MEASUREMENT METHODS FOR IMRT QA

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Outline

- Describe three common methods of IMRT QA measurements
- Describe the pros and cons of each
- Compare results between methods
- Review literature on method results

Three Most Common Measurement Methods

1. Beam-by-Beam (BbB) - perpendicular to chamber or diode array or EPID
2. Composite (summation) BbB (CBbB) - perpendicular to chamber or diode array or EPID
3. True composite - (all beams at actual planned positions) film + chamber or detector array in phantom

- Ion chamber only in true composite geometry
Overall, only 54% of these delivery errors would be detected if an ion chamber measurement were performed using a 3% clinical tolerance level and 2D measurements were not performed.

Nelms, JACMP 8, 2007

Survey Performed on Methods Used

Frequency of Single-Center-single-Composite Analysis

- Most common: 100%
- Next most common: 100%
- Rare: 0%

Tools of the Trade

Array: BbB or CbB
Or EPID

Film+Chamber:
True Composite
Beam-by-Beam Gamma Analysis (Detector Array)

Composite Beam-by-Beam Gamma Analysis

True Composite Gamma Analysis
Pros

- BbB and CBbB – Every part of every field is sampled, fast acquisition.
- CBbB – only one dose image to analyze.
  More uniform dose for analysis than BbB.
- True composite-Actual dose summation in a 2D slice of the 3D dose, couch, gantry errors included. Only one dose image to analyze.

Cons

- BbB, CBbB – no sense of 3D summation. Can’t know significance of regional errors in each beam.
- BbB - can get any Gamma result you want for relative dose mode by normalizing to a different place.
- CBbB – errors from each field may cancel on summation.
- True composite – more time consuming if film used.
  Does not sample every part of each beam. If an Array is to be used, less accurate for nearly lateral beams.

Angular dependence of MatriXX chamber Array

Han, Med. Phys. 37, 2010
**BbB Gamma Results Don’t Correlate to 3D Dose**

- 3 plans, an acceptable version (all IC doses within 4% of TPS) and an unacceptable version.
- 8-18 ion chamber measurements in high dose low gradient and critical structure locations for true composite IMRT plans compared to EPID or Matrix beam-by-beam Gamma passing rates.

Kruse, Med. Phys. 37, 2010

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**BbB Gamma Passing Rate Did Not Identify An Unacceptable Plan**

<table>
<thead>
<tr>
<th>Average gamma passing percentage: spatial analysis</th>
<th>2% dose2 mm TTA</th>
<th>3% dose3 mm TTA</th>
<th>5% dose5 mm TTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>94.0 (3.8)</td>
<td>98.3 (1.1)</td>
<td>99.2 (0.8)</td>
</tr>
<tr>
<td>Patient 2</td>
<td>92.4 (4.5)</td>
<td>96.8 (7.6)</td>
<td>97.0 (3.2)</td>
</tr>
<tr>
<td>Patient 3</td>
<td>92.0 (4.2)</td>
<td>98.0 (1.1)</td>
<td>99.5 (0.8)</td>
</tr>
</tbody>
</table>

Kruse, Med. Phys. 37, 2010

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**Reconstruction of Patient 3D Dose from Simulated BbB Measurements**

- Compared simulated BbB measurements with induced errors to calculated 3D doses in CTV and various organs at risk.
- Weak to moderate correlations between Gamma metric and DVH difference-based metrics.
- Large rate of false negatives (you think the plan is ok but it is not).
- The larger clinical errors happen for higher IMRT QA Gamma passing rates.

Are the Results of the Methods Comparable?
Intercomparison of Gamma Passing Rates for all 3 Methods
- 15 IMRT patient cases
- True Composite (film) vs. Mean BbB
- True Composite (film) vs. CBB
- 2%,2mm tolerance, 20% dose threshold, relative dose mode

No Correlation – BbB vs. True Composite

No Correlation – CBB vs. True Composite
True Composite vs. BbB (TG119)

Which Method is Best?
- Will one method detect failing plans better than another? BbB and TC better than CBbB.
- Are results from one method comparable to the other method? Generally No.
- If the Gamma metric passes, can relatively small regions with errors be related to the dose impact in the patient? TC.

Conclusions
- Each has its own pros and cons with variable ability to identify a delivery-to-TPS mismatch.
- One can not compare the results from one IMRT QA method to another.
- True composite provides at least a 2D slice out of a 3D dose distribution, CBbB risks masking errors.
- None of the methods discussed tells us the error in delivery of the 3D dose to the patient’s PTV or critical organs.