Fluoroscopy Credentialing
Refresher Training

Krueger-Gilbert Health Physics, Inc.
Educational Objectives

- Radiation bioeffects
- Sources of radiation for the US population
- Typical radiation doses in diagnostic imaging
- Maryland, FDA and JCAHO guidelines for fluoroscopy use and operator training
- Factors affecting fluoroscopic exposure outputs
- Radiation exposure management for the patient and operator
Radiation Bioeffects

- Cellular Level
- Deterministic Effects
- Stochastic Effects
Cells are made of simple and complex molecules composed of atoms held together by chemical bonds characterized by electron interactions.

Ionizing radiation can cause these bonds to break, resulting in:

- Production of toxic substances, changes in cell function, changes in cell genetic make-up, and cell death
### Biological Effects

#### Deterministic
- Analogy: chopping down tree
- Threshold dose
- Severity depends on dose
- Have not been shown at dose levels below 1 Gy, likely due to constant cellular repair mechanisms
- Examples: skin injury, cataracts

#### Stochastic
- Analogy: dodging a bullet
- No threshold dose
- Severity independent of dose
- Examples: cancer, genetic injury
Cataracts

- Current threshold dose (NCRP 116, 1993)
  - Acute: 2 Gy (200 rad)
  - Protracted: 5 Gy (500 rad)
  - MDE dose limit:
    - 0.15 Sv/y (15,000 mrem/y)

- ICRP (Apr 2011)
  - Considers threshold to be 0.5 Gy (50 rad)
  - Recommended dose limit:
    - 0.02 Sv/y (2,000 mrem/y)
    - Important that physicians in higher exposure environments utilize suspended shielding or lead glasses

Vano E, et al.
Br J Radiol July 1998
Background Radiation

An average U.S. resident receives a dose of approximately 3 mSv/yr (300 mrem/yr) from sources of natural background radiation.

The level of natural exposure varies around the globe, at some locations, natural background radiation exposure exceed the US average levels by a factor of 10 and sometimes even by a factor of 100.
Typical Entrance Skin Exposures in Diagnostic Radiology

<table>
<thead>
<tr>
<th>Projection</th>
<th>ESE, 200 speed (mR)</th>
<th>ESE, 400 speed (mR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdomen (A/P)</td>
<td>490</td>
<td>300</td>
</tr>
<tr>
<td>Lumbar spine (A/P)</td>
<td>570</td>
<td>330</td>
</tr>
<tr>
<td>Full spine (A/P)</td>
<td>260</td>
<td>145</td>
</tr>
<tr>
<td>Cervical spine (A/P)</td>
<td>135</td>
<td>95</td>
</tr>
<tr>
<td>Skull (lateral)</td>
<td>145</td>
<td>70</td>
</tr>
<tr>
<td>Chest (P/A) (w/o grid)</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Chest (P/A) (w/ grid)</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>

Source: Conference of State Radiation Control Program Directors. *Average patient exposure/dose guides*. Publication 92-4. CRCPD, 1992, Table 1.
# Effective Doses for Common Examinations

<table>
<thead>
<tr>
<th>Examination</th>
<th>Effective dose (mSv)</th>
<th>Effective dose (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>0.04</td>
<td>4</td>
</tr>
<tr>
<td>CT Chest</td>
<td>7.8</td>
<td>780</td>
</tr>
<tr>
<td>Skull</td>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>CT Head</td>
<td>1.8</td>
<td>180</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1.2</td>
<td>120</td>
</tr>
<tr>
<td>CT Abdomen</td>
<td>7.6</td>
<td>760</td>
</tr>
<tr>
<td>Thoracic spine</td>
<td>1.0</td>
<td>100</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>2.1</td>
<td>210</td>
</tr>
<tr>
<td>Pelvis</td>
<td>1.1</td>
<td>110</td>
</tr>
<tr>
<td>CT Pelvis</td>
<td>7.1</td>
<td>710</td>
</tr>
<tr>
<td>Mammography</td>
<td>0.1</td>
<td>10</td>
</tr>
</tbody>
</table>

