Measurements

- SI Units
  - Gray - Absorbed Dose
  - Sievert - Biological Effect

Gray

- Absorbed dose of Ionizing Radiation
- Absorbed Dose Delivered from Air to Patient
- Energy/Unit Mass
  - 1 Gy = 1 Joule/Kg
    - 1 Gy = 100 rad
    - 1 mGy = 100 mrad
    - 10 mGy = 1 rad

Sievert

- Biological Effect of Dose
- Also Energy/Unit Mass
  - 1 Sv = 100 rem
  - 1 mSv = 100 mrem
  - 10 mSv = 1 rem

From Machine to Patient

- 1. CT scanner Creates Exposure (Roentgen)
- 2. Air Kerma - Energy in Air (mGy)
- 3. Dose Equivalent (mSv) Accounts for Comparison of x, gamma, beta and alpha rays
- 4. Effective Dose - Biological Effect of Radiation on Patient

Exposure

- Energy of x-rays produced by the machine
- Unit - Roentgen
- Intensity of x-ray energy/unit mass of air
- Coulomb/kg
Air Kerma
- Kinetic Energy Released per unit Mass of Air
- Unit – Gray
- 1R = 8.7 Gy air kerma

Dose Equivalent
- Biological Effects of Radiation
- Unit - Sievert
- Radiation Weighting Factor
  - 1 for x and gamma rays
  - Therefore 1 Gy = 1 Sv for this term
  - 20 for alpha rays
  - Therefore 1 Gy = 20 Sv

Effective Dose (ED)
- Accounts for radiosensitivity of specific organs
- There is a conversion factor for specific organs-phantom size used by manufacturer critical
- Based on organs (e.g. Thyroid) in radiation field
- Unit-Sievert
- Conversion Factors for children still in flux
- 1 Gy does not = 1 Sv because of conversion factor

From Machine to Biological Effect on Patient
- Roentgen(R)
- Air Kerma(Gy)/Absorbed Dose(Gy)
- Equivalent Dose (Sv)
- Effective Dose (Sv)

Radiation Sources
- 1982 2006
- U.S. annual per capita effective radiation dose from various sources

CT Benefits
- Improved Diagnostic Accuracy
- Shorter hospital stays
- Less Exploratory Lap
- Less Negative Appendectomy
- Improved Stroke Diagnosis BUT High Dose With Perfusion Studies
**RISK**

- BEIR VII-2006 National Academy of Sciences
- 100 mSv - 1/100 lifetime risk of CA
  - 42/100 lifetime risk of CA baseline
- 10 mSv - 1/1000 lifetime risk of CA
  - Fatal and Non-Fatal CA
- 1/100 will get CA from 70yr Exposure to low energy background radiation
- Based on Linear No Threshold Model ! Controversial !

**Relative Risks of Fatality**

- 10 mSv – 1/2000 = 99.99% Non Fatal
- Car Travel 40,000 miles – 1/2000 Fatality
- NY Times June 11,2011
  - National Toxicology Program
  - Formaldehyde Listed as a carcinogen
  - Found in
    - Plywood
    - Nail Polish
    - Hair Products

**BEIR VII**

- Based On
  - A- Bomb survivors with low level Radiation
  - Medical Exposure
  - Nuclear workers

**Radiation Effects**

- Deterministic - Positive Threshold
- Stochastic – No Threshold
- BEIR VII - Linear No Threshold Model
- SPR Position is to Assume Risk

**Pediatric Issues**

- Dose Increases as size Decreases
- Younger Patients More Radiosensitive
- Longer Life Span
- Risk Higher for Females

**Risk Vs. Age**

- Cancer cases/100,000 people at 100 mGy

*Graph shows typical scanner output level (expressed as volume CT dose index [CTDIvol]) for a routine abdominal CT examination from the 1980s, when xenon detectors were used, to 2004, when 64 detector row CT systems were introduced.*

*Graph shows lifetime attributable risk of radiation-induced cancer incidence, as a function of age at exposure for males and females.*

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**Hricak H et al. Radiology 2011;258:889-905**

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Dose Vs. Weight
- Inverse relationship

Key Structures
- Lens
- Thyroid
- Breast
- Ovaries
- Testes

Some Good News
- Lower Dose with newer scanners

CTDvol
- **CT Dose Index Volume**
  - Unit - mGy
  - Measures Radiation output of CT for parameters Chosen (Kv, mAs, Pitch)
  - A good Comparative tool- Not exact patient dose
  - Based on Phantom Measurements
    - Head 16 cm
    - Pediatric Body 16cm
    - Adult Body 32cm

DLP
- **Dose Length Product**
  - CTDvol x L (Scan Length in cm)
  - Unit - mGy*cm
  - Energy Impacted per Scan
Effective Dose CT

- DLP x Conversion Factor

- Unit: mSv

- Will vary by age, Body part and Size

Phantom Size

- Siemens Uses 32cm Phantom to Establish CTDIvol & DLP for Body, 16cm Phantom for Head

- Therefore for Younger Patients (<15y/o) need to Multiply DLP (mGy) by @2 to calculate Effective Dose (mSv) for Soft Tissue Neck, Chest, Abd/Pelvis

