Estimating peak skin dose using available clinical data

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Disclosures

• President of FluoroSafety
Basic workflow

1. Start with $K_{a,r}$

2. Correct $K_{a,r}$ to the entrance surface of the patient

3. Correct incident air kerma to skin dose

4. Correct skin dose to peak skin dose
1. Start with $K_{a,r}$
Fluoroscopy time

• Don’t even bother

• PSD estimates produced from fluoroscopy time always underestimate the PSD and lead to mismanagement of the patient
Fluoroscopy time

• Don’t even bother

• PSD estimates produced from fluoroscopy time always underestimate the PSD and lead to mismanagement of the patient
\( P_{KA} \)

• In the absence of \( K_{a,r} \) (why would you not have this), \( P_{KA} \) can be used

• Convert \( P_{KA} \) to \( K_{a,r} \)

• However, you MUST USE the field size AT THE LOCATION OF THE PATIENT, and not at the image receptor (nominal FOV)
Where do I find these dose indices

- On the fluoroscope
- Secondary capture dose page in the procedure record
- RDSR
2. Correct $K_{a,r}$ to the patient surface
Important factors for this calculation

• Dose measuring device calibration factor

• Inverse square law correction
  • Magnitude depends on procedure type

• Backscatter factor

• Table and pad attenuation

• f-factor
Dose measuring device CF

• Report of AAPM TG 190 provides the method for measuring

• Space available to store single point calibration factor in RDSR
  • NEMA XR-27 provides the framework for actually storing this on the angio system

Beth Schueler, AAPM 2010
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Inverse square law correction

- Magnitude depends on procedure type

- Know the meaning of the data you are using
  - Distance Source to Patient

Correction often close to 1.0
Correct often offsets BSF
Inverse square law correction

- Magnitude depends on procedure type
- Know the meaning of the data you are using
  - Distance Source to Patient
Table and pad attenuation

• Can be measured during commissioning of any new fluoroscope (or pad)

• Varies with incidence angle and beam quality

• If you don’t have it, sources of data are available
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**Table 4. Table and Pad Transmission Factors**

<table>
<thead>
<tr>
<th>Measurement Method</th>
<th>Mean Transmission Factor (95% CI)</th>
<th>Transmission Factor Range</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow-beam</td>
<td>0.70 (0.69–0.71)</td>
<td>0.65–0.74</td>
<td>0.03</td>
<td>23</td>
</tr>
<tr>
<td>Broad-beam</td>
<td>0.76 (0.74–0.77)</td>
<td>0.70–0.85</td>
<td>0.04</td>
<td>22</td>
</tr>
</tbody>
</table>

CI = confidence interval; SD = standard deviation.
3. Correct IAK to skin dose
Backscatter factor

• Large magnitude, but varies within a small range

• Use of a single BSF (two at most) is usually sufficient
f-factor

• Ratio of mass energy absorption coefficient of skin to that of air

• Small (1.04 – 1.06)

• Very important caveat – for bone tissue is about 4
f-factor

• Ratio of mass energy absorption coefficient of skin to that of air

• Small (1.04 – 1.06)

• Very important caveat – for bone tissue is about 4
\[ D_{\text{skin}} = K_{a,r} \times CF \times \left( \frac{d_{IRP}}{d_{SPD}} \right)^2 \times TAF \times f \times BSF \]
\[ D_{\text{skin}} = K_{a,r} \times CF(kVp, filt) \times \left( \frac{d_{IRP}}{d_{SPD}} \right)^2 \times TAF(kVp, filt, FOV) \times f \times BSF(kVp, filt, FOV) \]
4. Convert skin dose to PSD
Accounting for changing gantry angle

• Procedural images (along with metadata) or RDSR is needed to study gantry angle

• If you do not have either of these, don’t attempt to make a correction
  • Assume all dose delivered to a single skin site – your calculated skin dose = PSD

• Gantry angle can be used as a radiation management strategy where appropriate
1308.286 / 6.962 = 188 cm²

Nominal FOV ~ 32 cm
### Table 1
Formats available for the two fluoroscopic systems simulated in this study and grouping of the formats as presented in figures in this work

<table>
<thead>
<tr>
<th>Format</th>
<th>Siemens Artis zee* (cm)</th>
<th>Format group</th>
<th>Philips Integris H5000F† (cm)</th>
<th>Format group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Zoom/Mag 0)</td>
<td>25</td>
<td>A</td>
<td>22.5 (9°)</td>
<td>A</td>
</tr>
<tr>
<td>2 (Zoom/Mag 1)</td>
<td>20</td>
<td>A</td>
<td>17.5 (7°)</td>
<td>B</td>
</tr>
<tr>
<td>3 (Zoom/Mag 2)</td>
<td>16</td>
<td>B</td>
<td>12.5 (5°)</td>
<td>C</td>
</tr>
<tr>
<td>4 (Zoom/Mag 3)</td>
<td>10</td>
<td>C</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Sizes are quoted as the diagonal of the field.
*Square fields.
†Octagonal fields.

