WISCONSIN

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

Dustin Jacqmin, PhD
Assistant Professor, Human Oncology
University of Wisconsin Madison

WISCONSIN

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

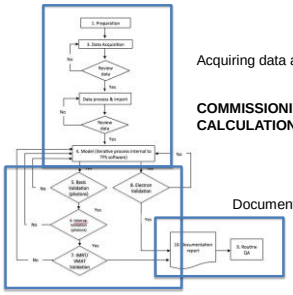
A Quick Show of Hands

- 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 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…

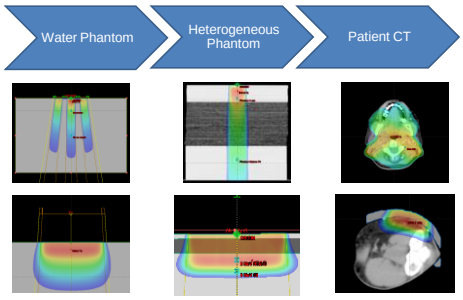
Now what?

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

WISCONSIN

MPPG 5.a Validation: Big Picture



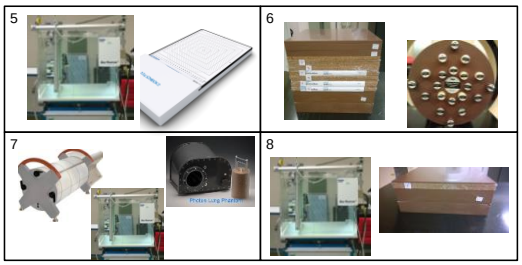
WISCONSIN

What tools do I need?

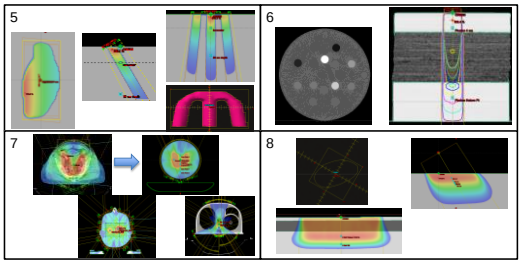
MPPG 5.a Section	*Test Number*	*Test Description*	*Measurement Equipment*	
5. Photon Beams: Basic Dose Algorithm Validation	5.1	Physics module versus planning module	None	TPS Only
	5.2	Clinical calibration geometry dose	Scanning water tank; Farmer-type ionization chambers	
	5.3	Planning module dose versus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

WISCONSIN

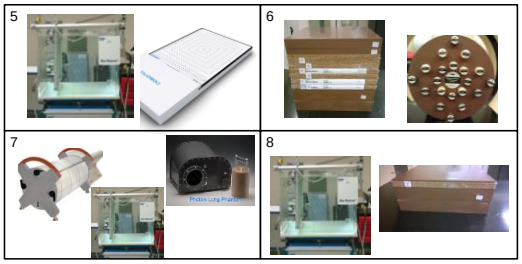
1. Gathering the Phantoms



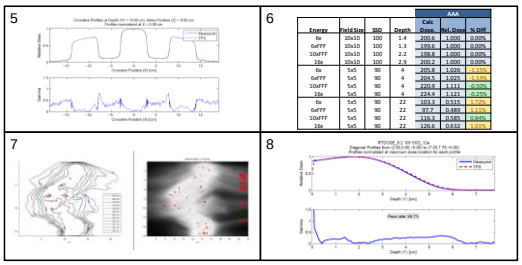
2. Calculating Treatment Plans



3. Making Measurements



4. Comparing Measured and Calculated Dose



				AAA		
Energy	Field Size	SSD	Depth	Calc Dose	Rel. Dose	% Diff
6x	10x10	100	1.4	200.6	1.000	0.00%
6xFFF	10x10	100	1.3	199.6	1.000	0.00%
10xFFF	10x10	100	2.2	198.8	1.000	0.00%
10x	10x10	100	2.9	200.2	1.000	0.00%
6x	5x5	90	4	205.8	1.026	-2.59%
6xFFF	5x5	90	4	204.5	1.025	-2.54%
10xFFF	5x5	90	4	220.9	1.111	-9.58%
10x	5x5	90	4	224.4	1.121	-12.25%
6x	5x5	90	22	101.3	0.515	1.72%
6xFFF	5x5	90	22	97.7	0.489	1.15%
10xFFF	5x5	90	22	116.3	0.585	0.84%
10x	5x5	90	22	126.6	0.632	1.04%

