Drivers for In-Vivo Dosimetry

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In-Vivo Drivers: Front-Page Headlines

Hospital error leads to radiation overdoses

A California hospital where a 2-year-old child received a massive overdose of radiation during a series of CT scans has been hit with a $25,000 fine by state regulatory authorities, who found that the facility did not follow its own written policies and procedures regarding radiation safety.
• Radiation Induced Effects are broken into the following categories:
  - **Stochastic**: An all-or-nothing effect whose probability of occurrence increases with dose (e.g. cancer)
    • No minimum dose
    • Effect is linear (double the dose, double the risk)
  - **Deterministic**: An effect whose severity increases with dose (e.g. skin erythema, necrosis, lens opacification)
    • Effects can be acute (appearing in hours or days) or chronic (appearing in years)
    • Acute effects typically occur after a threshold dose
      - ~ 2 Gy for erythema
      - ~ 3 Gy for epilation
      - ~20 Gy for necrosis

**Hair Loss**

**Erythema**

**Necrosis**

**Hair Loss**
Radiation Fundamentals – Radiation Induced Effects

- Our understanding of the long-term biological effects of radiation is limited to some very specific incidents (Hiroshima, Chernobyl, etc.)
- The dose level is relatively high (> 50 Rem)
- Risk is estimated at lower doses using a linear relationship
- The effectiveness of this model is widely debated for “low” doses
  - Biological effects which can repair or increase resistance of the cells must be accounted for

Excess Risk is ~5%/Sv or ~0.05%/Rem

Example: Entrance Dose of 1 Gy to the female breast
Weighting Factor: 0.05
Effective Dose: = 0.05 * 1Gy = 0.05Sv
ERR = 5%/Sv * 0.05Sv = 0.25%

Source: BEIR VII Report
Different Procedures Have Different Concerns…

• Radiology
  – Top concern is acute skin injury
  – Equivalent dose is small making the increased risk of cancer (stochastic effect) minimal

• Oncology
  – Injury to Nearby Organs/Systems
  – Treatment Efficacy
  – Acute Skin Injury
  – Stochastic Risk of Cancer
In-Vivo Measurements

• What is an in-vivo measurement…
  – A measurement made of the dose delivered during a medical procedure
  – Most commonly used in oncology due to the dose being delivered
  – Growing concern for diagnostic procedures such as interventional cardiology
    • Joint Commission sentinel event threshold of 15 Gy

• … and why do people make them???
  – Continuous Quality Improvement
    • Gives the medical physicist(s) information about their daily practices
    • It acts as an additional safeguard against major setup errors, calculation and transcription errors missed in routine chart checks
      • But, an estimate of misadministrations in the USA is 0.002%\(^1\). So why bother?
      • Still, significant and deadly treatment errors can occur\(^2\) that could be avoided with in vivo dosimetry
  – Legal basis
    • Can be used to demonstrate quality of care to the patient
    • Provides objective evidence in the event of a legal inquiry
  – Required by law in many European countries
    • Epinal, France accident
    • Scotland accident


Image Gently Campaign (Radiology)

- Focus is on pediatric treatments; however, many of the principles can be extended to adults
- Demonstrates growing awareness of the need to monitor the dose delivered to patients in diagnostic/interventional procedures
  - CT
  - Nuclear Medicine
  - Fluoroscopy/IR
- [http://www.pedrad.org/associations/5364/ig/](http://www.pedrad.org/associations/5364/ig/)
- Additional radiation safety resources can be found through the American College of Radiology:
AAPM Policies on In Vivo Dosimetry (Oncology)

• While the AAPM states that radiation therapy facilities should have access to in vivo dosimetry, it does not mandate their use, and recommends it in only a few situations.

• The Task Group 40 recommendations state that “In vivo dosimetry can be used to identify any major deviations in the delivery of treatment and to verify and document the dose to critical structures. Institutions should have access to TLD or other in vivo systems.”

• The Task Group 62 report emphasizes that serious errors in radiation dosing are extremely rare and states that “In vivo dosimetry is supplementary, not mandatory, to a good clinical QA program.”

Situations Where In Vivo Dosimetry is Recommended

- Doses to normal structures outside of the treatment fields such as:
  - Eye lens
  - Pacemakers
  - Fetal dose
  - Testicular dose
- “Strongly recommended” for total body irradiation
  - High doses over a small number of fractions
  - Treatment planning system calculations may be less accurate than with most procedures
- Task Group 63 recommends in vivo dosimetry for patients with hip prostheses during the first fraction of treatment
  - Prostheses can cause unpredictable effects to radiation fields

IVD: Pro and Con

• Pro:
  – IVD users appreciate the extra accuracy and quality assurance of in vivo dosimetry.
  – “Occasionally, maybe once a year, you will catch a mistake with in vivo dosimetry. That looks like a pretty low yield, but that is an important finding.”
  – “We will do in vivo dosimetry on a case by case basis, because we want to make sure that these patients with complicated cases are getting what the treatment planning system is calculating.”

