Implementing a Clinical Practice Guideline; Lessons From An Early Adopter of MPPG 5.a

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Disclosures

None
Outline

1. General experience with the implementation of MPPG 5.a
2. Benefits of implementation
3. Difficulties encountered during implementation
4. Development of organization and analysis tools
5. Availability of tools to the physics community
A Quick Show of Hands

• How many of you are familiar with Medical Physics Practice Guidelines?
• How many of you have put one into practice in your clinic?
What is an MPPG?

How does an MPPG contrast with a Task Group Report?

• Task groups are:
  • Long
  • Comprehensive
  • Numerous
  • Not updated often
  • Not often prescriptive
What is an MPPG?

How does an MPPG contrast with a Task Group Report?

• Medical physics practice guidelines are different
  • Shorter
  • More narrowly focused
  • Fixed sunset date

• Clearly defines scope of the medical physics practice in terms of:
  • Staffing
  • Equipment
  • Training requirements
  • Minimum standards for quality

• Written for an audience that includes physicists, administrators, accreditors, regulators
What is MPPG 5.a?

- MPPG 5.a seeks to provide guidance on commissioning and validation of radiotherapy dose calculations for photons and electrons
  1. Identify applicable AAPM reports and published literature
  2. Provide updated guidance on technologies that are newer
  3. Provide guidance on validation tests for dosimetric accuracy
  4. Provide guidance on tolerance values and evaluation criteria for clinical acceptability
  5. Provide a checklist for commissioning
What is MPPG 5.a?

Acquiring data and modeling

COMMISSIONING A DOSE CALCULATION MODEL

Validation

Documentation
So you’ve downloaded MPPG 5.a…

Now what?
What is MPPG 5.a asking of me?

• Read it to identify all of the things I need to do:
  • Sections 1-4: Guidance on the beam data acquisition and modeling process
  • Sections 5-8: Guidance on beam model validation
  • Sections 9-10: Wrapping it up
MPPG 5.a Validation: Big Picture

Water Phantom → Heterogeneous Phantom → Patient CT
### What tools do I need?

<table>
<thead>
<tr>
<th>MPPG 5.a Section</th>
<th>Test Number</th>
<th>Test Description</th>
<th>Measurement Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Photon Beams: Basic Dose Algorithm Validation</td>
<td>5.1</td>
<td>Physics module versus planning module</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>5.2</td>
<td>Clinical calibration geometry dose</td>
<td>Scanning water tank; Farmer-type ionization chambers</td>
</tr>
<tr>
<td></td>
<td>5.3</td>
<td>Planning module dose versus commissioning data</td>
<td>Scanning water tank; scanning ionization chambers</td>
</tr>
<tr>
<td></td>
<td>5.4-5.8</td>
<td>Basic photon beam tests</td>
<td>Scanning water tank; scanning ionization chambers</td>
</tr>
<tr>
<td></td>
<td>5.9</td>
<td>Non-physical wedge test</td>
<td>MapCHECK2</td>
</tr>
<tr>
<td>6. Photon Beams: Heterogeneity Correction Validation</td>
<td>6.1</td>
<td>CT-value-to-density calibration</td>
<td>Electron density phantom</td>
</tr>
<tr>
<td></td>
<td>6.2</td>
<td>Heterogeneity correction</td>
<td>Custom phantom; ionization chamber</td>
</tr>
<tr>
<td>7. Photon Beams: IMRT/VMAT Dose Validation</td>
<td>7.1</td>
<td>Small field PDD</td>
<td>Scanning water tank; scanning ionization chambers; diode detector</td>
</tr>
<tr>
<td></td>
<td>7.2</td>
<td>Output for small MLC-defined fields</td>
<td>Scanning water tank; diode detector</td>
</tr>
<tr>
<td></td>
<td>7.3-7.4</td>
<td>TG-119 and clinical tests</td>
<td>Delta4; MapCHECK2</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>External review</td>
<td>Radiochromic film; OSLDs</td>
</tr>
<tr>
<td>8. Electron Dose Validation</td>
<td>8.1-8.2</td>
<td>Basic electron fields and obliquity tests</td>
<td>Scanning water tank; scanning ionization chambers</td>
</tr>
<tr>
<td></td>
<td>8.3</td>
<td>Electron heterogeneity correction</td>
<td>Custom phantom; ionization chamber</td>
</tr>
</tbody>
</table>

