RE-IRRADIATION OF VERTEBRAL BODIES

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Stockholm
Sweden
Vertebral metastases

• Improvement in clinical care and therapy – patients are diagnosed and living longer

• 60–70% of patients with systemic cancer will have spinal metastasis

• 20% complete response after EBRT and partial response 60%

• 20% after eg 8 Gy will require re-irradiation due to pain progression,

• Longer length patients survivals eg 2 years 50-80% will have tumor progression
• Why they are important?

• Can involve the
  ❖ bone
  ❖ epidural space
  ❖ leptomeninges
  ❖ spinal cord

www.spineuniverse.com
Tumour of vertebral bodies

- Pain
- Mechanical instability
- Fracture
- Radiculopathy
- Neurological dysfunction related to malignant epidural spinal cord compression
Imaging of vertebral metastases

CT, Lung cancer

MR T1, Rectum cancer

CT, Breast cancer

PETCT, Prostate cancer

MR T2, Kidney cancer
Vertebral bodies radiotherapy

- Pain and other symptoms relief
- Preventing spine tumors growth
- As an option for surgery
- Shrinking tumors for easier removal
- Cure the patient
Re-irradiation of bone metastases

- 850 patients (237 spine): 8 Gy/1 fx vs 20 Gy/5 fx

- Primary RT: 6, 7, 8 Gy/1 fx, 18 Gy/4 fx, 20 Gy/5 fx, 24 Gy/6 fx, 27 Gy/8 fx, 30 Gy/10 fx

- Interval at least 4 weeks, 2 month assessment after re-irradiation

- 118 (28%) 8 Gy vs 135 (32%) 20 Gy had an overall pain response to treatment

- Pathological fractures 30 (7%) 8 Gy and 20 (5%) 20 Gy

- Spinal cord/cauda equina compressions 7 (2%) 8 Gy vs 2 (<1%) 20 Gy

Chow et al. Lancet Oncol 2014
Vertebral body radiosurgery

- Fewer fractions, shorter treatment, more convenient for the patient
- Higher doses are potentially more effective
- High precision – less normal tissue irradiation
- Small margins, large setup errors with inaccurate positioning
- High sensitivity of spinal cord to large fractions

Prostate cancer patient with whole vertebral bone and lymph node metastases August 2018
1995 – First spinal radiosurgery

- Linac delivery with circular collimators
- System accuracy < 2mm
- 8-10 Gy with no portion of cord receiving > 3 Gy

Hamilton et al. Neurosurgery 1995
The Epidural Spinal Cord Compression (ESCC) scale

- Grade 0  Bone-only disease
- Grade 1a  Epidural impingement, without deformation of thecal sac
- Grade 1b  Deformation of thecal sac, without spinal cord abutment
- Grade 1c  Deformation of thecal sac, with spinal cord abutment, without cord compression
- Grade 2  Spinal cord compression, with CSF visible around the cord
- Grade 3  Spinal cord compression, no CSF visible around the cord
# Neurologic, Oncologic, Mechanical, Systemic (NOMS) decision framework

