MPPG 5.a: Commissioning and QA of Treatment Planning Dose Calculations – MV Photon and Electron Beams

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Disclosures

• I have no disclosures, financial or otherwise
Outline

• Scope of MPPG 5.a
• Summary of MPPG 5.a
  – Motivation
  – Highlights
  – Clinical implementation

MPPG 5.a - Scope

• Commissioning and QA of TPS Calculations – MV Photon and Electron Beams
  – Typical SSD
  – Gantry mounted radiation source
  – Conventional and small fields
  – IMRT, VMAT, and helical tomotherapy
  – Tissue heterogeneity
  – MLC
MPPG 5.a – Outside the Scope

• Non-commercial TPS
• Small SRS fields - less than 2 x 2 cm²
• Secondary calculation software
• Optimization and leaf sequencing algorithms
• Biological and other non-dosimetric components

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Motivation

• Reliance on TPS as an essential component of the external beam treatment process
• Accuracy of dose distribution between calculated and delivered is paramount
• QMP is charged with verifying that the modeled beam matches the delivered beam
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  – Successes and suggestions

Bookkeeping

• QMP is responsible for commissioning and QA of TPS
  – Must evaluate the scope of work, and adequate time and resources to allocate
  – Determine which calculation algorithms to be commissioned and their respective uses
  – Tolerance values and evaluation criteria determined by QMP in accordance with needs of the clinic
  – Identify and reference applicable AAPM reports, publications, and vendor guidance
Bookkeeping

• Given 1.5 – 2.0 FTEs dedicated to commissioning:
  – Single photon energy: 2 to 4 weeks
  – Two photon and five electron energies: 6 to 8 weeks

• Equipment

Equipment

• QMP decides on appropriate equipment
  – Data collection
  – Data processing and analysis
  – Model verification and end-to-end testing

• QMP must also determine appropriate tolerance criteria
  – MPPG 5.a lists established minimum criteria for basic photon agreement, simple heterogeneity and basic electron beam validation
Workflow

• Iterative process
  – Compromises in accuracy considering clinical scenarios

• Logical workflow

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**Preparation**

- Beam scanning for modeling as well as validation
  - Vendor specifications and recommendations
  - Clinically significant requirements
- Measurement methods for individual components
  - Leaf end penumbra
  - MLC transmission
  - Binary MLC leaf timing
  - Small fields (IMRT/VMAT)

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**Data Review**

- Is data as expected?
  - Setup and measurement errors
  - Compare to reference dataset from same type of machine
- Data import errors
  - Spot-checking and graphical review
  - Data in TPS import module should be identical to water tank export
Modeling

• Vendor specific process
  – Adjustable parameters modified such that model matches measured data
• QMP to understand effect and magnitude of each parameter
  – How much can/should each parameter be adjusted to tweak the model?
  – At what point does measured dataset come under question?

Validation Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Comparison</th>
<th>Description</th>
<th>Tolerance</th>
</tr>
</thead>
</table>
| 5.1  | Dose distributions in planning module vs. modeling (physics) module | Comparison of dose distribution for large (> 30×30cm²) field. | Identical
| 5.2  | Dose in test plan vs. clinical calibration condition | Reference calibration condition check | 0.5% |
| 5.3  | Dose distribution calculated in planning system vs. commissioning data | PDD and off axis output factors for a large and a small field size | 2% |

a Identical to within the expected statistical uncertainty (considering noise and calculation grid size).
b TPS absolute dose at reference point.
Basic Photon Validation

7/23/18
# Clinical Photon Validation Tests

## Table 4. Basic photon beam validation tests summary

| Test | Description | Sample tests from literature
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4</td>
<td>Small MLC-shaped field (non SRS)</td>
<td>Photon Test 1</td>
</tr>
<tr>
<td>5.5</td>
<td>Large MLC-shaped field with extensive blocking (e.g., mantle)</td>
<td>Photon Test 3</td>
</tr>
<tr>
<td>5.6</td>
<td>Off-axis MLC shaped field, with maximum allowed leaf over travel</td>
<td>Photon Test 2</td>
</tr>
<tr>
<td>5.7</td>
<td>Asymmetric field at minimal anticipated SSD</td>
<td>Photon Test 6</td>
</tr>
<tr>
<td>5.8</td>
<td>10x10 cm² field at oblique incidence (at least 20°)</td>
<td>Photon Test 10</td>
</tr>
<tr>
<td>5.9</td>
<td>Large (&gt; 15 cm) field for each nonphysical wedge angle</td>
<td>-</td>
</tr>
</tbody>
</table>