# Mean Effective Dose for Selected Interventional Procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Fluoro Time (min)</th>
<th>Dose-area product (Gy-cm²)</th>
<th>Mean effective dose (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper extremity angio</td>
<td>3.6 – 8.1</td>
<td>2.5 – 29.8</td>
<td>30</td>
</tr>
<tr>
<td>Lower extremity angio</td>
<td>1.8 – 21.7</td>
<td>1.0 – 82.2</td>
<td>80</td>
</tr>
<tr>
<td>Carotid angiography</td>
<td>2.6 – 21.0</td>
<td>2.6 – 79.8</td>
<td>490</td>
</tr>
<tr>
<td>PTC</td>
<td>2.9 – 44.0</td>
<td>12.0 – 192</td>
<td>1,280</td>
</tr>
<tr>
<td>Abdominal angiography</td>
<td>1.8 – 27.1</td>
<td>13.0 – 102</td>
<td>1,890</td>
</tr>
<tr>
<td>Hepatic angiography</td>
<td>3.6 – 41.8</td>
<td>22.8 – 168</td>
<td>2,170</td>
</tr>
<tr>
<td>AV fistula angioplasty</td>
<td>4.8 – 57.9</td>
<td>0.2 – 96.3</td>
<td>30</td>
</tr>
<tr>
<td>Cerebral embolization</td>
<td>15.2 – 55.8</td>
<td>28.3 – 61.9</td>
<td>1,050</td>
</tr>
<tr>
<td>Renal angioplasty</td>
<td>11.4 – 27.2</td>
<td>5.4 – 190</td>
<td>1,360</td>
</tr>
<tr>
<td>TIPS</td>
<td>21.7 – 100</td>
<td>212 – 897</td>
<td>8,390</td>
</tr>
</tbody>
</table>

Reducing Patient Exposure

- Patient verification
- Perform correct examination on correct body part
- Use shielding when appropriate
- Use Automatic Exposure Controls when appropriate
- Use Anatomical Programming and adjust for patient size, especially pediatric patients
- Use collimation!
- Could you use ultrasound?
Precautions to Reduce Radiation Exposure

- Minimize use of CINE
- Minimize use of steep imaging projection angles
- Minimize use of magnification modes
- Minimize frame rates
- Keep II close to the patient
- Utilize collimation to the fullest extent possible
- Monitor patient dose in real time
- Keep table height as high as comfortably possible for operator
- Vary imaging beam angle to minimize exposure to any single skin area
- Keep patient’s extremities out of beam
Guidelines for Fluoroscopy Use

- Historical Perspective
- FDA Recommendations
- Maryland State Requirements
- JCAHO Guidelines
- AAPM – “Step Lightly” – Image Gently Campaign
Guidelines for Fluoroscopy Use

- Historical Perspective
  - Strict account should be kept of actual exposure. Tousey 1915
  - We may safely expect that ... Roentgen burns caused during diagnostic exposures will become more and more infrequent. But with the employment of the rays for therapeutic purposes burns have now become a rather common accident. Where cosmetic considerations alone are concerned, such heroic therapy is injudicious. Kassabian 1907
Guidelines for Fluoroscopy Use

- FDA Recommendations (1994)
  - Establish standard operating procedures and clinical protocols for each specific procedure performed. The protocols should address all aspects of the procedure, such as patient selection, normal conduct of the procedure, actions in response to complications and consideration of limits on fluoroscopic exposure time.
  - Know radiation dose rates for the specific fluoroscopic system and for each mode of operation used during the clinical protocol. These dose rates should be derived from measurements performed at the facility.
Guidelines for Fluoroscopy Use

- FDA Recommendations (1994)
  - Assess the impact of each procedure’s protocol for the potential of radiation injury to the patient
  - Modify the protocol, as appropriate, to limit the cumulative absorbed dose to any irradiated area of the skin to the minimum necessary for the clinical tasks, and particularly to avoid approaching cumulative dose that would induce unacceptable adverse effects. Use equipment that aids in minimizing absorbed dose.
  - Enlist a qualified medical physicist to assist in implementing these principles in such a manner so as not to adversely affect the clinical objectives of the procedure.
Guidelines for Fluoroscopy Use

• Maryland State Requirements (1995)
  • Licensed practitioner or radiological technologist may energize fluoroscopic x-ray systems
  • person must complete at least four (4) hours of training prior to clinical use
    • Training must include: biological effects of x-ray, principles of radiation protection, factors affecting fluoroscopic outputs, dose reduction techniques, principles & operation of specific fluoroscopic x-ray systems, fluoroscopic outputs and applicable regulations.
  • person must complete one (1) hour of continuing education every 24 months.
Guidelines for Fluoroscopy Use

