Dosimetric and Deformation Effects of Image-Guided Interventions during Stereotactic Body Radiation Therapy of the Prostate using an Endorectal Balloon

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Purpose

- Assess the dosimetric impact of manual interventions on endorectal balloon (ERB) position in patients receiving prostate SBRT
- Investigate the impact of ERB interventions on prostate shape

Methods

- 7 patients treated with 50 Gy in 5 fractions using an ERB. Daily CBCT was used to localize the target. If significant deviations were observed, the ERB was manually re-adjusted/re-inflated.
- 59 CBCT image sets analyzed. 24 pre-intervention, 24 post-intervention, 11 no intervention
- Prostate, bladder, and anterior rectal wall (ARW) were contoured on each CBCT.
- A deformable registration algorithm was used to track the location of each voxel in these structures between the plan CT (pCT) and CBCT. The displacement of each voxel relative to the radiotherapy plan was calculated.
- Based on this pCT-to-CBCT deformation field, dose was calculated to each structure in the CBCT. Additionally, doses were accumulated between fractions to assess the overall dosimetric impact on treatment.

Introduction

- Phase I/II trial evaluating SBRT for the treatment of low-intermediate risk prostate cancer
- An ERB was used to stabilize the prostate and displace the posterior rectal wall out of the high-dose region, but may also deform the prostate.
- In many cases, it was necessary to manually adjust the ERB volume and/or position after initial patient setup to allow for maximum agreement of the PTV, bladder, and rectal wall positions between the plan and treatment positions
- Do manual interventions lead to dosimetric improvements in treatment?
- Do errors in ERB position deform the prostate?

Single-fraction dosimetric effect of manual ERB adjustment (n=24)

<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention</th>
<th>Post-Intervention</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>PTV D95 (Gy/fx)</td>
<td>9.64 ±1.0</td>
<td>10.0 ±0.2</td>
<td>0.06</td>
</tr>
<tr>
<td>PTV Cov (%)</td>
<td>94.6 ±7.6</td>
<td>98.0 ±1.9</td>
<td>0.03</td>
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<tr>
<td>ARW V6 (cm³)</td>
<td>9.1 ±2.8</td>
<td>9.3 ±2.2</td>
<td>0.47</td>
</tr>
<tr>
<td>ARW V8 (cm³)</td>
<td>7.1 ±3.0</td>
<td>7.4 ±2.4</td>
<td>0.49</td>
</tr>
<tr>
<td>ARW V10 (cm³)</td>
<td>3.3 ±1.6</td>
<td>2.7 ±1.2</td>
<td>0.17</td>
</tr>
<tr>
<td>BLA V2 (cm³)</td>
<td>31 ±12</td>
<td>29 ±10</td>
<td>0.17</td>
</tr>
<tr>
<td>BLA V4 (cm³)</td>
<td>20 ±11</td>
<td>19 ±8.9</td>
<td>0.45</td>
</tr>
<tr>
<td>BLA V6 (cm³)</td>
<td>14 ±10</td>
<td>13 ±7.8</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Results

- Interventions increased prostate D95 from 9.6 ±1.0 Gy to 10.0 ±0.2 Gy (p=0.06) and increased coverage from 94.0 ± 8.5% to 97.8 ± 1.9% (p=0.03).
- ERB interventions reduced prostate deformation in the anterior-posterior (AP) direction, reduced errors in the sagittal rotation of the prostate, and increased the similarity in shape of the prostate to the radiotherapy plan (increased Dice coefficient from 0.76 ± 0.06 to 0.80 ± 0.04, p=0.01).

Discussion

- ERB position can have a significant impact on the dosimetry of each fraction, and manual interventions can bring about an increase in prostate D95 and coverage.
- Differences are small on average, but can be large for an individual patient.
- Implications that two CBCT scans are generally needed for adequate target localization: one after insertion of the ERB and one after adjustment (if necessary).
- Preliminary data indicates that errors in ERB position deform the prostate and lead to treatment errors.
- No significant reduction or improvement in dose metrics for the anterior rectal wall or bladder. However, the overall effect of ERB interventions was to reduce deformations in these structures between the planning and treatment position, resulting in delivered dose distributions that more closely resembled the treatment plan.

Effect of rectal balloon (ERB) position on prostate deformation in one sample treatment fraction. A patient is simulated with an ERB, and the prostate and ERB occupy the plan positions. During treatment, the ERB is misplaced, and the anterior edge of the ERB is displaced towards the base of the prostate. This causes the prostate to be displaced/deformed superiorly to the prostate treatment position.