Quality assurance in radiotherapy

م. أنور صلاح عطالله
ماجستير فيزياء طبية
فرنسا
Circuit of Radiotherapy

- **Imaging** => CT, MRI, PET
- **Simulation** => Conventional, virtual
- **Dosimetry** => Calculations on TPS, Transfer (R & V)
- **Controls** => Radiography, portal imaging or dosimetry in vivo
- **Irradiation** => Accelerator or cobalt
The «risk» of treatment

- Irradiation of the tumor
  - Very low dose → Recidive
  - Very high dose → Complications

- Irradiation of healthy tissue → very important

Goal: <5% error
Sources of Error (uncertainty)

- **Imaging**
  - Density curve, position (irreproducible)...

- **Simulation**
  - Bad position (conformation, lasers) ...

- **Dosimetry**
  - Algorithm failed, Bad parameters, Bad configuration of TPS...

- **Controls**
  - Incorrect repositioning, error measures ...

- **Irradiations**
  - The problem of R & V, machine problems, bad irradiation (filter) ...
Sources of Error (uncertainty)

- Patient localization
- Organ motion
- Imaging (resolution, distortions, …)
- Definition of anatomy (outlines, …)
- Beam geometry
- Dose calculation
- Dose display and plan evaluation
- Plan implementation
Ensure different co-ordinate systems match...
The types of errors

- **Random errors** *(one seance)*
  - Positioning
  - Irradiation, location

- **Systematic errors** *(all seances)*
  - Positioning, location
  - Dosimetric Calculations
  - Configuration of TPS, accelerator ...

*All errors are human but the machines must be reliable*
QUALITY as a goal

The totality of features or characteristics that bear on our ability to satisfy the stated or implied goal of effective patient care.”

What is Quality Assurance?

“All those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality.”

ISO 9000
QA and QC

- Quality Assurance is the overall process which is supported by Quality Control activities.

- Quality Control describes the actual mechanisms and procedures by which one can assure quality.

- **Good QA systems in radiotherapy**
  - Improves work practices
  - Would have prevented most of the major accidents

ISO 9000
QA systems

- Many QA systems exist - one important example is the ISO 9000 system
- They are highly successful in manufacturing industry because they do improve productivity and avoid costly mistakes
ISO 9000

- Comprehensive set of standards for QA (mainly in manufacturing and service industry)
- Adapted eg. by ESTRO to the radiotherapy environ
A Comprehensive QA Program typically comprises of:

- Quality Assurance Committee
- Policies and Procedures Manual
- Quality Assurance team
- Quality audit
- Resources
QA Committee Membership

- Must represent the many disciplines within the department
- Should be chaired by the Head of Department
- As a minimum must include a medical doctor, a physicist, a radiotherapy technologist and an engineer responsible for service and maintenance
- Must be appointed and supported by senior management
- Must have sufficient depth of experience to understand the implications of the process
- Must have the authority and access to the resources to instigate and carry out the QA process
Quality Assurance Committee

- Should ‘represent’ the department
- Should be ‘visible’ AND accessible to staff
- Oversees the entire Quality Assurance program
- Writes policies to ensure the quality of patient care
- Assists staff in tailoring the program to meet the needs of the Department (using published reports as a guide)
- Monitor and audit the program to ensure that each component is being performed and documented
Policies and Procedures Manual

- As a minimum, sections should exist for:
  - Administrative procedures
  - Clinical procedures
  - Treatment procedures
  - Physics procedures
  - Radiation safety
Continuous Quality Improvement

- CQI - many other acronyms are available for this
- Part of virtually all QA systems
- Improved methods on cancer patient management are documented in clinical trial reports.
- Quality assurance protocols are continuously under development in many countries
- Regular Quality Assurance meeting for all members of a Section
- Continuing education - lectures, workshops, journal clubs and must be available for all staff
Quality Assurance Program

- Control of machines
  - The imaging devices and the simulator
  - Particles Accelerators
- Control of TPS and R&V
- Control of treatment (of patients)
  - Control of Positioning:
    - radiography and portal imaging
    - The cone beam CT
  - Control of dose
    - In vivo dosimetry
    - Pre-Treatment Controls
Imagers

- The simulator (-CT)
- The CT simulation
The simulator (-CT)
The simulator (CT)

- Mechanical Control
  - Table (Coach) Movements (Levels and security)
  - Telemeter
  - Diaphragms
  - Scales of rotation
  - Movements of the intensifier
  - Anti-collision System
  - Iso centric Verification
  - Correspondence with light field and irradiated field
  - Lasers
The simulator (-CT)

- Image Control
  - Graphic / fluoroscopy
  - Adapted Phantom
  - Spatial resolution
  - Distortion, focal spot size

- Dose Control
  - Measurement of parameters of low energy (50-130 kV) => kV, mAs
The CT simulation
The CT simulation

