Minimizing Radiation in EOS

Jerry R. Dwek MD
Rady Children’s Hospital and Health Center
San Diego Imaging
University of California at San Diego
Ionizing Radiation

- Ionizing radiation is defined as high energy radiation that can cause ionization in exposed tissues
- X rays are a form of electromagnetic radiation whose photons are powerful enough to cause ionization
Radiation Dose Measurement

- **Absorbed dose**
  - Based on energy absorption in tissues
    - Measured in milligray (mGy)

- **Effective dose**
  - Takes into account biological effect of absorbed dose on target tissue
    - Measured in millisievert (mSv)
Nomenclature

- 1 Gray = the absorption of 1 joule of energy in 1 kg of tissue
- Sievert is Gray multiplied by a quality factor which takes into account the biological effects on specific tissues
- 1 Gray = 100 Rad (radiation absorbed doses)
- 1 Sievert = 100 Rem (radiation equivalent Man)
Deterministic vs. Stochastic

**Deterministic effects**
- Determined by dose
- Nonrandom
- No effect below threshold
- Generally high non-medical doses
  - Burns
  - Cataracts
  - Hair loss
  - Death

**Stochastic Effects**
- Not dose related
- Random
- No threshold?
- Generally low dose
  - severity independent of dose
  - Long latent effect
  - Carcinogenesis
  - Genetic effects
The Question

- Is there a threshold?
What is Evidence for No Threshold

• Data from Hiroshima periphery
  – Cancer rates increased in those exposed to lower levels of radiation
• Average exposure was high relative to diagnostic radiation dose and was administered all at once
Australian Study

- N = 680,000
- Only exposure is diagnostic radiation
- Average dose 4 mSv
- 9.38 excess cancers per 100,000 people

CONCLUSION: radiation even at low dose diagnostic radiation levels causes cancer

Mathews et al BMJ
2013
Most Accepted Model

- Linear No Threshold is the most accepted model.
- Note that background cancer risk and cosmic radiation confounds analysis.
Sievert in Context

- USA background dose at sea level = 3 mSv/year
- Denver = 2 x sea level dose (6 mSv)
- Flight from NYC to Seattle = 26 mSv
- Flight from DC to LAX = 17 mSv
Sievert in Context

- Set of dental films = 5-10 uSv
- Estimated maximum dose to those evacuated from close around Fukushima = 68 mSv
- Highest dose to worker responding to Fukushima crisis = 0.67 Sv
- Average fatal dose Goiania incident 4.5-6 Sv
# Sample Doses

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Dose</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 view ankle</td>
<td>.0015 mSv</td>
<td>1/14 cxr</td>
</tr>
<tr>
<td>2 view chest</td>
<td>.02</td>
<td>1</td>
</tr>
<tr>
<td>AP, Lat abdomen</td>
<td>.05</td>
<td>2 ½</td>
</tr>
<tr>
<td>Head CT</td>
<td>4</td>
<td>200</td>
</tr>
<tr>
<td>Abdomen CT</td>
<td>5</td>
<td>250</td>
</tr>
<tr>
<td>PA scoliosis</td>
<td>.140</td>
<td>7</td>
</tr>
<tr>
<td>CT spine</td>
<td>4-12</td>
<td>200-600</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td><strong>Medium</strong></td>
<td><strong>Low</strong></td>
</tr>
<tr>
<td>------------------</td>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Lymphoid Tissue</td>
<td>Skin</td>
<td>Muscle</td>
</tr>
<tr>
<td>Bone Marrow</td>
<td>Lens</td>
<td>Bone</td>
</tr>
<tr>
<td>GI Epithelium</td>
<td>Lung</td>
<td>Connective tissue</td>
</tr>
<tr>
<td>Gonads</td>
<td>Kidney</td>
<td>Cartilage</td>
</tr>
<tr>
<td>Embryo / Fetus</td>
<td>Liver</td>
<td>Brain</td>
</tr>
</tbody>
</table>