- **TPS Only**: MapCHECK2
- **Water Tank**: None / Scanning water tank
- **QA Devices**: Scanning ionization chambers, Farmer-type ionization chambers, diode detector, Delta4, Radiochromic film
- **Heterogeneous Phantom**: Electron density phantom, Custom phantom
1. Gathering the Phantoms
2. Calculating Treatment Plans
3. Making Measurements
4. Comparing Measured and Calculated Dose

<table>
<thead>
<tr>
<th>Energy</th>
<th>Field Size</th>
<th>SSD</th>
<th>Depth</th>
<th>Calc Dose</th>
<th>Rel. Dose</th>
<th>% Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>6x</td>
<td>10x10</td>
<td>100</td>
<td>1.4</td>
<td>200.6</td>
<td>1.000</td>
<td>0.00%</td>
</tr>
<tr>
<td>6xFFF</td>
<td>10x10</td>
<td>100</td>
<td>1.3</td>
<td>199.6</td>
<td>1.000</td>
<td>0.00%</td>
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<tr>
<td>10xFFF</td>
<td>10x10</td>
<td>100</td>
<td>2.2</td>
<td>198.8</td>
<td>1.000</td>
<td>0.00%</td>
</tr>
<tr>
<td>16x</td>
<td>10x10</td>
<td>100</td>
<td>2.9</td>
<td>200.2</td>
<td>1.000</td>
<td>0.00%</td>
</tr>
<tr>
<td>6x</td>
<td>5x5</td>
<td>90</td>
<td>4</td>
<td>205.8</td>
<td>1.026</td>
<td>-1.15%</td>
</tr>
<tr>
<td>6xFFF</td>
<td>5x5</td>
<td>90</td>
<td>4</td>
<td>204.5</td>
<td>1.025</td>
<td>-1.14%</td>
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<tr>
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<td>5x5</td>
<td>90</td>
<td>4</td>
<td>220.9</td>
<td>1.111</td>
<td>-0.50%</td>
</tr>
<tr>
<td>16x</td>
<td>5x5</td>
<td>90</td>
<td>4</td>
<td>224.4</td>
<td>1.121</td>
<td>-0.25%</td>
</tr>
<tr>
<td>6x</td>
<td>5x5</td>
<td>90</td>
<td>22</td>
<td>103.3</td>
<td>0.515</td>
<td>1.72%</td>
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<tr>
<td>6xFFF</td>
<td>5x5</td>
<td>90</td>
<td>22</td>
<td>97.7</td>
<td>0.489</td>
<td>1.11%</td>
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<tr>
<td>10xFFF</td>
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<td>90</td>
<td>22</td>
<td>116.3</td>
<td>0.585</td>
<td>0.84%</td>
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<tr>
<td>16x</td>
<td>5x5</td>
<td>90</td>
<td>22</td>
<td>126.6</td>
<td>0.632</td>
<td>1.01%</td>
</tr>
</tbody>
</table>
Overall Experience

- MPPG 5.a is a do-able, well-organized approach to dose calculation validation
- Dose calculation algorithms in Pinnacle, Eclipse and Mobius3D are capable of meeting the tolerances specified in MPPG 5.a for both Elekta and Varian linacs
- Total time commitment is ~79 hours
  - 26 hours involve time on the machine and the reminder is preparation and analysis
  - Approximately half of the time involves preparing, measuring and analyzing IMRT and VMAT plans
Benefits of MPPG 5.a

1. The dataset needs to be measured once per machine, but the analysis can be repeated again and again on new dose calculation algorithms.

2. The wide variety of tests in MPPG 5.a can probe your model and finds real weaknesses.

3. The built-in end-to-end testing verifies the full clinical workflow.
Versatility of the Validation Dataset

- Medical University of South Carolina
  - Eclipse TPS commissioning for two TrueBeams
  - Mobius3D commissioning for two TrueBeams
  - Eclipse TPS upgrade
- Beloit Memorial Hospital
  - Pinnacle TPS upgrade
  - Mobius3D commissioning for Elekta Infinity
- University of Wisconsin Hospital
  - Pinnacle TPS commissioning for one TrueBeam
Versatility of the Validation Dataset

- The MPPG 5.a validation data will come to define your treatment unit:
  - Define the scope of future model validation, saving you the overhead of planning what to test
  - Serves as a benchmark for comparing different algorithms
  - A model that agrees well with this data is clinically acceptable
Finding Real Weaknesses

