ALGORITHMS- QA & COMMISSIONING

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Disclosure: None

EDUCATIONAL OBJECTIVES

To review the minimum requirements for TPS dose algorithm commissioning & QA.

To review the important issues for consideration during data acquisition, beam modelling, and validation tests.

MANY KEY DOCUMENTS AND RESOURCES

Just list a few:

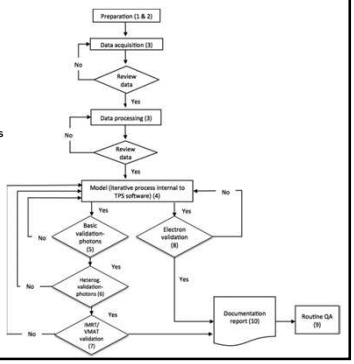
- TG53: TPS acceptance, commission and on-going QA.
- TG106: beam data commissioning equipment and procedures.
- IAEA technical report #430: commissioning and QA of TPS.
- TG65: tissue inhomogeneity corrections
- TG119: guidance document on IMRT
- MPPG5A: commissioning and QA of treatment planning dose calculations
- And many many more…

AAPM MEDICAL PHYSICS PRACTICE GUIDELINE 5.A.: COMMISSIONING AND QA OF TREATMENT PLANNING DOSE CALCULATIONS

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 16, NUMBER 5, 2015

AAPM Medical Physics Practice Guideline 5.a.: Commissioning and QA of Treatment Planning Dose Calculations — Megavoltage Photon and Electron Beams

Medical Physics Practice Guideline: Jennifer B. Smilowitz, Chair, Indra J. Das, Vladimir Feygelman, Benedick A. Fraass, Stephen F. Kry, Ingrid R. Marshall, Dimitris N. Mihailidis, Zoubir Ouhib, Timothy Ritter, Michael G. Snyder, Lynne Fairobent, AAPM Staff



TIME REQUIRED FOR COMMISSIONING

Assuming 12–16 QMP work hours per day (1.5 to 2.0 FTEs), reasonable time estimates are

- two to four weeks for a single energy photon beam
- six to eight weeks for two photon energies and five electron energies.
- Addition of a second algorithm for a given beam will increase commissioning time and effort.

This will depend strongly on how much commissioning data need to be collected and the availability and experience of the QMP(s) involved, the adequacy and availability of the equipment used, and the access to the accelerator

Ref: MPPG5A

DATA ACQUISITION

Follow the recommendations from the TPS vendor for the required dataset.

- Depth dose curves on the central axis
- Profiles (X and/or Y, and/or diagonal)
- Output factors
- Absolute dose calibration point for reference field size
- MLC characteristics

Accurate measurement is the requirement for accurate modelling

PDDs and Profiles open fields — Beam quality _____ [MV]

Field size (cm x cm)	File name	X profile at depths:	Y profile at depths:	Output factor
1 x 1				
2 x 2 *				
3 x 3 *				
4 x 4				
5 x 5 *				
5 x 20 *				
6 x 6				
7 x 7				
8 x 8				
9 x 9				
10 x 10 *				
12 x 12				
15 x 15 *				
20 x 5 *				
20 x 20 *				
25 x 25				
30 x 30 *				
35 x 35				
40 x 40 *				

RayStation TPS

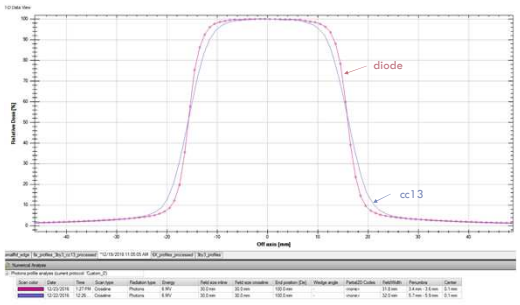
IDENTIFY THE REQUIRED EQUIPMENT

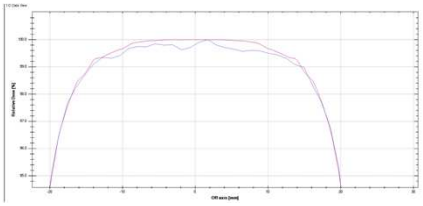
MPPG5A

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.[37])
Electron diodes and film	Beam scanning for electrons, output factors (film)	QMP must confirm the effective point of measurement	TG-25 (Khan et al.[103]), TG-70 (Gerbi et al.[40])
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.[37]), TG-120 (Low et al.[105]) Yunice, et al.[34]
Large ion chamber	Aggregate MLC transmission factors	Interleaf transmission	LoSasso et al.[39]
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.[37]), TG-120 (Low et al.[105]), IAEA TRS-430[17]