<table>
<thead>
<tr>
<th>Neurologic</th>
<th>Oncologic</th>
<th>Mechanical</th>
<th>Systemic</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-grade ESCC + no myelopathy</td>
<td>Radiosensitive</td>
<td>Stable</td>
<td></td>
<td>cEBRT</td>
</tr>
<tr>
<td>Radiosensitive</td>
<td>Unstable</td>
<td></td>
<td></td>
<td>Stabilization followed by cEBRT</td>
</tr>
<tr>
<td>Radioresistant</td>
<td>Stable</td>
<td></td>
<td></td>
<td>SRS</td>
</tr>
<tr>
<td>Radioresistant</td>
<td>Unstable</td>
<td></td>
<td></td>
<td>Stabilization followed by SRS</td>
</tr>
<tr>
<td>High-grade ESCC ± myelopathy</td>
<td>Radiosensitive</td>
<td>Stable</td>
<td></td>
<td>cEBRT</td>
</tr>
<tr>
<td>Radiosensitive</td>
<td>Unstable</td>
<td></td>
<td></td>
<td>Stabilization followed by cEBRT</td>
</tr>
<tr>
<td>Radioresistant</td>
<td>Stable</td>
<td>Able to tolerate surgery</td>
<td></td>
<td>Decompression/stabilization followed by SRS</td>
</tr>
<tr>
<td>Radioresistant</td>
<td>Stable</td>
<td>Unable to tolerate surgery</td>
<td></td>
<td>cEBRT</td>
</tr>
<tr>
<td>Radioresistant</td>
<td>Unstable</td>
<td>Able to tolerate surgery</td>
<td></td>
<td>Decompression/stabilization followed by SRS</td>
</tr>
<tr>
<td>Radioresistant</td>
<td>Unstable</td>
<td>Unable to tolerate surgery</td>
<td></td>
<td>Stabilization followed by cEBRT</td>
</tr>
</tbody>
</table>

- **Radiosensitive**: seminoma, lymphoma, breast, ovarian, prostate
- **Radioresistant**: sarcoma, melanoma, renal, thyroid, gastrointestinal, NSCLC
International Sterotactic Radiosurgery Society practice guidelines

• Following cEBRT, retreatment with SBRT is a recommended therapeutic option in suitable patients based on multidisciplinary assessment
  level of evidence III

• Following SBRT, retreatment with SBRT is a recommended therapeutic option in suitable patients based on multidisciplinary assessment
  level of evidence III

• For patients with clinical features concerning for malignant epidural spinal compression, mechanical instability, or baseline vertebral body compression, fracture, the radiation oncologist should consult a spine surgeon before the patients undergoes SBRT
  level of evidence II

Myrehaug et al. J Neurosurg Spine 2017
Treatment Planning

• Where is the target?
• What kind of toxicity we have?
• What was the primary total dose and dose per fraction?
• What kind of toxicity we expect?
• What was the time between irradiations?
• What we can achieve?

• ....Do it carefully
Volume delineation in spinal radiosurgery

Red indicates contours and orange indicates consensus

Cox et al. IJROBP 2012
### Summary of contouring guidelines for GTV, CTV, and PTV in spinal stereotactic radiosurgery

<table>
<thead>
<tr>
<th>Target volume</th>
<th>Guidelines</th>
</tr>
</thead>
</table>
| GTV           | • Contour gross tumor using all available imaging  
               • Include epidural and paraspinal components of tumor |
| CTV           | • Include abnormal marrow signal suspicious for microscopic invasion  
               • Include bony CTV expansion to account for subclinical spread  
               • Should contain GTV  
               • Circumferential CTVs encircling the cord should be avoided except in rare instances where the vertebral body, bilateral pedicles/lamina, and spinous process are all involved or when there is extensive metastatic disease along the circumference of the epidural space without spinal cord compression |
| PTV           | • Uniform expansion around CTV  
               • CTV to PTV margin ≤3 mm  
               • Modified at dural margin and adjacent critical structures to allow spacing at discretion of the treating physician unless GTV compromised  
               • Never overlaps with cord  
               • Should contain entire GTV and CTV |

**Abbreviations:** CTV = clinical target volume; GTV = gross tumor volume; PTV = planning target volume.
Volume delineation
What about the dose?
Combined dose to the normal tissue

