LINEAR ACCELERATOR QUALITY ASSURANCE
TG-40 → TG-142

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AAPM Task Group 40 Report "Comprehensive QA for Radiation Oncology"

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- Performance-based, comprehensive guidelines for preventing correctable systematic errors
- Scope:
  - Guidelines for administrators
  - Cobalt-60 Teletherapy Units
  - Brachytherapy
  - Conventional Simulators
  - CT Scanners
  - Measurement Equipment for Dosimetry
  - Treatment Planning Computer Systems
  - External Beam Treatment Planning Process
  - External Beam QA for Individual Patients
  - QA of Clinical Aspects
  - QA of Medical Electron Accelerators → **Now TG-142**

Linac QA TG-40 (1994)

TABLE II. QA of medical accelerators.

Frequency	Procedure	Tolerance[a]
Daily	Dosimetry	
	X-ray output constancy	3%
	Electron output constancy[b]	3%
	Mechanical	
	Localizing lasers	2 mm
	Distance indicator (ODI)	2 mm
	Safety	
	Door interlock	Functional
	Audiovisual monitor	Functional

Daily

Monthly	Dosimetry	
	x-ray output constancy[c]	2%
	Electron output constancy[c]	2%
	Backup monitor constancy	2%
	x-ray central axis dosimetry parameter (PDD, TAR) constancy	2%
	Electron central axis dosimetry parameter constancy (PDD)	2 mm @ therapeutic depth
	x-ray beam flatness constancy	2%
	Electron beam flatness constancy	3%
	x-ray and electron symmetry	3%
	Safety Interlocks	
	Emergency off switches	Functional
	Wedge, electron cone interlocks	Functional
	Mechanical Checks	
	Light/radiation field coincidence	2 mm or 1% on a side[d]
	Gantry/collimator angle indicators	1 deg
	Wedge position	2 mm (or 2% change in transmission factor
	Tray position	2 mm
	Applicator position	2 mm
	Field size indicators	2 mm
	Cross-hair centering	2 mm diameter
	Treatment couch position indicators	2 mm/1 deg
	Latching of wedges, blocking tray	Functional
	Jaw symmetry[e]	2 mm
	Field light intensity	Functional

Monthly

Frequency	Test	Tolerance
Patient Specific	Check of MLC-generated field vs. simulator film (or DRR) before each field is treated	2 mm
	Double check of MLC field by therapists for each fraction	Expected field
	On-line imaging verification for patient on each fraction	Physician discretion
	Port film approval before second fraction	Physician discretion
Quarterly	Setting vs. light field vs. radiation field for two designated patterns	1 mm
	Testing of network system	Expected fields over network
	Check of interlocks	All must be operational
Annually	Setting vs. light vs. radiation field for patterns over range of gantry and collimator angles	1 mm
	Water scan of set patterns	50% radiation edge within 1 mm
	Film scans to evaluate interleaf leakage and abutted leaf transmission	Interleaf leakage <3%, abutted leakage <25%
	Review of procedures and in-service with therapists	All operators must fully understand operation and procedures

*This table is reproduced in part from Klein, Low, and Purdy (1996).

MLC QA per TG-50 (2001)

TABLE IV. Frequency of QA tasks.

Interval	Task (P—physicist, M—manufacturer, E—engineer, T—therapist)
Daily	Inspect imager housing (T) Test collision interlock (T) Acquire day's first image during machine warm-up procedure to verify operation and image quality (T) Verify sufficient data capacity for day's images (P or designate)
Monthly	Acquire image and inspect for artifacts (P) Perform constancy check of SNR, resolution and localization (P) Review image quality Perform image and disk maintenance (P) Mechanical inspection [latches, collision sensors, optical components (P,E)] Electrical connections (P,E) Test collision interlock (P) Hardcopy output (P)
Annual	Perform full check of geometric localization accuracy (P)

TG-58 (EPIDs) (2001)

TG-142: "QA of Medical Accelerators"

Med. Phys. 36(9) 2009

- Fills gap between TG-40 and TG-100
- Gives performance-based recommendations, but incorporates process-oriented concepts and advancements in linacs since 1994
- Scope: (replaces Table II of TG-40)
  - Linac QA: acceptance testing, commissioning, CQI
  - Ancillary treatment devices
    - Asymmetric jaws
    - Dynamic/virtual/universal wedge
    - MLC
    - TBI/TSET
    - Radiographic imaging
    - Respiratory gating