5. Is my model good enough yet?

MPPG 5.a proposes a set of **minimum tolerances** and **evaluation criteria** for each test

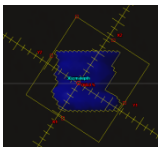
- Minimum Tolerances
  - Widely accepted tolerances based on published guidelines, IROC dosimetry audits, and other published results
  - Considered a minimum standard, not a recommended stopping point for model improvement
- Evaluation Criteria
  - Given where no widely accepted tolerances are available
  - Designed to emphasize areas of disagreement and highlight opportunities for further investigation and improvement

5. Is my model good enough yet?

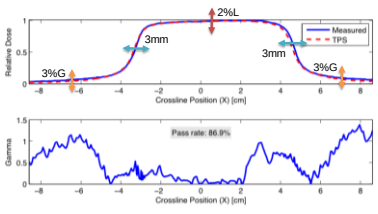
5 **Minimum Tolerances** Reference calibration geometry (0.5%) High dose (2% local) Penumbra (3 mm) Low-dose tail (3% global)	6 **Minimum Tolerances** Dose above and below heterogeneity in regions of CPE (3% local on CAX)
7 **Minimum Tolerances & Evaluation Criteria** Ion chamber in low-gradient target (2% of Rx) Ion chamber in OAR region (3% of Rx) Film or array-based IMRT/VMAT QA (2%/2mm) End-to-end test (5%)	8 **Minimum Tolerances** High-dose/low-gradient regions in water (3%) PDDs in water (3%/3mm) Oblique incidence in water (5% on CAX) Heterogeneity correction (7% on CAX)

Application of Minimum Tolerances

High dose (2% local)
Penumbra (3 mm)
Low-dose tail (3% global)

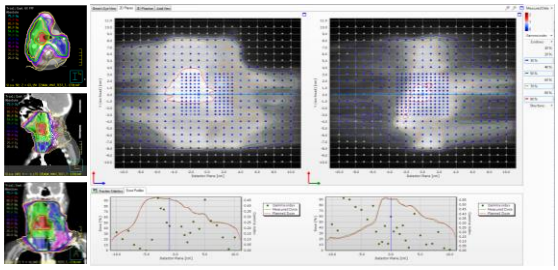


MPPG Test 5.7



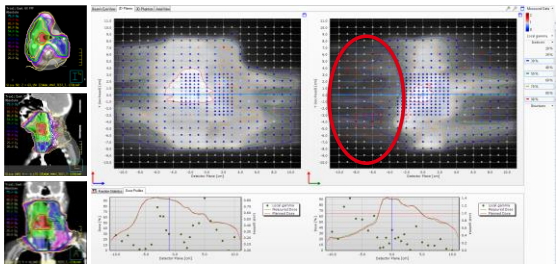
Application of Evaluation Criteria

MPPG Test 7.4: 3%G/3mm



Application of Evaluation Criteria

MPPG Test 7.4: 2%L/2mm



Why Recommend 2%/2mm?

- A stricter evaluation criteria can:
  - Identify easily correctable modeling errors
  - Highlight weaknesses in a dose calculation algorithm
  - Are more sensitive to changes in beam model parameters

Radiation therapy physics

Evaluating IMRT and VMAT dose accuracy: Practical examples of failure to detect systematic errors when applying a commonly used metric and action levels

Benjamin E. Nelms, Maria F. Chan, Geneviève Jarry, Matthieu Lemire, John Lowden, Carnell Hampton, Vladimir Feygelman

First published: 25 October 2013

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 remainder 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

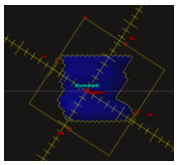
- Medical University of South Carolina
  - Eclipse TPS commissioning for two TrueBeams
  - Mobius3D commissioning for two TrueBeams
  - Eclipse TPS upgrade
- Beloit Memorial Hospital
  - Pinnacle TPS upgrade
  - Mobius3D commissioning for Elekta Infinity
- University of Wisconsin Hospital
  - Pinnacle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

