Don’t Electrocute Me!:
Common Misconceptions in Imaging and Radiation Safety
(and What to Do About Them)

Rebecca Milman Marsh, Ph.D.
University of Colorado
Department of Radiology

Who in the Facility Works With/Around Radiation?

- Radiologists
- Radiation Oncologists
- Technologists
- Non-radiology physicians
  - Anesthesiologists
  - OB/Gyn
  - Cardiologists
  - Pain Management
  - Surgeons
  - ER physicians
- Nursing staff in multiple departments

Staff should understand what the risks are and what the risks are not

- Make well-informed choices concerning their own well-being
- Make well-informed choices about patients’ medical care
- Communicate risks (or lack thereof) to patients
  - Allows patients to make well-informed decisions about their own health care
  - Allows patients to make well-informed decisions about their own health care
# 1  “My personnel dosimeter will stop the radiation.”

# 1a “These latex gloves will protect me from the radiation”

Take-home message: Understand what protects you from radiation and what doesn’t.

# 2  “If one lead apron is good, then two must be better.”

Lead Aprons & Thyroid Shields
• 0.5mm Pb-equivalent material attenuates about 98% of scattered X-rays

[Image of Lead Aprons & Thyroid Shields]

Reported Spine Problems (invasive cardiologists)**
- Spine: 42%
- Hip, knee, ankle: 28%
- General population: 27.4%

Annual: 1 mSv

2% of X-rays get through

Annual: 0.02 mSv

0.54% of X-rays get through


** Goldstein et al., Cath Cardi Int. 2004.
# 2  "If one lead apron is good, then two must be better."

Lead Aprons & Thyroid Shields
- 0.5mm Pb-equivalent material attenuates about 98% of scattered X-rays*

Is the added dose savings biologically significant?

Annual Dose Limit
50 mSv
Pregnant Radiation Workers:
0.5 mSv/month to the fetus

UCH Notification Levels:
ALARA 1: 10%
ALARA 2: 20%

# 2a  Give me lead underwear!!

- Recent data (IAEA 2011) suggest a lens dose threshold of 500 mSv (thought to be cumulative)
- NCRP recommends a maximum eye dose of 20 mSv/year with no single year exceeding 50 mSv

Dose to the lens per exam: 0.3 mSv (.01 mSv – 0.55 mSv) (NCRP 168)

0.75mm Pb-equivalent > 98% of X-rays blocked*

0.012 mSv (1667 exams/year)

0.1 mSv (67 exams/year)

# 2a  Give me lead underwear!!
One study showed that using a leaded hat reduced dose to the temple by 72%.

Threshold for effects to the brain from acute doses of radiation:

300 mSv

<table>
<thead>
<tr>
<th>ESE per case (uGy)</th>
<th>Effective Dose, considering brain sensitivity &amp; skull attenuation (uSv)</th>
<th># of cases it would take to reach 300 mSv</th>
<th>Cases per year (45 year career)</th>
</tr>
</thead>
<tbody>
<tr>
<td>without hat</td>
<td>200</td>
<td>&gt; 200,000</td>
<td>&gt; 5,000</td>
</tr>
<tr>
<td>with hat</td>
<td>56</td>
<td>&gt; 800,000</td>
<td>&gt; 17,000</td>
</tr>
</tbody>
</table>

Reeves, Society of Cardiovascular Angiography and Interventions (2014)

Recent studies:

* Placing a lead shield on the patient, and using a non-lead cap, reduced operator dose by 75% (2014 College of Cardiology conference)

* Placing a lead shield on the patient decreased operator dose (under the operator’s lead apron) by almost 70% for trans-radial interventions (Masallan et al., Catheterization and Cardiovascular Interventions, December 2014)

Decreased the dose per procedure from 0.53 µSv to 0.17 µSv

(All of about 3100 mGy for each procedure)

**“Placing a lead apron on the patient will reduce operator dose.”**

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**# 2a** Give me lead underwear!!

**# 2b** "Placing a lead apron on the patient will reduce operator dose."

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**II**

90 deg

30 deg

60 deg

90 deg

120 deg

2 m

With no Pb apron on the phantom

With an apron wrapped around the phantom

With an apron on the phantom and an apron in front of the scatter detector

With no apron on the phantom and an apron in front of the scatter detector
**# 2b** “Placing a lead apron on the patient will reduce operator dose.”

<table>
<thead>
<tr>
<th>Radiation Exposure to the Fetus</th>
<th>Increased Probability of Fetal Malformation or Miscarriage</th>
<th>Probability of Developing Childhood Cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>2nd or 3rd Trimester</td>
<td>0.07%</td>
</tr>
<tr>
<td>10 mGy</td>
<td>2nd or 3rd Trimester</td>
<td>0.25%</td>
</tr>
<tr>
<td>50 mGy</td>
<td>2nd or 3rd Trimester</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

**Take-home message:**
Understand the limitations of protective equipment, and the risks associated with its over-use.

**With no Pb apron on the phantom**

**With an apron wrapped around the phantom**

**With an apron on the phantom and an apron in front of the scatter detector**

**With no apron on the phantom and an apron in front of the scatter detector**

NQT is a statistically significant difference.

