Clinical Implementation of Technology & Quality Assurance in Radiation Oncology

For the course: Survey of Clinical Radiation Oncology

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Quality Assurance of Radiotherapy Equipment

Outline:

A. Criteria for quality assurance programs in a radiation therapy department
B. Specifications for radiation therapy equipment
C. Quality assurance of mechanical & radiation aspects of radiotherapy machines
D. Quality assurance of cobalt teletherapy units
E. Quality assurance of electron linear accelerators
F. Quality assurance of Orthovoltage and superficial X- ray units (refer to handout)

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Process of technology Development

- Clinical Implementation of Technology Developed in-house
- Clinical Implementation of Purchased Technology
  - Clinical Needs assessment
  - Selection & purchase process
  - Acceptance testing
  - Commissioning
  - Training
  - Clinical use
  - Quality Assurance

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QA Concepts & Terminology

- QA in Rx dept includes procedures that ensure a consistent & safe fulfillment of dose Px, with minimal dose to normal tissues & minimal exposure to personnel(2)
- Organizations that issued reports dealing with QA in Radiotherapy departments:
- ICRU, AAPM, ACMP, ACR, WHO,…

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Quality Assurance Rationale

Establish Goals of Quality Assurance Program.

- Level of accuracy for delivery of treatment dose
  - AAPM Report #13
  - ICRU Report #24

- Clinically detectable dose: ≥ 7% (3)
- Acceptable level ±5% tolerance (2 &3)

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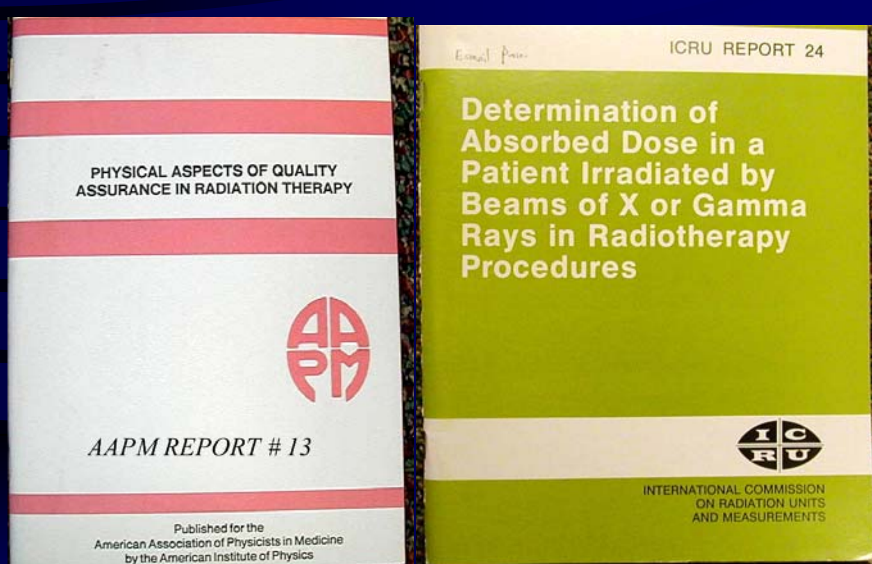

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Identify Sources Of Error

- Tumor localization
- Lack of patient immobilization
- Field placement
- Errors in calibration
- Computational errors
- Daily patient set up
- Equipment related problems

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General Categorization in Sources of Errors

A. Dosimetric uncertainties

See Figure 1 (AAPM Report #13)

B. Spatial uncertainties

See Figure 2 (AAPM Report #13)

