Verification of the Radiation Treatment Planning Process: 
“Did We Get It Right?”

Jacob Van Dyk
Consultant, IAEA, Vienna, Austria
Professor, University of Western Ontario, London, Canada
Stages of Radiation Therapy Process

1. Patient Assessment/ Diagnosis
2. Decision to Treat
3. Positioning/ Immobilization
4. Imaging and Volume Determination
5. Treatment Planning and Prescription
6. Treatment Verification
7. Treatment Delivery

Did we get it right?
Evolution of Radiation Treatment Process

- 2-D RT
- 3-D CRT
- IMRT
- DART
- 4-D CT & 4-D delivery
- Real-time 4-D DART
- Increased imaging for planning: CT, MR, PET, 4-D
- More conformal dose delivery: 2-D, 3-D, IMRT, 4-D
- Imaging for IGRT: port films, EPID, MV-kV CT, CBCT, 4-D MV-kV CT, 4-D CBCT, dose warping...
- MORE QA: “Did we get it right?”

Presently available
Still evolving

↑ IMAGING FOR IGRT: PORT FILMS, EPID, MV-kV CT, CBCT, 4-D MV-kV CT, 4-D CBCT, DOSE WARPING...

MORE QA: “Did we get it right?”

IAEA
“Get it right?”

• Accuracy requirements
  • Four considerations:
    1. Slope of dose-effect curves
    2. Level of dose differences that can be detected clinically
    3. Statistical estimates of level of accuracy needed for clinical studies
    4. Level of dose accuracy that will be practically achievable
“Get it right?”

Sample Criteria of Acceptability

- Abs/dose…normal/pt: 1%
- Central ray: 1-2%
- Inner beam: 2-3%
- Outer beam: 2-5%
- Penumbra: 2-3 mm
- Build-up region: 20-50%

IAEA TRS-430, 2005
Accuracy Requirements for IMRT

RPC Criteria of acceptability

Calculated

Film

±7%

4 mm

Courtesy Geoff Ibbott, RPC, Houston, TX
IMRT: Patterns of Variability

“… Figure 1 shows clear evidence of wide dosimetric variation in radiation treatments using IMRT.”

Das, JNCI, 100: 300; 2008

803 patients, 5 institutions, 3 sites: brain (12%), H&N (26%), prostate (62%)
“Getting it Right!”

- Four key considerations
  - Education
  - Documentation
  - Verification
  - Communication
“Getting it Right!”

- **Education**
  - Training in acquisition/implementation/use of:
    - New technologies
    - New dosimetry procedures
    - New imaging procedures
- **Literature**
  - Journal publications
  - International/national task group reports
- Conferences/workshops/courses/…
- Vendors’ users meetings
“Getting it Right!”

- **Documentation**
  - Record keeping
    - “*When you leave, will the new person know what you have done?*”
  - Protocol development
    - Does everyone know how to implement the new procedure?
The average variation of all the treatments of the 76 patients exceeded the prescribed dose by approximately 50%.

Due to an ion chamber that was too large for the small stereotactic fields!

*Alphonso, Med Phys 35: 5179; 2008*
Ion Chambers for Beam Calibration

Photon beams

Electron beams
Detectors for Dosimetry Measurements

small volume detectors
2-D Diode Array for IMRT QA
Detector Size Effects - Penumbra

Sahoo, Med Phys 35: 5124; 2008
"Getting it Right!"

- Radiation detectors
  - Parallel-plate chamber
  - Low-noise “thimble” chamber
  - Small diameter “thimble” chamber
  - Anthropomorphic phantom: TLDs, OSLs
  - IMRT: Small diameter ion chamber, film, Gafchromic film, gel

AAPM TG53
“Getting it Right!”

• Communication
  • Clear understanding on use of terms such as GTV, CTV, PTV, ITV, PRV, margin sizes
• Dose-volume constraints
  • Departmental limits re maximum doses & doses/fraction for specific clinical scenarios
• Treatment set-up for specific techniques
• Treatment protocols
• Dose prescription
• Dose normalization
“Did we get it right?”

• “End-to-end” assessment
  • Identical to patient process
    • CT scan anthropomorphic phantom
    • Physician defines:
      • Target volumes
      • Dose-volume constraints
      • Prescription
    • Treatment planner develops plan
    • Physician approves plan
    • Transfer plan to treatment unit
    • Verify treatment setup with IGRT
    • “Treat” phantom loaded with dosimeters (TLD or OSL), including surface in vivo dosimeters
  • Assess agreement between calculations and measurements
    • Review & evaluate differences
Commercial Phantoms for “End-to-End” Tests
TP & Delivery QA

- Example
- QA at various stages
In Vivo Dosimetry

• Useful … but …
  • Be careful about interpretation … inaccuracies…
    • Measured on skin – want dose at depth
    • Patient set-up variation
      • esp. near junction or near dose gradient
      • Statistical deviation in readings
  • Useful as redundancy check
  • Useful as initial check of treatment
  • Accurate in low dose-gradient regions
Fig. 2. Radiotherapy incidents with adverse patient outcomes (1976–2007) by stage of treatment.
### WHO Risk Profile: Top 3 Interventions

<table>
<thead>
<tr>
<th>Solution</th>
<th>Stage</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning &amp; Immobilization</td>
<td>Incorrect patient positioning</td>
<td>Incorrect immobilization position</td>
</tr>
<tr>
<td>Simulation, imaging &amp; volume determination</td>
<td>Incorrect treatment modalities and beam positioning</td>
<td>Incorrect field size and orientation</td>
</tr>
<tr>
<td>Treatment Information transfer</td>
<td>Incorrect transfer of prescription</td>
<td>Inadequate checking of treatment parameters</td>
</tr>
<tr>
<td>Patient setup</td>
<td>Wrong positioning</td>
<td>Too many fractions or too few</td>
</tr>
<tr>
<td>Independent checking</td>
<td>Incorrect omission of accessories</td>
<td>Inadequate checking of treatment parameters</td>
</tr>
<tr>
<td>Prescribing treatment protocol</td>
<td>Ad hoc alterations of prescriptions</td>
<td>Incorrect positioning of reference points and gantry</td>
</tr>
</tbody>
</table>

#### Planning protocol checklist

- **Planning protocol checklist**
- **Independent checking**
- **Competency certification**
“Did we get it right?”

- Audit
  - Internal
    - Independent
    - Other physicist
    - Other detectors
  - External
    - Independent
    - Other physicist
    - Other detectors
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Revised 2007 (Res. 17)*

PRACTICE GUIDELINE FOR INTENSITY-MODULATED RADIATION THERAPY (IMRT)

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the proper selection and application of treatment, and the utilization of resources for any individual patient, rests with the medical practitioner and the patient who receives that care.

Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

ACR-ASTRO: Practice Guideline for Intensity-Modulated Radiation Therapy (IMRT) 2007

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Summary

- Education
- Training
- Literature
- Conferences
- Vendors
- Documentation
- Record keeping: acceptance, commissioning, QC
- Protocols
Summary

- Verification
  - Measurements
    - Appropriate “tools”
  - Checks
  - Audits
- Communication
  - Prescription
    - Dose-volume constraints
  - Techniques
    - Protocols
  - Encourage questions
  - Incident reporting/learning
  - QA committee
  - “QA culture”

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