Testing the limits of stereotactic radiosurgery for multiple brain metastases

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The Study

- Increasing trend to employ stereotactic radiosurgery in treatment of brain metastases
- 50-60% of patients presenting with brain metastases have multiple lesions
- Several guidelines recommend SRS for patients with up to 4 lesions
  - Bhatnagar et al. (2006) reported that number of mets was not a significant factor in survival period for patients with more than 4 mets treated with SRS
- V12 in brain is most significant factor in predicting radionecrosis
  - occurring in 2-14% of patients
  - Risk is high when V12 exceeds 5-10 cc, increasing by 8% for every 1 cc increase in V12
- This study examined the feasibility and deliverability of static conformal arc treatments for patients with up to 12 mets
The Phantom

- 5 multiple brain met presentations were generated on CT of CIRS head phantom
  - 4, 6, 8, 10, 12 mets; 0.5 to 2.0 cm diameter
  - Largest met located on film plane
- EBT3 film was calibrated for doses between 0 and 26 Gy
- Pre- and post- scanned using Epson V800
- netOD polynomial fit
- Maximum uncertainty = 2.6%
Static conformal arc treatments planned for BrainLab m3 micro-MLC system on a Varian 21iX (6 MV)

- Planned in BrainLab iPlan TPS
- Prescription of 24 Gy to 90% isodose
  - Wanted high dose for better out of field response
  - 24 Gy is value used in RTOG trial for 1-3 mets
- Forward planned by a radiation therapist, with angular separation between non-coplanar arcs maximised, with care taken to prevent mechanical collisions

<table>
<thead>
<tr>
<th># Mets</th>
<th>Total Vol. (cc)</th>
<th># Arcs</th>
<th>Mean dose (Gy)</th>
<th>Total MU per plan</th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>4.39</td>
<td>21</td>
<td>26.8</td>
<td>3031</td>
</tr>
<tr>
<td>6</td>
<td>4.95</td>
<td>34</td>
<td>26.7</td>
<td>4073</td>
</tr>
<tr>
<td>8</td>
<td>5.96</td>
<td>44</td>
<td>26.7</td>
<td>5520</td>
</tr>
<tr>
<td>10</td>
<td>6.99</td>
<td>58</td>
<td>26.6</td>
<td>6600</td>
</tr>
<tr>
<td>12</td>
<td>8.01</td>
<td>69</td>
<td>26.7</td>
<td>7947</td>
</tr>
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</table>
The Delivery

- Phantom immobilised with thermoplastic mask and BrainLab cranial array
- Film from calibration batch cut to fit CIRS phantom
- Treatments delivered over 3 days
  - Each treatment took at least an hour
  - ExacTrac kV x-ray pair used to verify position before deliveries (so much imaging!)
The Evaluation

- Prescription poorly chosen, V12 exceeded 10 cc for all plans
- V12 increased with number of mets, as expected
- Gamma evaluation performed for film plane with 3%/1.5 mm criteria using SNC MapCheck software
  - Local action level is 90%
- Disagreement between film and TPS calculations more pronounced for 10 and 12 met plans
- Aside: film area receiving 12 Gy was not a good predictor for V12 calculated in TPS

<table>
<thead>
<tr>
<th># Mets</th>
<th>GAI</th>
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<tbody>
<tr>
<td>4</td>
<td>96.4%</td>
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<tr>
<td>6</td>
<td>96.9%</td>
</tr>
<tr>
<td>8</td>
<td>96.8%</td>
</tr>
<tr>
<td>10</td>
<td>91.4%</td>
</tr>
<tr>
<td>12</td>
<td>92.0%</td>
</tr>
</tbody>
</table>
The Evaluation

- What if we used 16 Gy as prescription (reported as median dose for 205 patients with 4 or more mets by Bhatnagar et al.)?
  - Linear relationship between total metastatic volume and V12 in healthy brain ($R^2 = 0.999$)

<table>
<thead>
<tr>
<th># Mets</th>
<th>Total met volume (cc)</th>
<th>V12 (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4.39</td>
<td>7.98</td>
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<td>4.95</td>
<td>9.86</td>
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<td>8</td>
<td>5.96</td>
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<td>16.18</td>
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<tr>
<td>12</td>
<td>8.01</td>
<td>19.36</td>
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</tbody>
</table>
The Evaluation

- Film results and TPS calculations agree in high dose and beam penumbrae regions.
- Dose differences up to 3% in periphery regions of films were evident.
- Possible causes?
  - Greater probability of treatment delivery error with increasing number of lesions?
  - Increased peripheral dose and inefficiency of TPS to estimate out-of-field accurately?
    - iPlan calculates dose using discrete 5 degree gantry control points – error compounds with more mets
  - In the film plane, these dose differences aren’t contributing to V12 differences, even for this high prescription
Conclusion

- Treatment of more than 5 cc of metastatic volume comes with a risk of radionecrosis
- Peripheral dose calculation in iPlan is inaccurate
- Film is a wonderful tool!