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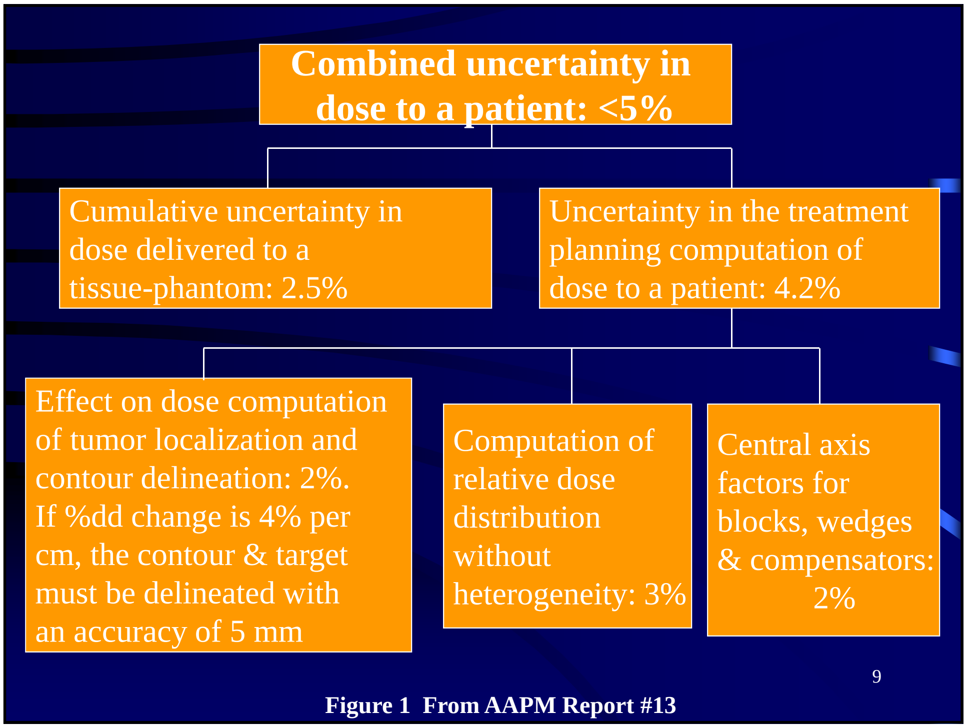

Figure 1 From AAPM Report #13

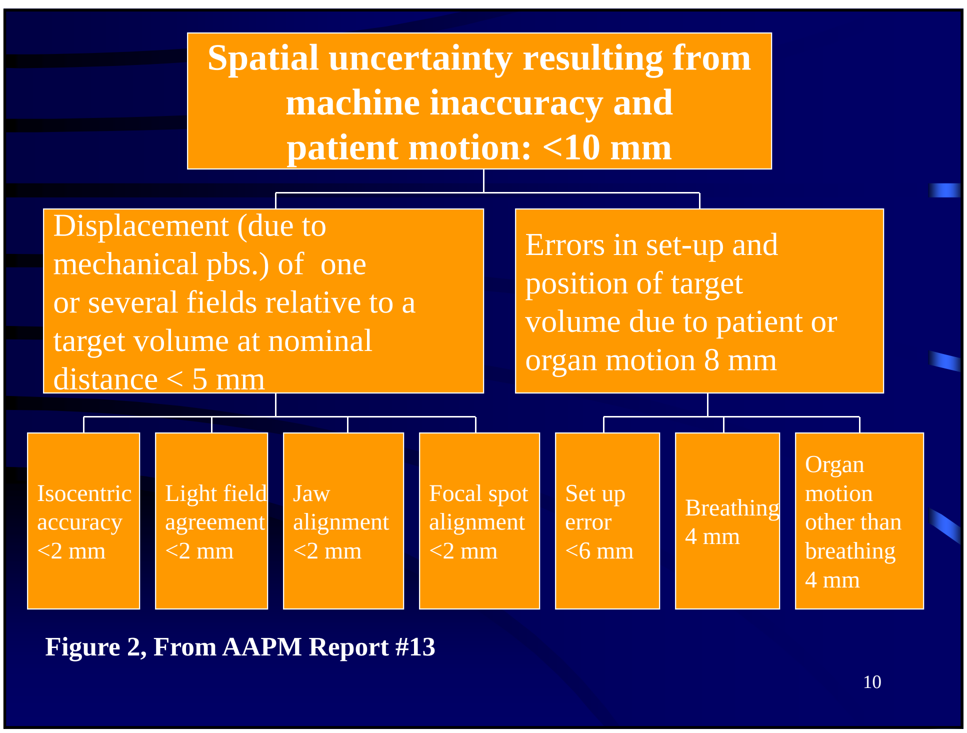

Figure 2, From AAPM Report #13

From Figures 1 & 2:

