Quality Assurance

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Introduction

Quality Assurance / Quality Management

- A set of policies and procedures to maintain and control quality of patient care.
- ICRU recommends that the dose be delivered to within ±5% of prescribed dose.

Sources of Uncertainty

- Tumor localization.
- Precise matching between calculated and measured beam data.
- Accurate calibration of treatment machines.
- Patient immobilization throughout treatment.

Overall uncertainty in dose at a point

step	(2-σ) uncertainty (%)
dosimeter calibration	1.6
daily calibration	2.0
methods and parameters	3.0
effective depth	2.0
SSD	2.0
wedges	2.0
block trays	2.0
cumulative	5.6

Required & Recommended Quality Assurance

Recommended

- NRC / Agreement States
  10 CFR Part 35
  http://www.physics.isu.edu/radinf/Files/10cfr35.exe
- *JCAHO*
  http://www.jcaho.org

Required

- AAPM
  AAPM Report No. 46 (TG 40)
  Comprehensive QA For Radiation Oncology
  http://www.aapm.org/pubs/reports/index.html
- ACR
- ACMP

Acceptance Testing

- **General Rule:** It is required on any piece of equipment that is used in conjunction with a patient's treatment
- It is a time to see that the machine meets the specifications/criteria set forth by the manufacturer
- The best condition of equipment is at acceptance testing

Acceptance Testing

- Purpose:
  1. Provides the mechanism by which the Institution determines that is received what it intended to purchase
  2. It assures the safety of the patients and the machine/equipment operators
  3. It provides critical base-line data for future QA reviews

Acceptance Testing of LINAC

Mechanical tests

- Safety interlocks
- Collimator axis of rotation
- Jaw motion
- Light field/radiation field congruence
- Gantry angle indicators
- Gantry axis of rotation
- Radiation isocenter
- Optical Distance Indicator
- Field size accuracy
- Table rotation & motion
- Laser Alignment

Acceptance Testing of LINAC

- Radiation Therapy Performance
  - Electron Beam
    - Energy specifications, flatness, symmetry, penumbra, & colimation
  - Photon Beam
    - Energy specification, flatness, symmetry, & penumbra
  - Radiation Survey of Facility
- General Tests
  - Reproducibility
  - Machine Demonstration

Commissioning of LINAC

- LINAC cannot be used for patient treatment until it has been calibrated and all the beam data & necessary parameters for treatment planning have been obtained
- After all the necessary data has been acquired and adopted to the treatment planning system, then the machine can be released or commissioned for clinical use.

Annual Calibration, Quarterly, Weekly, and Daily Quality Assurance Checks

Frequency of QA for Radiotherapy Equipment

External Beam Units: **AT / C, A, M, W, D** (Linacs, Co-60 Units)

Brachytherapy Units: **AT / C, M / D** (whenever treating a patient)

Simulators: **AT / C, Q, D**

AT - Acceptance Testing
C - Commissioning
A- Annually
Q - Quarterly
M - Monthly
W - Weekly
D - Daily

LINAC Commissioning Measurements

1. CAX Percent Depth Dose Curves for all modalities and energies at various field sizes.
2. Inplane / Crossplane / Diagonal Profiles for all modalities and energies at various field sizes and depths.
3. Dose / MU Calibration for all modalities and energies.
4. Output Factors for all modalities and energies ($S_{c,p}$, S_c, S_p for photons and Cone Ratios for electrons).
5. Tray and Wedge Transmission Factors.
6. Off-Center Ratios.
7. Inverse square verification for photons and VSD for electrons.

Percent Depth Dose Curves For Photons

Setup: CAX
SSD = 100 cm
Depth = From surface to ~35 cm
At various field sizes, including 10 x 10
At open and wedged fields

Tolerance: ± 2%

Frequency: Commissioning/Annually/Monthly (TMR spot check)

Percent Depth Dose Curves For Electrons

Setup: CAX
SSD = 100 cm and 110 SSD
Depth = From surface to ~35 cm
At all available square and circular cone sizes

Tolerance: ± 2%

Frequency: Commissioning/Annually/Monthly (spot check)

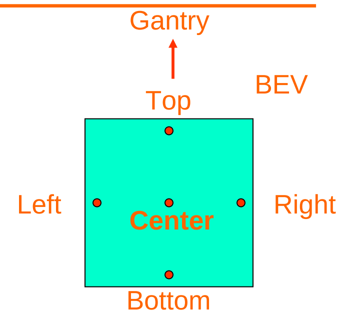
Dose Profiles For Photons

Setup: SSD = 100 cm
Depth = d_{max} and at 5.0 cm increments
At various field sizes, including 10 x 10
At open and wedged fields
Direction = Inplane, Crossplane, Diagonal (40x40)

Tolerance: Flatness ± 2%
Symmetry ± 3%

Frequency:Commissioning/Annually/Weekly (Films or Profiler)

Symmetry and Flatness



$$Symmetry_{Inplane} = \frac{Top - Bottom}{Top + Bottom} \times 100$$

$$Symmetry_{Crossplane} = \frac{Left - Right}{Left + Right} \times 100$$

$$Flatness_{Inplane} = \frac{Highest\ (T, C, B) - Lowest\ (T, C, B)}{Highest\ (T, C, B) + Lowest\ (T, C, B)} \times 100$$

$$Flatness_{Crossplane} = \frac{Highest\ (L, C, R) - Lowest\ (L, C, R) \times 100}{Highest\ (L, C, R) + Lowest\ (L, C, R)}$$

Dose Profiles For Electrons

Setup: SSD = 100 cm and 110 cm
Depth = d_{max} + Chamber Offset
At all available square and circular cone sizes
Direction = Inplane, Crossplane

