Fluoroscopic Radiation Exposure

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FLUOROSCOPIC RADIATION EXPOSURE

Tony Brown
OVERVIEW

• Radiation Physics Units
• Effects of Radiation
• SI Units and Equations
• Fluoroscopy and Clinical Application
• Project Limitations/Feedback
• References
PURPOSE

1. To provide a very basic foundational understanding of radiation
2. To highlight specific terms and units that are often convoluted in the literature
3. To present preliminary resident radiation exposure findings and future directions
• **Absorbed dose**: energy absorbed per unit mass
  • Gray (Gy) is an SI unit and is equivalent to 1 Joule/kg

• **Equivalent dose**: absorbed dose derivative weighted by the relative effect of the type and energy of the radiation encountered
  • 3 factors: absorbed dose, radiation type, exposed organs/tissues
  • Used to establish dose limits for occupational exposures for deterministic effects

• **Effective dose**: global sum of equivalent doses in exposed organs/tissues
  • Used to establish dose limits for occupational exposures for stochastic effects
RADIATION EFFECTS\textsuperscript{1,4,5}

- **Deterministic effect**: side effect of ionizing radiation that occurs above a certain threshold
  - Severity increases with increasing dose
  - Effects do not occur if threshold is not met
- **Stochastic effect**: side effect of ionizing radiation that occurs by chance
  - Increasing dose increases the risk of developing effect; severity does not change
  - Used to form a cancer induction model
## Deterministic Effect

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Effect</th>
<th>Acute dose threshold (Gy)</th>
<th>Protracted dose threshold (Gy)</th>
<th>Time to effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>Early transient erythema</td>
<td>2</td>
<td></td>
<td>Hours</td>
</tr>
<tr>
<td></td>
<td>Temporary epilation</td>
<td>3</td>
<td></td>
<td>3–6 weeks</td>
</tr>
<tr>
<td></td>
<td>Main erythema</td>
<td>6–8</td>
<td>30</td>
<td>3–6 weeks</td>
</tr>
<tr>
<td></td>
<td>Permanent epilation</td>
<td>7</td>
<td>50–60</td>
<td>3–6 weeks</td>
</tr>
<tr>
<td></td>
<td>Moist desquamation</td>
<td>10</td>
<td></td>
<td>4–6 weeks</td>
</tr>
<tr>
<td></td>
<td>Dermal necrosis</td>
<td>18</td>
<td></td>
<td>&gt;10 weeks</td>
</tr>
<tr>
<td></td>
<td>Dermal atrophy</td>
<td></td>
<td>35–40</td>
<td>14–20 weeks</td>
</tr>
<tr>
<td></td>
<td>Telangiectasia</td>
<td></td>
<td>40</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td>Skull</td>
<td>Bone necrosis</td>
<td></td>
<td></td>
<td>&gt;6 months</td>
</tr>
<tr>
<td>Eye lens</td>
<td>Lens opacity</td>
<td>2</td>
<td>6</td>
<td>&gt;1 year</td>
</tr>
<tr>
<td></td>
<td>Cataract</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parotid glands</td>
<td>Reduced function</td>
<td>3</td>
<td>30</td>
<td>Hours</td>
</tr>
<tr>
<td></td>
<td>(bilateral dose)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
STOCHASTIC EFFECT\textsuperscript{5}
THE SIEVERT\textsuperscript{7,8}

- **Sievert (Sv):** SI unit of dose equivalence that represents stochastic effects of ionizing radiation
  - Adjusted by a tissue weighting factor to account for differing responses of different human tissues to ionizing radiation and the differing effect of different forms of energies of this radiation
- **Dose equivalence (H\textsubscript{T}):** a measure of radiation dose to tissue that factors in biological properties of differing tissues
  - H\textsubscript{T} = absorbed dose × radiation weighting factor

- \begin{tabular}{l}
  \textit{W}_T = 0.12: stomach, colon, lung, red bone marrow, breast, remainder tissues \\
  \textit{W}_T = 0.08: gonads \\
  \textit{W}_T = 0.04: urinary bladder, esophagus, liver, thyroid \\
  \textit{W}_T = 0.01: bone surface, skin, brain, salivary glands
\end{tabular}
Dose/air-kerma area product (DAP) is used for the assessment of patient dose (C-arm radiation calculation)

- Ionization chamber mounted on the collimator of the X-ray tube
- Measured in units of Gy•cm²
- DAP can be converted to Sv using conversion factors specified for various imaging techniques and tissues
The intensity of radiation exposure is inversely proportional to the distance from the source.

