Dosimetric Evaluation of the Interplay between LINAC Movement and Tumor Motion in Respiratory Gated VMAT of Lung Cancer

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Purpose
Respiratory gated radiation therapy is one way to manage respiratory motion during therapy. This technique allows smaller target volumes to be used as treatment delivery is limited to certain predetermined phases of respiratory cycle. As the treatment volume is reduced, treatment side effects can be minimized. Volumetric modulated arc therapy (VMAT) is another novel technique which produces a highly conformal dose distribution in less treatment time.

However, in gated VMAT delivery, the interplay effect between the LINAC movement (both the MLC and gantry) and the tumor motion may result in undesirable hot and cold spots. This could mean reduced target coverage or overdosing the critical structures. In this study, we investigated the possible dosimetric errors caused by the interplay between the tumor motion and the LINAC movement for gated VMAT lung cancer treatment.

Methods
We studied 2 lung cancer cases. 4DCT thoracic scan was done with a 16 slice CT scanner. The 4DCT scans generated volumetric datasets for 10 phases of the respiratory cycle.

Patient 1 had a T2 tumor of volume 254.79 cc located in the RLL. Patient 2 had a T1 tumor of volume 22.88 cc located in the LUL. GTVs were contoured on each of the 10 phases of 4DCT. The end-expiration phase and 3 neighboring phases were chosen for gating (40%-70%). The GTV gating consisted of the GTVs of the 4 phases. The residual 3D tumor mobility within the gating window was 7.1 ± 4 mm for patient 1 and 1.8 ± 1.1 mm for patient 2. 25.5 mm margin was added to the GTV gating to create the CTV gating and 8 mm margin was added to generate the PTV gating. For both cases, 60 Gy was given in 30 fractions.

A highly modulated single arc VMAT plan (RapidArc, Varian Medical Systems) was derived for each case based on the 50% phase image. The plans aimed to minimize dose to the spinal cord and healthy lung, while maintaining PTV coverage. For each case, over 95% of the PTV received the prescribed dose.

A program was written to segment the arc in the original plan with 177 control points into 88 mini arcs with 3 control points each. Each mini arc spanned about 0.67 second and was assumed to irradiate 1 phase of the gating window during which there should be relatively little movement of the anatomy. Every one in four arcs was then inserted into a VMAT plan irradiating each of the 4 phases, thus generating 4 plans each having 22 mini arcs.

Dose calculation was done for each plan on the CT image for the particular phase. The resulting dose from each plan was then mapped to the base phase image (50%) and finally summed with a deformable dose accumulation software (MIM Maestro, MIM Software). The resulting dose was compared to the original dose distribution.

Results

- **Table 1. Summary of dosimetric results**

<table>
<thead>
<tr>
<th>Case</th>
<th>PLAN</th>
<th>GTV Vol</th>
<th>PTV D95%</th>
<th>PTV D1%</th>
<th>Mean Lung Dose</th>
<th>Spinal Cord D1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VMAT</td>
<td>254.8 cc</td>
<td>60.0 Gy</td>
<td>66.7 Gy</td>
<td>19.2 Gy</td>
<td>41.6 Gy</td>
</tr>
<tr>
<td>2</td>
<td>VMAT</td>
<td>22.9 cc</td>
<td>60.4 Gy</td>
<td>63.9 Gy</td>
<td>7.0 Gy</td>
<td>7.0 Gy</td>
</tr>
<tr>
<td>Sum 4 Phases Plan</td>
<td>254.8 cc</td>
<td>59.7 Gy</td>
<td>66 Gy</td>
<td>19.3 Gy</td>
<td>41.0 Gy</td>
<td></td>
</tr>
<tr>
<td>Sum 4 Phases Plan</td>
<td>22.9 cc</td>
<td>59.3 cc</td>
<td>63.4 cc</td>
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<td>7.3 cc</td>
<td></td>
</tr>
</tbody>
</table>

Discussion
For both cases, there is very little difference in dose to the critical structures when we take into account the interplay between the respiratory related motions and gantry movements. Decrease in tumor coverage is observed especially for the smaller size tumor (case 2). However, there is very little change in the tumor control probability. The TCP changed from 55.2% to 54.9% for case 1 and 52.9% to 51.9% for case 2.

Conclusion
The dosimetric effect of the interplay between tumor motion and LINAC movement was studied for 2 lung cancer cases. It was found that there was no significant difference in tumor coverage when the original plan was done assuming a static target. The dose to critical structures also remained very close to the original plan. It can be concluded that interplay between LINAC movement and tumor motion will not affect the dosimetric quality of gated VMAT plans for lung cancer.