- Every model has its weak points:
  - Eclipse Acruos struggles with out-of-field dose, particularly at deeper depths

![Graph showing dose profiles and gamma values with a pass rate of 86.9%](image-url)
Finding Real Weaknesses

• Every model has its weak points:
  • Older versions of Mobius3D did not have a leaf-offset table
Finding Real Weaknesses

- Every model has its weak points:
  - Pinnacle’s "Electron 3D" model is difficult to tune over a full range of profile depths
Built-in End-to-end Testing

- Every step of the planning and delivery process is tested by MPPG 5.a
  - Simulation and image import
  - Beam generation and dose calculation
  - Export to OIS
  - Generation and measurement of QA plans
  - Image guidance and treatment
Difficulties with MPPG 5.a

- Difficulties encountered during MPPG 5.a
  - Deciding how difficult to make a test
  - Applying tolerances and evaluation criteria
  - Basic electron output check test is missing
  - Order of the testing is somewhat confusing
Difficulties with MPPG 5.a

- Deciding how difficult to make a test
Difficulties with MPPG 5.a

- Applying the tolerance criteria

<table>
<thead>
<tr>
<th>Region</th>
<th>Evaluation Method</th>
<th>Tolerance&lt;sup&gt;a&lt;/sup&gt; (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 changes&lt;sup&gt;b&lt;/sup&gt;</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>

<sup>a</sup> Tolerances are relative to local dose unless otherwise noted.

<sup>b</sup> For example, off-axis with physical wedge.
## Difficulties with MPPG 5.a

- Basic electron output check test is missing

### Pinnacle 9.8

<table>
<thead>
<tr>
<th>Energy</th>
<th>Ref. Depth</th>
<th>MU</th>
<th>Ref. Dose [cGy]</th>
<th>Gy (10 cm)</th>
<th>Dose/MU (REF)</th>
<th>% Diff.</th>
<th>Within 0.5%?</th>
<th>PDD10 (Eclipse)</th>
<th>PDD10 (Commissioning)</th>
<th>% Diff.</th>
<th>Within 0.5%?</th>
</tr>
</thead>
<tbody>
<tr>
<td>6x</td>
<td>1.4</td>
<td>500</td>
<td>4.99</td>
<td>3.312</td>
<td>0.998</td>
<td>-0.20%</td>
<td>Yes</td>
<td>66.2%</td>
<td>66.4%</td>
<td>-0.24%</td>
<td>Yes</td>
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<tr>
<td>6x FFF</td>
<td>1.3</td>
<td>500</td>
<td>5.012</td>
<td>3.163</td>
<td>1.002</td>
<td>0.24%</td>
<td>Yes</td>
<td>63.3%</td>
<td>63.5%</td>
<td>-0.38%</td>
<td>Yes</td>
</tr>
<tr>
<td>10x</td>
<td>2.3</td>
<td>500</td>
<td>5.01</td>
<td>3.668</td>
<td>1.002</td>
<td>0.20%</td>
<td>Yes</td>
<td>73.4%</td>
<td>73.5%</td>
<td>-0.19%</td>
<td>Yes</td>
</tr>
<tr>
<td>10x FFF</td>
<td>2.2</td>
<td>500</td>
<td>4.983</td>
<td>3.545</td>
<td>0.997</td>
<td>-0.34%</td>
<td>Yes</td>
<td>70.9%</td>
<td>71.1%</td>
<td>-0.28%</td>
<td>Yes</td>
</tr>
<tr>
<td>15x</td>
<td>2.7</td>
<td>500</td>
<td>4.999</td>
<td>3.831</td>
<td>1.000</td>
<td>-0.02%</td>
<td>Yes</td>
<td>76.6%</td>
<td>76.7%</td>
<td>-0.10%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Pinnacle v9.8

