MERCY HEALTH
LACKS CANCER CENTER

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

ALAN MAYVILLE, M.S.
MERCY HEALTH, SAINT MARY'S
GRAND RAPIDS, MI

A Member of Trinity Health

7/23/18

MERCY HEALTH
LACKS CANCER CENTER

Disclosures

- I have no disclosures, financial or otherwise

MERCY HEALTH
LACKS CANCER CENTER

Outline

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

MERCY HEALTH
LACKS CANCER CENTER

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

MERCY HEALTH
LACKS CANCER CENTER

MPPG 5.a – Outside the Scope

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

7/23/18 5

MERCY HEALTH
LACKS CANCER CENTER

Outline

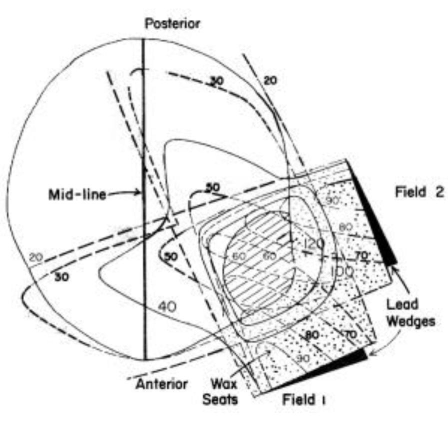
- Scope of MPPG 5.a
- Summary of MPPG 5.a
  - –Motivation
  - –Highlights
  - –Clinical implementation

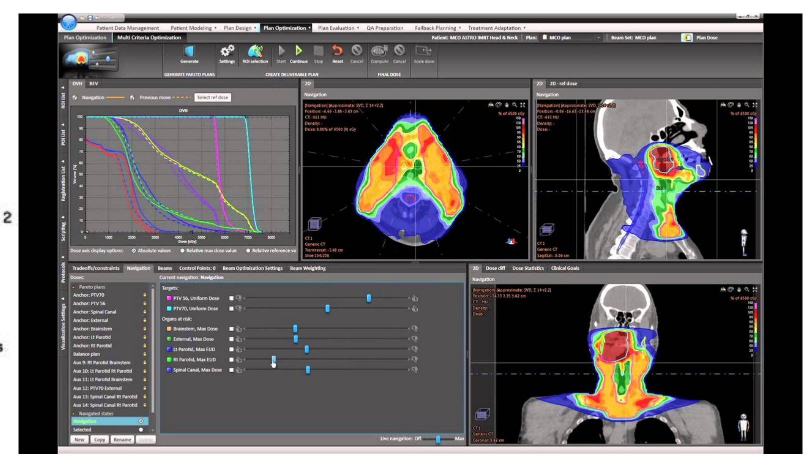
7/23/18 6

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

Motivation





MERCY HEALTH
LACKS CANCER CENTER

Outline

- Scope of MPPG 5.a
- Summary of MPPG 5.a
  - Motivation
  - Highlights
  - Clinical implementation
  - Successes and suggestions

7/23/18 9

MERCY HEALTH
LACKS CANCER CENTER

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

7/23/18 10

MERCY HEALTH
LACKS CANCER CENTER

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

TABLE 1. Detectors suitable for TPS commissioning and validation of photon and electron beams.

Detector	Use	Comments	Reference
Scanning ion chambers	Beam scanning for photons and electrons	Typical scanning chambers have an air cavity of 4–6 mm diameter, (minimum of 2 chambers for measurement and reference)	TG-106 (Das et al.[5])
Electron diodes and film	Beam scanning for electrons, output factors (film)	QMP must confirm the effective point of measurement	TG-25 (Khan et al.[45]), TG-70 (Gerbi et al.[46])
Small field detectors	• Small field scanning & output factors[a], • IMRT/VMAT point measurement • MLC intraleaf measurement & penumbra	Carefully select the detector type and size to fit the application. When scanning for penumbra, diodes are recommended.	TG-106 (Das et al.[5]), TG-120 (Low et al.[18]) Yunice, et al.[16]
Large ion chamber	Aggregate MLC transmission factors	Interleaf transmission	LoSasso et al.[20]
Film and/or array detector	2D dose distributions, including dynamic/virtual wedge and planar fluence maps, intraleaf measurements[b]	• Absolute dosimetry preferred; relative dosimetry adequate. • Desirable if the device can be mounted on the gantry and/or in a phantom at different geometries	TG-106 (Das et al.[5]), TG-120 (Low et al.[18]), IAEA TRS-430[7]

