Updates and challenges in detector technology: Detectors used in radiotherapy audits

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IDOS
IAEA 2019
Disclosure

• No conflicts related to this presentation
Scope of dosimetry audits

• Range of audit complexity:
  – Reference beam output verification
  – Measurements of basic dosimetry parameters
  – End-to-end complex radiotherapy measures

• There must be accuracy
  – Pass test = good radiotherapy quality
  – Fail test = bad radiotherapy quality

• There must be consistency
  – Day to day, result is the same
  – Different auditing groups, conducting things differently, should produce the same result
Challenge

• How accurately/consistently do detectors perform
  – e.g., TLD vs. alanine (straight forward comparison)
  – Point dose vs. planar (more complicated?)

• Not just detector, must also consider its use

• Detector protocols
  – TRS-398 vs. TG-51

• Readout procedures
  – Calibration, reference conditions, correction factors…. 
  – Well defined for ion chambers, what about TLD, arrays, etc.

• Analysis methods
  – Point dose measurements yield percent difference. This is pretty clear.
  – Planar/volumetric measurement: Myriad flavours of gamma analysis
• Measurements of reference beam output IROC vs. ACDS
  – Same machine, same time
  – Different Farmer-type ion chambers
  – Different calibration protocols
    • TG-51 vs. TRS-398
  – Different water tanks
  – Different setups

<table>
<thead>
<tr>
<th>Energy</th>
<th>IROC:Facility</th>
<th>ACDS:Facility</th>
<th>Difference IROC-ACDS</th>
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<td>1.016</td>
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</table>
More success

- Reference conditions
- Passive dosimeters
- Intercomparisons (2012+)
  - Different detectors
  - Different readout procedures
- Results are consistent
  - Equivalent within uncertainty
- Many accurate and precise options
Added complexity

• What about planar dosimetry?

• On-site audits – arrays may be used
• End-to-end audits of radiotherapy delivery, planar dosimetry is important.
  – Film is a standard tool for remote dosimetry

• Now need to worry about dosimeter performance and analysis
Dosimeter consistency: Film

- Impact on gamma pass rate vs Noise
  - 1%, 2% randomly introduced per pixel
- Scan resolution
- Software (OmnioPro, DoseLab)
- Reference vs evaluated dataset
- 10 clinical IMRT plans
  - 6 passed IMRT QA
  - 4 failed IMRT QA
Dosimeter consistency: Film

- Noise – affects % of pixels passing gamma
  - Depends on which dataset is reference
  - Depends on which software package is used (data processing)
Dig Deeper into Gamma analysis

- 3 plans with numerous simulated errors: 17 error datasets
  - noise, errors in: MLC, dose calibration, collimator angle
- Virtual/computational dataset
  - Doesn’t include measurement or processing uncertainty
- Analysis controlled
- Just different software
  - 6 groups performed analysis
Controller Evaluation!

- Evaluated for gamma using consistent parameters
  - Global normalization, 20% low dose threshold, un-normalized datasets, measured = reference.
- Different software, different physical locations, different people

![Graph showing pass rate for different groups and thresholds](image)

- 3%/3mm
- 2%/2mm
Key thoughts

• Gamma is computationally hard to compute, so lots of shortcuts. Hence different values even for the same input data.

• This is not well managed or understood. AAPM TG-218 report on gamma analysis doesn’t differentiate gamma criteria based on gamma calculation implementation.

• Based on previous slides, easy to understand that gamma has not been found to correlate with plan quality.
Beyond just gamma analysis

- 24 unmodified clinical plans
  - Some good, some concerning
- Doses measured with ion chamber readings in a body phantom
- All plans delivered to a range of devices
  - Single ion chamber
  - Map check
  - Arc Check
  - Film
- Irradiation and analysis methods varied

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<th>Plan</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<td>-1.8%</td>
<td>-0.7%</td>
<td></td>
<td></td>
<td>Y</td>
</tr>
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</table>

Toward optimizing patient-specific IMRT QA techniques in the accurate detection of dosimetrically acceptable and unacceptable patient plans

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When comparing devices, we should have:
- 100% sensitivity, 100% specificity
- “Pass” vs. “Fail” should be consistent

Varied with
- Software
- Device
- How device used
  - Composite vs. field by field
Summary

• Point dosimeters perform consistently under normal conditions
  – Consistent across numerous detectors
  – Consistent across different calibration protocols
  – Challenging cases exist (small fields)

• Planar dosimeters involve more complex analysis and interpretation
  – Usually use computational analysis tools
  – Different programs handle data differently

• Gamma analysis is a major concern
  – Sensitive to noise and resolution – i.e., device characteristics and handling
  – Sensitive to software implementations of gamma calculation
  – Sensitive to detector
  – Sensitive to use of detector
There is substantial uncertainty when trying to define an “acceptable/unacceptable” audit result.

- Result depends on device, irradiation technique, software, noise, etc.
- Documented (not solved) for just the gamma analysis step within audit framework
- Less well documented for different devices/irradiation techniques
  - Ongoing research

Major issue.

- For audits, this impedes consistent interpretation of audit results and intercomparisons between audit groups (accuracy and consistency).
- Not a stationary problem: detectors and software evolve.
- Global Harmonisation Group is trying to tackle this (rtqaharmonization.org)
Questions?