LINAC and MLC QA for IMRT-Consequences in Treatment Plans

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Learning Objectives
- Understand different IMRT delivery methods and their specific QA issues.
- Understand effect of QA on the IMRT delivery accuracy.
- Understand the importance of proper commissioning of the planning system to avoid confusion with dose delivery issues.

Treatment planning Related Considerations
Double Focused MLC

- Focused in in-plane (Y)
- Focused in cross plane (X)

Single Focused MLC

- Focused in in-plane (Y)
- Focused in cross-plane (X)

Rounded Leaf End vs Penumbra

- (a)
- (b)

Physical Leaf Length vs. Over-travel Distance

- The MLC physics leaf length (project to iso-center) is 16 cm, 30 cm, 32.5 cm for Varian, Siemens, and Elekta Accelerators, respectively.
- The distance that each individual leaf passes over iso-center is called over-travel distance, without leaving a uncovered region behind the leaf.
Over-travel Distances

- For Siemens and Elekta machines, the over-travel distances are 10cm and 12.5 cm, respectively.
- For Varian MLC, X jaw is used to cover the uncovered region of MLCs. The over-travel distance = 2 cm (x jaw over-travel distance) + 15 cm = 17 cm (20 cm for Millennium)
- The maximum differences between the leading leaf and the trailing leaf ≤15 cm

Leaf Motion Constraints

- Interleaf motion (Varian)
- No Interleaf motion (Siemens)
- Minimum Gap (Elekta)
**MLC Leakage and Backup Jaws**

- MLC leakage can be minimized by letting backup jaws following each IMRT segment.
  - Varian: Backup jaws do not follow each MLC segment.
  - Siemens: Backup jaws follow each segment.
  - Elekta: Backup Jaws follow each segment.

**Special Issues**

**Step and Shoot Delivery Using DMLC**

Every 50 ms

- MLC controller
- MU console

Positions of each segment
- Control total MU

Communication delay ~ up to 100 ms between segments

8 MU port film 96 MU EDR film Fluence Map
# Experiment

<table>
<thead>
<tr>
<th># of Segment</th>
<th>0.25 MU/seg</th>
<th>1.0 MU/seg</th>
<th>4.0 MU/seg</th>
<th>16.0 MU/seg</th>
<th>25.0 MU/seg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 MU/min</td>
<td>400 MU/min</td>
<td>600 MU/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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</tbody>
</table>

1 MU/seg delivered with static mode (CL2300, 6MV, 100 SSD, 1.5 cm depth)

1 MU/seg delivered with dose mode (CL2300, 6MV, 100 SSD, 1.5 cm depth)

Delivered with dose mode at 400MU/min (CL2300, 6MV, 100 SSD, 1.5 cm depth)
Simulation of Leaf Position Errors - Random and Systematic

Random and Systematic Errors

- Introduce random leaf position errors (± 2 mm) to each segment of IMRT plans
- Introduce systematic leaf position errors (± 1 mm) to each segment of IMRT plans
- Include 17 head and neck cases, and 12 treated with simple IMRT plans (< 60 segments) and 5 treated with complex IMRT plans (> 100 segments).
What We Found?

• The dosimetric effect was insignificant for random MLC leaf position errors up to 2 mm for both simple and complex plans.
• Systematic MLC leaf position errors could result in significant dosimetric differences between the simple and complex IMRT plans.
• Complex IMRT plans are more sensitive to the leaf position errors than the simple plans.

MLC Scatter and Low Dose Regions

• Jang et. al. from MD Anderson recently reported underestimation of low-dose radiation in IMRT plans
• Low dose radiation is particularly important for lung patients.
• It is found that V20, V10, and V5 are important parameters to predict pulmonary toxicity.

Jang et. al., Int. J. Radiation Oncology Biol. Phys. In press

MLC Modeling

• Errors in the dose–volume histograms of the normal lung were small (<5%) above 10 Gy.
• Underestimation of dose <10 Gy was found to be up to 25% in patients with large target volumes.
• It was caused by inadequate modeling of MLC transmission and leaf scatter in commercial TPSs.
• The degree of low-dose errors depends on the target volumes and the degree of intensity modulation.

Modeling in Low Dose Regions
Summary

- It is important to understand that MLC quality assurance can affect plan quality, deliverability, and dose accuracy of IMRT plans.
- Simplified IMRT plans can reduce dosimetric MLC leaf position uncertainties.
- Improved MU efficiency can reduce scatter dose from MLC, which has significant clinical impact on patients with lung cancer since low dose matters in lung irradiation.