<table>
<thead>
<tr>
<th>Energy</th>
<th>MU</th>
<th>Nominal D_{max}</th>
<th>Dose at Nominal D_{max}</th>
<th>Dose at TPS D_{max}</th>
<th>Dose/MU</th>
<th>% Diff.</th>
<th>Within 0.5%?</th>
<th>% Diff.</th>
<th>Within 0.5%?</th>
</tr>
</thead>
<tbody>
<tr>
<td>6e</td>
<td>500</td>
<td>1.3</td>
<td>4.971</td>
<td>0.9942</td>
<td>-0.58%</td>
<td>No</td>
<td></td>
<td>1.4</td>
<td>5</td>
</tr>
<tr>
<td>9e</td>
<td>500</td>
<td>2.1</td>
<td>4.994</td>
<td>0.9988</td>
<td>-0.12%</td>
<td>Yes</td>
<td></td>
<td>2.2</td>
<td>5</td>
</tr>
<tr>
<td>12e</td>
<td>500</td>
<td>2.8</td>
<td>4.997</td>
<td>0.9994</td>
<td>-0.06%</td>
<td>Yes</td>
<td></td>
<td>2.9</td>
<td>5</td>
</tr>
<tr>
<td>15e</td>
<td>500</td>
<td>3.15</td>
<td>5</td>
<td>1</td>
<td>0.00%</td>
<td>Yes</td>
<td></td>
<td>3</td>
<td>5.004</td>
</tr>
</tbody>
</table>
Difficulties with MPPG 5.a

- Order of testing is somewhat confusing
Development of Organization and Analysis Tools for MPPG 5.a

- Automated Profile Comparison Tool
  - Overview
  - Measured Data
  - Dose Calculation Data
  - Analysis Options
  - Analysis Summary
- DICOM Renamer
- Organizational Spreadsheet
The Profile Comparison Tool

• The MPPG #5 Profile Comparison Tool (PCT) is a simple but powerful profile comparison tool designed to be used during the commissioning and QA of external beam treatment planning systems.

• The program accepts profile data from scanning water tank systems and DICOM-RT DOSE files from commercial treatment planning system, co-registers the data sets, and performs a 1D gamma analysis on the profiles.

• The user may specify a number of analysis and export settings.
Overview

Get Measured Dose File
Get Calculated Dose File

Measurement File: P06_Open_10x10_TB.ASC
Measurement Status: 5 inline, 5 crossline, 1 depth-dose, and 0 other profiles
DICOM-RT DOSE File: RTDOSE_6xAAA_2-25^3_10x10.dcm
DICOM Status: DICOM-RT DOSE is from Varian Medical Systems. Accompanying DICOM-RT PLAN was found. A POI called "ORIGIN" was not found in the DICOM-RT PLAN. Accompanying DICOM-RT STRUCT was not found. Offset entered manually by the user.

DICOM Offset: (0.000, -29.940, 0.000)

Depth-Dose Normalization Options:
- Normalize Depth Dose Profile To: $D_{\text{max}}$, Depth (Y)
- Depth (Y) = 10.0 cm

Profile Normalization Options:
- Normalize Inline and Crossline Profiles To: $D_{\text{max}}$, Position (X,Z)
- Crossline (X) = 0.0 cm
- Inline (Z) = 0.0 cm

Gamma Analysis Options:
- Dose Diff. (%): 2
- DTA (mm): 2
- Dose Analysis: Global

Output Options:
- Use Threshold?
- Create CSV File
- Create PDF

Run
Measured Data

- Accepts exported data from scanning software:
  - W2CAD (Eclipse TPS import)
  - OmniPro ASCII
- PCT automatically determines profile type
Dose Calculation Data

- Accepts exported DICOM-RT DOSE files from TPS
  - Available from all commercially available TPS
  - PCT automatically extracts the PDDs and profiles from 3D dose distribution
Co-registration of Datasets

- PCT can automatically co-register the measured and calculated data
Analysis Options

- Normalization options for PDD and profiles
- Gamma analysis options
  - Dose difference, DTA and global/local comparisons
Analysis Summary