- Uniformity of Phantom
- Scale densities (dosimetry)
The Accelerators
The Accelerators

- **Internal control**
  - **Daily CQ**
    - Mechanical and dosimetric
  - **Weekly CQ**
    - Mechanical
  - **Monthly CQ**
    - Mechanical and dosimetric
  - **Semestriel CQ**
    - Mechanical and dosimetric
  - **Annual CQ**
    - Mechanical and dosimetric

- **External Dose Control**
External Beam Radiotherapy

Examples for daily QA

- **Safety**
  - door and other interlocks
  - radiation warning lights *(door, bunkers, equipment room)*
  - Verification of surveillance systems *(camera + intercom)*
  - radiation area monitor

- **Mechanical/optical “pointers”**

- **Radiation constancy check**
  
  TOPS

PTW Linacheck
Every day, for all photon energies and at least one electron energy

Tolerance < 2%
### Example for weekly QA summary

From Constantinou 1992
weekly QA

Iso-point

Electronic level

Iso-align
weekly QA

- Checking the reference field size

Field size 20 x 20 cm
SSD = 100 cm

Tolerance < 2 mm
Quality Assurance - Monthly

Dosimetry
- Output constancy
- Backup monitors
- Central axis %DD constancy
- Flatness/symmetry constancy
- Timer end effect
Quality Assurance - Monthly

- **Safety interlocks**
  - emergency
  - wedge etc

- **Light/ radiation field coincidence**

- **Scales**

- **Isocentre position**

- **Cross hair position**
Quality Assurance - Monthly

- Field size indicators
- Distance measuring indicators
- Jaw symmetry
- Latching of wedges, trays etc.
- Wedge position (factors etc.)
Time requirements for QA

- **External beam per megavoltage unit**
  - daily: 30 minutes
  - weekly: 2 hours
  - monthly: > 4 hours
  - annual: 2 days +

- These are estimates only - a qualified expert must decide on the actual requirements for a particular treatment unit
Monthly Mechanical CQ

- Verification of Anti collision systems
Monthly Mechanical CQ

- Checking accessories (filters, door accessories, extension, ...)

[Image of medical equipment and accessories]
Monthly Mechanical CQ

- Checking angular scales of the collimator and Gantry

± 1° de tolerance
Monthly Mechanical CQ

- Correspondence of the mechanical axis of the collimator with the axis of the beam
Monthly Mechanical CQ

- Determining the position of the isocenter
Monthly Mechanical CQ

- Check the dimensions of the radiation field

2 mm of tolerance
Monthly Mechanical CQ

- Correspondence between the irradiated field and light field

Correspondance ?
Monthly Mechanical CQ
Monthly Dosimetric (Beam performance) CQ

Using of the water phantom (with its software), ionization chambers, cable and electrometer:
Monthly Dosimetric CQ

- Ionisation chambers:
Monthly Dosimetric CQ

- PDD Acquisitions of photons:
  - Measuring conditions:
    - SSD = 100 cm, normalization to the depth of maximum dose
    - Field Size 10 x 10 cm
    - All energy photons
    - 0 to 25 cm depth
Monthly Dosimetric CQ

- PDD Acquisitions of photons:
Monthly Dosimetric CQ

- Acquisitions profiles for uniformity and symmetry of photon fields:
Monthly Dosimetric CQ

- Homogeneity and symmetry

- Symmetric
  - Homogeneous

- Non sym
  - Not Good

- Non homogene
  - Not Good
Monthly Dosimetric CQ

- Transmission of filter:
  - Measure in the presence and absence of filter
  - Tolerance <2% compared to the reference

Standard Motorise Dynamique
Monthly Dosimetric CQ

- **PDD Acquisitions of electron:**
  - **Conditions of Measurement:**
    - SSD = 100 cm, normalisation à la profondeur du maximum de dose
    - SSD = 100 cm, normalization to the depth of maximum dose
    - Field Size 10 x 10 cm
    - Applicator 10 x 10 cm
    - All energy electrons
    - 0 to 25 cm depth
Monthly Dosimetric CQ

- PDD Acquisitions of electron:

