Radiation Safety:
How to Protect Yourself and the Patient

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Conflicts of interest

• Nothing to disclose
ALARA principle

- As Low As Reasonably Achievable
- Optimize/minimize radiation dose
- **TIME** (exposure time → radiation dose)
- **DISTANCE** (inverse square law)
- **SHIELDING** (lead aprons, glasses, shields)

Radiation dose delivered during fluoroscopy depends highly on the operator
Interventional fluoroscopy

- Radiation beam targeted at a specific organ/anatomy through small patch of skin for substantial amount of time
- Consider alternative image guidance (none, ultrasound, MR)
- Rapidly evolving field (interventional cardiology, interventional radiology, vascular surgery, gastroenterology, urology, etc)
### Radiation-induced injuries

<table>
<thead>
<tr>
<th>Effect</th>
<th>Threshold dose (Gy)</th>
<th>Time of onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early transient erythema</td>
<td>2</td>
<td>2-24h</td>
</tr>
<tr>
<td>Main erythema reaction</td>
<td>6</td>
<td>≈ 1.5 wks</td>
</tr>
<tr>
<td>Permanent epilation</td>
<td>7</td>
<td>≈ 3 wks</td>
</tr>
<tr>
<td>Dry desquamation</td>
<td>14</td>
<td>≈ 4 wks</td>
</tr>
<tr>
<td>Moist desquamation</td>
<td>18</td>
<td>≈ 4 wks</td>
</tr>
<tr>
<td>Lens opacity (detectable)</td>
<td>&gt;1-2</td>
<td>&gt; 5 years</td>
</tr>
<tr>
<td>Lens cataract</td>
<td>&gt;5</td>
<td>&gt; 5 years</td>
</tr>
<tr>
<td>Dermal necrosis</td>
<td>&gt;12</td>
<td>&gt;52 weeks</td>
</tr>
<tr>
<td>Skin cancer</td>
<td>Unknown</td>
<td>&gt;15 years</td>
</tr>
</tbody>
</table>

Radiation exposure

Cases of Interventional Radiology and Interventional Neuroradiology Procedures that Resulted in a Cumulative Dose >5 Gy

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Number &gt;5 Gy, n (%)</th>
<th>Total Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatic chemoembolization</td>
<td>2 (1.6)</td>
<td>126</td>
</tr>
<tr>
<td>Nephrostomy: stone access</td>
<td>1 (1.6)</td>
<td>64</td>
</tr>
<tr>
<td>Renal/visceral angioplasty</td>
<td>3 (1.9)</td>
<td>156</td>
</tr>
<tr>
<td>Other tumor embolization</td>
<td>4 (4.4)</td>
<td>91</td>
</tr>
<tr>
<td>Gastrointestinal hemorrhage diagnosis/therapy</td>
<td>7 (7.4)</td>
<td>94</td>
</tr>
<tr>
<td>TIPS creation</td>
<td>11 (8.1)</td>
<td>135</td>
</tr>
<tr>
<td>Pelvic arterial embolization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibroid</td>
<td>8 (8.9)</td>
<td>90</td>
</tr>
<tr>
<td>AVM</td>
<td>2 (16.7)</td>
<td>12</td>
</tr>
<tr>
<td>Pelvic vein embolization: ovarian vein</td>
<td>1 (16.7)</td>
<td>6</td>
</tr>
<tr>
<td>Neuroembolization/head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aneurysm</td>
<td>26 (17.4)</td>
<td>149</td>
</tr>
<tr>
<td>AVM</td>
<td>40 (22.6)</td>
<td>177</td>
</tr>
<tr>
<td>Tumor</td>
<td>13 (23.2)</td>
<td>56</td>
</tr>
<tr>
<td>Neuroembolization/spine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tumor</td>
<td>5 (38.5)</td>
<td>13</td>
</tr>
<tr>
<td>AVM</td>
<td>6 (60.0)</td>
<td>10</td>
</tr>
</tbody>
</table>

Total 129 1,179

Patient dosimetry

Use of the structured report for hospital statistics.
Inverse square law

The energy twice as far from the source is spread over four times the area, hence one-fourth the intensity.
Radiation dose structured reports

- **KERMA**: Kinetic Energy Released in Mass

- **KERMA SI units**: \( J/kg = \text{Gray (Gy)} \)

- **Air Kerma Area Product (KAP) or Dose Area Product (DAP)** → \( \text{cGycm}^2 \)

- **NOTE**: DAP good index of stochastic risk

- **BUT**: No record of patient size, weight and geometry
Follow-up patients

*Radiation dose structured reports*

- Cumulative air kerma $>5$Gy
- Peak skin dose $>3$Gy (at reference point)
- Air kerma-area product $>500$Gy$\text{cm}^2$
- Fluoroscopy time $>60$min

