Accumulated Dose Comparison in SBRT for Lung Tumors Using Three Alignment Strategies

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Patient daily repositioning strategies

- Small margins are used for stereotactic body radiation therapy (SBRT) of the lung during treatment planning.
- Accurate patient setup is required prior to dose delivery.
- Commonly used patient setup methods:
  - External marker / tattoo based
  - Bony structure alignment (e.g. kV/MV-image)
  - Soft tissue alignment (e.g. conventional CT, kV/MV CBCT)
- Which alignments do you trust if bony structure based alignment disagrees with soft tissue based alignment?
Purposes

• Taking SBRT of lung as an example, retrospectively calculated and compared the accumulated dose over the whole treatment course for three setup scenario:
  - Maker/tattoo based
  - Bony structure based
  - Soft tissue based
CT image acquiring

- Six patients underwent lung SBRT were selected for this study
- Patients were immobilized using a vacuum cushion (BodyFix) and CT scanned for treatment planning
- At each fraction, patients were re-scanned within their immobilization devices using conventional scanner
- They were moved to treatment table within their immobilization devices for radiotherapy

BodyFIX double-vacuum whole-body immobilization system
Treatment planning and dose estimation for each fraction

- Treatment plans were performed on free-breathing CT
- Homogeneity was used by following the RTOG 0236 protocol
- Plan normalization:
  - 60 Gy (3 Fx) prescribed to 85% isodose line
- PTV = ITV (union of GTVs) + 5 mm uniform margin
- Dose received at each Fx was estimated by:
  - assuming setup using marker/tattoo, bony structure and soft tissue
  - ISO center determined for each scenario
  - plan parameters copied onto each daily conventional CT
  - dose recalculated with heterogeneity correction
Accumulated dose calculation

• Daily CT obtained at each fraction was registered to the simulation CT
  ▪ B-Spline based deformable registration algorithm
• Registration field provided the trajectory of voxel motion over the treatment course
• The recalculated dose at each fraction was summed along voxel trajectories to generate the accumulated dose
• The accumulated dose = the total dose delivered to the patient
## Patient information

<table>
<thead>
<tr>
<th>Patient</th>
<th>Vol. (cc)</th>
<th>Location</th>
<th>Vector motion (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.1</td>
<td>Left/upper</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>19.7</td>
<td>Right/upper</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>15.2</td>
<td>Right/upper</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td>Left/upper</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>4.0</td>
<td>Right/upper</td>
<td>1.0</td>
</tr>
<tr>
<td>6</td>
<td>7.2</td>
<td>Left/upper</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Tumor volume calculated on free breathing CT
Alignments for a representative patient on fraction 1

The representative patient aligned using:

- Markers/tattoos
- Bony structure
- Soft tissue

Grayscale – conventional CT scan at fraction 1
Thermal – simulation CT
Fraction 1 dose and mapped dose for the representative patient

Dose received by the patient on fraction 1 if aligned by:

- markers/tattoos
- bony structure
- soft tissue

Conventional CT acquired at Fx 1

Dose mapped to simulation CT following deformable registration
DVH of fraction 1 dose estimated on simulation CT for the representative patient

Prescription: 20 Gy/Fx for 3 Fx to 85% isodose line
Dose accumulated over 3 Fx = total dose received by the patient

Prescription: 20 Gy/Fx for 3 Fx to 85% isodose line
Averaged tumor BED, NTD and coverage averaged over 6 patients on accumulated dose

<table>
<thead>
<tr>
<th>Alignment strategy</th>
<th>Marker / tattoo</th>
<th>Bony structure</th>
<th>Soft tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>BED (Gy)</td>
<td>212.6 ± 30.6</td>
<td>178.6 ± 71.8</td>
<td>253.2 ± 14.5</td>
</tr>
<tr>
<td>NTD (Gy)</td>
<td>190.8 ± 25.9</td>
<td>148.9 ± 59.8</td>
<td>211.0 ± 12.1</td>
</tr>
<tr>
<td>V60 (%)</td>
<td>84.0 ± 24.0</td>
<td>55.2 ± 46.9</td>
<td>99.2 ± 1.6</td>
</tr>
<tr>
<td>D100 (Gy)</td>
<td>53.4 ± 9.1</td>
<td>44.4 ± 7.7</td>
<td>44.4 ± 7.7</td>
</tr>
</tbody>
</table>

V60 = percent volume receiving at least 60 Gy
D100 = dose received by 100% of volume
BED = biologically effective dose
NTD = normalized total dose delivered in 2 Gy/Fx

\[ \text{BED} = \text{total dose} \times \left(1 + \frac{d}{(\alpha/\beta)}\right) \]
\[ d = \text{local dose per fraction} \]
\[ \alpha/\beta = 10 \text{ Gy for tumor, 3 Gy for lung} \]

\[ \text{NTD} = \frac{\text{BED}}{1 + 2 \text{ Gy}/(\alpha/\beta)} \]
Lung BED, NTD, mean dose and V20

BED, NTD mean lung dose and V20 averaged over 6 patients on accumulated dose

<table>
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<tr>
<th>Alignment strategy</th>
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<th>Soft tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>BED (Gy)</td>
<td>7.0 ± 2.9</td>
<td>6.9 ± 2.7</td>
<td>6.9 ± 3.0</td>
</tr>
<tr>
<td>NTD (Gy)</td>
<td>5.8 ± 2.4</td>
<td>5.7 ± 2.2</td>
<td>5.6 ± 2.5</td>
</tr>
<tr>
<td>MLD (Gy)</td>
<td>3.6 ± 1.6</td>
<td>3.7 ± 1.4</td>
<td>3.5 ± 1.6</td>
</tr>
<tr>
<td>V20 (%)</td>
<td>5.4 ± 1.4</td>
<td>5.4 ± 1.2</td>
<td>5.1 ± 1.4</td>
</tr>
</tbody>
</table>

BED = biologically effective dose
NTD = normalized total dose delivered in 2 Gy/Fx
MLD = mean lung dose
V20 = percent of lung received at least 20 Gy
• Marker based and bony structure (kV/MV-image) based patient alignments are inaccurate for aligning patients in lung SBRT
• Soft tissue (e.g. conventional CT, CBCT) based alignment is necessary to match the prescribed dose delivered to the tumors