WHAT IS THE REAL RISK OF RADIATION EXPOSURE FROM MEDICAL IMAGING?

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I have no disclosures, financial or otherwise, to report.
OBJECTIVES

• Understand the reasons for concern about radiation exposure from medical imaging
• Learn basic radiobiology and radiation dosimetry
• Discuss evidence and consensus opinions on the risks of radiation
• Identify strategies to minimize radiation exposure for patients
“Off hand, I'd say you're suffering from an arrow through your head, but just to play it safe, I'm ordering a CT scan!”
QUESTION 1

CT scan of the abd/pelvis with and without contrast results in an effective radiation dose similar to:

A: One transatlantic flight
B: 10 chest radiographs
C: Average exposure of Japanese atomic bomb survivors
D: A block of kryptonite
QUESTION 2

According to modern risk models, what percentage of cancers in the US are attributable to radiation from CT scans?

A: Definitely none, there is no risk of cancer
B. Probably none, the risk is only theoretical
C: 0.01%
D: 1.5 to 2.0%
HOW OTHERS FARED

- Survey of radiologists and ER docs
  - 75% significantly underestimated radiation dose from CT
  - 53% of radiologists and 91% of ER docs did not think CT scans increase the risk of cancer
OBJECTIVES

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• Learn basic radiobiology and radiation dosimetry

• Discuss evidence and consensus opinions on the risks of radiation

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BENEFITS OF MEDICAL IMAGING

- Earlier and more accurate diagnosis of disease
- Non-invasive
- Screening tool
- Reassurance
HARMS ASSOCIATED WITH IMAGING

- Radiation exposure
- False positives: unnecessary follow-up testing, psychological distress, resource utilization
- Incidental findings: cascade of testing to rule out disease
- Overdiagnosis: unnecessary treatment
- Contrast reactions: some major, most minor
- Healthcare costs
FEAR OF RADIATION: WHY NOW?

• Marked increase in radiation exposure from medical imaging

• Radiation overdoses (Mad River, Cedars-Sinai) leading to lay press activity

• Xrays classified as carcinogens by WHO, CDC, NIEHS
RADIATION EXPOSURE FROM CT

- 3 million CT scans in 1980
- Almost 70 million in 2007
- Imaging rate has tripled in last 10 years
Rising Use Of Diagnostic Medical Imaging In A Large Integrated Health System

The use of imaging has skyrocketed in the past decade, but no one patient population or medical condition is responsible.

by Rebecca Smith-Bindman, Diana L. Miglioretti, and Eric B. Larson

### EXHIBIT 1
Cross-Sectional Imaging Tests Per Thousand Enrollees Per Year, 1997–2006

<table>
<thead>
<tr>
<th>Tests per thousand enrollees</th>
<th>1997</th>
<th>1999</th>
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<tr>
<td>Ultrasound</td>
<td>200</td>
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<tr>
<td>Nuclear medicine</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
</tr>
</tbody>
</table>

**SOURCE:** Group Health Cooperative data.
UTILIZATION OF MEDICAL IMAGING: CT

RADIATION EXPOSURE OF US PUBLIC HAS DOUBLED DUE TO MEDICAL IMAGING

1985: total 3.7 mSv
75% from natural sources
25% imaging

2006: total 6.2 mSv
50% from natural sources
50% imaging
RADIATION FEAR: HISTORY

- Marie Curie
- Nobel prize for work in physics and chemistry
- Died of aplastic anemia
- Her papers from the 1890s are considered too dangerous to handle due to high radioactivity
RADIATION FEAR: CONTEMPORARY

- Arcata, CA 2008
- CT head ordered for 2 ½ year old boy in ER
- Technician erroneously scanned same 3mm slice 151 times
RADIATION FEAR: CONTEMPORARY

• Cedars-Sinai Medical Center, 2008-2009
• 206 stroke patients receiving brain perfusion imaging
• Software malfunction resulted in administration of 8 times the maximum dose
RADIATION FEAR: RECENT STUDIES

- Exposure to Low-Dose Ionizing Radiation from Medical Imaging Procedures. NEJM, Number 9 Volume 361:849-857 Reza Fazel, M.D., et. Al
  - Collected CT data from 5 Healthcare markets from 2005-2007
  - Categorized effective radiation doses into 4 categories:
    - Low (<3mSv):
    - Moderate (>3-20mSv): 19.4% of enrollees
    - High (>20-50mSv): 1.9% of enrollees
    - Very high (>50mSv): .19% of enrollees
RADIATION DOSES FROM CT: HIGH AND VARIABLE