To create a good quality assurance Program:

- Evaluate the overall impact of individual components
- Expend appropriate effort on each component such that the overall error is acceptable
- Reduce the error in areas where more certainty can be achieved

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Important To Note:

A machine where the physicist has spent infinite time to obtain an output calibration of close to 0% error, does the patient no good if a part of the tumor is missed due to a large error in light-radiation field coincidence.

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Elements of A Quality Assurance Program

- Commitment by management and making available sufficient resources
- Staff to carry out the Q.A. Program
- Adequate equipment
- A review system to oversee the program
- Oversight of the program managed through A quality assurance committee

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QA Committee

- Small Department:
  - Radiation Oncologist ➡ Chair of Rx Dept. ➡ Hospital Administration
  - A Medical Physicist
  - Radiation Therapist
- Additional Staffing for a Large Department:
  - Nursing Staff
  - Radiation Safety
  - Management

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Reviews of a QA Program in a QAC Meeting

- QA in: ext beam dosimetry, brachy, teletherapy equipt, calibration equipt, imaging units, afterloaders, etc. (Medical physicist)
- QA in: Tx planning & peripherals, dosimetry and plan review (medical physicist)
- Proper set-up and Tx, port films, pat. Safety, proper charting and documentation (therapist)

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Reviews of a QA Program in a QAC Meeting …Cont.

- Patient QA procedures, "port film review, chart review, mortality and morbidity review" (physician)
- Review of incidents, deviations, related regulatory issues
- Regularly scheduled audits of charts, films and QA procedures

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A QA Committee Should:

- Recommend action on the result of any of the audits and assure the action is taken
- Report the results of these meetings to management and chair of Rad Onc Dept
- Assure ongoing education program
- Include the findings of QA tests to continually improve the process of patient care
- Institute continuous quality improvement committee (CQI)

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HOW TO AVOID <u>LARGE</u> ERRORS!

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General Recommendations for Avoiding Large Errors ...

- Large errors recorded by RPC range from <u>15% - 400%</u> different from those intended.

1. Regard redundancy as a virtue and not as a mark of inefficiency.
2. Regard computer calculations with suspicion.
3. Perform weekly chart check for accumulating dose, etc.

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General Recommendations for Avoiding Large Errors …Cont.

4. Check accelerator parameters according to TG- 40 on a daily, monthly and annual basis
5. Check the exposure rate or output dose rate of a machine after each alteration or repair
6. Check for organs that may be overdosed

{ The overlap of treatment fields
Is not always obvious }

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General Recommendations for Avoiding Large Errors …Cont

7. Verify barometer pressure by more than one technique
8. Review accumulated daily data and look for unusual trends
9. Employ an external method to verify the absorbed dose rate implemented in the clinic
10. Periodically verify patient dose using in-vivo Techniques

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Quality Assurance of Instrumentation

Any system that relies on human reliability is inherently unreliable!

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1. Q.A. Of the Q.A. Equipment

– Regular intercomparison with an independent system
– Outside review of your department's dosimetry

2. Quality assurance of therapy machines

– A. Q.A. Of mechanical aspects
– B. Q.A. Of radiation parameters

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QA of Instrumentation

- Ion chamber electrometer system => ADCL
- Periodically expose the local standard ion chamber to a long lived radioactive source in a reproducible geometry
- Such devices (low activity source, geometrically reproducible placement) available commercially (e.g. Sr-90 source)
- Keep a constancy record

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Mechanical QA of Therapy Units

A complete list of daily, monthly and annual checks given in appendix III (TG-40)

- Stability of gantry & collimator axis
- Coincidence of gantry, collimator and table axis at the isocenter
- Verification of jaw symmetry
- Verification of radiation light congruence
- Accuracy readouts for field size, gantry & collimator angle

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Mechanical QA of Therapy Units

… Cont.

