Creating long term, effective QA programs, with a focus on measurement vs software methods

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Regional Training Course on Basics of Intensity Modulated Radiotherapy
Melbourne Australia, 9-13 September 2015
Content Overview

• Why do QA and what are we really looking for?

• QA Approaches

• Linking Treatment Planning, Commissioning & QA
  - understanding the impact of plan quality

• Clinical Experience & Case Studies
  - Mobius 3D/FX (independent dose calc)
  - FractionLab (dynalog analysis)
  - MapCheck Analysis
Regional Training Course on Basics of Intensity Modulated Radiotherapy

Melbourne Australia, 9-13 September 2015
January 23, 2010

Radiation Offers New Cures, and Ways to Do Harm

By WALT BOGDANICH

As Scott Jerome-Parks lay dying, he clung to this wish: that his fatal radiation overdose — which left him deaf, struggling to see, unable to swallow, burned, with his teeth falling out, with ulcers in his mouth and throat, nauseated, in severe pain and finally unable to breathe — be studied and talked about publicly so that others might not have to live his nightmare.

A New York City hospital treating him for tongue cancer had failed to detect a computer error that directed a linear accelerator to blast his brain stem and neck with errant beams of radiation. Not once, but on three consecutive days.
Physical Wedge Dose Modulation
- 1 Dimensional -

MLC Based Dose Modulation
- 2 Dimensional -
Comparison of different systems

2D Measurements

• Using Gamma Function
  - what does it mean to an RO?
  - what does changing criteria tell you?
  - Identifying patterns in failure position
  - Normal distributions and trends
  - what would a different instrument say?

• Be careful. The Gamma Function is a useful index for comparing like system but a lot of information can also be obtained from
  - The distribution of gamma fails [ even spread, clumped together]
  - Dose diff profiles
  - Normal (or otherwise) distribution of dose differences

Should be observed over time for trends
Fluence Editor

Optimal Fluence

Tool options

Brushes

Brush size: 1.00 cm
Transmission Factor: 0.112

Visualization

- Use colors
  Lower: 0.000
- Isolevels
  Upper: 0.418
- Use Shading
- Show actual fluence with resolution used in dose calculation

Opacity

OK  Cancel  Apply
POINT/COUNTERPOINT

Suggestions for topics suitable for these Point/Counterpoint debates should be addressed to Colin G. Orton, Professor Emeritus, Wayne State University, Detroit: ortonc@comcast.net. Persons participating in Point/Counterpoint discussions are selected for their knowledge and communicative skill. Their positions for or against a proposition may or may not reflect their personal opinions or the positions of their employers.

Patient-specific QA for IMRT should be performed using software rather than hardware methods

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[http://dx.doi.org/10.1118/1.4794929]
## Target Coverage

<table>
<thead>
<tr>
<th>TPS Name</th>
<th>Mean Dose</th>
<th>90% Coverage</th>
<th>Stray Voxels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TPS</td>
<td>M3D</td>
<td>% Diff</td>
</tr>
<tr>
<td>CTV</td>
<td>21.5 Gy</td>
<td>21.8 Gy</td>
<td>1.63%</td>
</tr>
<tr>
<td>CTV DIBH_CW</td>
<td>21.5 Gy</td>
<td>21.8 Gy</td>
<td>1.13%</td>
</tr>
<tr>
<td>DVH PTV</td>
<td>21.3 Gy</td>
<td>21.7 Gy</td>
<td>1.82%</td>
</tr>
<tr>
<td>IMRT FLASH PTV</td>
<td>1.62 Gy</td>
<td>3.1 Gy</td>
<td>6.36%</td>
</tr>
<tr>
<td>IMRT PTV BOL</td>
<td>20.6 Gy</td>
<td>21 Gy</td>
<td>1.77%</td>
</tr>
<tr>
<td>PTV DIBH</td>
<td>20.6 Gy</td>
<td>21.1 Gy</td>
<td>1.81%</td>
</tr>
</tbody>
</table>
### 3D Gamma

<table>
<thead>
<tr>
<th>Passing Rate</th>
<th>Criteria</th>
<th>Reference Dose</th>
<th>Threshold Dose</th>
<th>TPS Voxels</th>
<th>M3D Voxels</th>
</tr>
</thead>
<tbody>
<tr>
<td>85.7%</td>
<td>3% / 3 mm</td>
<td>23.2 Gy (Max Dose)</td>
<td>2.32 Gy</td>
<td>3 mm, 2.5 mm, 2.5 mm</td>
<td>3 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transverse Gamma</th>
<th>Transverse Isodose</th>
<th>Coronal Gamma</th>
<th>Coronal Isodose</th>
<th>Sagittal Gamma</th>
<th>Sagittal Isodose</th>
</tr>
</thead>
</table>

#### Coronal Plane at 0 cm from Max Dose

ROI "BODY" used as external surface; density outside of "BODY" set to zero.

