A Method of Dose Reconstruction for Moving Targets with Dynamic Treatments

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Background and Aim

Organ motion during radiotherapy treatment delivery may lead to target dose distributions that differ markedly from the planned dose. The aim of this study was to develop a method that allows a treatment planning system (TPS) to perform accurate dose reconstruction for moving targets with any dynamic treatment type. The method was validated in phantom measurements for a range of treatments including IMRT, VMAT, and dynamic MLC tracking.

Materials and Methods

Dose reconstruction: Figure 1 summarizes the dose reconstruction method. The central step is to generate a motion mimicking Dicom treatment plan and import this plan into the TPS (Eclipse, Varian Medical Systems) for dose reconstruction. The motion mimicking treatment plan was generated by an in-house developed computer program that divided the original treatment plan into a multitude of sub-beams. Each sub-beam represented the part of the treatment that was delivered while the target was located at a specific position. The target shift was modeled by shifting the sub-beam isocenter. For dynamic MLC tracking treatments, the motion mimicking treatment plan incorporated the actual MLC motion since this differed from the planned MLC motion. Dose calculation of the motion mimicking treatment plan by the TPS resulted in the reconstructed target dose including the effects of MLC shape changes, 3D target translations, interplay effects, and changes in the physical path length.

Figure 1: Overview of the dose reconstruction method.

Figure 2: Thorax phantom with tumor insert (A) for film dosimetric validation.

Experimental validation of dose reconstruction: Several treatments were delivered to a CIRS thorax phantom with a solid water tumor insert that was either static or performed a sinusoidal motion (20 mm peak-to-peak, 4 sec period, Figure 2). The delivered dose distributions were measured with Gafchromic EBT2 films and compared with the reconstructed doses using gamma analysis with 2mm/2% pass criteria. The investigated treatment plans were:

- 5-field conformal plan
- 5-field IMRT plans (dynamic and step-and-shoot)
- 2-arc VMAT plan (RapidArc)
- 1-field conformal plans with and without dynamic MLC tracking

Conclusions

A method for accurate dose reconstruction for moving targets with dynamic treatments was developed and validated in experiments. The method can be integrated into a TPS and used to:

- Reconstruct the dose delivered to moving tumors
- Test the robustness of a given plan against a given target motion
- Calculate the target dose delivered with dynamic MLC tracking

Results

Figure 3: Examples of calculated and film measured 2D dose distributions. Note the large interplay effects in the single field case (upper row).

Figure 4: Examples of calculated and film measured 2D dose distributions with and without dynamic MLC tracking.

Table 1: Comparison of measured and reconstructed doses. 2mm/2% gamma pass rates.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Static target</th>
<th>Moving target</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-field conformal plan</td>
<td>99.6%</td>
<td>100%</td>
</tr>
<tr>
<td>5-field dynamic IMRT plan</td>
<td>99.7%</td>
<td>100%</td>
</tr>
<tr>
<td>5-field step-and-shoot IMRT plan</td>
<td>99.5%</td>
<td>100%</td>
</tr>
<tr>
<td>2-arc VMAT plan</td>
<td>99.4%</td>
<td>99.8%</td>
</tr>
<tr>
<td>1-field conformal with MLC tracking</td>
<td>99.6%</td>
<td>99.5%</td>
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</table>

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