- Smith-Bindman et al., *Arch Intern Med*
  - Study of 4 facilities in San Francisco Bay area
  - Adults, median age 59 years
  - January 1 – May 30 2008
- Dose from CT 1.5 to 5 times higher than cited
  - Higher than necessary for diagnosis
- Wide variability in dose for same test and indication
  - Vary 15-20 times among facilities
  - Even greater variation among patients
  - Expect ~2 fold variation due to difference in body habitus
## VARIATION ACROSS FACILITY AND PATIENT

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>Site 4</th>
<th>Range Across Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Head</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Routine head</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>0.3 – 6</td>
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<tr>
<td>Suspected stroke</td>
<td>18</td>
<td>15</td>
<td>8</td>
<td>29</td>
<td>4 – 56</td>
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<tr>
<td><strong>Chest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Routine chest</td>
<td>6</td>
<td>12</td>
<td>11</td>
<td>7</td>
<td>2 – 24</td>
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<tr>
<td>Suspected PE</td>
<td>8</td>
<td>21</td>
<td>9</td>
<td>9</td>
<td>2 – 30</td>
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<tr>
<td>Coronary angiogram</td>
<td>21</td>
<td>20</td>
<td></td>
<td></td>
<td>7 – 39</td>
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<tr>
<td><strong>Abdomen-pelvis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Routine</td>
<td>12</td>
<td>19</td>
<td>20</td>
<td>12</td>
<td>4 – 45</td>
</tr>
<tr>
<td>Multiphase</td>
<td>24</td>
<td>35</td>
<td>45</td>
<td>34</td>
<td>6 – 90</td>
</tr>
</tbody>
</table>

Smith-Bindman et al., *Arch Intern Med*, 2009
VARIATION ACROSS FACILITY AND PATIENT

Smith-Bindman et al., Arch Intern Med, 2009
VARIATION ACROSS FACILITY AND PATIENT

Average exposure among Japanese atomic bomb survivors

Smith-Bindman et al., Arch Intern Med, 2009
RADIATION EXPOSURE

• Risks associated with radiation are not new
• Dramatic increase in exposure to ionizing radiation is the issue
OBJECTIVES

• Understand the reasons for concern about radiation exposure from medical imaging

• *Learn basic radiobiology and radiation dosimetry*

• Discuss evidence and consensus opinions on the risks of radiation

• Identify strategies to minimize radiation exposure for patients
Classic Paradigm of Radiation Injury (High Dose)

- Chemical "Repair" (ions recombine)
- Damaged non-DNA molecules replaced
- Enzymatic DNA Repair

Ionizations = Chemical changes (Free radical formation, etc.)

DNA Damage

- Unrepaired, Misrepaired DNA

Cell Deaths - many

- Developmental Effects (fetal)
- Late Effects of Radiation Damage
- Early Effects Radiation Sickness

Mutant Cell

- Germ line
- Somatic (Malignant Transformation)

Cancer

Cell Microenvironment

(Damaged at high doses; cannot protect itself)

< 1 Second — Min - Hours — Days - Decades
Low Doses show other pathways....

Ionizations = Chemical changes
(Free radical formation, etc)

Ionizing Radiation

Excitations

Heat

Ionizations

Chemical "Repair"
(ions recombine)

Damaged non-DNA molecules replaced

Enzymatic DNA Repair

Enhanced DNA Repair

Cell repopulation

Cell Deaths—few

DNA Damage

Unrepaired, Misrepaired DNA

Altered antioxidant status

Altered DNA Repair

Molecular sensors trigger altered activity

Microenvironment

(Protects multi-cellular organism at low doses)

< 1 Second — Min - Hours — Days - Decades

Developmental Effects (fetal)

Late Effects of Radiation Damage

Early Effects Radiation Sickness

Heritable Genetic Effects

Cancer

Suppression of cancer phenotype

Germ line

Somatic

(Malignant Transformation)

Apoptosis

More Efficient

Mutant Cell

Radiation Biology
BIOLISTIC EFFECTS OF RADIATION

• Stochastic effects

• Deterministic effects
STOCHASTIC EFFECTS

• “All or none” effect from exposure to low-dose radiation
• Severity independent of dose
• No “safe” threshold dose (probability of biological effect increases with dose)
• May take many years (or a lifetime) to manifest
• Carcinogenesis and genetic effects
DETERMINISTIC EFFECTS