The Resource Problem

- Lack of adequate guidance for resource allocation
- Lack of qualified personnel
- Rapid implementation of new technology
  - More sophisticated equipment
  - More resources
  - Clinics are under pressure to implement new technology
- Lack of timely guidelines

Task Group No. 100: Method for Evaluating QA Needs in Radiation Therapy

- Initially "Replacement for TG-40"
- Radical departure from previous AAPM recommendations and philosophy
- Based on "Failure Modes and Effects Analysis"
- Individual departments responsible for development of unique QA programs
- Based on procedures and resources performed at individual institutions

Task Group 100 Review e-mail

Dear QASC,

Cancel you vacations, TG 100 is here. All 188 pages, all 4700 lines, not to mention an alternate version chapter VII (itself only 114 pages). See Saiful's email below.

As you know, this much-awaited report has the potential to make a significant change to the way we do QA. We need to read this document carefully and consider how it can best be presented to allow implementation in the clinic. It is not just an educational document.

I would recommend you read through it the first time without trying to make any corrections or only ones you think are glaring. Get a feel for the whole thing. Then go back and re-read. I have read/skimmed most of it.

I would like us all to take about a month to read the document and be able to start to discuss. Let me know if you don't like that timeframe. After a month, I will set up a telecon for a general discussion. Dont worry about detailed line-by-line critique at this stage.

Art

Task Group 142: QA of Medical Accelerators

Members

- Chair: Eric E. Klein, Ph.D., Washington University
- Joseph Hanley, Ph.D., Hackensack Univ Medical Center
- John Bayouth, Ph.D., University of Iowa
- Fang-Fang Yin, Ph.D., Duke University
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- Consultants: Carlos Sandin (Elekta), Todd Holmes (Varian Medical Systems)

Task Group 142: Philosophy

- **The types of treatments delivered with the machine should also have a role in determining the QA program that is appropriate for that treatment machine.**
- **For example, machines that are used for SRS/SBRT treatments, TBI or IMRT require different tests and/or tolerances.**

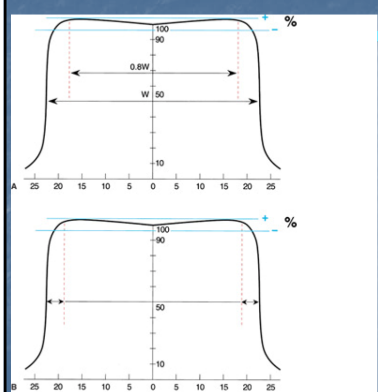
BACKGROUND

- **Baseline dosimetric values entered into TPS to characterize and/or model the treatment machine directly affect calculated plans**
- **Values can deviate from their baseline as a result of;**
  - **Machine malfunction**
  - **Mechanical breakdown**
  - **Physical accidents**
  - **Component failure**
  - **Major component replacement**
  - **Gradual changes as a result of aging**
- **These patterns of failure must be considered when establishing a periodic QA program**

TG-142 vs. TG-40

- TG-40 tests beam flatness/symmetry
  - A +/-3% drift in symmetry, while within TG-40 tolerance, means a 6% change in beam profile
  - New development: beams without flattening filters
- TG-142 recommends:
  - Beam profile measured with a QA device or portal imager
  - Several off-axis locations evaluated
  - Average of multiple points should be within tolerance values

Task Group 142: General



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- **A *Consistent* *beam profile* is an important quantity for accurate and reproducible dose delivery in radiotherapy.**

Task Group 142: General

Chosen O.A. points that fall within core of the field

$$\frac{1}{N}\cdot\sum_{L=1}^{N}\left|\frac{TP_L - BP_L}{BP_L}\right|\cdot 100\% \leq Tolerance\ \%$$

- **where: TP_L and BP_L are off-axis ratios at Test and Baseline Points, respectively, at off axis Point L**
- **N is the number of off-axis points**
- **$TP_L = (MP_L / MP_C)$ where *M* represents the measured value, and *C* is the central axis measurement.**
- **Similarly, the baseline points are represented by $BP_L = (MBP_L / MBP_C)$**