- Determine location of x-hair & verify that all the isocenter locators (front pointer, ODI & lasers) identify the same point in space
- Identify that this point coincides with the isocenter

For electrons:

- Assure automatic setting of the jaw with applicator size

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QA of Radiation Parameters

- Measure OPF for commonly used field sizes and distances; Follow the most current calibration protocol (TG-40)
- Linearity of dose rate
- Accumulated dose termination
- Beam energy
- Field flatness and symmetry

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QA of Radiation Parameters

…Cont.

Arc/Rotations:

- Termination criteria
  (i.e., angle, accumulated MU)
- Reproducibility of total dose
- MU/degree stability

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For Routine Checks of Therapy Units

- Check the constancy on daily, weekly, and monthly basis
  - Base line determined at the time of commission
  - Level of deviation from TG-40
- Check constancy after any machine service
- Create tests to accomplish specific tasks if not listed in TG-40 (e.g., Dynamic wedge, MLC)

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Special Tests

- Dynamic wedge (DW) => created by moving jaw
- Validate DW by using film or diode array
  - Measure profile of DW
  - Compare the profile with various wedge angles
- Independent jaw used for matching fields
  - (e.g., Test for under-lap or over-lap)

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Special Tests …Cont.

- Expose film on one jaw closed to zero and the other jaw open
- Reverse the jaw position and re-expose the film
- Look for overlap and under-lap

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Special Tests …Cont.

For centers using port film devices, check the port film system routinely

- Phantoms available (e.g. Vegas phantom)
- Determine electronic images of the phantom and find the smallest and shallowest holes that can be resolved
- Check against resolution obtained at the time of system acceptance
- Frequency of the tests =>experience of the institution

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QA of Cobalt-60 Units

- Introduced in 1950s as the first high energy photon machines in Rx departments
- Still the mainstay of treatment in developing countries
  - Simpler machine design => little technical support
  - Many applications for H&N and other shallower tumor sites

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QA of Cobalt-60 Units …Cont.

- Safety Aspects
  - Continuous radioactive decay
  - Room never at background radiation level
  - Personnel safety, minimize time spent in the room
  - Test the source integrity at least twice/yr
    - Wipe tests by a physicist or the RSO

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QA of Cobalt-60 Units …Cont.

- Timer error checked at least monthly
  - Graph timer setting vs. reading
  - Extrapolate to intersect the time axis at the timer error value
- Mathematical definition of timer error
  - Measure doses R1 and R2 at times t1 and t2
  - Since the dose rate is constant, by definition:
  - R1=output rate x (t1-TE)
  - R2=output rate x (t2-TE)
  - From these two equations, solve for TE

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QA of Cobalt-60 Units …Cont.

- QA, in general similar to the one described for linear accelerators (Appendix III)
- Additional QA for Co-60 units should include:
  - Monthly timer error
  - Semi-annual tests of source leakage
  - Safety surveys of the machine vault after each Cobalt source exchange

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QA of Simulators

QA of mechanical and imaging aspect:

Mechanical checks, the same as accelerators with similar tolerances

- Imaging parameters:
  - Focal spot size
  - II focus
  - Low contrast detectability
  - Auto brightness system

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QA of Safety Devices of Radiotherapy Machines

- Deadman switch
- Anti-collision devices
- "Beam-on" interlocks
- "Beam-ON" termination monitoring/conditions
- Energy switch photon/electron interlocks
- Retractable beam stopper interlocks
- Console indications
  1. Wedge
  2. Photon/electron status
  3. Electron energy
- Full-field (Portal Film) radiography dose limits
- Emergency stop switches

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QA of Film Processor

- Expose film to a sensitometer and take subsequent densitometer readings and compare to a base line
- Periodic preventative maintenance

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CT-simulation

- A patient is set on the CT table
- An arbitrary set of fiducial marks are placed as a starting reference point
- Many thin CT slices are taken and a virtual patient is created in computer system
- All decisions of isocenter, field placement are made in this virtual environment

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CT-simulation …Cont.