[a] If a diode detector is used for small field measurements, a "daisy chain" approach is recommended to minimize the energy dependence effects; the diode is first cross-compared with an ion chamber for a 4×4cm^2 field and then is used to measure the smaller fields.
[b] Using film for intraleaf transmission is usually less precise than interleaf transmission.

TABLE 2. Equipment required for TPS commissioning of photon and electron beams.

Equipment	Use	Comments	Reference
3D water phantom	Beam scanning	Must have sufficient scanning range and lateral/depth scatter	TG-106 (Das et al.[5]), TG-70 (Gerbi et al.[46])
Electrometers and cables	Beam scanning, output calibration, relative and absolute dosimetry	ADCL calibration, low noise and leakage with wide dynamic range and linear response	TG-106 (Das et al.[5])
Buildup cap or miniphantom	In-air output factor measurement	Measurements required for some planning systems, most second check systems	Yunice, et al.[16]
Water-equivalent phantom material in slab form	Buildup and backscatter for measurements	> 20 cm of total thickness in varying increments, width and length ≥ 30 cm, cavity for detector(s)	TG-106 (Das et al.[5]), TG-120 (Low et al.[18]), IAEA TRS-430[7]
CT density phantom	CT number to electron or mass density calibration	Should include tissue-equivalent materials spanning the clinical range of low-density lung to high-density bone.	TG-66 (Mutic et al.[13])
Heterogeneity phantom with lung-equivalent material	End-to-end testing	Include cavities for detectors, useful for annual QA reference test	TG-65 (Papanikolaou & Stathakis[26]), IAEA TRS-430[7]
Anthropomorphic phantom	Anatomic model testing, end-to-end testing, use testing	Include cavities for detectors	IAEA TRS-430[7]
Software for data processing	Processing, comparing, and analyzing profiles, depth-dose curves, and other beam data	May be included with the 3D water tank scanning software	TG-106 (Das et al.[5])
IMRT/VMAT or arc therapy phantom	VMAT or arc therapy	Options include a solid phantom holding a planar array, 3D detector arrays, film inside a phantom, other	TG-120 (Low et al.[18])

MERCY HEALTH
LACKS CANCER CENTER

Equipment

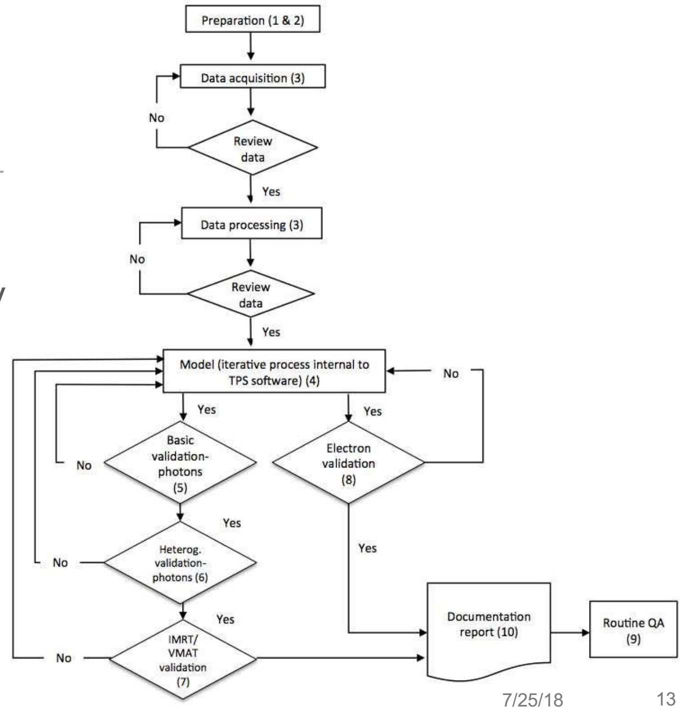
- QMP decides on appropriate equipment
  - Data collection
  - Data processing and analysis
  - Model verification and end-to-end testing
- QMP must also determine appropriate tolerance criteria
  - MPPG 5.a lists established minimum criteria for basic photon agreement, simple heterogeneity and basic electron beam validation