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**# 3** “I would never let my pregnant wife get a head CT exam.”

[Image of a pregnant woman with a diagram of radiation exposure]


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**# 3** “I would never let my pregnant wife get a head CT exam.”

<table>
<thead>
<tr>
<th>Exam</th>
<th>Typical Dose to the Fetus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammography (both breasts)</td>
<td>&lt; 0.001 mSv</td>
</tr>
<tr>
<td>DEXA</td>
<td>&lt; 0.001 mSv</td>
</tr>
<tr>
<td>X-ray</td>
<td>&lt; 0.003 mSv</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>1 mSv</td>
</tr>
<tr>
<td>Abdomen or pelvis</td>
<td>2 mSv</td>
</tr>
<tr>
<td>Fluoroscopy</td>
<td></td>
</tr>
<tr>
<td>Small-bowel study</td>
<td>7 mSv</td>
</tr>
<tr>
<td>Double-contrast barium enema study</td>
<td>7 mSv</td>
</tr>
<tr>
<td>CT</td>
<td>&lt; 1 mSv</td>
</tr>
<tr>
<td>Head, Neck, Extremity, or Chest</td>
<td>4 mSv</td>
</tr>
<tr>
<td>Abdomen CT</td>
<td>20 mSv</td>
</tr>
</tbody>
</table>

Exam Typical Fetal Dose

| CT Scout                      | < 0.5 mSv                 |
| Extremity                     | < 0.01 mSv                |
| Chest (including for PE)      | 0.3 mSv                   |
| Abdomen                       | 4 mSv                     |
| Abdomen & Pelvis              | 25 mSv                    |
| Head                          | Not Measurable             |


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  - Abdomen + Pelvis CT: 20 mSv
**# 3** “I would never let my pregnant wife get a head CT exam.”

*Suggested Key Points to Use When Discussing Radiation Risk with Pregnant Patients*
- “We assess the appropriateness of every exam for every patient and have determined that this exam is to help provide you with the best care possible.”
- “It is much more likely that you will benefit from the information provided by this exam than you or your child will experience any harm from the exam.”
- “There is a risk associated with not having a medically indicated CT exam.”

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**# 4** “Fluoro and cine mode have the same dose rate.”

Studies have found that the dose rate for cine acquisitions is **10 to 13 times higher** than for fluoro modes.*

* Cusma et al., JAC Cardiology 1999.

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**# 4a** “Room X always results in higher doses than Room Y”

<table>
<thead>
<tr>
<th>Room</th>
<th>AK (mGy)</th>
<th>Fluoro Time (min)</th>
<th># DSA Images</th>
<th># Single Shot Images</th>
<th>Patient Size (BMI)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Y1</td>
<td>3180</td>
<td>35.4</td>
<td>165</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Room Y2</td>
<td>2880</td>
<td>36.7</td>
<td>226</td>
<td>11.4</td>
<td></td>
</tr>
<tr>
<td>Room X (New Room)</td>
<td>4657</td>
<td>53.3</td>
<td>776</td>
<td>19.8</td>
<td></td>
</tr>
<tr>
<td>Patient Case</td>
<td>7000</td>
<td>100</td>
<td>505</td>
<td>56</td>
<td></td>
</tr>
</tbody>
</table>

Take-home message:
Air Kerma, and hence patient exposure, is affected by many factors.
Who works in this area?

- Vascular surgeons
- OR nurses
- Anesthesiologists
- OB staff
- NICU staff

“Radiation was spilling out of the room.”  “I saw a fetus with radiation burns.”

A lack of information can cause rumors to get out of hand very quickly.

“But do you mean the emitted CTDI_{vol} or the absorbed CTDI_{vol}?"

“The CTDI_{vol} for an adult abdomen exam should never be above 25 mGy.”

“The CTDI_{vol} for an adult abdomen exam should never be above 25 mGy.”

<table>
<thead>
<tr>
<th>ACR CT Accreditation Dose Pass/Fail Criteria and Reference Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Examination</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Adult Head</td>
</tr>
<tr>
<td>Adult Abdominal</td>
</tr>
<tr>
<td>Pediatric Head (1 year old)</td>
</tr>
<tr>
<td>Pediatric Abdomen (40-60 lb)</td>
</tr>
</tbody>
</table>
---