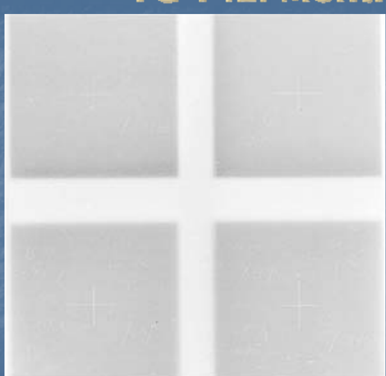
TG-142 vs. TG-40

- Spirit and intent of TG-40 maintained but clarified:
  - Action levels
    - Level 1: inspection action
      - investigate a sudden change in a usually non-varying parameter even if still within tolerance
    - Level 2: scheduled action
      - if a parameter is consistently close to failing, or failed once by a small margin, schedule an investigation within 1 or 2 days of event
    - Level 3: immediate action
      - stop treatment and investigate in cases of, e.g., safety interlock failure, or significant dosimetric error

TG-142 vs. TG-40

	TG-40	TG-142 changes
Daily		
Dosimetry		
Mechanical		***Differentiate for SRS/SBRT and IMRT. Also added test for Collimator setting for SRS***
Localizing lasers	2mm	
Distance indicator (ODI)	2mm	

TG-142: Monthly



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Light and Radiation Coincidence

Only needed if clinical setups using a light field is conducted

TG-142 vs. TG-40

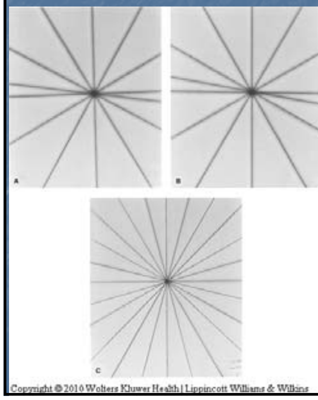
Monthly		
	TG-40	TG-142 changes
Dosimetry		
x-ray central axis dosimetry parameter (PDD, TAR) constancy	2%	Removed
Electron central axis dosimetry parameter constancy (PDD)	2mm	2%/2mm
x-ray beam flatness constancy	2%	***Replaced with 1% constancy of profile***
Electron beam flatness constancy	3%	
x -ray and electron symmetry	3%	
Interlock Checks		
Emergency Off	Functional	Removed
Wedge, "cone"	Functional	
Mechanical		
Light/radiation field coincidence	2 mm or 1%/side	***Only if clinical setups performed***
Field size indicators	2mm	1mm/side
Cross-hair centering	2mm	1mm
Treatment couch position indicators	2 mm/1 deg	Tighter for SRS/SBRT

Annual

*If PDD_{10}, measured during TG51 calibration deviates >1%, discretion to measure more PDD points

Procedure	Machine Type Tolerance		
	non-IMRT	IMRT	SRS/SBRT
Dosimetry			
X-ray flatness change from baseline	1%		
X-ray symmetry change from baseline	±1%		
Electron flatness change from baseline	1%		
Electron symmetry change from baseline	±1%		
SRS arc rotation mode (range: 0.5 to 10 MU/deg)	NA	NA	Monitor units set vs. delivered:1.0 MU or 2%
			Gantry arc set vs. delivered: 1.0 deg or 2%
X-ray/electron output calibration (TG-51)	±1%(absolute)		
Spot check of field size dependent output factors for X-ray (2 or more FS)	2% for field size < 4x4 cm^2, 1% ≥4x4 cm^2		
Output factors for electron applicators (spot check of 1 applicator/energy)	±2% from baseline		
X-ray beam quality (PDD_{10} or TMR_{10}^{20}) *	**±1% from baseline**		
Electron beam quality (R_{50})	±1mm		

Annual: Mechanical & Radiation Isocenters



TG-142 vs. TG-40

Annual		
	TG-40	TG-142 changes
Dosimetry		
x-ray/electron output calibration constancy	2%	+,- 1%
Field size dependence of x-ray output constancy	2%	Spot check 2 or more FS
Output factor constancy for electron applicators	2%	Combination of energies & applicators (i.e.,Varian -5)
Central axis parameter constancy (PDD, TAR)	2%	± 1% for TG-51 purpose
Off-axis factor constancy	2%	± 1% from baseline
Wedge transmission factor constancy	2%	Unique for wedge systems
Monitor chamber linearity	2%	Unique for delivery system
x-ray output constancy vs gantry angle	1%	± 1% from baseline
Electron output constancy vs gantry angle	2%	
Off-axis factor constancy vs gantry angle	2%	