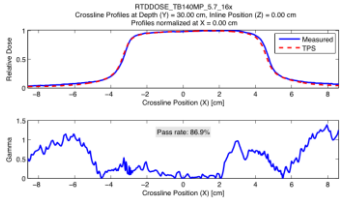
Versatility of the Validation Dataset

- 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

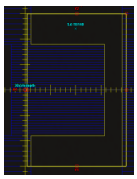
- Every model has its weak points:
  - Eclipse Acruos struggles with out-of-field dose, particularly at deeper depths

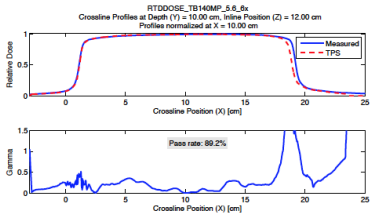




Finding Real Weaknesses

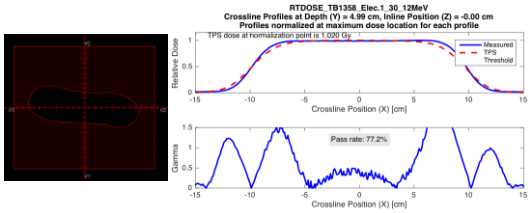
- Every model has its weak points:
  - Older versions of Mobius3D did not have a leaf-offset table





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



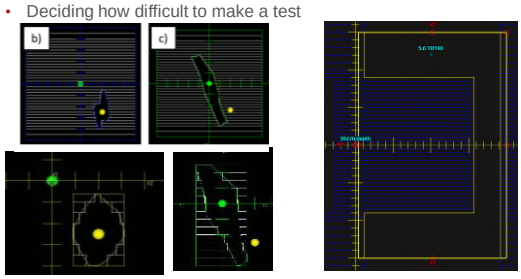
Difficulties with MPPG 5.a

- 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

WISCONSIN

Difficulties with MPPG 5.a

- Deciding how difficult to make a test



WISCONSIN

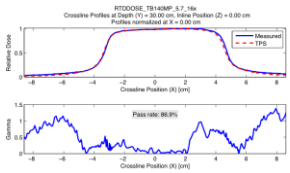
Difficulties with MPPG 5.a

- Applying the tolerance criteria

TABLE 3. Basic TPS photon beam evaluation methods and tolerances.

Region	Evaluation Method	Tolerance[a] (consistent with IROC Houston)
High dose	Relative dose with one parameter change from reference conditions	2%
	Relative dose with multiple parameter changes[b]	5%
Penumbra	Distance to agreement	3 mm
Low-dose tail	Up to 5 cm from field edge	3% of maximum field dose

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



WISCONSIN

Difficulties with MPPG 5.a

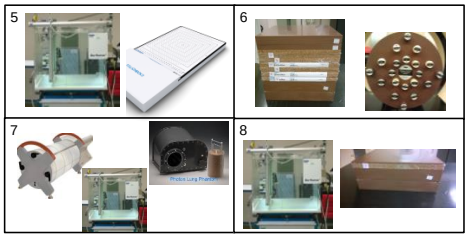
- Basic electron output check test is missing

		Pinnacle 9.8									
		TPS Data			Dose/MU at Dmax			Percent Depth Dose at Reference Depth			
Energy	Ref. Depth	MU	Ref. Dose [cGy]	Gy [10 cm]	Dose/MU (REF)	% Diff.	Within 0.5%?	PDD10 (Scalar)	PDD10 (Commissioning)	% Diff.	Within 0.5%?
6e	1.6	500	4.99	3.312	0.998	-0.20%	Yes	66.2%	66.4%	-0.24%	Yes
6x FFF	1.3	500	5.012	3.163	1.002	0.24%	Yes	63.3%	63.5%	-0.38%	Yes
10x	2.1	500	5.01	3.668	1.002	0.20%	Yes	73.4%	73.5%	-0.19%	Yes
10x FFF	2.2	500	4.983	3.545	0.997	-0.34%	Yes	70.9%	71.1%	-0.28%	Yes
15e	2.7	500	4.999	3.831	1.000	-0.02%	Yes	76.6%	76.7%	-0.15%	Yes