- Result from high dose radiation exposure
- Severity is dose dependent
- Threshold concept applies
- Ex: hair loss, cataracts, skin changes, GI effects, reproductive damage, death
DETERMINISTIC EFFECTS: BAND ALOPECIA
RADIATION MEASUREMENTS

- **Activity (Becquerel)**

- **Absorbed dose (Gray = 100 rad)**
  - 1 joule of energy deposited per kg

- **Effective dose (Sievert):** takes into account type of radiation (gamma vs x-rays) and tissue sensitivity
  - Sievert = Gray * Q * N
    - Q, quality (photons/electrons = 1, alpha particles = 20)
    - N depends on body tissue
      - Most tissues ~ 0.05
      - Gonads ~ 0.2
      - Bone marrow, colon, lung, stomach = 0.12
# Tissue Radiosensitivity

<table>
<thead>
<tr>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lymphoid Tissue</td>
<td>Skin</td>
<td>Muscle</td>
</tr>
<tr>
<td>Marrow</td>
<td>Vascular endothelium</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>Embryos</td>
<td>Liver</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lens</td>
<td></td>
</tr>
</tbody>
</table>
MODELS TO DETERMINE RADIATION RISK

- **Linear no-threshold (LNT)**
  - Risk of stochastic health effects increases linearly with biologically effective absorbed dose
  - Implies there is risk even to low levels of radiation
  - Most widely accepted model

- **Linear with threshold**
  - Risk increases linearly with exposure after exposure crosses a threshold level
  - Implies that low levels of radiation does not have any risk

- **Hormesis**
  - Low doses of radiation are beneficial whereas high doses are harmful
  - Widely rejected
Models for the Health Risks from Exposure to Low Levels of Ionizing Radiation
RADIATION MEASURES FOR CT

• $\text{CTDI}_{\text{VOL}}$: volume CT dose index (mGy)

• DLP: Dose length product (mGy-cm)
CT RADIATION MEASUREMENTS: CTDI

- $\text{CTD}_{VOL} (\text{mGy})$
  
  - Represents radiation dose of a single CT slice using plastic "phantoms" either 16 or 32cm in diameter.
CT RADIATION MEASUREMENTS: DLP

- DLP (mGy-cm)
  - $\text{CTDI}_{\text{VOL}} \times \text{scan length}$
  - Represents integrated dose across scan length
  - Can be multiplied by conversion factor to yield estimate of effective dose
CT RADIATION MEASUREMENTS

- CTDI$_{vol}$ and DLP are shown on modern CT scanners
- Useful for comparing CT protocols between scanners
- Do NOT represent effective dose (mSv)
- Can be used to estimate effective dose using tissue conversion factors
Exam Information
Study ID: 50795
Time: Feb 11, 2013, 19:40:15
Total DLP: 1638.2 mGy*cm
Estimated Dose Savings: 19%

Dose
<table>
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<tr>
<th>#</th>
<th>Description</th>
<th>Scan Mode</th>
<th>mAs</th>
<th>kV</th>
<th>CTDIvol (mGy)</th>
<th>DLP (mGy*cm)</th>
<th>Phantom Type (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCOUT</td>
<td>Surview</td>
<td>1</td>
<td>120</td>
<td>0.08</td>
<td>4.5</td>
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<tr>
<td>2</td>
<td>ABD/PEL W/O 3X3</td>
<td>Helical</td>
<td>451</td>
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<td>29.17</td>
<td>1633.7</td>
<td>BODY 32 CM</td>
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</table>
Exam Information
Study ID: 51233
Total DLP: 3350.6 mGy*cm
Estimated Dose Savings: 6%