- Not necessary for ~> 15y/o or Head/Cspine

CT Conversion Factors

Shrimpton et al NRPB 2004

32cm Phantom for adult Chest, Abd & Pelvis. All other 16 cm Phantom

Head CT DLP 200/newborn ED=200 x 0.011 = 2.2 mSv (@3x)

Head CT DLP 200/Adult ED =200 x 0.0021 =0.42 mSv

<table>
<thead>
<tr>
<th>Exam</th>
<th>Relevant Organ</th>
<th>Range of Absorbed Dose (CTDIvol)</th>
<th>Range of Effective Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head CT (Unadjusted)</td>
<td>Brain</td>
<td>23-49</td>
<td>1.8-3.8</td>
</tr>
<tr>
<td>Head CT (Adjusted)</td>
<td>Brain</td>
<td>11-15</td>
<td>0.9-1.9</td>
</tr>
<tr>
<td>Abdomen CT (Unadjusted)</td>
<td>Stomach</td>
<td>21-41</td>
<td>10-24</td>
</tr>
<tr>
<td>Abdomen CT (Adjusted)</td>
<td>Stomach</td>
<td>5-11</td>
<td>3-6</td>
</tr>
<tr>
<td>CXR PA</td>
<td>Lung</td>
<td>.04-08</td>
<td>.01-03</td>
</tr>
<tr>
<td>CXR Lateral</td>
<td>Lung</td>
<td>.04-10</td>
<td>.03-06</td>
</tr>
</tbody>
</table>

Head Protocol

1 y/o

Effective Dose = DLP x 0.0067 (Conversion Factor for Age)

ED=194 x 0.0067 = 1.30 mSv

Normal Study
Protocol: R/o Appendicitis

5 y/o

Effective Dose = DLP x 0.0200 x 2

ED = 350 x 0.0200 x 2 = 6mSv

RelativeEffective Dose

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Dose (mSv)</th>
<th>Bkgd Eqiv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background~ 3mSv/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coakley et al AJR 2011; 196:659-655</td>
<td></td>
<td></td>
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<tr>
<td>X-Country Air .04 mSv = 4 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CXR-2 view</td>
<td>.66-1</td>
<td>8-12 days</td>
</tr>
<tr>
<td>Abd XR</td>
<td>5-7</td>
<td>62-88 days</td>
</tr>
<tr>
<td>Mamogram</td>
<td>35-7</td>
<td>16-88 days</td>
</tr>
<tr>
<td>L-spine</td>
<td>1.8</td>
<td>7 months</td>
</tr>
<tr>
<td>Head CT</td>
<td>2.0</td>
<td>8 months</td>
</tr>
<tr>
<td>Chest CT</td>
<td>8.0</td>
<td>3 years</td>
</tr>
<tr>
<td>A/P CT</td>
<td>10.0</td>
<td>3 years</td>
</tr>
<tr>
<td>PET/low dose CT</td>
<td>8.5-10.3</td>
<td>3 years</td>
</tr>
<tr>
<td>PET/full CT</td>
<td>15.7-16.4</td>
<td>8-9 years</td>
</tr>
<tr>
<td>CoronaryAngio with Intervention</td>
<td>7.5-17</td>
<td>2-19 years</td>
</tr>
</tbody>
</table>

What Can Be Done?

- Justification
- Alternative Modalities
  - US
  - MRI
- Optimization

Pediatric CT Use

- 5 x Increase 1995-2008

Justification

- ACR Appropriateness Criteria
- Computerized Imaging Order Systems
- Consider Alternative Modalities
  - US
  - MRI
- Education
- EMR to Search for and Share Prior Studies
1 y/o with fever, ? Seizures

- Effective Dose = 83 x 0.030 x 2 = 4.98 mSv

Trauma

14 y/o 103 lb

Effective Dose
Head, Orbit, Cspine
DLP x Conversion Factor
Head 417 x 0.032 = 13.3 mSv
Orbit 142 x 0.032 = 4.5 mSv
Csp 119 x 0.032 = 0.38 mSv
Abdomen/Pelvis
DLP x 2 x Factor
A/P 402 x 2 x 0.015 = 12 mSv
Total 14.16 mSv

Head Trauma

- Head CT
- Orbit CT

MRI

- Pregnant Patients
- Repeat Studies
- IBD

US

- Pelvic Pain
- r/o Appendicitis Especially in Females
- Consult with Radiologist For Most Appropriate Test
Alternative Modality

- Normal Appendix in Pregnancy

13-year-old woman at 19 weeks gestation with acute lower abdominal pain

IBD

- CT
- MRI

12-year-old boy with known Crohn disease and increasing abdominal pain

Optimization

- ALARA
- Image Gently
- Right Sizing for the Patient
- Tube Current Modulation
- Avoid Multiple Phase Scans
- Lower Settings on Repeat Exams
- Limit Scan to Area of Interest
- Try to Avoid Sensitive Organs

High Vs. Low Dose

- 440 mAs
- 80 mAs

Radiography

- The Next Frontier
- CR/DR
Fluoroscopy

- Pause and Pulse
- Image Capture
- Pulsed Fluoroscopy
- ALARA

Luxembourg Gardens

Masada