**PRESENTATION TITLE**

4DMRI-based 4D dose calculation for MR-guided proton therapy of pancreatic cancer

**AUTHOR(S)**

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**ABSTRACT**

**Purpose:**

By providing precise motion information and high image quality without applying any additional imaging dose, time-resolved magnetic resonance imaging (4DMRI) is foreseen to have many advantages and potentials for MR-guided radiotherapy (MRgRT). In this study, we performed 4D dose calculations to investigate dosimetric impacts of respiratory motion for two pancreatic cancer patients undergoing PBS proton treatments, based on 4DMRI measurements.

**Materials & Methods:**

4DMR images for both patients were acquired at a 1.5T MRI (Siemens, Aera) under free breathing using the gradient recalled echo sequence radial VIBE (FoV 40cm\(^2\), coronal slices, pixel spacing 1.6x1.6mm\(^3\), slice thickness 4mm, TR=3.3ms, TE=1.49ms, \(\alpha = 12^\circ\)). For patient 1 (P1) five 4D-MR images were acquired during the six-week treatment, while for patient 2 (P2) one 4DM image was acquired. All 4DMRI data were reconstructed using an iterative reconstruction algorithm, based on the demons algorithm. Synthetic 4D-CTs were created by warping the respective reference static 3DCT geometry with the extracted deformation vector fields from 4DMRI. To evaluate dosimetric influences of respiratory motion for pancreatic cancer, a 3D dose plan was optimized on the PTV of the reference 3DCT using two oblique dorsal fields. For P1, 4D dose distributions in presence of varied respiratory
motion (breathing periods between 6.6s-9.7s) were calculated using each of the five synthetic 4D-CTs. For P2, the breathing period of the synthetic 4D-CT was modulated between 3s-10s to simulate a total of four different motion scenarios. For both patients, motion distributions in the CTV were calculated and compared. Dose distributions of a single-fraction treatment (2Gy) and multi-fraction treatments in the presence of motion were calculated by randomly accumulating 4D dose distributions of different starting phases. 4D plan quality in terms of dose homogeneity d5/d95 and v95 in the CTV were compared among the static 3D plan, the single fraction 4D plan and the 4D plan with 28 fractions.

Results:
The observed target motion was larger and more deformable for P1 with motion amplitudes up to 15 mm compared to 2 mm for P2 (see figure 1). Larger motion amplitudes transferred into larger interplay effects for P1 than P2 with pronounced hot and cold spots seen in the CTV. However an averaging of the interplay effect by an increasing number of treatment fractions was observed, resulting in improved dose homogeneity after fractionated proton therapy (see figure 2). Consistently, the dose coverage of the tumour was improved by fractionation, especially for P1. Moreover, we observed an increased maximum dose in the CTV caused by the interplay effects when comparing 4D to 3D dose calculations. The resulting motion and dose quantities are listed in table 1.

Table 1: Extracted motion and 4D dose quantities for P1 and P2

<table>
<thead>
<tr>
<th></th>
<th>Patient 1</th>
<th>Patient 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median CTV motion (RL / AP / IS) [mm]</td>
<td>0.9 / 1.7 / 6.2</td>
<td>0.1 / 0.6 / 2.0</td>
</tr>
<tr>
<td>d5/d95 for 1/28 fractions</td>
<td>1.14 / 1.04</td>
<td>1.07 / 1.02</td>
</tr>
<tr>
<td>v95 for 1/28 fractions [%]</td>
<td>91 / 100</td>
<td>99.8 / 100</td>
</tr>
<tr>
<td>Maximum normalized CTV dose after 28 fractions for 3D/4D dose calculation [%]</td>
<td>103.3 / 106.2</td>
<td>103.3 / 104.3</td>
</tr>
</tbody>
</table>

Conclusions:
We showed that repeated 4DMRI measurements are able to provide important and useful motion information for subsequent 4D dose evaluation for PBS scanned proton therapy of pancreatic cancer treatment. Such an approach with synthetic instead of repeated 4D-CTs can provide tumor motion information without any substantial amount of dose, offering more accurate quantification for treatment optimization with MRgRT in future.