Radiation Safety for Staff in Fluoroscopy Suites

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Learning Objectives

- For staff performing fluoroscopically-guided interventional procedures:
  - What are typical radiation exposure levels?
  - How should the radiation exposure to staff be monitored?
  - What type of radiation safety education is needed?
  - Is there anything new and novel available that can help reduce staff exposure levels?
Resources

- Joint SIR / CIRSE Guideline for Occupational Radiation Protection in IR (Miller et al, 2010)

Operator Exposure During Fluoroscopy Procedures

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>Mean Dose per Procedure (µSv)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Neck</td>
<td>Lens</td>
</tr>
<tr>
<td>Mixed general IR</td>
<td>30-325</td>
<td>300</td>
</tr>
<tr>
<td>ERCP</td>
<td>450</td>
<td>550</td>
</tr>
<tr>
<td>Endovascular surgery</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>Percutaneous coronary intervention</td>
<td>10-130</td>
<td>10-170</td>
</tr>
<tr>
<td>Cardiac ablation</td>
<td>8-200</td>
<td>50-320</td>
</tr>
</tbody>
</table>
Typical Operator Exposure Levels

- Annual doses for a workload of 1000 procedures
  - Neck: 10-450 mSv
  - Lens of the eye: 10-550 mSv
  - Hand: 30-640 mSv

- Survey of interventional radiologists with a mixed workload (Marx et al, 1992)
  - Mean annual dose (dosimeter on chest over protective apron): 49 mSv (range: 3-115 mSv)

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- Mean: 73 mSv
Operator Exposure Levels

- Typical doses for operators performing fluoroscopically-guided interventional procedures are high
  - May exceed annual dose limits
    - Lens of the eye: 150 mSv
    - Hands: 500 mSv
  - Values generally well exceed those for other healthcare workers
    - Annual US healthcare workers (NCRP Report No. 160): 81% with recordable dose are < 1 mSv

Personnel Dose Monitoring

- Due to the potential for high occupational doses, appropriate monitoring is critical
- Monitoring considerations:
  - 1-dosimeter or 2-dosimeter monitoring?
  - Dose calculation method?
  - When should dose readings be investigated?
Personnel Dose Monitoring

1-Dosimeter Method:
At neck, outside apron

2-Dosimeter Method:
At neck, outside apron and at waist or chest, under apron

- Dosimeter method recommended (NCRP Report No. 168)
  - Provides an indication of apron attenuation
  - Allows for better estimate of operator effective dose
  - Dosimeters should be clearly labeled to avoid mix-ups

Beth Schueler, AAPM Annual Meeting 2011
Dose Assignment with Protective Aprons

- Various calculation models exist and state regulations vary
- CRCPD SSRs (Webster’s method)
  - $H_E = 1.5 \times \text{under-lead reading} + 0.04 \times \text{neck over-lead reading}$
    - $H_E$: effective dose equivalent
- NCRP Report No. 122 recommendation
  - $E = 0.5 \times \text{under-lead reading} + 0.025 \times \text{neck over-lead reading}$
    - $E$: effective dose

Operator Exposure During Fluoroscopy Procedures

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>Mean Annual Effective Dose* (mSv)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed general IR</td>
<td>2 - 15</td>
<td>NCRP 168</td>
</tr>
<tr>
<td>ERCP</td>
<td>21</td>
<td>NCRP 168</td>
</tr>
<tr>
<td>Endovascular surgery</td>
<td>23</td>
<td>NCRP 168</td>
</tr>
<tr>
<td>Percutaneous coronary intervention</td>
<td>0.2 - 9</td>
<td>Kim et al, 2008</td>
</tr>
<tr>
<td>Cardiac ablation</td>
<td>0.2 - 10</td>
<td>Kim et al, 2008</td>
</tr>
</tbody>
</table>

* assuming workload of 1000 procedures per year
Annual Dose Limits

- NCRP Report No. 116 recommendation:
  - Effective dose: 50 mSv

- ICRP Publication 60 recommendation:
  - Effective dose: 20 mSv, averaged over 5 years, not to exceed 50 mSv in a single year

Lens Exposure

- Annual dose limit recommendations (NCRP Report No. 116):
  - Lens of the eye: 150 mSv

- Measurements for an annual workload of 1000 procedures,
  - Lens of the eye (unprotected): 10-550 mSv
Lens Dose Estimation

- Exposure level at the eye is typically somewhat lower than at the neck
  - Lens:Neck dose ratio varies with C-arm angulation
- Neck dosimeter reading provides conservative estimate (NCRP No. 168)

Leaded Eyewear

- Typical lead equivalent thickness of radiation protective eyewear is 0.75 mm
  - 98% attenuation
- Actual lens dose is higher due to
  - Exposure from the side and from below
  - Backscatter from head
Leaded Eyewear