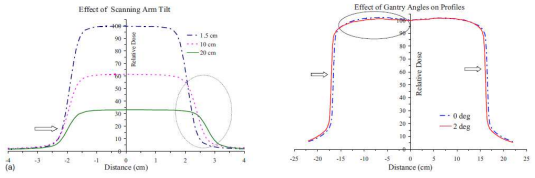
[a] If a diode detector is used for small field measurements, a "daisy chain" approach is recommended to minimize the energy dependence effects; the diode is first cross-compared with an ion chamber for a 4×4cm² field and then is used to measure the smaller fields.
[b] Using film for intraleaf transmission is usually less precise than interleaf transmission.





Scanning speed

The water tank, scanning system, detector mount need to be carefully checked for leveling and alignment.



Ref: Das et al.: TG-106: Accelerator beam data commissioning

CONSIDERATIONS FOR FFF BEAMS

A change in beam profile shape

An increase in dose rate

A reduced scatter

A softer beam energy spectrum (Varian) due to reduction in beam hardening.

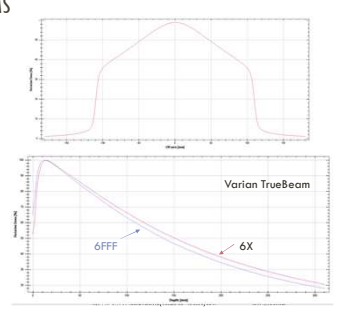


Table 1. Beam characteristics for 6 and 10 MV FFF and cFF beams from Varian and Elekta. See Xiao *et al* (2015) for Siemens data.

		Nominal energy (MV)	Filtration	Effective energy (MV)[a]	d_{max} (cm)	D_{10} (%)	$TPR_{20/10}$	Max dose rate (MU min^{-1})	Dose (mGy) per pulse[b]
Varian	FFF	6	0.8 mm	4	1.3	64.2	0.630	1400	0.8
		10	Brass plate	8	2.2	71.7	0.705	2400	1.3
	cFF	6	6/10 MV	6	1.4	66.4	0.666	600	0.3
		10	flattening filter	10	2.3	73.6	0.738	600	0.3
Elekta	FFF	6	2.0 mm stainless	6	1.7	67.5	0.684	1400	0.6
		10	steel plate	10	2.4	73.0	0.734	2200	0.9
	cFF	6	6/10 MV	6	1.5	67.5	0.678	600	0.2
		10	flattening filter	10	2.1	73.0	0.721	600	0.4

[a] Clinical effective energy, based on $TPR_{20/10}$ and percentage depth dose falloff.
[b] Measured at d_{max} on beam central axis for standard reference conditions.
Note: D_{max} refers to depth of maximum dose. MU are monitor units.

Ref: G Budgell et al. IPEM topical report 1: guidance on implementing flattening filter free (FFF) radiotherapy. PMB. **61** (2016) 8360

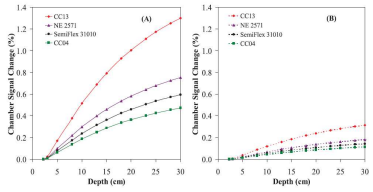
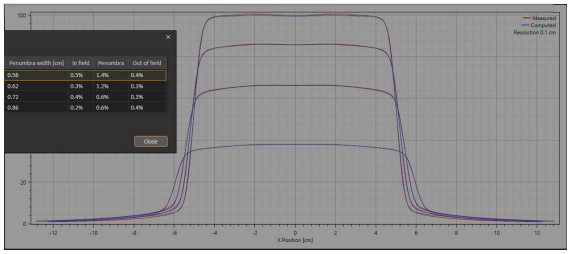
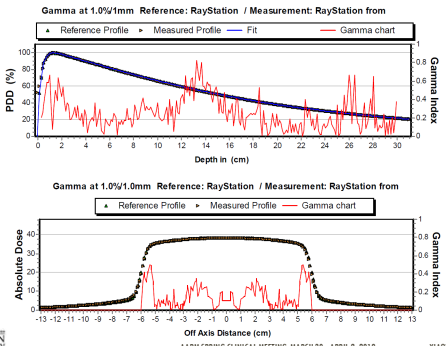