Pinnacle v9.8										
		Dose at Nominal D_{max}					Dose at TPS D_{max}			
Energy	MU	Nominal D_{max}	Dose $D_{max,nom}$	Dose/MU	% Diff.	Within 0.5%?	TPS D_{max}	Dose $D_{max,TPS}$	Dose/MU	% Diff.	Within 0.5%?
6e	500	1.3	4.973	0.9942	-0.58%	No	1.4	5	1	0.00%	Yes
9e	500	2.1	4.994	0.9988	-0.12%	Yes	2.2	5	1	0.00%	Yes
12e	500	2.8	4.987	0.9974	-0.26%	Yes	2.9	5	1	0.00%	Yes
15e	500	3.15	5	1	0.00%	Yes	3	5.004	1.0008	0.08%	Yes

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

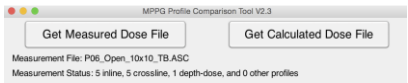
The Profile Comparison Tool

- 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

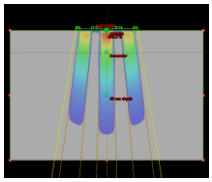
Measured Data

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



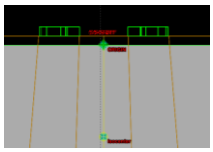
Dose Calculation Data

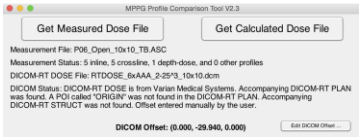
- Accepts exported DICOM-RT DOSE files from TPS
  - Available from all commercially available TPS
  - PCT automatically extracts the PDDs and profiles from 3D dose distribution



Co-registration of Datasets

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





Analysis Options

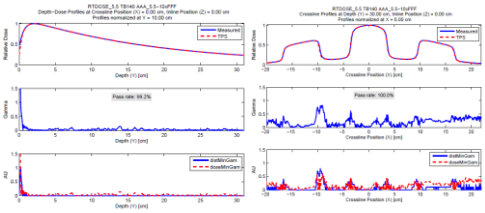
- Normalization options for PDD and profiles
- Gamma analysis options
  - Dose difference, DTA and global/local comparisons

Analysis Summary

- PDF of PDDs and profiles
- Summary Spreadsheet

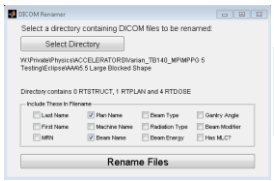
Measurement Filename	Calculated Filename	Axis	Depth	Max Gamma	Average Gamma	Std Dev Gamma	Passing Rate (%)
MPPG_5.5_10xFFF_CC04_PDD_Profile s.ASC	RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm	Z		11.441059	0.080202	0.600987	99.225806
MPPG_5.5_10xFFF_CC04_PDD_Profile s.ASC	RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm	X	2.2	0.722118	0.285596	0.142493	100
MPPG_5.5_10xFFF_CC04_PDD_Profile s.ASC	RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm	X	10	0.654576	0.22734	0.123505	100
MPPG_5.5_10xFFF_CC04_PDD_Profile s.ASC	RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm	X	30	0.824168	0.201455	0.150919	100
MPPG_5.5_10xFFF_CC04_PDD_Profile s.ASC	RTDOSE_5.5 TB140 AAA_5.5-10xFFF.dcm	Y	10	0.64197	0.229955	0.118242	100

Analysis Summary

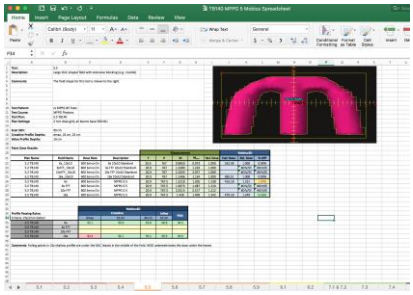


DICOM-RT File Renaming Tool

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



Organizational Spreadsheet



WISCONSIN

Availability of Tools to the Physics Community

GitHub (most up-to-date)

- https://github.com/Open-Source-Medical-Devices/MPPG

Dustin Jacqmin

- jacqmin@humonc.wisc.edu

WISCONSIN

Questions?

Dustin Jacqmin

- jacqmin@humonc.wisc.edu