Spinal cord max: 7.6, 5.6, 18.1

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SpinalCord</td>
<td>3.6</td>
<td>100.0</td>
<td>99.9</td>
<td>5.188</td>
<td>29.684</td>
<td>23.964</td>
</tr>
<tr>
<td>CaudaEquana</td>
<td>2.5</td>
<td>100.0</td>
<td>100.8</td>
<td>12.578</td>
<td>34.973</td>
<td>23.689</td>
</tr>
<tr>
<td>Kidney_L</td>
<td>274.7</td>
<td>100.0</td>
<td>100.0</td>
<td>1.748</td>
<td>23.393</td>
<td>6.565</td>
</tr>
<tr>
<td>Kidney_R</td>
<td>224.1</td>
<td>100.0</td>
<td>100.1</td>
<td>4.777</td>
<td>46.331</td>
<td>17.190</td>
</tr>
<tr>
<td>Bowel</td>
<td>2909.5</td>
<td>100.0</td>
<td>100.0</td>
<td>1.222</td>
<td>47.656</td>
<td>14.094</td>
</tr>
<tr>
<td>Liver</td>
<td>2327.5</td>
<td>100.0</td>
<td>100.0</td>
<td>1.134</td>
<td>26.586</td>
<td>5.392</td>
</tr>
<tr>
<td>ThecalSac</td>
<td>20.3</td>
<td>100.0</td>
<td>99.8</td>
<td>5.724</td>
<td>46.125</td>
<td>24.436</td>
</tr>
</tbody>
</table>
## Re-irradiation of vertebral bodies

<table>
<thead>
<tr>
<th>Reference</th>
<th>Contoured spinal cord structure</th>
<th>Median initial dose</th>
<th>Retreatment SBRT total dose/fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed 2012</td>
<td>Spinal cord</td>
<td>30 Gy/10 fractions</td>
<td>24 Gy/3 (median)</td>
</tr>
<tr>
<td>Boyce-Fappiano 2017</td>
<td>NR</td>
<td>30 Gy/10 fractions</td>
<td>16 Gy/1</td>
</tr>
<tr>
<td>Chang 2012</td>
<td>Thecal sac</td>
<td>39 Gy (mean)</td>
<td>20.6 Gy/1 (median)</td>
</tr>
<tr>
<td>Choi 2010</td>
<td>NR</td>
<td>40 Gy/20 fractions</td>
<td>20 Gy/2 (median)</td>
</tr>
<tr>
<td>Damast 2011</td>
<td>NR</td>
<td>30 Gy/10 fractions</td>
<td>20 Gy/5 or 30 Gy/5</td>
</tr>
<tr>
<td>Garg 2012</td>
<td>Spinal cord</td>
<td>30 Gy/10 fractions</td>
<td>30 Gy/5 or 27 Gy/3</td>
</tr>
<tr>
<td>Hashim 2016</td>
<td>Spinal cord + spinal canal</td>
<td>30 Gy/10 fractions</td>
<td>16.6/1 or 24 Gy/3 (median)</td>
</tr>
<tr>
<td>Mahadevan 2011</td>
<td>Thecal sac</td>
<td>30 Gy/10 fractions</td>
<td>25–30 Gy/5 or 24 Gy/3</td>
</tr>
<tr>
<td>Sahgal 2009</td>
<td>Spinal cord + 1.5 mm PRV or thecal sac</td>
<td>36 Gy/14 fractions</td>
<td>24 Gy/3</td>
</tr>
<tr>
<td>Thibault 2014</td>
<td>Spinal cord + 1.5 mm PRV or thecal sac</td>
<td>30 Gy/10 fractions</td>
<td>24 Gy/2</td>
</tr>
<tr>
<td>Thibault 2015</td>
<td>Spinal cord + 1.5 mm PRV or thecal sac</td>
<td>24 Gy/2 or 24 Gy/2 + 30 Gy/10 fractions</td>
<td>30 Gy/4 (median)</td>
</tr>
<tr>
<td>Sahgal 2012</td>
<td>Spinal cord + 1.5 mm PRV or thecal sac</td>
<td>24 Gy/5, 30 Gy/10, 37.5 Gy/15</td>
<td>40 Gy/20 or 45 Gy/25</td>
</tr>
<tr>
<td>Recommendations</td>
<td></td>
<td></td>
<td>50 Gy/25</td>
</tr>
</tbody>
</table>
## Response to re-irradiation