Figure 4. Effect on ionisation chamber signal at depth due to recombination losses for various detectors for (A) 10 MV FFF photons and (B) 10 MV flattened photons for a Varian TrueBeam. Measurements are for a 10×10 cm field at 100 cm SSD, using an operating potential of −350 V for all chambers. The ion chamber volumes are respectively: IBA CC13 0.13 cm^3, NE 2571 0.6 cm^3, PTW 31010 0.125 cm^3, IBA CC04 0.04 cm^3.

G Budgell et al. Phys. Med. Biol. **61** (2016) 8360

MODELLING





VALIDATION TESTS

- Non measurement "sanity checks"
- Basic photon beam validation
- Heterogeneity correction validation
- IMRT/VMAT
- E2E test

VALIDATION TESTS I: NON-MEASUREMENT "SANITY" CHECK

Field configurations are the same as those used for modeling

TABLE 3. TPS model comparison tests and tolerances. MPPG5A

Test	*Comparison*	*Description*	*Tolerance*
5.1	Dose distributions in planning module vs. modeling (physics) module	Comparison of dose distribution for large (> 30×30cm^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.

VALIDATION TESTS II –BASIC PHOTON BEAM VALIDATION

Validation tests for
- clinical revenant SSD.
- field shaping using the MLC with jaws at clinical relevant position.
- oblique beam angles
- Wedges

measurements in the high-dose region, penumbra, and low-dose tail regions should be compared to calculated values at various depths.

TABLE 5. Basic TPS photon beam evaluation methods and tolerances. MPPG5A

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.

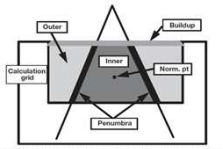


FIG. 11. Regions of different accuracy capabilities for photon beam dose calculations. Reproduced, with permission, from Ref. [18].

Ref: IAEA technique report 430

TABLE 18. EXAMPLE ILLUSTRATING DEVIATIONS (δ) FOR DIFFERENT REGIONS
(Adapted, with permission, from Ref. [67].)

	Location	Type of region	1. Simple geometry (homogeneous)	2. Complex geometry (wedge, inhomogeneity, asymmetry)	More complex geometry (combinations of 1 and 2)
δ_1	Central beam axis	High dose, small dose gradient	2%	3%	4%
δ_2[a]	Buildup region of central axis and penumbra region of profiles	High dose, large dose gradient	2 mm or 10%	3 mm or 15%	3 mm or 15%
δ_3	Outside central beam axis region	High dose, small dose gradient	3%	3%	4%
δ_4	Outside beam edges	Low dose, small dose gradient	3%[b] (30%)	4%[b] (40%)	5%[b] (50%)
$RW_{0.5}$	Radiological width		2 mm or 1%	2 mm or 1%	2 mm or 1%
δ_{build}	Beam fringe		2 mm	3 mm	3 mm

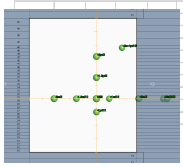
[a] These values are preferably expressed in mm. A shift of 1 mm corresponding to a dose variation of 5% is assumed to be a realistic value in the high dose, large dose gradient region.
[b] This percentage is applicable to the following equation, $\delta_2 = 100\% \times (D_{true} - D_{meas})/D_{cax,true}$, where $D_{cax,true}$ is the dose on the central beam axis, since it is not always practicable to compare with the local dose. The values in brackets are those determined from Eq. (6).