Dose
<table>
<thead>
<tr>
<th>#</th>
<th>Description</th>
<th>Scan Mode</th>
<th>mAs</th>
<th>kV</th>
<th>CTDIvol [mGy]</th>
<th>DLP [mGy*cm]</th>
<th>Phantom Type [cm]</th>
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</thead>
<tbody>
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<td>Surview</td>
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<td>1</td>
<td>80</td>
<td>0.02</td>
<td>1.2</td>
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<tr>
<td>2</td>
<td>A/P W/O</td>
<td>Helical</td>
<td>349</td>
<td>120</td>
<td>22.56</td>
<td>1221.3</td>
<td>BODY 32 CM</td>
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<tr>
<td>4</td>
<td>locator</td>
<td>Stationary</td>
<td>N/A</td>
<td>120</td>
<td>8.77</td>
<td>8.8</td>
<td>BODY 32 CM</td>
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<tr>
<td>5</td>
<td>locator</td>
<td>Stationary</td>
<td>N/A</td>
<td>120</td>
<td>8.72</td>
<td>8.7</td>
<td>BODY 32 CM</td>
</tr>
<tr>
<td>6</td>
<td>tracker</td>
<td>Stationary</td>
<td>N/A</td>
<td>120</td>
<td>17.54</td>
<td>17.5</td>
<td>BODY 32 CM</td>
</tr>
<tr>
<td>7</td>
<td>ART 0.9X0.45</td>
<td>Helical</td>
<td>249</td>
<td>120</td>
<td>16.12</td>
<td>875.8</td>
<td>BODY 32 CM</td>
</tr>
<tr>
<td>8</td>
<td>VENOUS 3X3</td>
<td>Helical</td>
<td>346</td>
<td>120</td>
<td>22.36</td>
<td>1217.3</td>
<td>BODY 32 CM</td>
</tr>
</tbody>
</table>
ESTIMATING EFFECTIVE DOSE FOR CT

- Effective dose estimates can be calculated by multiplying DLP by tissue specific conversion factors
  - Effective dose (mSv) = DLP x k(E/DLP)
  - Adult values for k(E/DLP)
    - Head = .0021
    - Head/neck = .0031
    - Chest = .014
    - Abdomen/pelvis = .015
    - Trunk = .015
Exam Information
Study ID: 51233
Total DLP: 3350.6 mGy*cm
Estimated Dose Savings: 6%

<table>
<thead>
<tr>
<th>#</th>
<th>Description</th>
<th>Scan Type</th>
<th>mAs</th>
<th>kV</th>
<th>CTDIvol [mGy]</th>
<th>DLP [mGy*cm]</th>
<th>Phantom Type [cm]</th>
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<tbody>
<tr>
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<td>1</td>
<td>90</td>
<td>0.02</td>
<td>1.2</td>
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<td>BODY 32 CM</td>
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<tr>
<td>2</td>
<td>A/P W/O</td>
<td>Helical</td>
<td>349</td>
<td>120</td>
<td>22.56</td>
<td>1221.3</td>
<td>BODY 32 CM</td>
</tr>
<tr>
<td>4</td>
<td>locator</td>
<td>Stationary N/A</td>
<td>120</td>
<td>8.77</td>
<td>8.8</td>
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<tr>
<td>5</td>
<td>locator</td>
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<td>120</td>
<td>8.72</td>
<td>8.7</td>
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<td>BODY 32 CM</td>
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<tr>
<td>6</td>
<td>tracker</td>
<td>Stationary N/A</td>
<td>120</td>
<td>17.54</td>
<td>17.5</td>
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<tr>
<td>7</td>
<td>ART 0.9X0.45</td>
<td>Helical</td>
<td>249</td>
<td>120</td>
<td>16.12</td>
<td>875.8</td>
<td>BODY 32 CM</td>
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<tr>
<td>8</td>
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<td>346</td>
<td>120</td>
<td>22.36</td>
<td>1217.3</td>
<td>BODY 32 CM</td>
</tr>
</tbody>
</table>
EXAMPLE: EFFECTIVE DOSE FROM ADULT CT HEAD

