SRS: Cranial and Spine

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Overview

- Linac SRS
  - Spine
  - Cranial
- Proton SRS
Overview: Spine

- Several treatment options exist for spinal metastases:
  - Surgery: decompression, en bloc resection, stabilization, minimally invasive
  - Augmentation: vertebroplasty or kyphoplasty
  - Radiation therapy: conventional or stereotactic radiosurgery

Spine metastases

- About 40% of cancer patients develop vertebral metastases: serious consequences pain, paralysis, quality of life
  - Common primary sites: breast, melanoma, renal, lung, and prostate
  - Palliative low-dose radiotherapy is well established evidence-based treatment
  - Limited long-term efficacy of conventional palliative RT

- Dose-intensified spine radiosurgery / SBRT
  - Practiced by 44% of US Radiation Oncologists (Pan Cancer 2011)
  - Quicker and more durable pain relief and local tumor control

Overview

- Focus on minimizing morbidity of spine care in order to:
  - Improve pain control and quality of life
  - Maximize opportunities for systemic therapy
  - Retain durable local control

- Use of intensity modulated treatment modalities to increase dose to GTV/CTV/PTV while avoiding dose to critical structures: cord, cauda, esophagus
Spine Radiosurgery

- **Benefits**
  - Single session
  - Higher dose to tumor ("radioresistant")
  - Retreatment after failed conventional RT ("salvage")
  - Multimodality therapy to minimize extent of resection ("separation surgery")

- **Potential drawbacks**
  - Vertebral body fractures which are dose-dependent
  - Reoccurrence local to the cord

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**Case #1: Solitary and radioresistant metastasis**
68 yo with metastatic RCC and solitary L4 metastasis causing back and left leg pain

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Stereotactic Body Radiation Therapy
“Spine Radiosurgery”

- SRS: Delivery of a high radiation dose (18-24 Gy) in a single fraction with high precision
- SBRT: Fractionation of ablative doses (2-5 fractions)
Stereotactic Body Radiation Therapy: Outcomes

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>N (tumors)</th>
<th>Fractionation (median)</th>
<th>Are salvage RT</th>
<th>pain relief</th>
<th>local control</th>
</tr>
</thead>
<tbody>
<tr>
<td>UI Pitt</td>
<td>2007</td>
<td>500</td>
<td>20 Gy x 1</td>
<td>0%</td>
<td>88%</td>
<td>88%</td>
</tr>
<tr>
<td>MDACC</td>
<td>2007</td>
<td>74</td>
<td>6 Gy x 3, 9 Gy x 3</td>
<td>56%</td>
<td>NR</td>
<td>77%</td>
</tr>
<tr>
<td>MSKCC</td>
<td>2008</td>
<td>103</td>
<td>24 Gy x 3</td>
<td>0%</td>
<td>NR</td>
<td>90%</td>
</tr>
<tr>
<td>PMH</td>
<td>2009</td>
<td>60</td>
<td>8 Gy x 3</td>
<td>62%</td>
<td>67%</td>
<td>85%</td>
</tr>
<tr>
<td>Taiwan</td>
<td>2009</td>
<td>127</td>
<td>7.75 Gy x 2</td>
<td>22%</td>
<td>88%</td>
<td>97%</td>
</tr>
</tbody>
</table>

Histology: N (tumors) dose pain relief local control

<table>
<thead>
<tr>
<th>Histology</th>
<th>N (tumors)</th>
<th>dose</th>
<th>pain relief</th>
<th>local control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast</td>
<td>83</td>
<td>20 Gy x 1</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Lung</td>
<td>80</td>
<td>20 Gy x 1</td>
<td>93%</td>
<td>100%</td>
</tr>
<tr>
<td>Renal cell</td>
<td>93</td>
<td>20 Gy x 1</td>
<td>94%</td>
<td>97%</td>
</tr>
<tr>
<td>Melanoma</td>
<td>38</td>
<td>20 Gy x 1</td>
<td>96%</td>
<td>91%</td>
</tr>
</tbody>
</table>