<table>
<thead>
<tr>
<th>Study type</th>
<th>Target treated</th>
<th>Local control</th>
<th>Overall survival</th>
<th>Pain response</th>
<th>VCF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed 2012</td>
<td>Prospective</td>
<td>22</td>
<td>1 year, 83%</td>
<td>1 year, 28%</td>
<td>NR</td>
</tr>
<tr>
<td>Boyce-Fappiano 2017</td>
<td>Retrospective</td>
<td>237</td>
<td>1 year, 71%</td>
<td>Dose range</td>
<td>NR</td>
</tr>
<tr>
<td>Chang 2012</td>
<td>Retrospective</td>
<td>54</td>
<td>1 year, 81%</td>
<td>Median, 11 months</td>
<td>81%</td>
</tr>
<tr>
<td>Choi 2010</td>
<td>Retrospective</td>
<td>51</td>
<td>1 year, 73%</td>
<td>1 year, 68%</td>
<td>NR</td>
</tr>
<tr>
<td>Damast 2011</td>
<td>Retrospective</td>
<td>92</td>
<td>1 year, 66%</td>
<td>Median, 13.6 months</td>
<td>77%</td>
</tr>
<tr>
<td>Garg 2012</td>
<td>Prospective Phase I/II</td>
<td>63</td>
<td>1 year, 68%</td>
<td>1 year, 76%</td>
<td>Improvement at 6 months</td>
</tr>
<tr>
<td>Hashimi 2016</td>
<td>Multi-institutional pooled analysis</td>
<td>247</td>
<td>1 year, 83%</td>
<td>1 year, 48%</td>
<td>74.3%</td>
</tr>
<tr>
<td>Mahadevan 2011</td>
<td>Retrospective</td>
<td>81</td>
<td>1 year, 93%</td>
<td>Median, 11 months</td>
<td>79%</td>
</tr>
<tr>
<td>Sahgal 2009</td>
<td>Retrospective</td>
<td>37</td>
<td>1 year, 82%</td>
<td>Median, 21 months</td>
<td>NR</td>
</tr>
<tr>
<td>Thibault 2014</td>
<td>Retrospective</td>
<td>11</td>
<td>1 year, 83%</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Thibault 2015</td>
<td>Retrospective</td>
<td>56</td>
<td>1 year, 81%</td>
<td>Median, 10 months</td>
<td>NR</td>
</tr>
</tbody>
</table>

NR, not reported; VCF, vertebral compression fracture.
* Pooled analysis included both single and median dose/fractionation is provided for both treatment options.

No RM 1st: EQD2 39.8 Gy2/2 (29.0–64.5 Gy), 15 mts (5–85)
2nd: 24 Gy (10–30 Gy) in 3 (1–5) fractions

RM 1st: EQD2 38 Gy2/2 (18.3–52.5 Gy2), 18 mts (11–81)
2nd: 20 Gy2/2 (12-32) in 1-3 fractions
Adverse effects

- Acute pain – self-resolving; dexamethasone reduce the risk of pain flare from 53% to 26% after cEBRT
  
  Chow et al. Lancet Oncol 2015

- It is effective both as a rescue for pain flare and as prophylactic treatment with 4 or 8 mg orally per day started on day 1 of SBRT and for 4 days after

  Khan Support Care Cancer 2015

- Early VCF - an intense inflammatory reaction and tissue necrosis that causes destabilisation of the bony architecture, resulting in mechanical compromise

- Late VCF phase of radiation necrosis and fibrosis may result in continued changes in the strength of the bone that renders it weaker and unable to sustain the loading forces