MERCY HEALTH
LACKS CANCER CENTER

Workflow

- Iterative process
  - Compromises in accuracy considering clinical scenarios

- Logical workflow



MERCY HEALTH
LACKS CANCER CENTER

Outline

- Scope of MPPG 5.a
- Summary of MPPG 5.a
  - Motivation
  - Highlights
  - Clinical implementation

MERCY HEALTH
LACKS CANCER CENTER

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)

MERCY HEALTH
LACKS CANCER CENTER

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

MERCY HEALTH
LACKS CANCER CENTER

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?

7/25/18 17

MERCY HEALTH
LACKS CANCER CENTER

Validation Tests

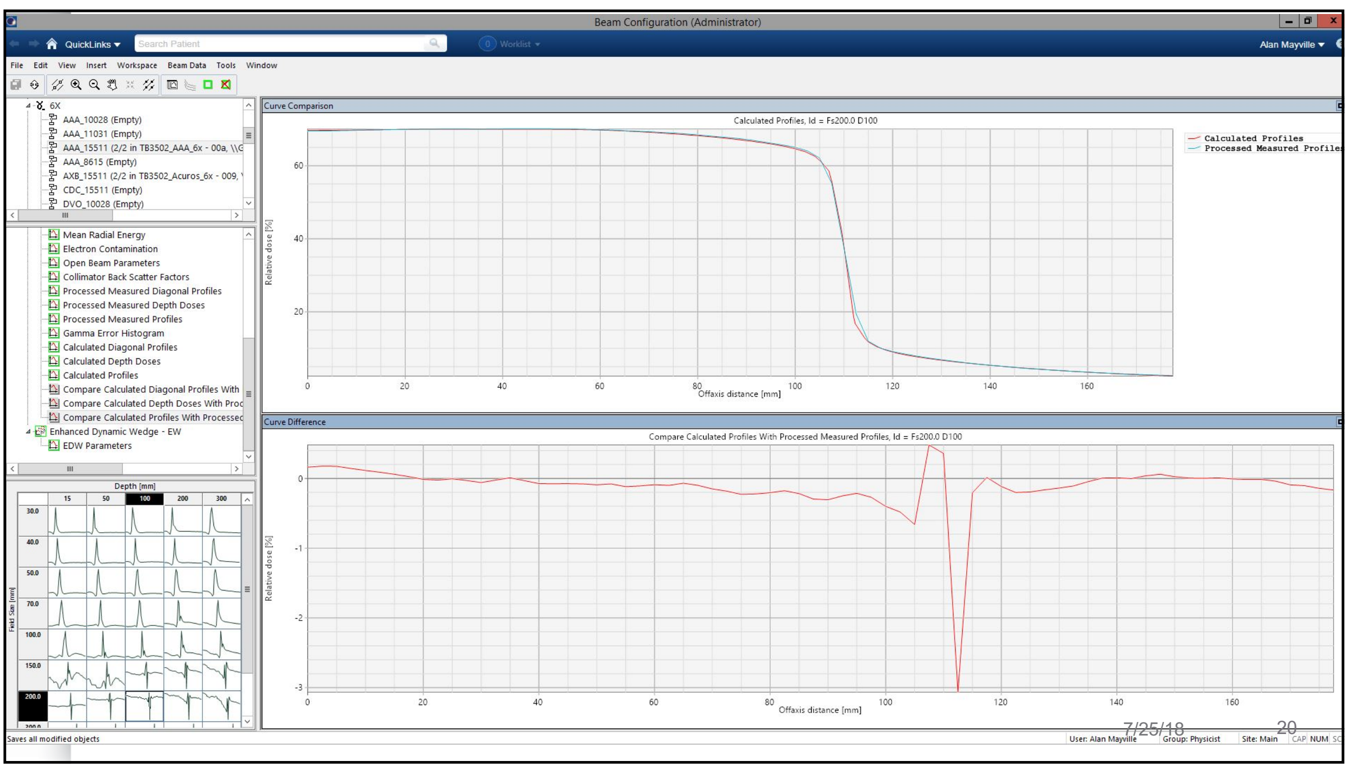
TABLE 3. TPS model comparison tests and tolerances.