1.5 cm
3 cm
6 MeV
9 MeV
12 MeV
16 MeV
20 MeV
Monthly Dosimetric CQ

- Acquisitions profiles for uniformity and symmetry of photon fields:
These criteria are valid for the normal clinical use of radiation therapy equipment and not (necessarily) for brachytherapy, intraoperative, dynamic, palliative and whole body radiation therapy equipment. In addition, radiation therapy treatment simulators are excluded from consideration. As indicated in the Introduction, the criteria presented may be used as remedial levels at which corrective action needs to be initiated. In a very few occasions, it might be justified to use the equipment clinically, even if the remedial level has been exceeded. Such a decision can only be taken after careful consideration of the responsible clinical physicist, with the knowledge of the clinicians and radiographers. For example, curative treatments demand a high stability of the treatment table height, especially during lateral irradiation. If due to mechanical tolerances the table height cannot be adjusted within the tolerance level, it still may be justified to perform palliative posterior anterior or anterior-posterior treatments if no alternatives are present at all. The values given in Table 1 are based on recommendations in WHO (1988) and NCS (1995), with some modifications.
<table>
<thead>
<tr>
<th>Test</th>
<th>remedial action level</th>
</tr>
</thead>
<tbody>
<tr>
<td>✤ Gantry rotation:</td>
<td>± 1°</td>
</tr>
<tr>
<td>✤ Yoke rotation:</td>
<td>± 0.2°</td>
</tr>
<tr>
<td>✤ Isocentre:</td>
<td>± 2 mm</td>
</tr>
<tr>
<td>✤ Source distance indicators:</td>
<td>± 2 mm</td>
</tr>
<tr>
<td>✤ Beam axis indicators:</td>
<td>± 2 mm</td>
</tr>
<tr>
<td>✤ Numerical field indicators:</td>
<td>± 2 mm</td>
</tr>
<tr>
<td>✤ Light field indication:</td>
<td>± 2 mm</td>
</tr>
<tr>
<td>✤ Collimation system rotation:</td>
<td>± 1°</td>
</tr>
<tr>
<td>✤ Treatment couches:</td>
<td></td>
</tr>
<tr>
<td>✤ Treatment couches:</td>
<td></td>
</tr>
<tr>
<td>- lateral and longitudinal scales</td>
<td>2 mm</td>
</tr>
<tr>
<td>- vertical scales</td>
<td>2 mm</td>
</tr>
<tr>
<td>- vertical deflection (with patient load)</td>
<td>5 mm</td>
</tr>
<tr>
<td>✤ Treatment verification systems:</td>
<td>manufacturer's specification</td>
</tr>
<tr>
<td>(gantry angle, field size, collimator rotation, treatment time or monitor units, beam energy, etc.)</td>
<td></td>
</tr>
<tr>
<td>✤ Immobilization devices</td>
<td>± 2 mm</td>
</tr>
<tr>
<td>moulds, casts, breast bridges, head supports, arm or leg supports, bite-blocks, etc.)</td>
<td></td>
</tr>
<tr>
<td>Patient alignment devices</td>
<td>± 2 mm</td>
</tr>
<tr>
<td>✤ Light field indication (density measurements):</td>
<td>± 1 mm per edge</td>
</tr>
<tr>
<td>✤ Central axis dose calibration at reference position in phantom:</td>
<td>± 3% (photons)</td>
</tr>
<tr>
<td>✤ Constancy checks</td>
<td>± 4% (electrons)</td>
</tr>
</tbody>
</table>
In regions involving very steep dose gradients, the observed position of a given isodose curve should differ from its calculated position by less than 0.3 cm.

A computerized dose distribution can be considered as sufficiently accurate if calculated and measured doses differ by less than 2% at points of relevance for the treatment.

- Precision
- Linearity
- dose rate effect
- Stability
- gantry angle

<table>
<thead>
<tr>
<th>Test</th>
<th>remedial action level</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray beam</td>
<td>± 3%</td>
</tr>
<tr>
<td>- beam flatness</td>
<td>± 3%</td>
</tr>
<tr>
<td>- beam symmetry</td>
<td></td>
</tr>
<tr>
<td>Cobalt-60 and cesium-137 units</td>
<td>± 3%</td>
</tr>
<tr>
<td>- beam symmetry</td>
<td></td>
</tr>
<tr>
<td>Orthovoltage X-ray units</td>
<td>± 6%</td>
</tr>
<tr>
<td>- beam symmetry</td>
<td></td>
</tr>
<tr>
<td>Electron beams</td>
<td>± 3%</td>
</tr>
<tr>
<td>- flatness and symmetry</td>
<td></td>
</tr>
<tr>
<td>Transmission factor of wedges and compensators</td>
<td>± 2%</td>
</tr>
<tr>
<td>Dose monitoring system</td>
<td>± 0.5%</td>
</tr>
<tr>
<td>- Precision</td>
<td>± 1%</td>
</tr>
<tr>
<td>- Linearity</td>
<td>± 2%</td>
</tr>
<tr>
<td>- dose rate effect</td>
<td>± 2%</td>
</tr>
<tr>
<td>- Stability</td>
<td>± 3%</td>
</tr>
<tr>
<td>- gantry angle</td>
<td></td>
</tr>
<tr>
<td>Treatment Planning System</td>
<td></td>
</tr>
</tbody>
</table>

A computerized dose distribution can be considered as sufficiently accurate if calculated and measured doses differ by less than 2% at points of relevance for the treatment.

- In regions involving very steep dose gradients, the observed position of a given isodose curve should differ from its calculated position by less than 0.3 cm.