- CT abdomen/pelvis multiphase
  - CTDI_{VOL} = 96.09 mGy
  - DLP = 3350.6 mGy-cm
  - Effective dose estimate: DLP x 0.015
    - 50.3 mSv
<table>
<thead>
<tr>
<th>Procedure</th>
<th>Average Effective Dose</th>
<th>Annual Effective Dose per Person</th>
<th>Proportion of the Total Effective Dose from All Study Procedures</th>
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</thead>
<tbody>
<tr>
<td><strong>millisieverts</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Myocardial perfusion imaging</td>
<td>15.6†</td>
<td>0.540</td>
<td>22.1</td>
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<tr>
<td>CT of the abdomen</td>
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<td>0.446</td>
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<td>CT of the pelvis</td>
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<td>0.297</td>
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<td>CT of the chest</td>
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<td>0.184</td>
<td>7.5</td>
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<td>Diagnostic cardiac catheterization</td>
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<td>0.113</td>
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<tr>
<td>Radiography of the lumbar spine</td>
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<td>0.080</td>
<td>3.3</td>
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<tr>
<td>Mammography</td>
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<tr>
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<td>0.049</td>
<td>2.0</td>
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<td>Nuclear bone imaging</td>
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<td>1.4</td>
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<td>0.028</td>
<td>1.1</td>
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<tr>
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<td>0.020</td>
<td>0.8</td>
</tr>
<tr>
<td>CT of the lumbar spine</td>
<td>6</td>
<td>0.018</td>
<td>0.7</td>
</tr>
<tr>
<td>Chest radiograph</td>
<td>0.02‡</td>
<td>0.016</td>
<td>0.7</td>
</tr>
<tr>
<td>Thyroid uptake</td>
<td>1.9</td>
<td>0.016</td>
<td>0.7</td>
</tr>
<tr>
<td>Intravenous urography</td>
<td>3</td>
<td>0.014</td>
<td>0.6</td>
</tr>
<tr>
<td>CT of the neck</td>
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<td>0.014</td>
<td>0.6</td>
</tr>
<tr>
<td>Cardiac resting ventriculography</td>
<td>7.8</td>
<td>0.014</td>
<td>0.6</td>
</tr>
</tbody>
</table>
OBJECTIVES

• Understand the reasons for concern about radiation exposure from medical imaging

• Learn basic radiobiology and radiation dosimetry

• Discuss evidence and consensus opinions on the risks of radiation

• Identify strategies to minimize radiation exposure for patients
RISKS OF RADIATION FROM MEDICAL IMAGING

• No data directly attributing cancer to CT scanning (yet…)

• Assumptions must be made based on other forms of radiation exposure with comparable doses
  • Most commonly used source: Atomic bomb survivors
  • Radiation used for medical purposes
ATOMIC BOMB LIFESPAN STUDY

- 120,000 survivors
- Median dose of survivors 40 mSv
- 25,000 in range of 2-20 mSv
- Followed incidence of cancer over 55 years
- Even at low dose (10 mSv), significant increase in cancer risk
MEDICALLY IRRADIATED POPULATIONS

• Malignant disease
  • Patients receiving XRT for malignant disease are at increased risk of secondary cancers
  • In Hodgkin’s survivors, radiation-induced malignancy is a leading cause of mortality
MEDICALLY IRRADIATED POPULATIONS

• Benign disease

• XRT commonly used 1930-1960 for benign conditions
  • Tinea capitis
  • Enlarged tonsils
  • Acne
  • Breast conditions (postpartum mastitis)
  • Peptic ulcer disease

• Increased risk of radiosensitive cancers
  • Thyroid, salivary gland, CNS, skin ad breast
MEDICALLY IRRADIATED POPULATIONS

• Groups receiving repeated radiography
  • Tuberculosis
  • Scoliosis
  • Children requiring cardiac catheterizations

• All significant increased risk of developing cancer
### Table 4. Thyroid cancer after childhood radiotherapy.\(^\dagger\)

<table>
<thead>
<tr>
<th>Study</th>
<th>Reference</th>
<th>Mean dose</th>
<th>$\text{ERR}_{Gy}$</th>
<th>$\text{EAR (10}^3 \text{ PY Gy}^{-1}$</th>
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</thead>
<tbody>
<tr>
<td>Childhood cancer</td>
<td>Tucker et al. 1991</td>
<td>12</td>
<td>4.5 (3.1–6.4)</td>
<td>0.4 (0.2–0.5)</td>
</tr>
<tr>
<td>Tuberculosis, adenitis</td>
<td>Hanford et al. 1962</td>
<td>8.2</td>
<td>37 (16–72)</td>
<td>7.7 (3.3–15)</td>
</tr>
<tr>
<td>Chicago head and neck</td>
<td>DeGroot et al. 1983</td>
<td>4.5</td>
<td>12 (6.6–20)</td>
<td>3.5 (2.0–5.9)</td>
</tr>
<tr>
<td>Thymus adenitis</td>
<td>Maxon et al. 1980</td>
<td>2.9</td>
<td>4.5 (2.7–7.0)</td>
<td>1.2 (0.7–1.8)</td>
</tr>
<tr>
<td>Rochester enlarged thymus</td>
<td>Shore et al. 1993</td>
<td>1.4</td>
<td>9.5 (6.9–13)</td>
<td>3.0 (2.2–4.0)</td>
</tr>
<tr>
<td>Michael Reese enlarged thymus</td>
<td>Schneider et al. 1993</td>
<td>0.6</td>
<td>3.0 (2.6–3.5)</td>
<td>38 (32–43)</td>
</tr>
<tr>
<td>Stockholm hemangioma</td>
<td>Lundell et al. 1994</td>
<td>0.3</td>
<td>4.9 (1.3–10)</td>
<td>0.9 (0.2–1.9)</td>
</tr>
<tr>
<td>Lymphoid hyperplasia</td>
<td>Potten et al. 1990</td>
<td>0.2</td>
<td>5.9 (1.8–12)</td>
<td>9.1 (2.7–18)</td>
</tr>
<tr>
<td>Israeli tinea capitis</td>
<td>Ron et al. 1989</td>
<td>0.1</td>
<td>34 (23–47)</td>
<td>13 (9.0–18)</td>
</tr>
<tr>
<td>New York tinea capitis</td>
<td>Shore 1992</td>
<td>0.1</td>
<td>7.7 (&lt;0–60)</td>
<td>1.3 (&lt;0–10)</td>
</tr>
<tr>
<td>Gotenburg hemangioma</td>
<td>Lindberg et al. 1995</td>
<td>0.1</td>
<td>7.5 (0.4–18)</td>
<td>1.6 (0.09–3.9)</td>
</tr>
</tbody>
</table>