Test	*Comparison*	*Description*	*Tolerance*
5.1	Dose distributions in planning module vs. modeling (physics) module	Comparison of dose distribution for large (> $30\times30 cm^2$) field.	Identical[a]
5.2	Dose in test plan vs. clinical calibration condition[b]	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.

7/23/18 18

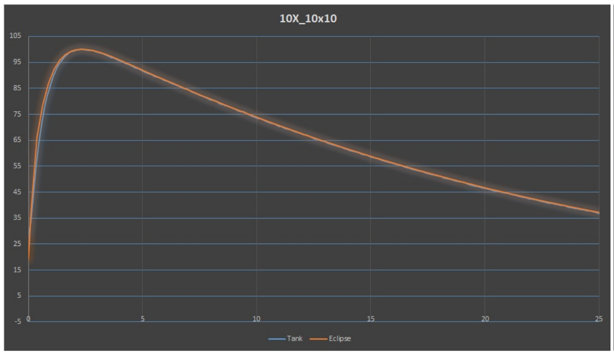
7/25/18 19

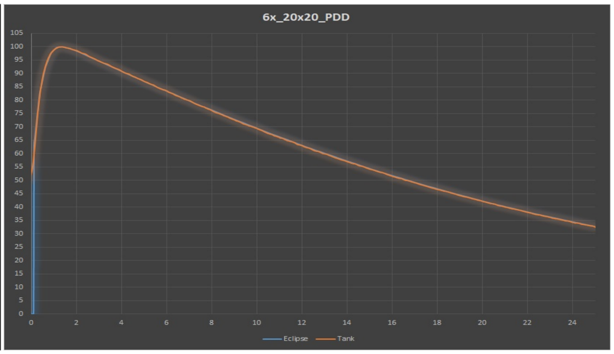


7/25/18 20

MERCY HEALTH
LACKS CANCER CENTER

Basic Photon Validation

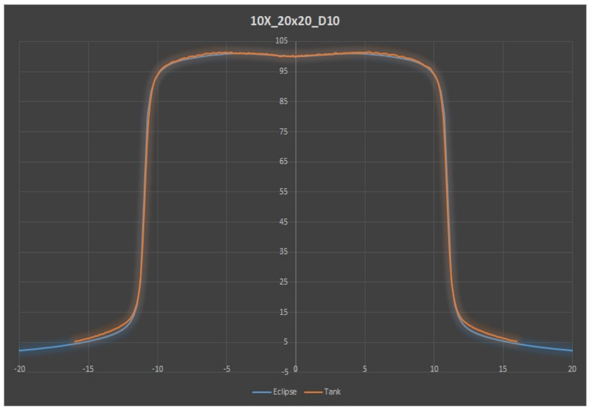


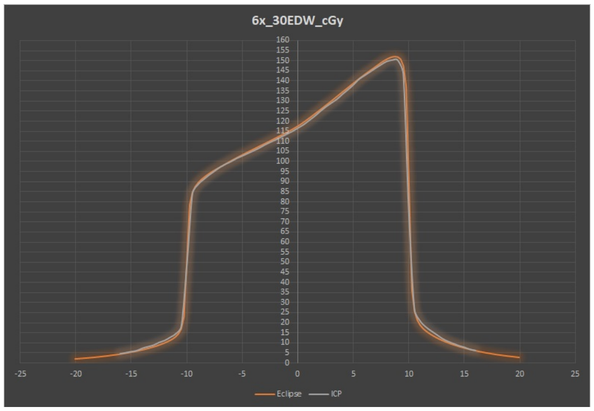


7/23/18 21

MERCY HEALTH
LACKS CANCER CENTER

Basic Photon Validation





7/23/18 22

MERCY HEALTH
LACKS CANCER CENTER

Clinical Photon Validation Tests

TABLE 4. Basic photon beam validation tests summary[a].