  Myrehaug et al. Clinical Oncology 2017
Critical organs

- Spinal cord
- Cauda equina
- Large vessels
- Brain
- Larynx
- Thyroid
- Oesophagus
- Stomach
- Trachea
- Lung
- Heart
- Liver
- Kidney
- Small and large bowel
- Blader
- Rectum
<table>
<thead>
<tr>
<th>Study</th>
<th>Follow up schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choi 2010</td>
<td>MRI every 2-3 months</td>
</tr>
<tr>
<td>Thibault 2014</td>
<td></td>
</tr>
<tr>
<td>Garg 2011</td>
<td></td>
</tr>
<tr>
<td>Navarria 2012</td>
<td></td>
</tr>
<tr>
<td>Damast 2011</td>
<td>MRI every 3-4 months</td>
</tr>
<tr>
<td>Ahmed 2012</td>
<td>MRI at 2 months then every 6 months ± PET</td>
</tr>
<tr>
<td>Chang 2012</td>
<td>MRI/PET at 3, 6, &amp; 12 months</td>
</tr>
<tr>
<td>Mahadevan 2011</td>
<td>CT 1 month, otherwise not defined</td>
</tr>
<tr>
<td>Hashimi 2016</td>
<td>MRI/PET not specified</td>
</tr>
<tr>
<td>Sahgal 2012</td>
<td>Clinically 1 month &amp; every 3-6 months</td>
</tr>
</tbody>
</table>
## Dose constrains for spinal cord

<table>
<thead>
<tr>
<th>Structure</th>
<th>Single-Fraction SRS</th>
<th>Hypofractionated SRS (3 fxn)</th>
<th>Hypofractionated SRS (5 fxn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal cord</td>
<td>$D_{\text{max}} = 14 \text{ Gy or } 12 \text{ Gy max circumferential dose}$ (myelogram defined cord MSKCC)</td>
<td>$D_{\text{max}} = 21 \text{ Gy total (myelogram defined cord)}$</td>
<td>$D_{\text{max}} = 25 \text{ Gy total (myelogram defined cord)}$</td>
</tr>
<tr>
<td></td>
<td>$D_{\text{max}} = 13 \text{ Gy QUANTEC (myelopathy &lt; 1%)}$</td>
<td>$D_{\text{max}} = 20.3 \text{ Gy (Sahgal myelopathy &lt; 5%)}$</td>
<td>$D_{\text{max}} = 25.3 \text{ Gy (Sahgal myelopathy &lt; 5%)}$</td>
</tr>
</tbody>
</table>

$D_{\text{max}} = 14 \text{ Gy}$
RTOG 0915
$V_{7 \text{ Gy}} < 1.2 \text{ cm}^3$
$D_{\text{max}} = 10 \text{ Gy}$
RTOG 0631
And $V_{10} < 0.35 \text{ cm}^3$
And $V_{14} < 0.03 \text{ cm}^3$
$D_{\text{max}} = 12.4 \text{ Gy (Sahgal myelopathy < 5%)}$
## Re-irradiation of vertebral bodies

