Design, development, and evaluation of a modified, anthropomorphic, head and neck, quality assurance phantom for use in stereotactic radiosurgery

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Results:
The TLD results from the three irradiations agreed with the calculated target dose to within 4.3% with a coefficient of variation of ±2.0%. Gamma analysis using a ±5%/3mm criteria in the film planes showed an average point by point passing rate of 99.9% and 99% in the coronal and sagittal planes, respectively. A gamma analysis using 3%/2mm criteria showed the percent of total pixels passing to be 87% and 79%, respectively.

Conclusions:
A modified anthropomorphic QA SRS phantom has been designed that can measure the dose delivered accurately and precisely while providing a more realistic clinical planning and delivery challenge that can be used to credential institutions wanting to participate in NCI funded clinical trials.

Methods:
A phantom was constructed from a water equivalent, plastic, head-shaped shell. Modifications, from an existing QA phantom design containing only a single spherical target, included the addition of structures resembling a nonspherical target (pituitary) and an adjacent (within 2mm) OAR (optic chiasm) simulating structures encountered when treating acromegaly. A separate dosimetry insert for treatment delivery evaluation contained 2 thermoluminescent dosimeters (TLD) for absolute dosimetry and radiochromic film (sagittal and coronal planes) for relative dosimetry. The target and OAR proximity provided a more realistic and challenging treatment planning and dose delivery exercise than the original simpler design. The spatial relation between the target and center of the dosimetry insert was verified through two CT scans of the phantom, one for each insert, which were then fused together.

Figure 1: Image of phantom (left) evaluated with dosimetric insert (center) and imaging insert (right)

Figure 2: Transverse view of patient MRI (left) with pituitary (blue) and optic apparatus (purple) contoured and transverse view of phantom with proposed target (red) and OAR (green).

Table 1: Dose limits for treatment of pituitary adenoma according to RTOG report 0930 (unpublished)

<table>
<thead>
<tr>
<th>Structure</th>
<th>RTOG 0930 Specification</th>
<th>Modified Dose Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pituitary Adenoma</td>
<td>25 Gy (RBE) to at least 90% of GTV</td>
<td>25 Gy (RBE) to at least 90% of GTV</td>
</tr>
<tr>
<td>Optic Apparatus (chiasm and optic nerves)</td>
<td>&lt; 10 Gy (RBE) maximum dose (0.01cc)</td>
<td>&lt; 10 Gy (RBE) maximum dose (0.01cc)</td>
</tr>
<tr>
<td></td>
<td>&lt;=1% volume should receive 8 Gy (RBE)</td>
<td>&lt;=10% volume should receive 8 Gy (RBE)</td>
</tr>
</tbody>
</table>

Figure 3: Sagittal view of original phantom design with proposed addition of target (red) and organ at risk (green).

Table 2: TLD results including measured dose (Gy) and difference in measurement and reported (Gy)

<table>
<thead>
<tr>
<th>TLD</th>
<th>Measured</th>
<th>Difference</th>
<th>σ</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Post. Sup.</td>
<td>18.38</td>
<td>-0.68</td>
<td>0.29</td>
<td>3.7</td>
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<tr>
<td>Right Ant. Inf.</td>
<td>22.31</td>
<td>-0.95</td>
<td>0.46</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Figure 4: Sagittal view of Gamma Knife treatment plan

Future Work:
Currently, the phantom is undergoing evaluation on a standard linear accelerator based treatment system and a CyberKnife robotic radiosurgery system.

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