Test	*Description*	*Sample tests from literature*[7]
5.4	Small MLC-shaped field (non SRS)	Photon Test 1
5.5	Large MLC-shaped field with extensive blocking (e.g., mantle)	Photon Test 3
5.6	Off-axis MLC shaped field, with maximum allowed leaf over travel	Photon Test 2
5.7	Asymmetric field at minimal anticipated SSD	Photon Test 6
5.8	10×10 cm^2 field at oblique incidence (at least 20°)	Photon Test 10
5.9	Large (> 15 cm) field for each nonphysical wedge angle[b]	–

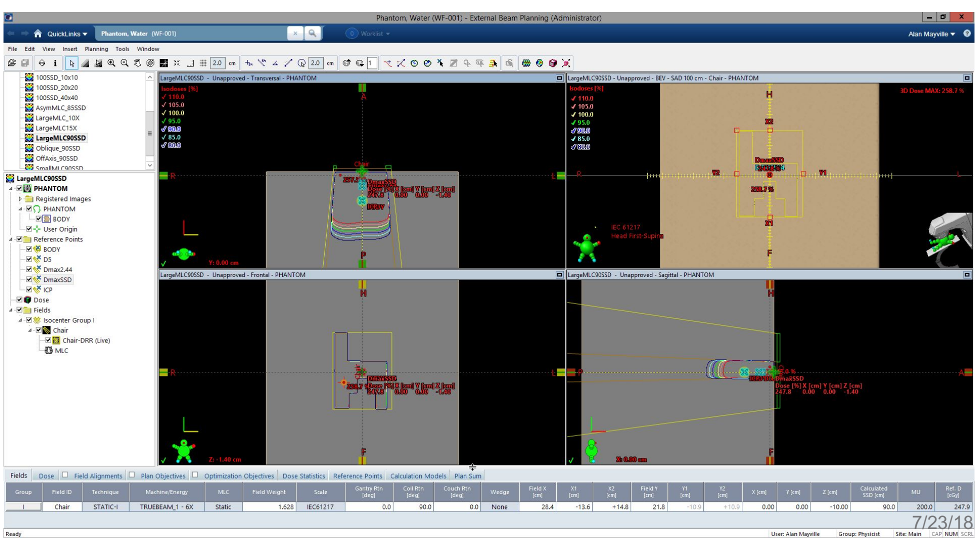
[a] For all tests, measurements in the high-dose region, penumbra, and low-dose tail regions should be compared to calculated values at various depths (including slightly beyond dmax, midrange/10–15 cm, and deep/25–30 cm). SSDs, other than those used at commissioning and that reflect the clinically expected 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.