### #6 CTDI<sub>vol</sub>

<table>
<thead>
<tr>
<th>Scan</th>
<th>kV</th>
<th>mAs</th>
<th>ref</th>
<th>CTDI&lt;sub&gt;head&lt;/sub&gt;</th>
<th>CTDI&lt;sub&gt;body&lt;/sub&gt;</th>
<th>OLP</th>
<th>DLP</th>
<th>TIs</th>
<th>CSE</th>
<th>mlGy/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>35 mAs</td>
<td>0.09 L</td>
<td>22.95 mGy</td>
<td>22.95 mGy</td>
<td>5</td>
<td>6.3</td>
<td>0.6</td>
<td>200 mGAs</td>
<td>20 mGy</td>
</tr>
<tr>
<td>2</td>
<td>140</td>
<td>28 mAs</td>
<td>113 L</td>
<td>25.74 mGy</td>
<td>25.74 mGy</td>
<td>1.3</td>
<td>0.5</td>
<td>0.6</td>
<td>200 mGAs</td>
<td>20 mGy</td>
</tr>
<tr>
<td>3</td>
<td>140</td>
<td>230 mAs</td>
<td>113 L</td>
<td>23.95 mGy</td>
<td>23.95 mGy</td>
<td>180</td>
<td>0.5</td>
<td>0.6</td>
<td>200 mGAs</td>
<td>20 mGy</td>
</tr>
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</table>

**CTDI<sub>vol</sub> = 22.95 mGy**

Scan length = 
22.95 mGy * 47.89 cm = 1099 mGy*cm

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**CTDI ≠ Patient Dose**

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**Which patient received a higher dose?**

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CTDI<sub>vol</sub> = 20 mGy

What about Image Quality?

CTDI<sub>vol</sub> = 20 mGy

300 mAs

200 mAs

Take-home message:
We expect CTDI<sub>vol</sub> to be higher for larger patients.

# 6a “We want to have the lowest CT dose in town”

What are the key goals in diagnostic radiology?

To provide images that allow physicians to make accurate diagnoses, putting the patient at as little risk as possible to achieve this goal.
What are the key goals in diagnostic radiology?

To provide images that allow physicians to make accurate diagnoses, putting the patient at as little risk as possible to achieve this goal.

How low is too low?

### #6a “We want to have the lowest CT dose in town”

<table>
<thead>
<tr>
<th>Exam</th>
<th>Site median CTDIvol (mGy)</th>
<th>Compared to Other Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEST WO IVCON</td>
<td>10</td>
<td>25&lt;sup&gt;th&lt;/sup&gt;–50&lt;sup&gt;th&lt;/sup&gt; percentile</td>
</tr>
<tr>
<td>Pelvis WO IVCON</td>
<td>30</td>
<td>50&lt;sup&gt;th&lt;/sup&gt; – 75&lt;sup&gt;th&lt;/sup&gt; percentile</td>
</tr>
<tr>
<td>ABDOMEN</td>
<td>8</td>
<td>&lt; 25&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
</tr>
<tr>
<td>HEAD</td>
<td>75</td>
<td>&gt; 75&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
</tr>
</tbody>
</table>

Where do we want to be?

Understanding the role and limitations of dose indices is vitally important.

**Take-home message:**
Understanding the role and limitations of dose indices is vitally important.

**Effects of Magnification**

<table>
<thead>
<tr>
<th>FOV (cm)</th>
<th>Dose Rate (mGy/min)</th>
<th>Relative Dose Rate of Primary Beam (Meas./Theory)</th>
<th>Relative DAP Rate (Meas.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12”</td>
<td>10</td>
<td>1 / 1</td>
<td>1</td>
</tr>
<tr>
<td>9”</td>
<td>1.13 / 1.78</td>
<td>0.64</td>
<td>0.92</td>
</tr>
<tr>
<td>7”</td>
<td>1.38 / 2.04</td>
<td>0.47</td>
<td>0.70</td>
</tr>
</tbody>
</table>

**OEC 9800 Plus**

**Philips Pulsera 650**

“**I mag up to collimate.**"
**# 7** “I mag up to collimate.”

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>12&quot;</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6.2&quot;</td>
<td>1</td>
<td>0.27</td>
</tr>
</tbody>
</table>

**Effects of Collimation**

**Effects of Magnification**

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<td>0.47</td>
</tr>
</tbody>
</table>

**Take-home message:**
Collimating is preferable to magging up, when possible.

**# 8** “Since you’re not scanning a patient, can I take this tire iron into the MR scanner room?”

![Image of a tire iron and caution signs]

**Mumbai, Nov 2014**

**# 8** “Since you’re not scanning a patient, can I take this tire iron into the MR scanner room?”

![Image of a tire iron and technician]

**Mumbai, Nov 2014**
# 8  “Since you’re not scanning a patient, can I take this tire iron into the MR scanner room?”

# 8a  “How much dose will my patient get from his MRI?”

Take-home message:
People don’t pay attention to signs.

# 9  “Your risk of developing cancer from this imaging exam is 2%”

Take-home message:
Resist the urge to take the easy road.

≠

"1 in 16 women will develop lung cancer in their lifetime"

"You have a 1 in 16 chance of developing lung cancer"

Models of radiation risk were never meant to be applied to an individual
Summary

• Tell them not to worry about it and that you know it’s okay (this rarely works)
• Show them physics test results (this never works)
• Show them complete data (including number of acquisitions and/or patient size)
• Give them specific examples
• Compare these data with similar studies in the literature (when possible)
• “Trickle up” theory: Inform the technologists, nursing staff, and residents
• Try to predict when misunderstandings may occur (new rooms, equipment, etc.)
• Maintain a presence in the clinic
• Be patient

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