Median follow-up = 23 months

Toxicity

Acute toxicity

<table>
<thead>
<tr>
<th>Tox assessment</th>
<th>Dermatitis</th>
<th>Dysphagia</th>
<th>Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>G0</td>
<td>322</td>
<td>324</td>
<td>348</td>
</tr>
<tr>
<td>G1</td>
<td>307</td>
<td>290</td>
<td>290</td>
</tr>
<tr>
<td>G2</td>
<td>15</td>
<td>31</td>
<td>35</td>
</tr>
<tr>
<td>G3</td>
<td>0</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

Fracture

<table>
<thead>
<tr>
<th>Tox assessment</th>
<th>New fracture</th>
<th>Progressive Fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>403</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>17 (4.2%)</td>
<td>21 (5.3%)</td>
</tr>
</tbody>
</table>

- Low rates and low grade acute toxicity
- 10% fracture rate, but 50% progressive fracture
- No case of radiation induced myelopathy

Case #1 revisited: Solitary and radioresistant metastasis

ASTRO 2013 - Multi-institutional Spine SBRT
Guckenberger M, et. al.
Oh K, et. al.
Immobilization and Visualization

- Rigid immobilization using custom body mold and vacuum bag (BodyFix) or QFix (Mask) for upper T-spine and C-Spine
- Real-time imaging in treatment position with integrated robotic couch

Treatment Planning

- Dose constraints:
  - Spinal cord < 10-14 Gy x 1
  - Cauda equina < 16 Gy x 1
  - Sacral plexus < 18 Gy x 1

Planning

- IMRT or VMAT
- Coplanar 7-9 beams/2-3 arcs
- Posterior (Anterior used for Cervical Vertebral locations)
- ~20 deg separation
- Collimator Rotation Can Reduce MUs
Final Dose

IMRT versus VMAT

Linac Cranial SRS
Diseases

- Cranial lesions
- Mets from Lung, Breast, Melanoma, other sites
- Gliomas
- Benign: schwannomas, meningiomas, Acromegaly
- AVMs

SRS dose

Factors to consider

- histology
- size
- proximity to OARs
- prior radiation therapy
- patient situation
- Typical range of 18-24 Gy with normalizations of 70-90%

Patient care after SRS

Potential Side-Effects

**Acute (hours)**

- Seizure
- Fatigue
- Hair loss
- Nausea/vomiting (uncommon)
- Edema from pin sites

**Late (months-years)**

- Radionecrosis requiring steroids and/or surgery
**Immobilizations**

**Mask and Frame**

**Photon Planning**

- Photons planning questions
  - MLC versus Cones
  - Field Size Effects: Dosimetric Uncertainty
  - MLC field size uncertainty
  - Penumbra
Linac SRS Photon Planning

- Cones
- 3D CRT
- IMRT
- Dynamic Conformal Arcs
- VMAT

Photon Planning: Cranial

- Classic Planning
- Considerations: OAR and other lesion proximity
Linac Plans

IMRT with SIB

Single Isocenter Cone

DCA versus VMAT

Linac versus GK

Gavaert, et al 2016 Rad Onc

Abracioglu, et al 2014 Rad Onc
VMAT for multiple lesions

- **BENEFITS**
  - Efficient
  - Increase patient comfort
  - Machines capable

- **CHALLENGES**
  - QA Difficult
  - Setup uncertainty
  - Margins
  - TPS Beam Model

Proton Cranial SRS

Diseases

- Cranial lesions
  - Benign: schwannomas, meningiomas, Acromegaly
  - AVMs
  - Gliomas
  - Some mets
Protons

- No distal dose
- Sharper Penumbra (many caveats)
- Less Integral Dose
- Lower NTCP, especial late effects

Integral Dose

Proton SRS Treatment Planning Overview

- Field Size/MCS
- Beam positions
- Heterogeneities
- Penumbra Regions
- Distal Positions
- LET/RBE
- More beams → More Conformal/Less Uncertainties from single beam