- **JCAHO Guidelines (MS. 5.14)**
  - For physicians who use or operate fluoroscopic x-ray systems, the hospital delineates clinical privileges based on evidence of completion of specific training as conferred by appropriate board certification or completion of specific training courses.
  - The hospital requires specific documentation of appropriate training before granting fluoroscopic privileges, and evidence of appropriate training with respect to the operation of the specific fluoroscopic systems used in the facility before such use.
  - In addition, the hospital provides annual in-service training, or requires evidence of continuing medical education in radiation safety and management, for all physician granted privileges to use fluoroscopic x-ray equipment.
Guidelines for Fluoroscopy Use

- AAPM “Step Lightly” – Image Gently Campaign
  - The American Association for Physicists in Medicine (AAPM) – Alliance for Radiation Safety in Pediatric Imaging offer free Interventional Radiology dose reduction and IR patient education materials
- Website: www.imagegently.org
  - Includes: downloadable slide presentation, checklist, outline and patient brochure
Patient Management

- Do you explain possible radiation-related side effects to the patient?
- Do you actively manage radiation dose during the procedure?
- When do you stop the procedure?
- Does the patient know what to look for after the procedure?
Consent Topics?

- Potential radiation risks include:
  - A slightly elevated risk for cancer several years later in life. This risk is typically low compared to the normal incidence of human cancer.
  - Hair loss often occurs. This is usually temporary; regrowth of hair may be incomplete.
  - Skin rashes occur infrequently; on very rare occasions they may result in tissue breakdown and possibly severe ulcers. The likelihood depends on the complexity of the procedure and your sensitive to radiation due to previous procedures, disease, or genetic conditions.
  - Cataracts occur rarely.

Based on Wagner, L. (AAPM SS 02)
Post Procedure

- If dose exceeded deterministic thresholds, then discuss possible effects and their management with the patient and family.
- Have patient or family member notify you if deterministic effects occur.
- Consider a clinical follow-up plan for the patient.
Radiation Induced Skin Injury

18 – 21 months after multiple coronary angiography and angioplasty procedures

Courtesy of D. L. Miller, M.D.
Is There a Threshold Dose For Skin Injury?

- If so, what is it?
  - 1 Gy?, 2 Gy?, 5 Gy?
- What’s a “Gy”, again?

2 Gray = 200 rad
## Threshold Skin Doses

<table>
<thead>
<tr>
<th>Effect</th>
<th>Dose (Gy)</th>
<th>Onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transient erythema</td>
<td>2</td>
<td>Hours</td>
</tr>
<tr>
<td>Temporary hair loss</td>
<td>3</td>
<td>~ 3 weeks</td>
</tr>
<tr>
<td>Permanent hair loss</td>
<td>7</td>
<td>~ 3 weeks</td>
</tr>
<tr>
<td>Dermal atrophy (1\textsuperscript{st} phase)</td>
<td>10</td>
<td>&gt; 12 weeks</td>
</tr>
<tr>
<td>Dermal atrophy (2\textsuperscript{nd} phase)</td>
<td>10</td>
<td>&gt; 1 year</td>
</tr>
<tr>
<td>Telangiectasia</td>
<td>10</td>
<td>&gt; 1 year</td>
</tr>
<tr>
<td>Induration (fibrosis)</td>
<td>10</td>
<td>&gt; 1 year</td>
</tr>
<tr>
<td>Delayed skin necrosis</td>
<td>&gt; 12</td>
<td>&gt; 1 year</td>
</tr>
</tbody>
</table>

Adapted from Koenig TR, et al. AJR 2001; 177:3 & ICRP Publication 85
How Much Radiation Can I Use?

As much as the patient needs, but no more
What’s the Goal?

- Optimize radiation dose
- Not the same as minimizing dose
- Use the least possible amount of radiation which still permits adequate image quality for fluoroscopic guidance and diagnostic imaging
- There is no “maximum allowable dose”
OK, Controlling Skin Dose is Important—How Do I Do it?

Two ways to minimize skin dose

- Optimize dose in general
- Use specific techniques to minimize skin dose
  - Dose spreading
  - Collimation
  - Maximize distance from x-ray source
Optimize Radiation Dose

- Manage exposure time
  - Control fluoroscopy time
  - Control the number of images
  - Use last image hold
- Manage dose rate
  - Control fluoroscopy dose rate
  - Control technical factors
Fluoroscopy Time

- Single most important determinant of patient dose for most fluoroscopy procedures

Pay attention to your foot!