\(^\dagger\) Adapted from Shore (1992) and UNSCEAR (2000).
BIER VII REPORT

- US National academies of Sciences Biological Effects of Radiation (BIER) Committee conducted comprehensive review of literature on health risks of low dose radiation exposure
- Members: leading scientists from broad range of disciplines
- Estimated cancer risk based on dose and age of exposure using variety of studies
“The current scientific evidence is consistent with the hypothesis that there is a linear no-threshold dose response relationship between the exposure to ionizing radiation and the development of cancer in humans.”
## BIER VII Risk Estimates
Per Population of 100,000 Exposed

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excess cases from exposure to 100mSv</strong></td>
<td>800 (400-1600)</td>
<td>1300 (690-2500)</td>
</tr>
<tr>
<td><strong>Cases in the absence of exposure</strong></td>
<td>45,500</td>
<td>36,900</td>
</tr>
<tr>
<td><strong>Excess deaths from exposure to 100mSv</strong></td>
<td>410 (200-830)</td>
<td>610 (300-1200)</td>
</tr>
<tr>
<td><strong>Deaths in absence of exposure</strong></td>
<td>22,100</td>
<td>17,500</td>
</tr>
</tbody>
</table>
ESTIMATING THE RISK

  - Sponsored by NIH and NCI
  - Estimated *29,000* new cancers from CTs performed in 2007
  - Estimates based on BEIR VII risk modeling
CANCER RISKS ARE NOT NEGLIGIBLE

Smith-Bindman et al., Arch Intern Med, 2009
CANCER RISKS ARE NOT NEGLIGIBLE

If 1000 20 year old women undergo a CT abd and pelvis, 4 are estimated to develop cancer from the test (range in estimate 2-12).

Smith-Bindman et al., Arch Intern Med, 2009
• Rate of Major Coronary Events According to Mean Radiation Dose to the Heart, as Compared with the Estimated Rate with No Radiation Exposure to the Heart.
RISKS OF RADIATION FROM MEDICAL IMAGING: SUMMARY

• Risks of CT scanning are NOT hypothetical or based on major extrapolations in dose

• Risks are based directly on measured radiation-related cancers in populations receiving the same dose as CT

• Although the risk is small, it is cumulative
  • Statistically significant increase in cancer risk above 50mSv
  • Repeat exams are problematic

• The benefits of an indicated CT exam outweigh the risks, but…
OBJECTIVES

• Understand the reasons for concern about radiation exposure from medical imaging

• Learn basic radiobiology and radiation dosimetry

• Discuss evidence and consensus opinions on the risks of radiation

• Identify strategies to minimize radiation exposure for patients
RADIATION EXPOSURE FROM CT

• Collective dose to population is increasing
  • Increasing dose per exam (prettier pictures)
  • Increasing indications
  • Increasing availability
  • Quicker and easier to perform
CT DOSE REDUCTION

Appropriate utilization + Optimize CT protocols
REASONS FOR OVER-UTILIZATION

• “Defensive” imaging
  • Estimated that 30% of medical imaging is unnecessary, doesn’t change management