• Con:
  – Medical physicists believe that the TPS is, in general, very accurate.
  – “The precision and accuracy is such that there does not seem to be a need for patient-specific diode measurements or in vivo dosimetry. There really isn’t any justification for it, as everything should be covered in QA.”
  – “The computer models that we use are very good at predicting doses. We feel pretty confident with those and double check them, so I don’t see a huge need for in vivo dosimetry.”
IVD: Why Do It???

• “Our machines are well calibrated and the TPS is pretty accurate, so making the measurements doesn’t tell us much.”
• Intrinsically trust the TPS more than they do their ability to make measurements
  – Disagreement between the measurement and TPS becomes more common, creating more work on both ends (measurement and investigation)

• So, if IVD creates more work with little benefit that clinics can only get marginally reimbursed for, then why do it???
IVD: Demonstrating the Need…

The
RPC’s QA Activities
in Support of Clinical Trials

Provided by Geoffrey S. Ibbott, Ph.D.
and the RPC Staff
RPC’s Conventional Monitoring

- Annual checks of machine output
  - 1,580 institutions, 13,729 beams measured with TLD (2007)
    - 30 institutions in Canada, 35 outside of North America
- On-site dosimetry reviews
  - 40 institutions visited (~250 beams measured)
- Credentialing
  - Phantoms, benchmarks, questionnaires, rapid reviews
- Treatment record reviews
  - Review for GOG, NSABP, NCCTG, RTOG (brachy)
- Independent recalculation of patient dose
  - Continue to find errors
## On-Site Dosimetry Review

**Selected discrepancies discovered during 2007**

<table>
<thead>
<tr>
<th>Errors Regarding</th>
<th>Percent of Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review QA Program</td>
<td>(84%)</td>
</tr>
<tr>
<td>*Photon Depth Dose</td>
<td>(30%)</td>
</tr>
<tr>
<td>Switch to TG-51</td>
<td>(24%)</td>
</tr>
<tr>
<td>*Wedge Transmission</td>
<td>(24%)</td>
</tr>
<tr>
<td>*Photon Calibration &amp; FSD</td>
<td>(24%)</td>
</tr>
<tr>
<td>*Electron Calibration</td>
<td>(22%)</td>
</tr>
<tr>
<td>*Off-axis Factors</td>
<td>(16%)</td>
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</tbody>
</table>

Calibration expected to agree within 3%, relative factors should agree within 2%.

95% of the institutions received at least one recommendation while 70% received at least one of the significant dosimetry recommendations (noted by *)
RPC Phantoms

Pelvis (10)

Thorax (13)

H&N IMRT (31)

SRS Head (4)

Liver (2)
**Phantom Results**

- Comparison between institution’s plan and delivered dose
  - Criteria for agreement: 7% or 4 mm DTA (5%/5mm for lung)
  - **Generous by TG 40 standards**

<table>
<thead>
<tr>
<th>Site</th>
<th>Technique</th>
<th>Irradiations</th>
<th>Acceptable irradiations</th>
<th>Institutions acceptable</th>
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<tbody>
<tr>
<td>H&amp;N</td>
<td>IMRT</td>
<td>558</td>
<td>425</td>
<td>377</td>
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<tr>
<td>Pelvis</td>
<td>IMRT</td>
<td>109</td>
<td>89</td>
<td>74</td>
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<tr>
<td>Lung</td>
<td>SBRT/IMRT</td>
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<td>42</td>
<td>35</td>
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<tr>
<td>Liver</td>
<td>SBRT</td>
<td>13</td>
<td>6</td>
<td>6</td>
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<tr>
<td>Benchmark</td>
<td>IMRT</td>
<td>89 (19)</td>
<td>55 (18)</td>
<td></td>
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</tbody>
</table>

*Pass rate now ~80% (up from ~67%)

⇒ 20% did NOT Pass
IVD: Drivers Summary

- No formal regulatory guidance
  - Direction is being “suggested” by specific states and/or institutions
- Views differ from institution to institution depending upon the level of confidence in the medical physics staff regarding their programs
- There is a resistance to implement this on every patient due to time and reimbursement considerations
  - Virtually all physicists feel that the measurements do provide useful information for continuous improvement in their clinics
- Reimbursement is done through the “Special Dosimetry” code; however, this is not intended for use on every patient or every fraction
- Why do it??
  - Most clinics do a good job of properly delivering dose to their patients
    - Objective evidence shows that at least 20% have some issues which may be affecting the quality of care they provide
    - Intrinsic part of a good QA program as it continually forces the clinic to thoroughly understand the treatments they’re providing
  - “Stay out of the news!”