Patient Dose Calculation: Fluoroscopy and Interventional Radiology

William F. Sensakovic, PhD, DABR, MRSC
Medical Physicist – Florida Hospital
Co-Founder, Telerad Physics Teaching, LLC
Asso. Prof. – University of Central Florida
Clin. Asst. Prof. – Florida State University
Adj. Prof. – Adventist University

Twitter: @wfsensak
E-mail: wfsensak@gmail.com
www.teleradphysics.com

July 30, 2018

Relevant Conflicts of Interest

Paid Speaker, Bayer

Who Do We Need to Monitor

• Radiology
• Cardiology
• Interventional Endoscopy
• Pain Medicine
• Speech Language Pathology
• Surgery
• List is longer than this

July 30, 2018
<table>
<thead>
<tr>
<th>Effect</th>
<th>Threshold</th>
<th>Onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transient Erythema</td>
<td>2 Gy</td>
<td>Hours</td>
</tr>
<tr>
<td>Temporary Epilation</td>
<td>3 Gy</td>
<td>3 Weeks</td>
</tr>
<tr>
<td>Main Erythema</td>
<td>6 Gy</td>
<td>10 Days</td>
</tr>
<tr>
<td>Permanent Epilation</td>
<td>7 Gy</td>
<td>3 Weeks</td>
</tr>
<tr>
<td>Dry Desquamation</td>
<td>10 Gy</td>
<td>4 Weeks</td>
</tr>
<tr>
<td>Invasive Fibrosis</td>
<td>10 Gy</td>
<td></td>
</tr>
<tr>
<td>Dermal Atrophy</td>
<td>11 Gy</td>
<td>&gt; 14 Weeks</td>
</tr>
<tr>
<td>Telangiectasis</td>
<td>12 Gy</td>
<td>&gt; 52 Weeks</td>
</tr>
<tr>
<td>Moist Desquamation</td>
<td>15 Gy</td>
<td>4 Weeks</td>
</tr>
<tr>
<td>Late Erythema</td>
<td>15 Gy</td>
<td>6-10 Weeks</td>
</tr>
<tr>
<td>Dermal Necrosis</td>
<td>18 Gy</td>
<td>&gt; 10 Weeks</td>
</tr>
<tr>
<td>Secondary Ulceration</td>
<td>20 Gy</td>
<td>&gt; 6 Weeks</td>
</tr>
<tr>
<td>Moist Desquamation</td>
<td>15 Gy</td>
<td></td>
</tr>
<tr>
<td>Late Erythema</td>
<td>15 Gy</td>
<td></td>
</tr>
<tr>
<td>Dermal Necrosis</td>
<td>18 Gy</td>
<td></td>
</tr>
<tr>
<td>Secondary Ulceration</td>
<td>20 Gy</td>
<td></td>
</tr>
</tbody>
</table>

**Radionecrosis of Skin and Bone**

- Stent
  - 22 min fluoro time
- 6 mo later failed recanalization
  - 47 min fluoro time
- 2 d later implanted two more stents
  - 78 min fluoro time

**Pediatric Skin**

- “Not significantly more radiosensitive than adults.”
  - UNSCEAR 2013 Vol.2 Anx.B
- More sensitive for epilation
- Less sensitive to moist desquamation
**When to Follow Up**

- We don't have peak skin dose
  – More on this later
- Currently have dose index cutoffs instead

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak skin dose (PSD)</td>
<td>3,000 mGy</td>
</tr>
<tr>
<td>Keelentrop point air</td>
<td>5,000 mGy</td>
</tr>
<tr>
<td>Kerma (K&lt;sub&gt;γ&lt;/sub&gt;)</td>
<td>500 Gy·cm&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Kerma-air product (K&lt;sub&gt;€&lt;/sub&gt;)</td>
<td>500 Gy·cm&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fluoroscopy time (FT)</td>
<td>60 min</td>
</tr>
</tbody>
</table>

**“Dose” Indices**

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>INSTRUCTIONS:</td>
</tr>
<tr>
<td>This measure is to be submitted each time fluoroscopy is performed in a hospital or outpatient setting during the performance period. There is no diagnosis associated with this measure. It is anticipated that eligible providers providing the services for procedures using fluoroscopy will submit this measure.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Flare-up exposure indices:</td>
</tr>
<tr>
<td>For the purposes of this measure, website exposure indices should:</td>
</tr>
<tr>
<td>1. Skin dose mapping.</td>
</tr>
<tr>
<td>2. Kerma-air product.</td>
</tr>
<tr>
<td>3. Kerma</td>
</tr>
<tr>
<td>When reporting values, the result must clearly state what radiation quantity is being submitted, that is, measuring skin dose in mGy. PDS or mGy is very different from kerma in mGy. For example, PDS = 10 mGy or kerma = 10 mGy.</td>
</tr>
<tr>
<td>The fluoroscopy measurement must not automatically present any of the above radiation exposure indices. When reporting values and kerma, all values must be in the same units.</td>
</tr>
</tbody>
</table>

**Fluoroscopy Time, Runs, & Spots**

- Fluoroscopy Time
  – In DICOM Header?
- Runs
  – All Sent?
- Photospots/Spots
  – All Sent?
Relative Dose Rule-of-Thumb

- 1 min of Cine = 10 min of fluoroscopy
- 1 min of DSA = 30 min of fluoroscopy
- Your mileage may vary

DAP/KAP/Area Dose Product

- Total Energy Delivered
  - Best for Effective Dose
- Correct to get field size at patient entrance
- Dicom in dGy*cm²
  - Maybe

K_{att}/CD/CAK

- Air Kerma at IRP
- No Backscatter
- Best Correlation with Peak Skin Dose
Several automated and semi-automated methods currently under construction

Tedious to try to do it all by hand

DICOM compliance is the Wild West for IR/Fluoroscopy

Information missing or wrong
  – Especially outside radiology/cardiology
Can You Trust the Tags?