• Patient demand
  • Imaging the “worried-well”
  • Perceived lack of disincentive

• Physician demand
  • Easy
  • Poor tolerance for ambiguity

• Physician self-referral (high profitability)

• Whole body CT screening
REASONS FOR OVER-UTILIZATION

• Patient expectation: “More is better”

• 2010 Archives of Internal Medicine
  • Patients with nontraumatic abdominal pain were evaluated with or without CT
  • Measured patient confidence in exam on 100-pt scale
    • Without CT: 20 (95% CI, 16 to 25)
    • With CT: 90 (85% CI, 88 to 91)
APPROPRIATE UTILIZATION

• Strategies to reduce radiation exposure from unnecessary CT scans
  • Consider other imaging tests
  • Avoid repeating studies (CTPA, CT A/P)
  • Trust history and physical exam
  • Tolerate some uncertainty
MGH RADILOGY ORDER ENTRY SYSTEM-DECISION SUPPORT (ROE-DS)

Head (Brain) MRI

Recurrent increasingly severe headaches
OPTIMIZE CT PROTOCOLS

• Ct technique should be individualized to each patient and his/her body habitus

• “Image gently” campaign, ALARA policy
OPTIMIZE CT PROTOCOL

- Peak KvP optimization: BMI or weight based protocols
- Tube current adjustment (mAs): AEC software
- Adjust pitch - increase pitch decreases dose
- Develop chart of tube-current settings based on patient weight or diameter and region of interest
- Avoid “multi-phasic” scans
- Limit scan range to necessary anatomic region
LIMIT MULTIPHASIC SCANS

- Almost never need “with and without” CT images
- Without contrast
  - CT head for acute hemorrhage
  - CT a/p for stone
  - CT chest when interested in lung parenchyma
- With contrast
  - CT neck
  - CT a/p for abdominal pathology
  - Metastatic disease evaluation
SURE EXPOSURE
DOSE REDUCTION SYSTEM

After the operator sets plan on scanogram, the scanner will calculate the absorption of patient body, and decide appropriate scan technique. During scanning, the scanner modulates mA with every gantry rotation. (right)

As a result, detector output is maintained. Therefore, the image noise of each slice is also maintained, providing the same Image Quality at a lower patient dose. (left)
FUTURE DIRECTIONS
TO REDUCE CT DOSE

• Hardware improvements from vendors
  • Move away from “slice wars” with emphasis on dose reduction
    • Volume scanning: Aquilion One
    • Dual energy- Siemens Definition Flash
    • More efficient detectors: GEMS

• Software improvements: iterative reconstruction techniques
  • ASIR: GEMS
  • IRIS: Siemens
ASIR FOR CT DOSE REDUCTION

Large Body Habitus

FBP

260lbs

ASIR

15 mSv

8.9 mSv
FUTURE DIRECTIONS TO REDUCE CT DOSE

- Requirements to display CTDI$_{\text{VOL}}$ and DLP with image data

- Programs to integrate patient dose profile at order entry level
  - Requires provider to “break the glass” if patient has exceeded agreed upon cumulative dose thresholds
FUTURE DIRECTIONS TO REDUCE CT DOSE

• Dose index registry (DIR)
  • part of National Radiology Data Registry (NRDR)
  • Collect and provide feedback on dose estimate information from different modalities
  • Will allow “fine-tuning” of protocols and increased awareness
FUTURE DIRECTIONS TO REDUCE CT DOSE

• Legislative and regulatory reform
• Congressional oversight and legislation to reduce medical radiation errors
• Goal to modify the currently fragmented oversight for medical use of radiation
• FDA regulations
WHAT CAN INTERNISTS DO?

• Become “dose aware”
  • Check CTDI$_{\text{VOL}}$ or DLP on imaging exams
  • Websites
    • www.acr.org
    • www.imagegently.com

• Appropriate utilization
  • ACR appropriateness criteria with RRL
    • http://www.acr.org/Quality-Safety/Appropriateness-Criteria

• Utilize radiologists as a resource
• INSERT appropriateness criteria here - headache
CONCLUSIONS

- Advances in CT technology have revolutionized the practice of medicine
- Increasing utilization has led to a marked increase in population radiation exposure
- Small but definite association between radiation exposure at CT doses and cancer
- Physicians have a role as primary “gatekeepers”
  - Appropriateness criteria
  - ALARA principle
  - Educate and counsel regarding radiation risks