Differences in patterns of failure between the Imaging and Radiation Oncology Core (IROC Houston) Lung and Spine phantoms

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IROC Houston Phantom Credentialing

• Clinical trial participation (Followill et al. 2012)
  – Irradiate phantoms that represent human anatomy
  – Over 2000 institutions in U.S. and abroad

Fig. 1 Thoracic phantom

Fig. 2 CT cross-sectional image
IROC Houston Phantom Credentialing

- Deliver 6 Gy to TLD and film

Moving lung phantom

Criteria:
- TLD ± 7 %, gamma 7 %, 5 mm

Failure rate:
- $\frac{141}{1052} = 13 \%$ (2012-2018)

SBRT spine phantom

Criteria:
- TLD ± 7 %, gamma 5 %, 3 mm

Failure rate:
- $\frac{46}{263} = 17 \%$ (2012-2018)

What types of failures exist in these phantoms?
Qualitative analysis of lung and spine

- Evaluated 158 phantoms total
  - 116 lungs
  - 42 spine
- Reviewed dose profiles & gamma results
- Categorized by failure type
Lung phantom results

**Systematic overdose**

**Localization: superior-inferior direction**
Lung phantom results

Introduction

Method

Results

Conclusion

Global Error: irregular dose distribution

Combo: AP localization + systematic underdose
## Lung phantom results

<table>
<thead>
<tr>
<th>Failure Type</th>
<th>Number of phantoms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systematic dose</td>
<td>35 (28%)</td>
<td>Underdosing or overdosing of PTV</td>
</tr>
<tr>
<td>Localization</td>
<td>79 (62%)</td>
<td>Dose distribution shift</td>
</tr>
<tr>
<td>Global</td>
<td>3 (2%)</td>
<td>Grossly irregular dose distribution</td>
</tr>
<tr>
<td>Combination category</td>
<td>10 (8%)</td>
<td>Two dependent failure modes</td>
</tr>
</tbody>
</table>
Spine phantom results

**Introduction**

**Method**

**Results**

**Conclusion**

Dose fall-off region

OAR overdose
# Spine phantom results

<table>
<thead>
<tr>
<th>Failure Type</th>
<th>Number of phantoms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systematic dose</td>
<td>25 (60%)</td>
<td>Underdosing or overdosing of PTV</td>
</tr>
<tr>
<td>Localization</td>
<td>6 (14%)</td>
<td>Dose distribution shift</td>
</tr>
<tr>
<td>Dose fall-off region</td>
<td>5 (12%)</td>
<td>Error in high dose gradient between PTV &amp; spinal cord</td>
</tr>
<tr>
<td>OAR overdose</td>
<td>6 (14%)</td>
<td>Overdose of the spinal cord structure</td>
</tr>
</tbody>
</table>
Conclusion

• **Lung**: mostly localization errors in direction of motion (50%)
  • Equivalent for gating and ITV/free-breathing

• **Spine**: mostly **systematic dose errors** (60%)
  • Head & Neck, also highly modulated IMRT treatment, showed similar results: 62% dosimetric (Carson et al. 2016)
Conclusion

• Clinically relevant errors likely to manifest in patient cases
  • Not due to mistakes, but errors in clinical process
  • Loose IROC criteria:
    • lung: 7%, 5 mm    spine: 5%, 3 mm

• Part of larger efforts at IROC to identify, quantify, and rectify institution errors
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