Courtesy Michael Callahan MD
CT Risk

- Primary source of medical radiation is CT
- 1996-2005 saw doubling of exam numbers below age 5yo
  - Triple from age 5-14yo
- 1980 3 million exams
- 2005 68 million
Measuring CT Dose

• Not possible without extra software and machinery
• Dose reported on console is not accurate
  – CTDI vs. DLP
CTDI vs. DLP vs. Effective Dose

- **CTDI** = total dose to a certain size volume measured by phantom
  - Most patients are smaller than a 32 cm phantom
    - Dose therefore larger

- **DLP** = CTDI x the length of the patient scanned
  - Both are helpful in determining dose but are more important to compare scanners and protocols
**Effective Dose**

- Calculated as the sum of the doses to each organ weighted by the radiosensitivity of the organ
- Uses DLP x dose conversion coefficients (k factor)
  - Still does not account for body size (girth)
• New software which allows reasonably accurate calculation of effective dose
• New software development spurred by California reporting law
Radimetrics

- Also allows analysis of dose by modality and operator
• Estimates lifetime cancer risk using atomic bomb data
  – 1 abdominal CT = 1 in 550
  – 1 head CT = 1 in 1500
  – Strong evidence for increased risk at > 100 mSv
  – Good evidence 50-100 mSv
  – Reasonable evidence 10-50 mSv
• N=178,000 people

• 1 head CT before the age of 10 YO = 1 excess leukemia and 1 brain tumor/10,000 people
Risk Estimates

• Vary greatly
  – National research council
    • 0.10% increase for a 10mSv exam
    • FDA estimates 0.05% risk increase
• One best guess
  – 1 in 500-1000 risk of cancer death from a single CT
Bottom Line

- Risk is miniscule compared to background risk of cancer (1 in 3)
- If the study is indicated the benefits always outweigh risk
- If study is NOT indicated, benefit never outweighs risk
Things To Consider

- Does exam need to be done
- Is there another way to get the appropriate data
- How can dose be decreased and still have diagnostic exam as low as reasonably achievable (ALARA)
Does Exam Need to Be Done

- Will information obtained change the approach?
- Will information obtained benefit the patient?
Is There Another Way To Get Information

Ultrasound  Physical Exam  MRI
Am I The Problem

- Lack of willingness to change and adapt
  - MRI can replace much of CT information
    - Can provide critical information of bone structure and form

- Think of goals and make decisions based on necessity not rote
Zero radiation vs. direct gonadal exposure...you be the judge
Zero radiation vs. low dose radiation to an extremity plus scatter, what would you want?

Physeal Bridge
MRI Has A Decided Advantage

MRI allows mapping of bridges for surgical planning
Methods of Decreasing Dose

• Decrease the number of surveillance exams
• Decrease dose from each exam
  – Technique
  – Raising mA in radiographs does not improve image

http://www.upstate.edu/radiology/education/rsna/radiography/issues/
But which image is good enough

Increasing mA does improve CT image
Decrease Dose From Each Exam

- Collimate
  - Immediate decrease
- Shield
  - Underutilized
    - 7-10x reduction
- PA vs. AP
  - Once patient can stand
- Decrease technique
  - Doesn’t have to look pretty
EOS System

• Uses low dose radiation to obtain frontal and lateral images as well as 3D images in a fraction of dose (7x lower)
EOS System

- Two thin fan shaped beams
- Two detectors
- Moving beam
- Excellent dose suppression
- Large reduction
How Is Reduction Achieved

- Thinly collimated beams
  - 0.5mm thick
  - Decreased scatter
- Detector changes
  - Detector signal amplification
Artifacts

• Slow acquisition can yield summation artifacts
The Bottom Line

- Risk from diagnostic radiation is there but very low
- An indicated exam will always have a better benefit for the risk
- An unindicated exam will never have a benefit that outweighs the risk
  - For an unindicated exam the benefit is zero and it will remain zero
Image Gently