- Traditional style
  - 0.75 mm lead equivalent lenses
  - 120 g
  - 28 cm² surface area

Leaded Eyewear

- Sport-wrap style
  - 0.75 mm lead equivalent lenses
  - 59 g
  - 16 cm² surface area
Leaded Eyewear Attenuation

<table>
<thead>
<tr>
<th>Leaded Eyewear Style</th>
<th>Attenuation Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0° Angle</td>
</tr>
<tr>
<td>Traditional</td>
<td></td>
</tr>
<tr>
<td>Sport-wrap</td>
<td>8.3</td>
</tr>
</tbody>
</table>

New Guideline on Lens Exposure

- ICRP issued a new recommendation (ICRP, 2011)
  - Lower threshold for cataract formation: 0.5 Gy (previous threshold 2-5 Gy)
  - Lower occupational eye dose limit: 20 mSv/yr averaged over 5 years with no year > 50 mSv
Radiation-Induced Cataract

- Problems with earlier studies:
  - Short follow-up period – latency period is longer for low doses
  - Insufficient sensitivity to detect early lens changes
  - Few subjects with doses below a few gray

- Significant studies:
  - Chernobyl nuclear reactor accident cleanup workers (Worgul et al, 2007)
  - US radiologic technologists (Chodick et al, 2008)

Hand Dose

- Ring dosimeters recommended if hand dose > 50 mSv in a year (NCRP Report No. 168)
- Monitor for a trial period of several months for new staff and new procedure types
- Wear with sensitive area toward exposure source
  - Inward for under-table x-ray tube configurations
Investigation of Dose Readings

- Recommended investigation trigger level (WHO, 2000):
  - Effective dose $> 0.5$ mSv/month
  - Lens dose $> 5$ mSv/month
  - Hand dose $> 15$ mSv/month
- Verify validity of measurement
- Look for changes in procedure volume, procedure type, equipment, ...

It is common for personnel who may receive a high occupational dose to not wear their dosimeters to avoid investigations.

- 43% of surveyed interventional radiologists indicate they rarely or never wear monitoring dosimeters (Marx et al, 1992)
- Dosimeter readings that are lower than expected for a specific work assignment should also be investigated (NCRP Report No. 168)
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Radiation Safety Education

- Credentials and privileges for fluoroscopy operators are needed
- Help for developing a program is coming
- AAPM TG 124 (Chair – Mary Moore)
  - “A Guide for Establishing a Credentialing and Privileging Program for Users of Fluoroscopic Equipment in Healthcare Organizations” is in the works
  - Will include suggestions to encourage your facility to approve a program, didactic content, evaluating competency and information resources for teaching
Occupational Radiation Safety Resources

- IAEA RPOP web pages
  - https://rpop.iaea.org/RPOP/RPoP/Cotent/InformationFor/HealthProfessionals/index.htm

- IAEA slide presentation series

- Image Gently pediatric IR presentation
  - http://www.pedrad.org/associations/A364/ag/

- RSNA/AAPM Online physics modules
  - “Radiation Safety and Dose in Interventional Radiology”
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Operator Shielding

- Overhead and table shields can be very effective
- But may be cumbersome for certain procedures:
  - C-arm angulation
  - Biliary or transjugular access
Orthopedic Complications from Lead Apron Use

- Back pain was reported by 50-75% of interventional physicians surveyed (Klein et al, 2009)
  - Compare to typical incidence of 27% in US adults
  - 25-30% reported that back problems had limited their work
- Options for relief
  - Lightweight aprons
  - Vest/kilt design

Radiation Protective Cabins

- ZeroGravity
  - 1.25 mm lead apron and 0.5 mm lead-equivalent face shield

Marichal et al, 2011
**Radiation Protective Cabins**

- **CATHPAX**
  - 2 mm lead walls and lead-equivalent windows

Dragusin et al, 2007

**Real-time Personnel Dose Monitoring**

- **DoseAware**
  - Displays cumulative dose and dose rate on a monitor
  - Can be networked between multiple procedure rooms
  - Allows for real-time feedback to avoid high scatter conditions and implement radiation reduction techniques

Sanchez et al, 2010
Heavy Metal Protective Patient Drapes

- **RADPAD**
  - Gel pad with tungsten-antimony
  - Sterile, dispose after procedure
  - 12× eye dose reduction
  - 29× hand dose reduction

Dromi et al, 2006

References

References (continued)

- Sanchez R, Vano E, Fernandez JM. Staff radiation doses in a real-time display inside the angiography room. Cardiovasc Intervent Radiol 2010; 33:1210-1214.