- At the end patient is shifted away from the initial arbitrary fiducials as per instructions from computer and a final set of marks are made.
- These marks will coincide with the treatment setup.

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QA of CT-Simulator

- Look at TG66 for a list of the daily, monthly, and annual QA tests
- Various specific phantoms needed to perform some of these tests
- Consult manufacturer

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QA of CT-simulator ...Cont.

- Check the laser system periodically to assure linearity of drive mechanism
- Assure coincidence of laser zero position with the CT gantry center and with the vertical
- Assure that lateral lasers are co-linear
- Check the movement of CT couch and its readouts

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QA of CT-simulator ...Cont.

- Performance test of CT as an imaging tool
  - CT numbers, density and low contrast resolution
  - Correct image is transferred to the simulation computer system
  - Image scaling and production of DRR’s (special phantom available for these tests)

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QA of Treatment Planning Systems (RTP)

Main documents available to be used for guidance:

- AAPM TG-53 (QA for clinical RTPs)
- AAPM TG-55 (radiation treatment planning verification)
- AAPM TG-23 (acceptance testing of commercial 3-D RTPs)

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QA of Treatment Planning Systems (RTP) …Cont.

- Familiarity of physics staff with details of computational techniques
- Know exactly how and when the system makes approximations
- Test the data input and validate the output results
- Test the peripheral devices associated with RTP system. (e.g.: correct scaling of digitizer, printer & plotter)

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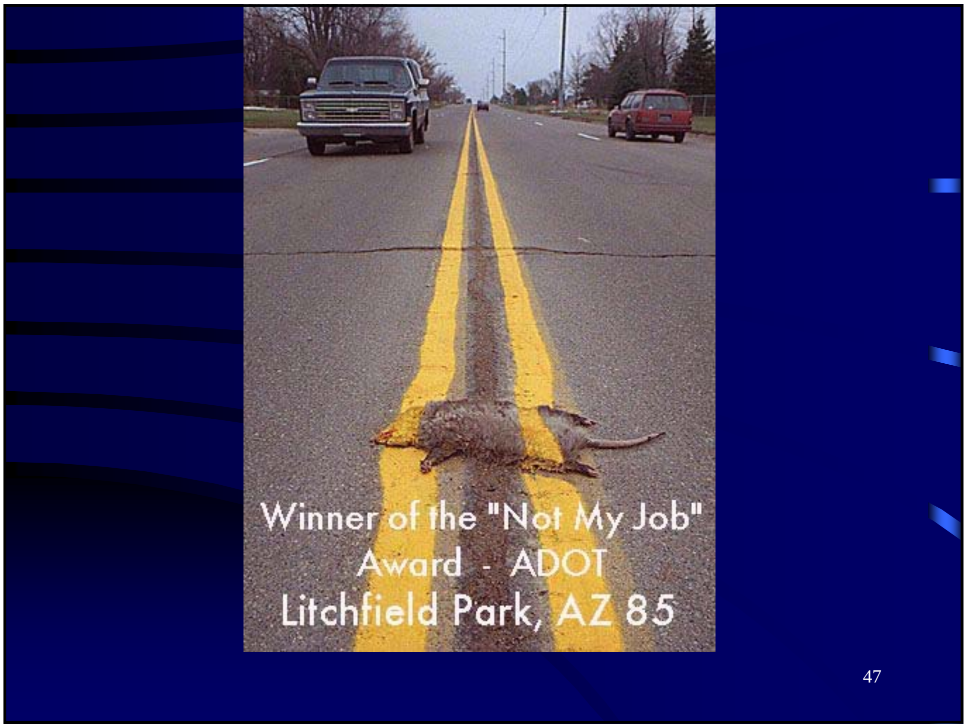

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