Multileaf Collimation

Procedure	Tolerance
Weekly (IMRT machines)	
Qualitative test (i.e. matched segments, aka, "picket fence")	Visual inspection for discernable deviations such as an increase in interleaf transmission
Monthly	
Setting vs. radiation field for two patterns (non-IMRT)	2mm
Backup diaphragm settings (Elekta only)	2mm
Travel speed (IMRT)	Loss of leaf speed > 0.5 cm/sec
Leaf position accuracy (IMRT)	1mm for leaf positions of an IMRT field for 4 cardinal gantry angles. (*Picket fence* test may be used, test depends on clinical planning – segment size)
Annually	
MLC Transmission (Average of leaf and interleaf transmission), All Energies	±0.5% from baseline
Leaf position repeatability	±1.0 mm
MLC spoke shot	≤1.0 mm radius
Coincidence of Light Field and X-ray Field (All energies)	±2.0 mm
Segmental IMRT (Step and Shoot) Test	*<0.35 cm Max Error RMS, 95% of error counts <0.35 cm*
Moving window IMRT (4 cardinal gantry angles)	<0.35 cm Max Error RMS, 95% of error counts <0.35 cm

Multileaf Collimation:
Weekly Qualitative *picket fence*

How to perform this test without a processor: EPID or Radiochromic film

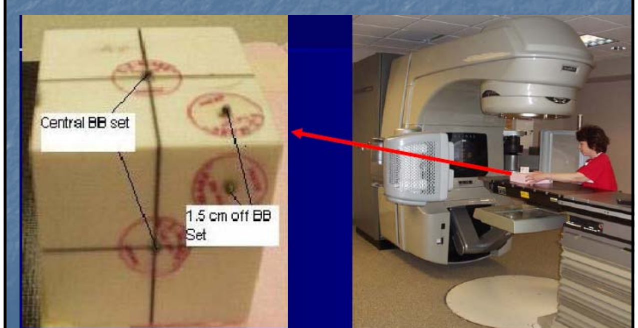
Imaging Tests: Daily

[1] Or at a minimum when devices are to be used during treatment day

Procedure	Application Type Tolerance	
	non-SRS/SBRT	SRS/SBRT
Daily[1]		
kV and MV (EPID) imaging		
Collision interlocks	Functional	Functional
Positioning/repositioning	≤ 2 mm	≤ 1 mm
Imaging & Treatment coordinate coincidence (single gantry angle)	≤ 2 mm	≤ 1 mm
Cone-beam CT (kV & MV)		
Collision interlocks	Functional	Functional
Imaging & treatment coordinate coincidence	≤ 2 mm	≤ 1 mm
Positioning/repositioning	≤ 1 mm	≤ 1 mm

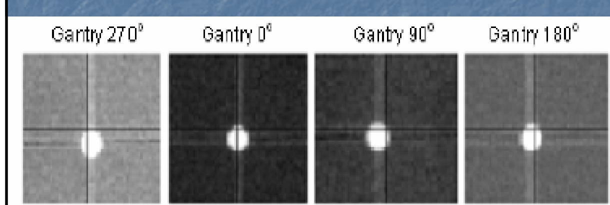
OBI QA

- Daily: Isocenter location and ability to shift accurately to a known location



OBI QA

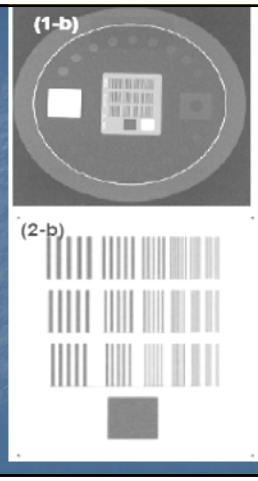
Isocenter accuracy over gantry rotation



OBI QA

Image Quality (KVS,KVD)

Use Leeds phantom (line pairs and low contrast)



SUMMARY OF RECOMMENDATIONS/ IMPLEMENTATION SCHEME

- QA team led by the QMP supports all QA activities & policies and procedures.
- The 1st step is to establish institution-specific baseline and absolute reference values.
- Daily QA tasks may be carried out by a RTT using a cross-calibrated dosimetry system that is robust and easy-to-setup.
- There is overlap of tests for daily, monthly, and annual that can achieve independence with independent measurement devices.

SUMMARY OF RECOMMENDATIONS/ IMPLEMENTATION SCHEME

- End-to-end system checks ensure fidelity of overall system.
- During the annual QA, absolute outputs should be calibrated as per TG51 and all secondary QA dosimeters cross-checked.
- Upon completion of an annual QA report be generated, signed and reviewed by the QMP and filed for future machine maintenance and inspection needs.