- Fluoro
- DICOM is the Wild West
- Information missing

300 Line Spreadsheet of what Sends to Tracking

An Aside for E

- Schmidt PNE et al. Conversion factors for the estimation of effective dose in pediatric cardiac angiography. Physics in Medicine & Biology, Vol45(10)
“Skin Dose”

- > 5 Gy
- Follow up
- Done?
  - Sure

Table 1: Thresholds for Patient Follow-up

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>peak skin dose (PSD)</td>
<td>300 mGy</td>
</tr>
<tr>
<td>reference point air (RPA)</td>
<td>500 mGy</td>
</tr>
<tr>
<td>kerma (Ker)</td>
<td>300 mGy/cm²</td>
</tr>
<tr>
<td>kerma air (KerAir)</td>
<td>300 mGy/cm²</td>
</tr>
<tr>
<td>fluoroscopy time (FT)</td>
<td>60 min</td>
</tr>
</tbody>
</table>

Angulation Map

- > 5 Gy
  - Follow up
- < 5 Gy
  - Maybe not
Assumptions

- Backscatter
  - Backscatter from patient
- Air Kerma
  - Patient position relative to IRP
- Display vs. Measured
- Attenuation/Forward Scatter
  - Table and pad
- Air to Tissue Conversion
- Geometry

Geometry

- IRP
  - 15 cm from iso towards tube
    - . . . most of the time
  - 30 cm thick and set at isocenter

Geometry

- Correct for real skin position
  - Inverse square
- Where is the skin position?
  - Table position
Table Attenuation/Forward Scatter

- 0.6 to 0.8 CF
  - Measured?
- Forward Scatter
  - 1.05 – 1.09

**Scatter Correction**

- **How much?**
  - 1.3 to 1.4
  - HVL & Energy
- **Measure?**


**Detector Correction**

- **We have seen 10% - 20%**
  - Have heard of much worse

**f-Factor**

- **Tissue Dose**
- **Not Air**

When In Doubt...

- Put a phantom on the table with a dosimeter and see what you get for similar settings and number of images.
- Fill in unknowns with “typical” for a procedure type

When In Doubt...

- Group similar angles together and use cumulative values if calculating by hand

What We Do Not Know

- Wedges and compensation filters are likely not accounted for
- Lateral and longitudinal patient table motion not accounted for
- Patient motion not accounted for
- Heal effect not accounted for
What We Do Not Know

- Error bars exist on every measurement
- Reports likely should include uncertainty

The Law

Old Joint Commission

- How long?
  - 6 mo ... Maybe
  - Dose tracking programs ... If you can get them working
• 21 CFR 803
  – Report serious injury from a device
  – Unless it is unlikely to happen again
Maintain records of Fluoroscopic use in the imaging arts.

States: Ohio

Maintain records of Fluoroscopic use in the imaging arts.

States: Texas
Massachusetts

Government

July 30, 2018
William F. Sensakovic PhD

### Relevant DICOM Tags

<table>
<thead>
<tr>
<th>Tag</th>
<th>Description</th>
<th>Tag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0018, 0020</td>
<td>kVP</td>
<td>0018, 1151</td>
<td>Source-to-Detector Distance</td>
</tr>
<tr>
<td>0018, 1158</td>
<td>Source-to-Isocenter Distance</td>
<td>0018, 1101</td>
<td>View Position</td>
</tr>
<tr>
<td>0018, 1156</td>
<td>Magnification Factor</td>
<td>0018, 1400</td>
<td>Table Position Macro</td>
</tr>
<tr>
<td>0018, 1159</td>
<td>Field of View Dimensions</td>
<td>0018, 1302</td>
<td>Intensifier Size</td>
</tr>
<tr>
<td>0018, 1155</td>
<td>Exposure Time</td>
<td>0018, 1700-1712</td>
<td>Exposure Current</td>
</tr>
<tr>
<td>0018, 1152</td>
<td>Exposure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0018, 1157</td>
<td>Radiation Setting</td>
<td>0018, 1153-1154</td>
<td>Collimator Size and Positions</td>
</tr>
<tr>
<td>0018, 1156</td>
<td>Intensifier Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0018, 1150-1152</td>
<td>Collimator Size and Positions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0018, 1153-1154</td>
<td>Primary &amp; Secondary Angles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
References

- Jones AK and Pasciak AS. Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods. JACR 2011; 12(4): 231-244.

Cite This Talk/Handout


Thank You!