- PDF of PDDs and profiles
- Summary Spreadsheet

<table>
<thead>
<tr>
<th>Measurement Filename</th>
<th>Calculated Filename</th>
<th>Axis</th>
<th>Depth</th>
<th>Max Gamma</th>
<th>Average Gamma</th>
<th>Std Dev Gamma</th>
<th>Passing Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPPG_5.5_10xFFF_CC04_PDD_Profile.s.ASC</td>
<td>RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm</td>
<td>Z</td>
<td>11.441059</td>
<td>0.080202</td>
<td>0.600987</td>
<td>99.225806</td>
<td></td>
</tr>
<tr>
<td>MPPG_5.5_10xFFF_CC04_PDD_Profile.s.ASC</td>
<td>RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm</td>
<td>X</td>
<td>2.2</td>
<td>0.722118</td>
<td>0.285596</td>
<td>0.142493</td>
<td>100</td>
</tr>
<tr>
<td>MPPG_5.5_10xFFF_CC04_PDD_Profile.s.ASC</td>
<td>RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm</td>
<td>X</td>
<td>10</td>
<td>0.654576</td>
<td>0.22734</td>
<td>0.123505</td>
<td>100</td>
</tr>
<tr>
<td>MPPG_5.5_10xFFF_CC04_PDD_Profile.s.ASC</td>
<td>RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm</td>
<td>X</td>
<td>30</td>
<td>0.824168</td>
<td>0.201455</td>
<td>0.150919</td>
<td>100</td>
</tr>
<tr>
<td>MPPG_5.5_10xFFF_CC04_PDD_Profile.s.ASC</td>
<td>RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm</td>
<td>Y</td>
<td>10</td>
<td>0.64197</td>
<td>0.229955</td>
<td>0.118242</td>
<td>100</td>
</tr>
</tbody>
</table>
Analysis Summary
DICOM-RT File Renaming Tool

- Automatically identifies and renames DICOM-RT plan, dose and structure set files that are from the same plan
### Organizational Spreadsheet

#### Test Info:
- **Description:** Large MVC shaped field with extensive blocking (e.g., mantle)
- **Comments:** The field shape for this test is shown to the right.

#### Test Parameters:
- **CT:** MPPG vs. MU
- **CT Setting:** 2 mm dose grid, all beams have 500 MU
- **Equal:** 90 cm

#### Crosshair Profile Depths:
- 3 cm, 20 cm, 25 cm
- 30 cm

#### Point Dose Results:

<table>
<thead>
<tr>
<th>Plan Name</th>
<th>Field Name</th>
<th>Dose Rate</th>
<th>Description</th>
<th>T</th>
<th>P</th>
<th>M</th>
<th>N(D0)</th>
<th>Ref. Dose</th>
<th>Calc Dose</th>
<th>Ref. Dose</th>
<th>% Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>S TBI 60</td>
<td>Gx, 10x0</td>
<td>600 Series Dr</td>
<td>6x 0x10 Standard</td>
<td>20.0</td>
<td>767</td>
<td>1.866</td>
<td>0.073</td>
<td>1.000</td>
<td>302.16</td>
<td>1.000</td>
<td>0.00%</td>
</tr>
<tr>
<td>S TBI 60</td>
<td>Gx, 10x0</td>
<td>600 Series Dr</td>
<td>6x 10x0 Standard</td>
<td>20.0</td>
<td>767</td>
<td>1.866</td>
<td>0.073</td>
<td>1.000</td>
<td>302.16</td>
<td>1.000</td>
<td>0.00%</td>
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<td>Gx, 10x0</td>
<td>600 Series Dr</td>
<td>6x 10x0 Standard</td>
<td>20.0</td>
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<td>1.000</td>
<td>0.00%</td>
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<tr>
<td>S TBI 60</td>
<td>Gx, 10x0</td>
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<td>1.000</td>
<td>302.16</td>
<td>1.000</td>
<td>0.00%</td>
</tr>
<tr>
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<td>Gx, 10x0</td>
<td>600 Series Dr</td>
<td>6x 10x0 Standard</td>
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<td>600 Series Dr</td>
<td>6x 10x0 Standard</td>
<td>20.0</td>
<td>767</td>
<td>1.866</td>
<td>0.073</td>
<td>1.000</td>
<td>302.16</td>
<td>1.000</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

#### Crosshair Profile Depths:
- 3 cm, 20 cm, 25 cm
- 30 cm

#### Crosshair Profile Passthrough:
- **CT:** MPPG vs. MVC
- **CT Setting:** 2 mm dose grid, all beams have 500 MU
- **Equal:** 90 cm

#### Comments:
- Filling points in 1x4 shallow profile are under the MVC leaves in the middle of the field. MVC undercuts make the dose under the leaves.

<table>
<thead>
<tr>
<th>Profile Passthrough</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gx, 10x0</td>
</tr>
</tbody>
</table>
Availability of Tools to the Physics Community

GitHub (most up-to-date)

• [https://github.com/Open-Source-Medical-Devices/MPPG](https://github.com/Open-Source-Medical-Devices/MPPG)

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Questions?

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