Quality Assurance

Quality Assurance

Quality Assurance is all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy the given requirements for quality.

As such, QA is wide ranging and covering:

- Procedures
- Activities
- Actions
- Groups of staff

Definitions

The need for QA in Radiotherapy

- QA programme provides measures to achieve the following:
  - Reduction of uncertainties and errors (in dosimetry, treatment planning, equipment performance, treatment delivery, etc.)
  - Reduction of the likelihood of accidents and errors occurring as well as increase of the probability that they will be recognized and rectified sooner
  - Full exploitation of improved technology and more complex treatments in modern radiotherapy

Requirement on accuracy in radiotherapy

- What accuracy is required on the absolute absorbed dose?
- What accuracy is required on the spatial distribution of dose? (geometrical accuracy of treatment unit, patient positioning etc.)

Current Paradigm in External Beam Radiation Therapy QA

1) Acceptance testing
   - Meets specifications in tender
2) Clinical Commissioning
   - Prepare for clinical work
3) Periodic QC Testing
   - Ensure stable, reproducible performance
4) Patient-specific QA

Table 4. Absolute and relative frequencies of initiating and contributing causes.

<table>
<thead>
<tr>
<th>Category</th>
<th>Errors</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Errors in judgement</td>
<td>16</td>
<td>5.7</td>
</tr>
<tr>
<td>Errors in procedures</td>
<td>84</td>
<td>29.8</td>
</tr>
<tr>
<td>Professional errors</td>
<td>47</td>
<td>16.7</td>
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<tr>
<td>Communication errors</td>
<td>44</td>
<td>15.7</td>
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<tr>
<td>Hardware and software errors</td>
<td>13</td>
<td>4.6</td>
</tr>
<tr>
<td>Training</td>
<td>24</td>
<td>8.3</td>
</tr>
<tr>
<td>Supervision</td>
<td>17</td>
<td>6.0</td>
</tr>
<tr>
<td>Error in interpretation</td>
<td>20</td>
<td>7.0</td>
</tr>
<tr>
<td>Other</td>
<td>17</td>
<td>6.0</td>
</tr>
</tbody>
</table>

IAEA-TECDOC-989, May 1995
**QA - 2D RT**

- Major Technology for 2D RT
  - Simple immobilization
  - Simulator
  - Treatment machine
    - Cobalt-60 or basic linear accelerator

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**QA – 3D CRT**

- Jacob (Jake) Van Dyk

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**QA – 3D CRT**

- Fraass et al.: Task Group 53 report on quality assurance

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**Beam calculation verification** - For analysis of agreement between calculations and measurements, the dose distribution due to a beam is broken up into several regions

- The inner beam (central high-dose portion of the beam)
- The penumbral region (0.5 cm inside and outside each beam/block edge)
- The outside region (outside the penumbra)
- The buildup region (from the surface to dmax, both inside and outside the beam)
- The central axis
- Absolute dose at the beam normalization point

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**Table: IMC Parameters**

<table>
<thead>
<tr>
<th>Procedure or item to be tested</th>
<th>Action level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I x ray output constancy</td>
<td>3%</td>
</tr>
<tr>
<td>Electron output constancy</td>
<td>3%</td>
</tr>
<tr>
<td>Beam axis</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Optical output constancy</td>
<td>2 mm</td>
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</tbody>
</table>

**IAEA-TECDOC-1588, May 2008**
Table 4-4 illustrates the suggested analysis and includes examples of acceptability criteria. These criteria are only an example of the kinds of variations in dose calculation agreement with measurements that might be expected for a sophisticated dose calculation algorithm.

Example for QA in 3D-CRT

**Absorbed dose verification**

**Methods**
- Square open field
- 45° Oblique for square open field
- Square open field with virtual wedge
- Rectangular open field in central axis point dose calculation (15x15...15x12, 2x15...12x15)
- Square field and Rectangular open field in off axis point dose calculation at depth 2.5, 12 cm.

**Results**
The averaged root mean square of the point dose difference between the simulation chamber measurement and calculation dose were less than 2%.

Example for QA in 3D-CRT

**Relative dose distribution verification**

**Methods**
- 8 non-opposing beam technique
- 6 non-opposing beam technique
- 5 oblique field technique
- 3 oblique open field technique
- 3 wedge field technique
- two opposing with wedge field technique

**Clinical test cases**

- AP field
- Two opposing tangent WF
- Corner block
- 4 field box technique
- Half beam inhomogeneity
- L shape
- Three field technique
- Non-coplanar technique

Example for QA in 3D-CRT

**Photon dosimetric evaluation of a 3D treatment planning system using a test package**

Siriwat Nontachat, MS, CMU

Example for QA in 3D-CRT

3D-Conformal radiation therapy dose verification by EDR2 films

Narong Chumpu, MS, CMU

Example for QA in 3D-CRT

Fraass et al.: Task Group 53 report on quality assurance
Example for QA in 3D-CRT

Clinical test cases

Methods
- AP field
- Two opposing tangent WF
- Corner block
- 4 field box technique
- Half beam inhomoogeneity
- L shape
- Three field technique
- Non- coplanar technique

Results (% diff)

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>0.16</td>
<td>0.07</td>
<td>0.13</td>
<td>-</td>
</tr>
<tr>
<td>%</td>
<td>0.13</td>
<td>0.24</td>
<td>0.14</td>
<td>-</td>
</tr>
<tr>
<td>%</td>
<td>0.15</td>
<td>0.16</td>
<td>0.18</td>
<td>-</td>
</tr>
<tr>
<td>%</td>
<td>0.14</td>
<td>0.34</td>
<td>0.63</td>
<td>-</td>
</tr>
<tr>
<td>%</td>
<td>0.34</td>
<td>0.63</td>
<td>0.34</td>
<td>-</td>
</tr>
<tr>
<td>%</td>
<td>0.14</td>
<td>0.34</td>
<td>0.63</td>
<td>-</td>
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Siriwat Nontatchat, MSc, CMU

Patient-specific QA

- This assumes that once the system is properly commissioned, the periodic QA checks of the subsystems will guarantee that all patients are treated with accuracy that is within the limits of established QA criteria.
- It is not necessary to perform patient-specific QA except when a clinical situation warrants the monitoring of dose to a specific area of interest with in-vivo dosimeters.
- The QA for 3-D CRT planning and delivery typically relies on the performance evaluation of individual parameters of the system only.