**ALERTS FOR SKIN INJURIES**
How to manage patients with >2Gy

• **0-2Gy** → Nothing – no visible effects expected

• **2-5Gy** → Advise patient about erythema – fade over time

• **5-10Gy** → Advise patient / relative to examine exposed skin area for erythema for 2-10 weeks following procedure

• **10-15Gy** → Medical follow-up appropriate because of risk of late skin effects – risk of pain and necrosis

• **>15Gy** → Medical follow-up mandatory because radiation induced wound may ulcerate and necrosis
Optimize patient dose

1. Maximize distance between x-ray tube and the patient
2. Minimize distance between patient and image intensifier
3. Limit use of electronic magnification
4. Control/limit fluoroscopy time
5. Pulsed fluoroscopy at low pulse rate (3.75fps)
Optimize patient dose

6. Control/limit digital angiographic runs
7. Employ ‘LAST IMAGE HOLD’ for reviewing/reference/storage purposes
8. Reduce exposed field size – tight collimation
9. Minimize exposed anatomy overlap
10. Dose saving features – body habitus
Occupational risks (1)

- Cancer risks in US technologists 1994-2008
- Nationwide cohort of 90,957 technologists

Cancer risk among RTs performing interventional fluoroscopy

<table>
<thead>
<tr>
<th>Type of cancer</th>
<th>Incidence hazard ratio</th>
<th>Mortality hazard ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cancers (except nonmelanoma skin cancer)</td>
<td>1.07</td>
<td>1.03</td>
</tr>
<tr>
<td>Brain cancer</td>
<td>--</td>
<td>2.16 x2</td>
</tr>
<tr>
<td>Female breast cancer</td>
<td>1.18</td>
<td>1.10</td>
</tr>
<tr>
<td>Melanoma</td>
<td>1.32</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Rajaraman P, AJR 2016
Occupational risks (2)

- Brain and neck tumours in interventionists
- 31 brain tumours (85% left-sided)
- 23 interventional cardiologists, 2 electrophysiologists, and 6 interventional radiologists
- Latency period 12-32 y, mean 23.5±5.9y
- 17 cases GBM, 2 astrocytoma, 5 meningioma

Ted Diethrich, famed heart surgeon, dead at 81

In later years, Diethrich said his cancer was likely the result of a surgical technique involving radiation.

Edward “Ted” Diethrich, the high-profile cardiac surgeon who started the Arizona Heart Institute and once performed open-heart surgery on live television, has died of brain cancer. He was 81.

Diethrich had said in interviews he believed his head tumors came from exposure to radiation during surgeries, using an imaging technique he helped pioneer.
Occupational dose thresholds

- EU: 20 mSv per annum (averaged over 5 years – no year > 50 mSv)
- 400 mSv lifetime dose limit (Germany)
- US: 50 mSv per annum & lifetime limit 10 mSv x age (years)
- US: 0.5 mSv per month for pregnancy
- Eye lens: 150 mSv per annum (under review)
- Hand and feet: 500 mSv

ICRP safety standards - European Commission 2012; IAEA 2014
Professional dosimetry

Tselikas L, Radiation dose management; presented @CIRSE 2016
Inverse square law in fluoroscopy

Schueler BA. Operator Shileding. Tech vasc Interv Radiol 13(3);2010
Minimize physician/staff dose

1. Hands away from the beam
2. Always use protective shielding
3. Maintain maximum distance from x-ray
4. Wear adequate personal protection (lead aprons, collars and glasses)
5. Avoid angulated projections (esp. LAO)
Personal Protective Equipment

- **Body protection:** lead aprons, thyroid shields, radiation protection cabins, and floor- and table-mounted shields
- **Eye protection:** leaded glasses, ceiling-mounted shields

Schueler BA. Operator Shileding. Tech vasc Interv Radiol 13(3);2010
Lead shields

Aggressive use of shielding recommended

Plus Aprons & Glasses

Open Journal of Radiology, 2013, 3, 143-151
http://dx.doi.org/10.4236/ojrad.2013.33024
RADPAD protection shields

Blocks 95% of scatter radiation directed to physician
Radiation protection cabins

Schueler BA. Operator Shileding. Tech vasc Interv Radiol 13(3);2010
Suspended radiation protection

Open Journal of Radiology, 2013, 3, 143-151
http://dx.doi.org/10.4236/ojrad.2013.33024
Suspended radiation protection

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Open Journal of Radiology, 2013, 3, 143-151
http://dx.doi.org/10.4236/ojrad.2013.33024 (Zerogravity by Biotronic)
The 10 commandments

• Maximize x-ray tube to patient distance
• Detector as close as possible to patient
• Adapt exposure settings to patient size (automatic)
• Pulsed fluoro mode – reduce frame rate
• Use tight collimation - Avoid magnification
• Avoid angled projection views
• Use roadmap & last image hold instead of runs
• Position yourself in a low scatter area
• Use protective shielding
• Wear your dosimeter and know your own dose
Thank you
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