</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>≤1% risk of RM</td>
<td>≤5% risk of RM</td>
</tr>
<tr>
<td>1</td>
<td>9.2</td>
<td>12.4</td>
</tr>
<tr>
<td>2</td>
<td>12.5</td>
<td>17.0</td>
</tr>
<tr>
<td>3</td>
<td>14.8</td>
<td>20.3</td>
</tr>
<tr>
<td>4</td>
<td>16.7</td>
<td>23.0</td>
</tr>
<tr>
<td>5</td>
<td>18.2</td>
<td>25.3</td>
</tr>
</tbody>
</table>

Rule of Thumb: $TD(5%) = 1 + 11 \times \sqrt{\text{Fractions}}$

Sagal, Lo, Ma and Sheehan: Image-Guided Hypofractionated SRS Ch 21.6, pg 328 (2016)
Estimate Risk Level of Unified Stereotactic Body Radiation Therapy Dose Tolerance Limits for Spinal Cord

Jimm Grimm, PhD, Arjun Bhoj, MD, Scott C. Velez, MD, Cary Loeb, PhD, Aashish Patel, MD, Scott Herbst, MD, Jeeva Kua, PhD, Lijun Ma, PhD, Ellen Youker, PhD, John R. Adler, MD, and Kris C. Gibbs, MD, FACR

First 100 Spine CK cases from Stanford

• 19 denovo cases
• 1 myelopathy

DVH Risk Map

• Spinal Cord

Gibbs et al. in SRO 2016

Best Young Investigator Award in 2015 ISRS Biannual Congress in Yokohama, JPN
Summary

- Robotic SRS/SRT utilizes fast 2D stereoscopic imaging (Cyberknife) as well as 3D CBCT (Vero)

- Data supports limiting point max and/or small volume spinal cord dose in SBRT