IAEA-TECDOC-1588, May 2008

QA - IMRT

Why do we need IMRT QA?

What’s the Worst that Could Happen?

Most severe health: Patient Death

Most severe complication: Severe Complication

Most severe management: Misadministration

Most severe treatment dev: Major Treatment Deviation

Most severe treatment: Minor Treatment Deviation

Most severe litigation: Litigation

Least revenue: Lost Revenue

Chester Ramsey, Ph.D. Thompson Cancer Center, U.S.A

QA - IMRT

The three most important characteristics of the IMRT delivery system include:

- mechanical integrity of the delivery system.
- precise spatial and temporal positioning of the MLC system.
- radiation beam fidelity for small number of monitor units (MUs).

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QA - IMRT

The MLC performance characteristics that require continuous monitoring include the following:

- the leaf position accuracy and reproducibility
- the leaf gap width reproducibility
- the leaf speed accuracy

IAEA-TECDOC-1588, May 2008
Quality assurance for IMRT not only includes quality control (QC) at the level of the equipment (machine output and treatment planning) but also at the patient level. Medical physicists should be familiar with the recommendations for patient-specific QC procedures that are part of the quality control process of IMRT.

Example for QA in IMRT

**Multileaf collimator based IMRT Implementation**

- The implementation of treatment planning system
- The IMRT inverse planning
- The measurement of MLC dosimetric characteristic
- Dose verification

A Guideline Multileaf collimator based Intensity Modulated Radiation Therapy Implementation

Waraporn Kuntatagoon, MS, CMU

Example for QA in IMRT

**Implementation of treatment planning system**

- Beam modeling
- Depth dose at surface to Dmax (within 3% diff.)
- Depth dose at Dmax to 35 cm. (within 1% diff.)
- Inside and outside beam profile (3%, 7%)
- MLC dosimetric characteristic
  - Interleaf leakage (1.13%)
  - Intraleaf leakage (0.79%)
  - Leaf end transmission (1.46%)
- Mean values of 1 cm. wide field penumbra
  - Side of all leaves (0.43 cm)
  - All leaf end (0.40 cm)
- MLC leaf position average accuracy (0.08 cm)

Waraporn Kuntatagoon, MS, CMU

Example for QA in IMRT

**Dose verification**

10 plans: Mean error is 1.27%

5 Beam

7 Beam

9 Beam

Waraporn Kuntatagoon, MS, CMU

Patient-specific QA

- For IMRT, the traditional QA is not sufficient. It is very difficult to anticipate all likely problems in IMRT.
- There is little correlation between the MU and the delivered dose from each intensity-modulated field.
- Therefore, direct measurements are commonly made of a “hybrid plan” which is generated by applying the intensity-modulated field from a patient plan to a CT study of a geometric phantom.

IAEA-TECDOC-1588, May 2008
Example for QA in IMRT

DQA of step and shoot IMRT in CMU.

rms of % difference = 2.11

DQA Point dose measurement

[Graph showing data points and trend]

Example for QA in IGRT

2D dosimetry
- Ion chamber array
- Diode array
- Radiochromic film
- EPID

3D, 4D dosimetry
- Gel
- 2 perpendicular diode array (Delta4)
- ArcCheck
- 4D Monte Carlo simulation

QA - IGRT

How does IGRT improve quality?

- Frequent imaging during a course of treatment as used to direct radiation therapy

Justification for IGRT

- **Accuracy**
  - verify target location (QA)
- **Precision**
  - tailor PTV margins (patient-specific)
- **Adaptation to on-treatment change**
  - Correct & moderate setup errors
  - Assess anatomical changes
  - Re-planning

QA - IGRT

Rationale for QA:

- **Geometric accuracy**
  - distance to shift is physically correct
- **Image quality**
  - highest quality images are available for IGRT

Objective is to ensure that the geometry of each is the same

Jean-Pierre Bissonnette, MMCPM

Example for QA in IGRT

Patient specific QA

2D dosimetry
- Ion chamber array
- Diode array
- Radiochromic film
- EPID

3D, 4D dosimetry
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Maria F. Chan, Memorial Sloan-Kettering Cancer Center
Example for QA in IGRT

Measure dose point with ion chamber and dose distribution with EDR2 film

rms of % difference = 1.39

DQA with Array devices

- Available array devices
  - Sun Nuclear - MapCHECK
  - IBA Dosimetry - Matrixx
  - PTW - 2D- ARRAY seven29

- Advantages:
  - Time savings
  - No film processing issues
  - Real time comparison

- Disadvantage:
  - Resolution

Tomo DQA with Mapcheck

- Initial tests have shown good results for TomoTherapy DQA
- Gamma test results
  - Absolute dose (3%, 3mm)
  - HN: 98.5% passing
  - Prostate: 99.6% passing

Conclusion

- It is important to understand that Advance techniques present a set of challenges that are significantly more complex than traditional forms of radiation treatment.

To assure the safety and Quality of treatment,
More work to be done
Further progress to be made,
Future refinement to be achieved

Maria F. Chan, Memorial Sloan-Kettering cancer center