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<thead>
<tr>
<th>Reference</th>
<th>Contoured spinal cord structure</th>
<th>Median initial dose</th>
<th>Retreatment SBRT total dose/fraction</th>
<th>Retreatment spinal cord dose</th>
<th>Cumulative cord/thecal sac EQU2</th>
<th>Reported myelopathy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed 2012</td>
<td>Spinal cord</td>
<td>30 Gy/10 fractions</td>
<td>24 Gy/3 (median)</td>
<td>Dmax 17 Gy (median)</td>
<td>70.1</td>
<td>1%</td>
</tr>
<tr>
<td>Boyce-Fappiano 2017</td>
<td>NR</td>
<td>30 Gy/10 fractions</td>
<td>16 Gy/1</td>
<td>10 Gy to 10% of spinal cord, Dmax 14 Gy</td>
<td>93.5</td>
<td>0.6%</td>
</tr>
<tr>
<td>Chang 2012</td>
<td>Thecal sac</td>
<td>39 Gy (mean)</td>
<td>20.6 Gy/1 (median)</td>
<td>Dmax 12 Gy (median)</td>
<td>83.4</td>
<td>0%</td>
</tr>
<tr>
<td>Choi 2010</td>
<td>NR</td>
<td>40 Gy/20 fractions</td>
<td>20 Gy/2 (median)</td>
<td>Dmax 19.3 Gy (median)</td>
<td>96.2</td>
<td>2%</td>
</tr>
<tr>
<td>Damast 2011</td>
<td>Spinal cord</td>
<td>30 Gy/10 fractions</td>
<td>20 Gy/5 or 30 Gy/5</td>
<td>14 Gy Dmax spinal cord</td>
<td>58.3</td>
<td>0%</td>
</tr>
<tr>
<td>Garg 2011</td>
<td>Spinal cord</td>
<td>30 Gy/10 fractions</td>
<td>30 Gy/5 or 27 Gy/3</td>
<td>16 Gy Dmaxcauda equina</td>
<td>48.7</td>
<td>0%</td>
</tr>
<tr>
<td>Hashimi 2016</td>
<td>Spinal cord + spinal canal</td>
<td>30 Gy/10 fractions</td>
<td>16.6/1 or 24 Gy/3 (median)</td>
<td>NR</td>
<td>47.5</td>
<td>0%</td>
</tr>
<tr>
<td>Mahadevan 2011</td>
<td>Thecal sac</td>
<td>30 Gy/10 fractions</td>
<td>25–30 Gy/5 or 24 Gy/3</td>
<td>Dmax 30 Gy (5 fractions)</td>
<td>97.5</td>
<td>0%</td>
</tr>
<tr>
<td>Sahgal 2009</td>
<td>Spinal cord + 1.5 mm PRV or thecal sac</td>
<td>36 Gy/14 fractions</td>
<td>24 Gy/2</td>
<td>12.2 Gy Dmax spinal cord</td>
<td>65.8</td>
<td>0%</td>
</tr>
<tr>
<td>Thibault 2014</td>
<td>Spinal cord + 1.5 mm PRV or thecal sac</td>
<td>30 Gy/10 fractions</td>
<td>24 Gy/2</td>
<td>12.2 Gy</td>
<td>75.5</td>
<td>0%</td>
</tr>
<tr>
<td>Thibault 2015</td>
<td>Spinal cord + 1.5 mm PRV or thecal sac</td>
<td>24 Gy/2 or 24 Gy/2 + 30 Gy/10 fractions</td>
<td>30 Gy/4 (median)</td>
<td>12.2 Gy Dmax spinal cord PRV or thecal sac</td>
<td>54.6</td>
<td>0%</td>
</tr>
<tr>
<td>Sahgal 2012</td>
<td>Recommendations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Recommendations

- **20 Gy/5, 30 Gy/10, 37.5 Gy/15**
  - 1 fraction: Dmax N/A
  - 2 fraction: Dmax 12.2 Gy
  - 3 fraction: Dmax 14.5 Gy
  - 4 fraction: Dmax 16.2 Gy
  - 5 fraction: Dmax 18.2 Gy

- **40 Gy/20 or 45 Gy/25**
  - 1 fraction: Dmax N/A
  - 2 fraction: Dmax 12.2 Gy
  - 3 fraction: Dmax 14.5 Gy
  - 4 fraction: Dmax 16.2 Gy
  - 5 fraction: Dmax 18.2 Gy

- **50 Gy/25**
  - 1 fraction: Dmax N/A
  - 2 fraction: Dmax 11.5 Gy
  - 3 fraction: Dmax 12.5 Gy
  - 4 fraction: Dmax 14.5 Gy
  - 5 fraction: Dmax 15.5 Gy

EQU2, equivalent dose to 2 Gy/day fraction size; NR, not reported; Dmax, maximum point dose; V10, volume receiving 10 Gy radiation; SBRT, stereotactic body radiotherapy; PRV, planning organ-at-risk volume.
Mean latency single course: 18.5 mo
Mean latency retreatment: 11.4 mo

