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Comparison of 2D and 3D Gamma calculations for an IMRT QA phantom

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Abstract. Gamma index pass rates were evaluated for an anthropomorphic phantom using both 2D and 3D calculations. The phantom was irradiated with the traditional dosimetry insert loaded with radiochromic film and TLD, and then with a 3D dosimetry insert. A comparison with the calculated dose distribution showed that both the PRESAGE\textsuperscript{®} dosimeter and the film and TLD system agreed with the plan to within 5\% using 2D gamma index criteria. The 3D gamma index showed a slightly higher pass rate than the 2D gamma index at 3\%/3mm, and comparable pass rates using more generous constraints. The acceptable number of pixels passing the tighter constraints (3\%/3mm) might be dependent upon the choice between a 2D calculation versus a 3D calculation.

1. Background
The ability for 3D dosimetry to obtain a large amount of data in a single irradiation is advantageous [1]. The benefits have led us to consider outfitting the Imaging and Radiation Oncology Core (IROC - formerly the RPC) anthropomorphic phantoms with 3D dosimeters. The phantoms currently use film and TLD; we propose to use PRESAGE\textsuperscript{®} dosimeters [2]. In doing so, we must also look at how we will evaluate the data. Currently, 2D gamma calculations from film measurements are the IROC standard for evaluating an irradiation. Moving to a 3D dosimeter would allow for a 3D gamma calculation and true volumetric quality assurance.

The extra dimension while searching for agreement in a gamma calculation should produce a higher pass rate when compared to a 2D gamma calculation using the same criteria [3, 4]. This study investigated gamma pass rates for identification of appropriate constraints for quality assurance evaluation.

2. Methods
An IROC head and neck (H\&N) phantom was fitted with a cylindrical insert to hold a 500 g cylinder of PRESAGE\textsuperscript{®}. The original IROC insert contained radiochromic film in the axial and sagittal planes and 8 TLD capsules. The PRESAGE\textsuperscript{®} insert covered the same volume as the structures and dosimeters in the original phantom. Both inserts are shown in figure 1.
A 9-beam IMRT plan was developed with a Pinnacle planning system (Philips Radiation Oncology Systems, Fitchburg, WI) for delivery with a Varian linear accelerator (Varian Medical Systems, Palo Alto, CA). The phantom containing the film/TLD insert was irradiated 3 times, then the phantom containing PRESAGE® was irradiated an additional 3 times. The film and TLD were evaluated according to the IROC standard procedures for the H&N phantom described by Molineu et. al. [5]. The PRESAGE® dosimeters were scanned using the Duke Midsized Optical Scanner for IROC (DMOS-IROC) using a 1 mm voxel edge for reconstruction. Change in optical density (OD) was measured by subtracting pre-irradiation scans from post-irradiation scans [6]. The dose was imported into the Computational Environment for Radiotherapy Research (CERR) for evaluation [7].

The film and PRESAGE® measured doses were scaled to the mean TLD dose at relevant locations and 2D gamma calculations were made in the axial and sagittal planes bisecting the primary target for the film and the PRESAGE®. 3D gamma measurements excluded the outermost 5 mm of each PRESAGE® dosimeter to eliminate edge artifacts. Gamma constraints of 3%/3mm distance to agreement (DTA), 5%/3mm DTA and 7%/4mm DTA were used in the study. The gamma-index analyses for the 3 irradiations for each insert were averaged together for comparison.

3. Results
The average pass rate from the 2D gamma calculations for each trial is shown in table 1. The results from a 3D gamma over the full volume are shown in table 2.

Table 1. Average 2D gamma pass rates

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Film</th>
<th>PRESAGE®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Plane</td>
<td>3%/3mm</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>5%/3mm</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td>7%/4mm</td>
<td>99%</td>
</tr>
<tr>
<td>Sagittal Plane</td>
<td>3%/3mm</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>5%/3mm</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>7%/4mm</td>
<td>99%</td>
</tr>
</tbody>
</table>

Table 2. Average 3D gamma pass rates

<table>
<thead>
<tr>
<th>Constraints</th>
<th>PRESAGE®</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%/3mm</td>
<td>90%</td>
</tr>
<tr>
<td>5%/3mm</td>
<td>95%</td>
</tr>
<tr>
<td>7%/4mm</td>
<td>99%</td>
</tr>
</tbody>
</table>
4. Discussion and Conclusions
The film and PRESAGE® 2D pass rates showed agreement within 5% for all gamma index criteria. Random uncertainties as well as small differences in registration of the separate dosimeters could account for the difference. The 3D gamma showed a slightly higher pass rate at 3%/3mm and comparable pass rates at the more generous constraints. This agrees with literature and studies predicting a higher pass rate; however, to our knowledge, the higher pass rate has not previously been demonstrated experimentally. Once the constraints were loosened the discrepancy in calculation space did not cause a large difference in passing pixels. However, when passing rates are high, as they are for the looser constraints, identifying a difference between dosimetry methods is not possible.

The gamma constraints useful for quality assurance do appear to differ between 2D and 3D gamma calculations. The number of passing pixels for the tighter constraint (3%/3mm) might need to differ when using 2D calculation versus a 3D calculation. More studies need to be performed to define an appropriate criterion. At this time, the best option might be to use both: an overall 3D gamma analysis for initial QA with select planar analysis at critical structures.

5. References