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*For all tests, measurements in the high-dose region, penumbra, and low-dose tail regions should be compared to calculated values at various depths (including slightly beyond dmax, midrange/10–15 cm, and deep/25–30 cm). SSDs, other than those used at commissioning and that reflect the clinically expected range, should be used. The MLC should be used for tests 5.4–5.6. The MLC or jaws may be used for tests 5.7–5.9.*

*b Tests 5.4–5.8 are intended for each open and (hard) wedged field. Nonphysical wedges are considered an extension of the corresponding open field in terms of spectra and only require the addition of Test 5.9.*

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7. Sample tests from literature: IAEA TRS Report 430

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## Validation Test 5.5
Validation Methods and Tolerances

Table 5. Basic TPS photon beam evaluation methods and tolerances.

<table>
<thead>
<tr>
<th>Region</th>
<th>Evaluation Method</th>
<th>Tolerancea (consistent with IROC Houston)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High dose</td>
<td>Relative dose with one parameter change from reference conditions</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Relative dose with multiple parameter changesb</td>
<td>5%</td>
</tr>
<tr>
<td>Penumbra</td>
<td>Distance to agreement</td>
<td>3 mm</td>
</tr>
<tr>
<td>Low-dose tail</td>
<td>Up to 5 cm from field edge</td>
<td>3% of maximum field dose</td>
</tr>
</tbody>
</table>

a Tolerances are relative to local dose unless otherwise noted.
b For example, off-axis with physical wedge.

Heterogeneous Validation Tests

Table 6. Heterogeneous TPS photon beam validation tests.

<table>
<thead>
<tr>
<th>Test</th>
<th>Objective</th>
<th>Description</th>
<th>Tolerancesa</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Validate planning system</td>
<td>CT-density calibration for air, lung, water, dense bone, and possibly additional tissue types</td>
<td>–</td>
<td>TG 65,(26)</td>
</tr>
<tr>
<td></td>
<td>reported electron (or mass)</td>
<td></td>
<td></td>
<td>IAEA</td>
</tr>
<tr>
<td></td>
<td>densities against known values</td>
<td></td>
<td></td>
<td>TRS-430(17)</td>
</tr>
<tr>
<td>6.2</td>
<td>Heterogeneity correction</td>
<td>5x5 cm², measure and calculate dose ratio above and below heterogeneity, outside of the buildup region</td>
<td>3%</td>
<td>IAEA</td>
</tr>
<tr>
<td></td>
<td>distal to lung tissue</td>
<td></td>
<td></td>
<td>TRS-430(17)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carrasco et al.(28)</td>
</tr>
</tbody>
</table>

a Tolerances are relative to local dose unless otherwise noted.
VMAT/IMRT Validation Tests

Table 7. VMAT/IMRT test summary.

<table>
<thead>
<tr>
<th>Test</th>
<th>Objective</th>
<th>Description (example)</th>
<th>Detector</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1</td>
<td>Verify small field PDD</td>
<td>≤ 2×2 cm² MLC shaped field, with PDD acquired at a clinically relevant SSD</td>
<td>Diode or plastic scintillator</td>
<td>Yunice et al.</td>
</tr>
<tr>
<td>7.2</td>
<td>Verify output for small MLC-defined fields</td>
<td>Use small square and rectangular MLC-defined segments, measuring output at a clinically relevant depth for each</td>
<td>Diode, plastic scintillator, manchamber or macroion chamber</td>
<td>Cadman et al.</td>
</tr>
<tr>
<td>7.3</td>
<td>TG-119 tests</td>
<td>Plan, measure, and compare planning and QA results to the TG119 report for both the Head and Neck and C-shape cases</td>
<td>Ion chamber, film and/or array</td>
<td>TG-119 (Ezzell et al.)</td>
</tr>
<tr>
<td>7.4</td>
<td>Clinical tests</td>
<td>Choose at least 2 relevant clinical cases, plan, measure, and perform an in-depth analysis of the results</td>
<td>Ion chamber, film and/or array</td>
<td>Nelms et al.</td>
</tr>
<tr>
<td>7.5</td>
<td>External review</td>
<td>Simulate, plan, and treat an anthropomorphic phantom with embedded dosimeters</td>
<td>Various options exist*</td>
<td>Kry et al.</td>
</tr>
</tbody>
</table>

* A bar pattern scanned with a diode can be used to obtain additional absolute dose profile comparison in the direction perpendicular to MLC movement

Summary

- Beam modeling and validation is an iterative process driven by the QMP
- A logical workflow from simple to complex avoids unnecessary repetition
- MPPG 5.a provides guidance on minimum standards for commissioning and modeling TPS beam models
Thank you!