#### Vertical Dose Profile

![Vertical Dose Profile](image)

#### Horizontal Dose Profile

![Horizontal Dose Profile](image)

#### Gamma M3D Dose

<table>
<thead>
<tr>
<th>Gamma</th>
<th>M3D Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 2.0</td>
<td>Hottest</td>
</tr>
<tr>
<td>1.5</td>
<td>Hotter</td>
</tr>
<tr>
<td>1.0</td>
<td>Hot</td>
</tr>
<tr>
<td>-1.0</td>
<td>Cool</td>
</tr>
<tr>
<td>-1.5</td>
<td>Cooler</td>
</tr>
</tbody>
</table>
Breast IMRT and M3D

• Total MUs and smoothing parameters important for deliverability

![Image of 3D Gamma and dose profile](image_url)
Breast IMRT and M3D

- Total MUs and smoothing parameters important for deliverability

- Re-planned 1897 MUs (1/3 reduction)

- $MF = \frac{1897}{265.6} \approx 7.4$
### Lung and M3D

#### 3D Gamma

<table>
<thead>
<tr>
<th>Passing Rate</th>
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<th>Threshold Dose</th>
<th>TPS Voxels</th>
<th>M3D Voxels</th>
</tr>
</thead>
<tbody>
<tr>
<td>84.3%</td>
<td>3% / 3 mm</td>
<td>53 Gy (Max Dose)</td>
<td>5.3 Gy</td>
<td>1 mm</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

#### Transverse Gamma | Transverse Isodose | Coronal Gamma | Coronal Isodose | Sagittal Gamma | Sagittal Isodose

**Transverse Plane at 0 cm from Max Dose**

**Vertical Dose Profile**

ROI "BODY" used as external surface; density outside of "BODY" set to zero.
Lung and M3D

<table>
<thead>
<tr>
<th>Passing Rate</th>
<th>Criteria</th>
<th>Reference Dose</th>
<th>Threshold Dose</th>
<th>TPS Voxels</th>
<th>M3D Voxels</th>
</tr>
</thead>
<tbody>
<tr>
<td>98.7%</td>
<td>3% / 3 mm</td>
<td>53.2 Gy (Max Dose)</td>
<td>5.32 Gy</td>
<td>3 mm, 2.5 mm, 2.5 mm</td>
<td>3 mm</td>
</tr>
</tbody>
</table>

Transverse Plane at 0 cm from Max Dose

ROI "BODY" used as external surface, density outside of "BODY" set to zero.

Vertical Dose Profile
<table>
<thead>
<tr>
<th>Passing Rate</th>
<th>Criteria</th>
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<th>M3D Voxels</th>
</tr>
</thead>
<tbody>
<tr>
<td>92.6%</td>
<td>3% / 3 mm</td>
<td>38.2 Gy (Max Dose)</td>
<td>3.82 Gy</td>
<td>3 mm, 2.5 mm, 2.5 mm</td>
<td>3 mm</td>
</tr>
</tbody>
</table>

**Transverse Plane at 0 cm from Isocenter**

ROI "Body" used as external surface; density outside of "Body" set to zero.

**Vertical Dose Profile**

**Horizontal Dose Profile**

<table>
<thead>
<tr>
<th>Gamma</th>
<th>M3D Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 2.0</td>
<td>Hottest</td>
</tr>
<tr>
<td>1.5</td>
<td>Hotter</td>
</tr>
<tr>
<td>1.0</td>
<td>Hot</td>
</tr>
</tbody>
</table>
3D Gamma

Passing Rate | Criteria | Reference Dose | Threshold Dose | TPS Voxels | M3D Voxels
--- | --- | --- | --- | --- | ---
76.9% | 3% / 3 mm | 38.3 Gy (Max Dose) | 3.83 Gy | 3 mm, 2.5 mm, 2.5 mm | 3 mm

Transverse Plane at 0 cm from Isocenter

ROI "Body" used as external surface; density outside of "Body" set to zero.

Vertical Dose Profile

Horizontal Dose Profile

<table>
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<tr>
<th>Gamma</th>
<th>M3D Dose</th>
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<tbody>
<tr>
<td>≥ 2.0</td>
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<td>1.5</td>
<td>Hotter</td>
</tr>
<tr>
<td>1.0</td>
<td>Hot</td>
</tr>
</tbody>
</table>
• Dynalog based Fluence Map Comparison
Dynalog based MLC Delivery Comparison

Delivery data
- Treatment type: Dynamic
- Delivery time: 12.1 s
- Beam on: 97.3%
- Number of segments: 129
- Number of beam holds: 1
- Max beam off lag: 2 cycles (0.1 s)
- MLC tolerance setting: 2.0 mm
- Carriage RMS: 0.04 mm

Error bin data
- Results for Bank A / Bank B
  - 0 - 0.05 mm: 63.2% / 55.1%
  - 0.05 - 0.5 mm: 37.9% / 38.2%
  - 0.5 - 1.0 mm: 8.1% / 8.1%
  - 1.0 - 1.5 mm: 0.7% / 0.6%
  - 1.5 - 2.0 mm: 0.0% / 0.0%
  - 2.0 - 2.5 mm: 0.0% / 0.0%
  - 2.5 - 3.0 mm: 0.0% / 0.0%
  - 3.0 - 3.5 mm: 0.0% / 0.0%
  - 3.5 - 4.0 mm: 0.0% / 0.0%
  - 4.0 - 4.5 mm: 0.0% / 0.0%
  - 4.5 - 5.0 mm: 0.0% / 0.0%
  - 5.0 - 6.0 mm: 0.0% / 0.0%
  - 6.0 - 7.0 mm: 0.0% / 0.0%
  - 7.0 - 8.0 mm: 0.0% / 0.0%
  - 8.0 - 9.0 mm: 0.0% / 0.0%
  - 9.0 - 10.0 mm: 0.0% / 0.0%
  - > 10.0 mm: 0.0% / 0.0%

95th percentile error: 0.6 mm / 0.6 mm

Beam off lag is red, beam off with no hold asserted is yellow, beam on is green
Planning Constraints – Many issues can be resolved here

• Fluence ≤ 0.4  (for eclipse) as rule of thumb

• Per field MU ~ 100x dose per fraction as rule of thumb

• Use an MU limit in optimiser if available

• Min MU for field length ~ 6MU/cm

• Use coll rotation to minimise leaf travel

THESE WORK FOR OUR SYSTEMS - THEY SHOULD NOT BE USED WITH VALIDATION
Questions ?