[7] *Sample tests from literature:* IAEA TRS Report 430

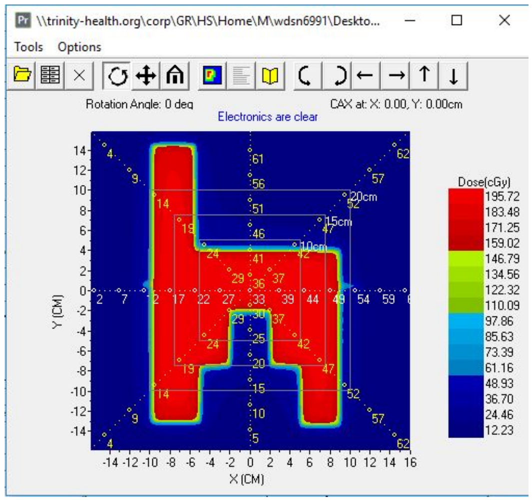
MERCY HEALTH
LACKS CANCER CENTER

Validation Test 5.5



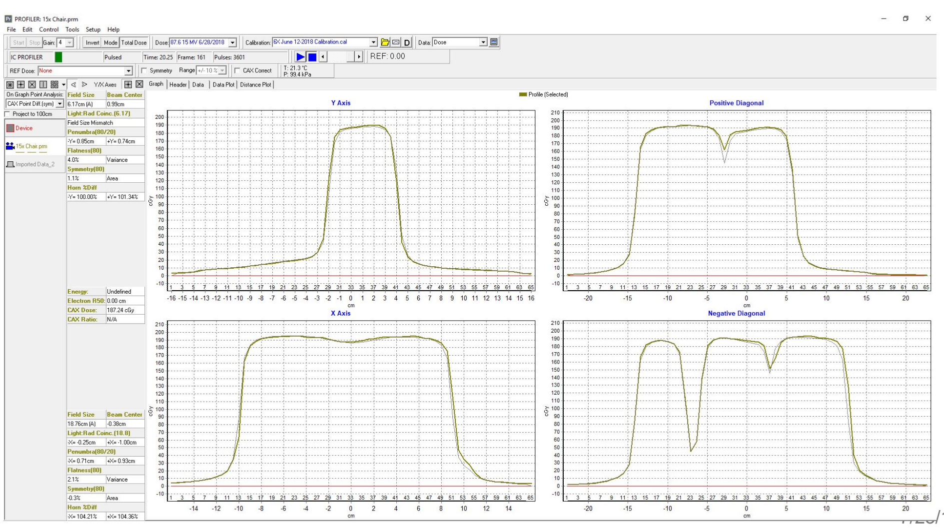
MERCY HEALTH
LACKS CANCER CENTER

Extracted Dose Plane



MERCY HEALTH
LACKS CANCER CENTER

IC Profiler Comparison



MERCY HEALTH
LACKS CANCER CENTER

Validation Methods and Tolerances

TABLE 5. 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.

MERCY HEALTH
LACKS CANCER CENTER

Heterogeneous Validation Tests

TABLE 6. Heterogeneous TPS photon beam validation tests.

Test	*Objective*	*Description*	*Tolerances*[a]	*Reference*
6.1	Validate planning system reported electron (or mass) densities against known values	CT-density calibration for air, lung, water, dense bone, and possibly additional tissue types	–	TG 65,[26] IAEA TRS-430[7]
6.2	Heterogeneity correction distal to lung tissue	5×5 cm^2, measure and calculate dose ratio above and below heterogeneity, outside of the buildup region	3%	IAEA TRS-430,[7] Carrasco et al.[28]

[a] Tolerances are relative to local dose unless otherwise noted.

MERCY HEALTH
LACKS CANCER CENTER

VMAT/IMRT Validation Tests

TABLE 7. VMAT/IMRT test summary.

Test	Objective	Description (example)	Detector	Ref
7.1	Verify small field PDD	≤ 2×2 cm^2 MLC shaped field, with PDD acquired at a clinically relevant SSD	Diode or plastic scintillator	Yunice et al.[16]
7.2	Verify output for small MLC-defined fields	Use small square and rectangular MLC-defined segments, measuring output at a clinically relevant depth for each[a]	Diode, plastic scintillator, minichamber or microion chamber	Cadman et al.[58]
7.3	TG-119 tests	Plan, measure, and compare planning and QA results to the TG119 report for both the Head and Neck and C-shape cases	Ion chamber, film and/or array	TG-119 (Ezzell et al.[37])
7.4	Clinical tests	Choose at least 2 relevant clinical cases; plan, measure, and perform an in-depth analysis of the results	Ion chamber, film and/or array	Nelms et al.[42]
7.5	External review	Simulate, plan, and treat an anthropomorphic phantom with embedded dosimeters.	Various options exist[b]	Kry et al.[39]

[a] A bar pattern scanned with a diode can be used to obtain additional absolute dose profile comparison in the direction perpendicular to MLC movement
[b] If IROC Houston service is used, they typically employ TLDs and radiochromic film. Certain commercial phantoms can accommodate ion chambers for point dose measurements

MERCY HEALTH
LACKS CANCER CENTER

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

MERCY HEALTH
LACKS CANCER CENTER

Thank you!

7/23/18 31