“Step Lightly”
## Entrance Exposure Rates

<table>
<thead>
<tr>
<th>Exposure Mode</th>
<th>Median EER (R/min)</th>
<th>3rd Quartile EER (R/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Output</td>
<td>&lt; 10</td>
<td></td>
</tr>
<tr>
<td>Maximum Output (Boost)</td>
<td>&lt; 20</td>
<td></td>
</tr>
<tr>
<td>Under Table X-ray tube</td>
<td>5.06</td>
<td>6.96</td>
</tr>
<tr>
<td>Above Table X-ray tube</td>
<td>5.18</td>
<td>6.10</td>
</tr>
<tr>
<td>Mobile C-arm</td>
<td>2.30</td>
<td>3.05</td>
</tr>
<tr>
<td>Cardiac Catherization</td>
<td>3.45</td>
<td>6.91</td>
</tr>
<tr>
<td>Cardiac Catherization Record Mode</td>
<td>17.20</td>
<td>38.48</td>
</tr>
</tbody>
</table>

Which Fluoroscopy Mode?

7.5 FPS Coronary
(150 mR/min)

15 FPS Coronary
(350 mR/min)
Which Magnification Mode?

<table>
<thead>
<tr>
<th>Magnification Mode</th>
<th>Entrance Exposure Rate (R/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (12 inch Image Intensifier)</td>
<td>1.0</td>
</tr>
<tr>
<td>Mag 1 (9 inch view)</td>
<td>1.5</td>
</tr>
<tr>
<td>Mag 2 (6 inch view)</td>
<td>2.0</td>
</tr>
<tr>
<td>Mag 3 (4.5 inch view)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Use digital zoom instead of electronic magnification.
Controlling Skin Dose

Courtesy of L. Wagner, Ph.D.
Peak Dose/Total Dose = 2098/2458 = 85%

Peak Dose/Total Dose = 1465/3481 = 42%

Courtesy of D. L. Miller, M.D.
Effect of Overlapping Radiation Fields

69 y/o male; L coronary PTA x 2 within 30 hr

Radiation-Induced Injury in Patients

Fig. 15. Two cases of injury to right arm for separate patients undergoing fluoroscopically guided ablation.
Effect of collimation
Patient & Personnel dose is reduced

Collimation:

- Proper collimation decreases the area of the patient being irradiated. Significantly reduces patient dose.

- Secondarily reduces operator dose through the production of less scatter radiation

<table>
<thead>
<tr>
<th>Field size</th>
<th>Scatter at Chest Level (mR/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 inch</td>
</tr>
<tr>
<td>Full</td>
<td>276</td>
</tr>
<tr>
<td>Half</td>
<td>89</td>
</tr>
</tbody>
</table>
Importance of Collimation
Does the distance from the II make a difference?

II Distance – maintain close to the patient

- Inverse square law, increased distance requires AEC systems
Radiation-Induced Injury in Physicians

- How does this happen?
Radiation-Induced Injury in Physicians

Dose @ entrance 10 R/min

Dose @ exit < 0.20 R/min

Place hands on exit side of patient.

Always Avoid!

Better Practice

Avoid chronic exposure!

Anterior to Posterior

Posterior to Anterior

Images from www.e-radiography.net
Win-Win Situation

- Your dose is due exclusively to scatter radiation coming off of the patient (unless you put your hands in the beam!)
- Reducing the dose to the patient reduces scatter radiation
- *What’s good for the patient is also good for you!*
Radiation Protection in the Laboratory

- Time
- Distance
- Shielding
- Dosimetry
Radiation Protection in the Laboratory

- **Time**
  - Radiation is only produced when the beam is on!
  - Irradiate only to observe motion
  - Last-image-hold and instant replay saves doses to patient and operator!
  - Decreasing your time in the area will decrease your exposure to ionizing radiation
Radiation Protection in the Laboratory

- Distance
- Take a step or two back if you can!

<table>
<thead>
<tr>
<th>Distance from Beam</th>
<th>1 step</th>
<th>2 steps</th>
<th>3 steps</th>
<th>4 steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Exposure Rate</td>
<td>100%</td>
<td>25%</td>
<td>11%</td>
<td>6%</td>
</tr>
</tbody>
</table>
Effect of distance on operator dose
Proximity of operator to x-ray tube

Remember:
If the c-arm is in a lateral position always stand on the side of the image intensify to reduce your exposure to scatter radiation.