Wong et al. 1994
### Late effects – spinal cord clinical

<table>
<thead>
<tr>
<th>Study</th>
<th>Cumulative EQD2 median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jackson 1987</td>
<td>65 Gy (58.5-65.5)</td>
</tr>
<tr>
<td>Baumann 1996</td>
<td>60.7 Gy (58.5-63)</td>
</tr>
<tr>
<td>Magrini 1990</td>
<td>57.8 Gy (47.8-67.8)</td>
</tr>
<tr>
<td>Wright 2006</td>
<td>47.5 Gy (11-56.5)</td>
</tr>
<tr>
<td>Navarria 2012</td>
<td>51.25 Gy (27.9-57.6)</td>
</tr>
<tr>
<td>Wong 1994</td>
<td>71.5 Gy (67-81.5)</td>
</tr>
<tr>
<td>Kawashiro 2016</td>
<td>59.1 Gy (47.5-82.3)</td>
</tr>
</tbody>
</table>

No myelopathy for cumulative EQD2 $< 67.5 \text{ Gy}_2$ if neither course exceeds 45 Gy$_2$
Spinal cord dose-volume effect

- $D_{\text{max}}$ 50.2 to 57.1 Gy
- 4 pts 0.5 cm$^3$ vol. 50.4–53.6 Gy
- 2 pts 1.0 cm$^3$ vol. 52.8–51.2 Gy

Zschaeck et al. Strahlenther Oncol 2017

- 0.5 cm$^3$ vol 45.5 Gy (40.7-53.3)


No neurological symptoms

Medin et al. IJROBP 2012
I RT – clinical example

- December 2013
- Paliative radiotherapy
- 2 AP-PA fields
- total dose: 30 Gy
- df: 3 Gy

\[
\text{EQD}_2 = D \left( \frac{d + \alpha/\beta}{2 + \alpha/\beta} \right) = 30 \left( \frac{3.0 + 2}{2.0 + 2} \right) = 37.5
\]
2 RT – clinical example

June 2014 Gated radiotherapy, Total dose: 32 Gy df: 8 Gy
2 RT – clinical example

- D max spinal cord 7.97 Gy

- Recalculated dose to 2 Gy?

\[ \text{EQD}_2 = D \left( \frac{d + \alpha/\beta}{2 + \alpha/\beta} \right) = 7.97 \left( \frac{2.0 + 2}{2.0 + 2} \right) = 7.97 \]

1 Rt + 2 RT \quad 37.5 + 7.97 = 45.47
Question:

How calculate the dose to the spinal cord?

\[ 1 \text{ Rt} + 2 \text{ Rt} + 3 \text{ RT} 37.5 + 7.97 + 4.53 = 50 \text{ Gy}_2 \]

\[ \text{EQD}_2 = D \left( \frac{d + \alpha/\beta}{2 + \alpha/\beta} \right) = 7 \left( \frac{0.47 + 2}{2.0 + 2} \right) = 4.31 \]

\[ 1 \text{ Rt} + 2 \text{ Rt} + 3 \text{ RT} 37.5 + 7.97 + 4.31 = 49.78 \text{ Gy}_2 \]
3 RT – clinical example

- Palliative radiotherapy total dose: 30 Gy, df: 2 Gy
- Spinal cord 6.2 Gy in 15 fx (3.7 Gy2)
Clinical example

- Inoperable
- Did not qualified to systemic treatment
- August 2017 Gastrostomy
- October 2017 Palliative brachytherapy
  
  Total dose: 18 Gy, df: 6 Gy
- August 2018 stable disease on CT, pain controlled with drugs, gastrostomy
Conclusion

• Re-irradiation of vertebral bodies is feasible

• Have to be performed with extreme accuracy and precision

• Dose constrains are not confirmed in a large trials
Thank you