Example 1: basic photon test: open field

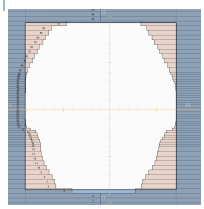
Test patient:	Test,TrueBeam
Case name:	MLC-shaped fields
Test plan:	open field
ion chamber:	cc13 (S/N 6285)
Data aquired by:	XL
Date:	2/8/2017
Note:	

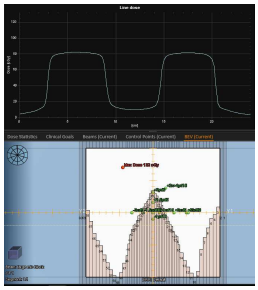
CAX
penumbra
out of field

SSD	gantry	x1	x2	y1	y2	Chamber position		Dose Measurement		TPS calculation	%(TPS vs Meas)	
						off Axis (cm)	depth (cm)	Reading	cGy	cGy	cGy for out of field	
90	0	5	3	4	6	0	2.5	1.762	115.7	116	0.23	
						0	5	1.557	102.3	102.5	0.24	
						0	10	1.180	77.5	77.6	0.07	
						0	20	0.653	42.9	42.9	0.03	
						+1x	15	0.868	57.0	57.1	0.14	
						+3x	5	0.381	25.0	24.7	-0.3cGy	<1 mm
						+5x	10	0.058	3.8	3.7	-0.1cGy	
						-3x	5	1.560	102.5	102.4	0.10	
						-1y	10	1.172	77.0	77.2	0.26	
						+3y	5	1.574	103.4	103.1	0.31	
						+2x+4y	15	0.832	54.7	54.8	0.26	



Example 2 & 3: basic photon test: Small & large MLC-shaped field

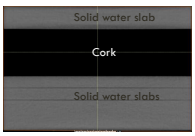




VALIDATION TESTS III- HETEROGENEITY CORRECTION VALIDATION

Confirmation of CT density table

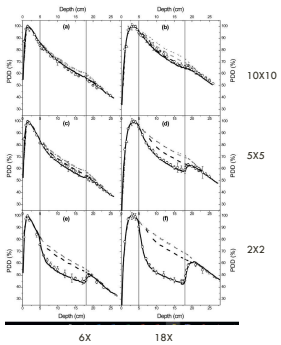
Verifies dose beyond low-density (lung) material. The ratio of the dose values above and below the heterogeneous medium be measured and compared.



	Measured		planned	Measured vs. planned
10X	Mraw	Normalized dose (cGy)	(cGy)	% difference
point 1	22.8	115.94	115.5	0.38
point 2	15.26	77.60	77.1	0.65
Ratio		1.49	1.50	-0.26

The QMP must understand the limitations of the dose algorithms, particularly in the context of known dose discrepancies, which should be distinguished from incorrect commissioning of the TPS. Particular care should be taken when evaluating calculated dose 1) within low-density tissue, 2) near the interface of heterogeneous tissues, and 3) beyond low/high density tissue.

Ref: Carrasco et al. Med Phys. 2004;31(10):2899–911.

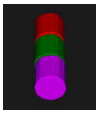
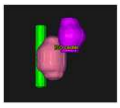


VALIDATION TESTS IV- IMRT/VMAT

- Verification of small MLC field PDD
- Verification output for small MLC fields
- TG119 tests
- Clinical case tests
- RPC Phantom

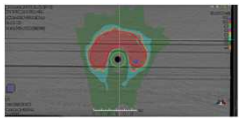
TG119

Multitarget | Prostate | Head & Neck | C Shape

Dose goals (easier version)

Structure		
CShape PTV	95% of volume to receive at least 5000 cGy	10% of volume to receive no more than 5500cGy
Core	5% of volume to receive no more than 2500 cGy	



TG119

Chamber measurements

test	prescribed dose/fmc	location	measured dose	planned dose	high dose region (meas-plan)/presc	low dose region (meas-plan)/presc
MultiTarget		isocenter				
		4 cm superior				
		4 cm inferior				
Prostate		isocenter				
		2.5 cm posterior				
Head/Neck		isocenter				
		4.0 cm posterior				
CShape (easy)		isocenter				
		2.5 cm anterior				
CShape (hard)		isocenter				
		2.5 cm anterior				
		mean				
		standard deviation				
		confidence limit = |mean| + 1.96 σ				