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Pasciak AS, Bourgeois AC, Jones AK. *Open Heart* 2014;1:e000141. doi:10.1136/openhrt-2014-000141

### Table 2
Patient sizes simulated in this study

<table>
<thead>
<tr>
<th>Size group</th>
<th>Population percentile</th>
<th>Male AP dimension (cm)</th>
<th>Male trans dimension (cm)</th>
<th>Female AP dimension (cm)</th>
<th>Female trans dimension (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>5</td>
<td>23.8</td>
<td>28.4</td>
<td>22.8</td>
<td>22.8</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>24.9</td>
<td>29.4</td>
<td>23.8</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>26.8</td>
<td>31.0</td>
<td>25.8</td>
<td>24.6</td>
</tr>
<tr>
<td>Average</td>
<td>50</td>
<td>29</td>
<td>32.9</td>
<td>28.5</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>31.4</td>
<td>34.7</td>
<td>31.7</td>
<td>27.1</td>
</tr>
<tr>
<td>Large</td>
<td>90</td>
<td>33.8</td>
<td>36.5</td>
<td>35.2</td>
<td>28.3</td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>35.4</td>
<td>37.5</td>
<td>37.2</td>
<td>29.0</td>
</tr>
</tbody>
</table>

AP, anteposterior; trans, transverse.
These simulations indicate that rotation between LAO and RAO angles of about 20 degrees can reduce PSD for most patients during cardiac interventions.
Goal of the dose estimate

• Broadly categorize the PSD and possible effects
  • Patient communication
  • Follow up
Reporting

- Standardized format
- Key information easily identifiable
- Report should include both the most likely value and a range that reflects uncertainty
Methods

• Hand calcs
  • Jones and Pasciak methods

• RDIM

• Real time monitoring software
Multiple procedures

• Biologically effective dose (BED) approach

• Likelihood and severity of late effects is reduced when dose is fractionated

• Radiobiology of late effects
  • For skin $\alpha/\beta \sim 3.5$ Gy
  • Complete repair in 24 hours
  • Repopulation in 2 months

Fluoroscopically Guided Interventional Procedures: A Review of Radiation Effects on Patients’ Skin and Hair

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Appendix E1

This approach uses models developed and tested for radiation therapy, which are used to calculate equivalent biologically effective doses when dose fractionation schedules are changed or to modify the subsequent dose if errors are found in the original dose prescription. The equations are based on the so-called linear quadratic model of cell survival, which takes account of the amount of repair of DNA damage between separate radiation exposures. For use with complex procedures consisting of multiple sessions, the full procedure should not extend over more than 1-2 months because the model has only been applied to standard radiation therapy schedules within this time scale. Initially a reference point is established for single dose procedure using the following equation:

$$\text{BED} = D \left(1 + \frac{D}{\alpha / \beta}\right), \quad (E1)$$

where $\text{BED}$ is the biologically effective dose to which the likely effects of a more complex procedure have to be compared, $D$ is the size of the dose from the single procedure, and $\alpha/\beta$ is a tissue-specific constant related to the survival characteristics of the cells in the tissue at risk. For late radiation damage to the skin, a value of 3-4 Gy is frequently applied (82,83).

For a complex procedure involving multiple sessions with 24 hours or more between each session, the total dose $D$ in the simple equation (ie, Eq [E1]) is replaced by the dose received at each stage, $d_1$, $d_2$, $d_3$, such that

$$\text{BED}_{\text{m}} = d_1 \left(1 + \frac{d_1}{\alpha / \beta}\right) + d_2 \left(1 + \frac{d_2}{\alpha / \beta}\right) + d_3 \left(1 + \frac{d_3}{\alpha / \beta}\right), \quad (E2)$$
Multiple procedures

• “Equivalent” single procedure dose is less than the sum of the individual doses

• One strategy (justified by radiobiology):
  • Procedures separated by < 24 hrs: sum doses
  • Procedures separated by 24 hrs to 8 weeks: BED approach
  • Procedures separated by > 8 weeks: completely independent (?)

\[
BED_m = 3.5 \left( 1 + \frac{3.5}{3.5} \right) + 5.9 \left( 1 + \frac{5.9}{3.5} \right),
\]

which yields a BEDm of 22.85. By using this BED value, the equivalent single dose can be calculated by using Equation (E1):

\[
22.85 = D \left[ 1 + \frac{D}{3.5} \right]
\]
Incidence of Chronic Radiodermatitis after Fluoroscopically Guided Interventions: A Retrospective Study

Mélanie Guesnier-Dopagne, MD, Louis Boyer, MD, PhD, Bruno Pereira, Joël Guersen, Pascal Motreff, MD, PhD, and Michel D’Incan, MD, PhD

ABSTRACT

Purpose: To assess the incidence and risk factors for chronic radiodermatitis after fluoroscopically guided interventions (FGIs) in high-risk patients.

Materials and Methods: Between 2010 and 2016, of 55,782 patients who underwent FGIs, 359 had a risk procedure for skin injury (maximal skin dose > 3 Gy, air kerma > 5 Gy, dose area product [DAP] > 500 Gy-cm², or fluoroscopy time > 60 minutes). Ninety-one of these patients were examined by a dermatologist for radiodermatitis (median time after procedure, 31.2 months [95% confidence interval, 14.2-50.7]). In each case, the clinical features and topography of the skin lesions were recorded and their incidence calculated. The characteristics of the patients and of the FGIs were tested as risk factors.

Results: Eight patients (8.8%) had chronic radiodermatitis; 19 (20.9%) had acute radiodermatitis. Body mass index, DAP value, and air kerma were the only risk factors identified.

Conclusions: This study shows that chronic radiodermatitis may be considered a frequent side effect in an at-risk population. The lesions are generally benign, but extensive scarring can occur. Patients should be better informed about the side effects and offered a skin exam periodically.
Other factors

• Oblique incidence
  • Table and pad attenuation
  • Shape of X-ray field on skin

• Heel effect

• Protraction of exposure during long procedures

Kevin Wunderle, AAPM 2019