Polymer gels enable volumetric dosimetry of dose distributions from an MR-guided linac

Yvonne Roed1,2, Jihong Wang3, Lawrence Pinsky1, Geoffrey Ibbott2

1Department of Physics, University of Houston, Houston, TX
2Department of Radiation Physics, UT MD Anderson Cancer Center, Houston, TX

Materials & Methods

Setup

Polymer Gel Dosimeters

Fig 2: Experimental setup in full phantom

Fig 3: Physical polymer gel dosimeters

MR Imaging

Coronal MR images were acquired at different times after irradiation with the MR component of the MR-linac using a 2D T2-weighted spin echo sequence with TR = 1000 ms and TE = 20, 40, 60, 80, and 100 ms. Spin-spin relaxation rate (R2) maps were generated and averaged line profiles across the dosimetric volume were analyzed. Sigmoidal curves were fit to the data from which both the 80/20 penumbra and the field edge position were calculated.

Results

Table 1: Penumbra width and field edge at different times

Scan Time Post irr Penumbra width (mm)

<table>
<thead>
<tr>
<th>Scan Time</th>
<th>Penumbra width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 min</td>
<td>5.2</td>
</tr>
<tr>
<td>80 min</td>
<td>5.4</td>
</tr>
<tr>
<td>22 h</td>
<td>5.6</td>
</tr>
<tr>
<td>20 min</td>
<td>6.1</td>
</tr>
<tr>
<td>55 min</td>
<td>6.2</td>
</tr>
<tr>
<td>22 h</td>
<td>6.5</td>
</tr>
</tbody>
</table>

A clear demarcation of the radiation field was visible in both dosimeters. The effect of the Lorenz force on secondary electrons could be seen in the different shape of the captured radiation field edges. R2 values increased with time after exposure indicating the ongoing polymerization of the gel which is reported to have stabilized one day after irradiation. The transition region from outside to fully inside the radiation field was visualized on R2 color maps showing a steeper fall-off on the patient right compared to the patient left. Measurements on the R2 maps confirmed the difference in fall-off of the field edges: at 22h after irradiation the penumbra on the patient left was 6.2 mm wide while the penumbra on the patient right measured 5.6 mm.

Discussion

Polymer gels have been used to measure complex 3D dose distributions with steep dose gradients and can be analyzed with MRI.

The magnetic field of an MRgRT system alters dose deposition by exerting Lorenz forces on secondary electrons. When a photon beam is delivered perpendicular to the magnetic field, Compton electrons are deflected orthogonally to both the beam direction and the magnetic field lines.

The influence of the magnetic field on the penumbra of the radiation field in a non-clinical MR-linac pilot system was investigated and updated measurements with polymer gel dosimeters are presented.

Polymers were intended as relative 3D QA devices to verify treatment plans with steep dose gradients for complex tumor volumes.

This study demonstrated that in the presence of a magnetic field steep dose gradients of a penumbra region of a radiation field could be detected and resolved with such dosimeters.

The gel dosimeters show promise for testing radiation treatment plans delivered by an MR-guided linac and will be used for further studies of 3D dose measurements.

Contact

This project is supported by MD Anderson funded research: Advanced Dosimetry for Radiation Therapy of the Future.

Contact: Yvonne Roed yroed@mdanderson.org

Ref


A broadening of both penumbrae by 0.4 mm was determined between MR image acquisition immediately after exposure compared with 22h post-irradiation. The field edge position on the patient right shifted 0.9 mm outward while there was essentially no shift on the patient left.

The differences in both penumbra width and field edge position fall within the uncertainty of positioning the line profiles (pixel size = 1.6 mm)