Tolerance: Flatness ± 3%
Symmetry ± 3%

Frequency: Commissioning
Annually
Weekly (Films or Profiler)

Photon Beam Calibration

$$\text{Output @ } d_{max} \text{ (cGy/MU)} = \frac{\text{Rdg} \times C_{tp} \times (N_{gas})_{sys} \times (L/\rho)^{med}_{air} \times P_{repl} \times P_{ion}}{\text{\# MU} \times \text{TMR}_{(D=5,\ FS=10x10)}}$$

Setup: CAX
SCD = 100 cm
Depth = 5.0 cm
Field Size = 10 x 10 cm

Tolerance: ± 2%

Frequency: Commissioning/Annually/Monthly

Electron Beam Calibration

$$\text{Output @ } d_{max} \text{ (cGy/MU)} = \frac{\text{Rdg} \times C_{tp} \times (N_{gas})_{sys} \times (L/\rho)^{med}_{air} \times P_{repl} \times P_{ion}}{\text{\# MU}}$$

Setup: CAX
SSD = 100 cm
Depth = d_{max} + Chamber Offset
Cone Size = 10 x 10 cm

Tolerance: ± 2%

Frequency: Commissioning/Annually/Monthly

Photon Scatter Factors: $S_{c,p}$, S_c, S_p

Setup: CAX
SCD = 100 cm
Depth = d_{max} ($S_{c,p}$); in-air w/ buildup caps (S_c)
At various field sizes, including 10 x 10

Tolerance: ± 2%

Frequency: Commissioning/Annual

Photon Tray And Wedge Transmission Factors

Setup: CAX
SCD = 100 cm
Depth = d_{max}
Field size = 10 x 10, 30 x 30 (TF);
Various (WF);

Tolerance: ± 2%

Frequency: Commissioning/Annual

Electron Cone Ratios

$$CR\ (CS;\ SSD) = \frac{Rdg\ (CS;\ SSD)}{Rdg\ (10 \times 10;\ 100\ SSD)}$$

Setup: CAX

SSD = 100 cm and 110 cm
Depth = d_{max} + Chamber Offset
At all available square and circular cone sizes

Tolerance: ± 2%

Frequency: Commissioning/Annually

Photon Off-Center Ratios (OCR)

$$OCR\ (OAD;\ depth) = \frac{Rdg\ (OAD;\ depth)}{Rdg\ (CAX;\ depth)}$$

Setup: SSD = 100 cm
At various depths, including d_{max}
Field Size = 40 x 40
At open and wedged fields

Tolerance: ± 2%

Frequency: Commissioning/Annually

Virtual Source Distance

$$VSD = \frac{gap}{\{[Rdg(SSD_{100}) / Rdg(SSD_{new})] - 1\}^{1/2}} - d_{max}$$

where gap = $SSD_{new} - SSD_{100}$

Setup: CAX
At two different SSDs including SSD_{100}
Depth = d_{max}
All Cone Sizes

Tolerance: ± 2%

Frequency: Commissioning & Annually

Safety Checks

The following interlocks need to be operational and checked:

- All cameras and monitors
- Intercom
- Emergency stops
- Interrupt button
- Door interlock
- Warning Lights
- Posting of door signs

Frequency: Commissioning, Annually, Weekly, & Daily

Mechanical Checks

Laser coincidence (≤ 2 mm)

Mechanical (MDI) Vs. Optical Distance Indicator (ODI (≤ 2 mm)

Field size display accuracy (± 2%)

Radiation / light field coincidence (≤ 2 mm)

Collimator and gantry rotation isocenter (≤ 2 mm diameter)

Collimator and gantry angle readout (≤ 1°)

Output variation with gantry angle (≤ 2%)

Frequency: Commissioning (All of the above)
Annually (All of the above)
Weekly (A, B, C, D, E)
Daily (A, B)

Output Constancy Check

Dose Output = $\text{Output}_{\text{Daily System}}$ x CF, where

$$CF = \frac{\text{Output}_{\text{Calibration System}}}{\text{Output}_{\text{Daily System}}}$$

Setup: CAX
SSD = 100 cm
Depth = Predetermined depth, near d_{max}
Field Size = 10 x 10

Tolerance: ± 3%

Frequency: Daily

Simulator QA

Daily	Laser coincidence (≤ 2 mm)
	SSD indicator accuracy for 100 cm SSD (≤ 2 mm)
	Field size display accuracy for 10 x 10 (± 2%)
	Couch height readout (≤ 2 mm)
	Safety Checks (warning lights, interlocks)
Quarterly	Laser Coincidence (≤ 2 mm)
	SSD indicator accuracy for various SSDs (≤ 2 mm)
	Field size display accuracy for various field sizes (± 2%)
	Gantry and collimator angle accuracy (≤ 1°)

Summary

- Commissioning Consists of:
  - Measuring
  - Compiling
  - Documenting

a complete set of beam data for use in both manual dosimeter calculations and computer treatment planning

Summary

- Quality assurance is needed in order to verify that the equipment operate within specifications
- Depending on the tendency to deviate from set limits and the importance and the of the specific components of the equipment QA are performed daily, weekly, monthly, quarterly and annually

- Most of the tolerances are set to 2%, 2mm, 2^o
- Wedge angle tolerance is 1^o
- Daily QAs have higher tolerances than monthly and annual

Inverse Square Verification for photons

Compare Rdg_{meas} (SSD_{new}) with Rdg_{theor} (SSD_{new}), where

$$Rdg_{theor}(SSD_{new}) = Rdg_{meas}(SSD_{100})\left(\frac{100}{SSD_{new}}\right)^2$$

Setup: CAX

At various SSDs with 5 cm increment, including SSD_{100}
Depth = d_{max}
Field Size = 10 x 10

Tolerance: ± 2%

Frequency: Commissioning & Annually