There is a significant reduction in dose as you move away from the beam.
Correct positioning of staff
Radiation Protection in the Laboratory

- Shielding
  - Structural
  - Mobile
  - Personal
Structural Shielding
Methods to Reduce Exposure

- **Where’s Waldo?**

<table>
<thead>
<tr>
<th>Set up</th>
<th>Scatter @ 1 meter (mR/hr)</th>
<th>Scatter @ 1 meter with suspended shield (mR/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV Lab, fluoro mode 40 cm II</td>
<td>45</td>
<td>4</td>
</tr>
<tr>
<td>Cath Lab, fluoro mode 20 cm II</td>
<td>80</td>
<td>8</td>
</tr>
</tbody>
</table>

- **Primary protective measure for operators eye!**
Personal Shielding

- Well tailored lead apron
  - Two piece type
  - Wrap-around type
  - Typical 0.5 mm apron reduces exposure by 90%
- Thyroid collar
- Eye protection?
  - Suspended shield or leaded glasses
- Gloves?
Radiation Protection in the Laboratory

- Dosimetry
  - Goals
  - Limits
  - Pregnancy
  - EDE correction
  - ALARA
  - Device Management
Regulatory Limits

**Goals:**
- Prevent deterministic effects by adhering to dose limits set below the observed thresholds
- Limit risk of probabilistic effects to acceptable levels observed in other industries

**Occupational Limits**
- Adult whole body = 5,000 mrem/year
- Lens of the Eye = 15,000 mrem/year
- Organ, skin, and extremity = 50,000 mrem/year

**Non-Occupational Limits**
- Whole body = 100 mrem/year
- The public generally receives negligible dose from radiological activities
Regulatory Limits (cont.)

Pregnant Worker

- The dose limit is 500 mrem during the gestational period of 9 months with respect to the fetus.

- The fetal dose should not exceed 50 mrem in any one month.

- A declared pregnant worker is defined as a woman who voluntarily informed her employer, in writing, of her pregnancy.

- Declared pregnant workers are given fetal badges that are worn at the abdomen level (under lead apron when indicated).
New EDE Calculation Approval

- Effective January 2012, MDE approved utilization of EDE\textsubscript{1} and EDE\textsubscript{2} calculations when assigning whole body effective dose equivalents for occupational workers in interventional radiology, cardiac catheterization, vascular surgery, electrophysiology and pain management.

- Calculations may not be performed until the year to date reading is 1250 mrem.

- Example: A participant’s year to date reading on collar badge is 1250 mrem, while waist badge reading is 25 mrem.
  - Prior to 2012 dose = 1250 mrem
  - EDE\textsubscript{1} calculated dose = 375 mrem
  - EDE\textsubscript{2} calculated dose = 88 mrem
ALARA

- Radiation Protection is a top-down approach
  - Regulatory limits set at maximum allowable level
  - Participants are asked to maintain exposure as low as reasonable achievable

- Investigational levels are set to track employee exposures and attempts are made to identify unusual exposure conditions or trends.

- When ALARA limits are exceeded, formal investigations may be warranted and remedial action may be necessary.

- RSO may issue warning letters or have participants complete written investigations when warranted.
Operator Dose

- Do you wear your dosimetry?
- Why not?
- Have you ever exceeded your quarterly allowable dose?
  - ALARA I = 10% of Maximum Permissible Dose (125 mrem)
  - ALARA II = 30% of Maximum Permissible Dose (375 mrem)
- If so, what did you do about it?
Device Management

- Single Badge Participants: Badge to be worn between collar and waist, outside of a lead apron.

- Dual Badge Participants: The collar badge must be worn at the collar level outside the lead apron. The waist badge is to be worn under the apron at waist level.

- When NOT in use, devices should be maintained in designated areas within the facility.

- WEAR your badge!!!
Proper Use of Badges

- Program requirements
  - Badges are changed the first week of each month.
  - They must be kept on the storage badge when not in use.
  - Report unusual occurrences
  - Spare badges are available
Conclusion

- Patient risks are real
  - Real risk of radiation injury
  - Related to acute high dose of radiation
- Optimizing patient dose (and minimizing skin dose) requires both knowledge and constant attention by the operator

Remember ALARA!

- As Low As Reasonably Achievable
- WEAR your badge!!!
- Radiation risk is similar to other ‘normal’ risks
Questions?
Contact your RSO