- Intensity = $1/\text{distance}^2$
## Preliminary Resident Radiation Exposure Data during Swallow Study Evaluations during PGY2

<table>
<thead>
<tr>
<th></th>
<th>Time (minutes)</th>
<th>Radiation (mGy)</th>
<th>Runs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>1.9</td>
<td>7.9</td>
<td>13.5</td>
</tr>
<tr>
<td>Median</td>
<td>1.8</td>
<td>7.2</td>
<td>13</td>
</tr>
<tr>
<td>Range</td>
<td>0.3 – 4.3</td>
<td>1.5 – 24.3</td>
<td>1 – 26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated Exposure/Rotation</th>
<th>Time (minutes)</th>
<th>Radiation (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>367.7</td>
<td>23.9</td>
</tr>
</tbody>
</table>
HYPOTHESES

1. The perceived amount of radiation exposure is likely higher than estimated.
2. Health care personnel not equipped with leaded glasses are at increased risk for eye damage and developing cataracts.
3. Badge data is either non-existent or unreliable.
QUESTIONS/FEEDBACK?
REFERENCES

5. https://radiopaedia.org/articles/stochastic-effects?lang=us
## IONIZING QUANTITIES AND UNITS

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Symbol</th>
<th>Derivation</th>
<th>Year</th>
<th>SI equivalence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity (A)</strong></td>
<td>becquerel</td>
<td>Bq</td>
<td>s⁻¹</td>
<td>1974</td>
<td>SI unit</td>
</tr>
<tr>
<td></td>
<td>curie</td>
<td>Ci</td>
<td>3.7 × 10¹⁰ s⁻¹</td>
<td>1953</td>
<td>3.7 × 10¹⁰ Bq</td>
</tr>
<tr>
<td></td>
<td>rutherford</td>
<td>Rd</td>
<td>10⁶ s⁻¹</td>
<td>1946</td>
<td>1,000,000 Bq</td>
</tr>
<tr>
<td><strong>Exposure (X)</strong></td>
<td>coulomb per kilogram</td>
<td>C/kg</td>
<td>C·kg⁻¹ of air</td>
<td>1974</td>
<td>SI unit</td>
</tr>
<tr>
<td></td>
<td>röntgen</td>
<td>R</td>
<td>esu / 0.001293 g of air</td>
<td>1928</td>
<td>2.58 × 10⁻⁴ C/kg</td>
</tr>
<tr>
<td><strong>Absorbed dose (D)</strong></td>
<td>gray</td>
<td>Gy</td>
<td>J·kg⁻¹</td>
<td>1974</td>
<td>SI unit</td>
</tr>
<tr>
<td></td>
<td>erg per gram</td>
<td>erg/g</td>
<td>erg·g⁻¹</td>
<td>1950</td>
<td>1.0 × 10⁻⁴ Gy</td>
</tr>
<tr>
<td></td>
<td>rad</td>
<td>rad</td>
<td>100 erg·g⁻¹</td>
<td>1953</td>
<td>0.010 Gy</td>
</tr>
<tr>
<td><strong>Equivalent dose (H)</strong></td>
<td>sievert</td>
<td>Sv</td>
<td>J·kg⁻¹ × Wᵣ</td>
<td>1977</td>
<td>SI unit</td>
</tr>
<tr>
<td></td>
<td>röntgen equivalent man</td>
<td>rem</td>
<td>100 erg·g⁻¹ × Wᵣ</td>
<td>1971</td>
<td>0.010 Sv</td>
</tr>
</tbody>
</table>
Dose quantities in SI units for external radiological protection

**Sources of external radiation**
- Monitored quantities
- Instrument responses
  - Measured in practice by Radiological Protection Instruments

**Physical quantities**
- Fluence, $\Phi$
- Kerma, $K$ (gray)
- Absorbed dose, $D$ (gray)

Dose equivalents calculated using absorbed dose and $Q(L)$, and simple phantoms (sphere or slab). Validated by measurements and calculations.

**Operational quantities**
- Ambient dose equivalent, $H^*(d)$
- Directional dose equivalent, $H^*(d,\Omega)$
- Personal dose equivalent, $H_P(d)$
  - Unit = sievert

These quantities are measurable, and used for practical evaluation of dose for regulation and assessment.

**Protection quantities**
- Organ absorbed dose, $D_T$ (gray)
- Organ equivalent dose, $H_T$ (sievert)
- Effective dose, $E$ (sievert)

These quantities are not measurable; they are calculated quantities used to compare against observed health effects, and to set limits for exposure.

A “phantom” is a device used to model and calculate the absorbed dose for an irradiated entity.

Calculated using anthropomorphic phantom for organ absorbed dose, then factors $W_a$ and $W_I$ for biological effect.

Related by instrument calibration.