Film measurements in phantom

test	plane	% gamma pass
MultiTarget	isocenter	
Prostate	isocenter	
	2.5 cm posterior	
Head/Neck	isocenter	
	4.0 cm posterior	
CShape (easy)	isocenter	
	2.5 cm anterior	
CShape (hard)	isocenter	
	2.5 cm anterior	
mean		
standard deviation		
confidence limit = (100 - mean) + 1.96 σ		

Field-by-Field % Gamma pass

Field	MultiTarget	Prostate	Head/Neck	CShape (easy)	CShape (hard)
1					
2					
3					
4					
5					
6					
7					
8					
9					
mean					
overall mean					
standard deviation					
confidence limit = (100 - mean) + 1.96 σ					

Test patient:	TG119											
Case name:	MultiTarget; Prostate, HeadNeck;Cshape											
Test plan:	IMRT 6X											
Ion Chamber/Array	MapCheck											
Data aquired by:	XL											
Date:	2/15/2017											
Note:												

	MultiTarget (MF = 3.29)			Prostate (MF = 1.83)			HeadNeck (MF = 4.7)			Cshape (MF = 4.57)		
Field	3%/3mm	3%/2mm	2%/2mm	3%/3mm	3%/2mm	2%/2mm	3%/3mm	3%/2mm	2%/2mm	3%/3mm	3%/2mm	2%/2mm
1	100.0%	100.0%	99.3%	100.0%	100.0%	100.0%	99.5%	95.6%	88.0%	99.5%	97.6%	90.5%
2	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	99.5%	97.3%	98.9%	94.7%	88.9%
3	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.7%	93.7%	100.0%	100.0%	100.0%
4	100.0%	99.4%	99.4%	100.0%	100.0%	99.1%	100.0%	100.0%	99.0%	100.0%	99.4%	99.4%
5	100.0%	100.0%	99.3%	100.0%	100.0%	100.0%	100.0%	100.0%	96.7%	99.5%	98.5%	89.2%
6	100.0%	98.7%	95.4%	100.0%	100.0%	98.9%	99.5%	98.9%	98.4%	100.0%	98.0%	92.5%
7	100.0%	99.3%	99.3%	100.0%	100.0%	100.0%	99.0%	97.0%	92.0%	100.0%	100.0%	98.7%
8							99.1%	97.3%	94.1%	100.0%	99.2%	98.4%
9							100.0%	99.4%	97.8%	99.5%	97.9%	93.2%
mean	100.0%	99.6%	99.0%	100.0%	100.0%	99.7%	99.6%	98.4%	95.2%	99.7%	98.4%	94.5%
Overall										3%/3mm	3%/2mm	2%/2mm
mean										99.8%	99.0%	96.8%
standard deviation										0.3%	1.4%	3.8%
confidence limit										0.8(99.2%)	3.7 (96.3%)	10.6(89.4%)

CLINICAL VMAT CASES VALIDATION

Cases	3%/3mm	3%/2mm	2%/2mm
T spine (c-shape) 1	99.3%	97.5%	94.7%
T spine (c-shape) 2	99.3%	96.9%	92.3%
prostate+nodes 1	99.9%	99.3%	95.3%
prostate+nodes 2	100.0%	99.9%	98.1%
prostate+nodes 3	99.8%	99.6%	98.3%
prostate+nodes 4	100.0%	99.9%	99.8%
prostate+nodes 5	99.9%	99.4%	98.0%
H&N 1	99.8%	99.3%	97.7%
H&N 2	99.7%	96.9%	92.5%
H&N 3	99.7%	99.2%	96.3%
H&N 4	100.0%	99.7%	98.5%
H&N 5	99.6%	99.0%	93.2%
lung 1	100.0%	99.6%	98.4%
lung 2	99.4%	98.4%	97.5%
mean	99.7%	98.9%	96.5%
standard deviation	0.3%	1.1%	2.5%
confidence limit	0.9(99.1%)	3.3(96.7%)	8.4(91.6%)