Cutaneous Radiation Injuries Created with Different Radiation Sources

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Sunburns – The Simple Example

First degree - Erythema
Second degree - Blistering
Third degree - Necrosis
Dermal Damage Severity

Types of Burns

First-degree burn
- Skin color is pink to red
- Slight swelling
- Skin is dry
- Burn can be anywhere from tender to severely painful

Second-degree burn
- Skin looks raw and is mottled red in color
- Skin is moist
- Blisters contain clear fluid
- Severe to extreme pain

Third-degree burn
- Skin is pearly-white, tan-colored, or charred
- Skin is dry and leathery
- Blood vessels and tissues may be visible under the skin
- Little or no pain, as nerve endings are destroyed

Recognizing burns
Use the size and symptoms of the burn to determine its degree. The cause of the burn will give clues as to severity and whether the injury is critical.

First-degree burn
- Only the top layer of the skin is damaged.

Second-degree burn
- Both layers of the skin are damaged.

Third-degree burn
- The full thickness of the skin, including tissues under the skin are damaged.
Photons
Dermal Interaction

• So what does that mean when it comes to sunburns?

• Ozone blocks some UV

• Wear broad-spectrum sunscreen
So to reduce radiation injury to the dermis, we should simply apply sunscreen and limit our time around the radiation source?

- Yes – for sunburns
  - Ozone and sunscreen block the relevant wavelengths for radiation induced injury
- Not true for all types of radiation
  - Photons
  - Particles
What about for Co-60 or Cs-137?

- They are also photons (gamma-emitters), so sunscreen should work, right?
  - Wrong, they have different energies
- Combinations of beta and gamma
Photons

Penetrates Earth’s Atmosphere?

Radiation Type
Wavelength (m)

Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma ray

Approximate Scale of Wavelength

Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei

Frequency (Hz)

Energy
Photon Penetration into Tissue

• Lovelace radiation generating instruments with high and low energies
  – Grenz – 20 kV (~10^{-7} m)
  – RT250 – 250 kV (~10^{-8} m)
  – LINAC – 6 MV (~10^{-9} m)
• Low energy
  – long wavelengths
  – low penetration
• High energy
  – Short wavelengths
  – high penetration
Lovelace Swine Radiation Burns

- Grenz – Irradiated with up to 150 Gy
- Followed out to 60 days
Lovelace Swine Radiation Burns

- RT250 - Irradiated with up to 150 Gy
  - 150 Gy, Day 6
  - 150 Gy, Day 12
  - 150 Gy, Day 8
  - 150 Gy – Day 6
  - 150 Gy – Day 12
  - 150 Gy – Day 18
  - 150 Gy – Day 12 (Grenz)
Lovelace Swine Radiation Burns

- RT250 - Irradiated with up to 150 Gy
- RT250 – both animals were euthanized as moribund by Day 21

150 Gy – Day 6
150 Gy – Day 12
150 Gy – Day 18
150 Gy – Day 12 (Grenz)
In both cases animals received a relatively soft x-ray—Most of the dose was to the surface.

LINAC resulted in animals euthanized within 9 days—Dermal wounds had not formed.

<table>
<thead>
<tr>
<th>Nominal energy</th>
<th>Depth of maximum dose (cm)</th>
<th>Skin dose (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 kV(p)</td>
<td>Surface</td>
<td>100</td>
</tr>
<tr>
<td>Cobalt-60</td>
<td>0.500</td>
<td>50</td>
</tr>
<tr>
<td>6 MeV</td>
<td>1.500</td>
<td>35</td>
</tr>
<tr>
<td>10 MeV</td>
<td>2.500</td>
<td>25</td>
</tr>
<tr>
<td>18 MeV</td>
<td>3.000</td>
<td>15</td>
</tr>
</tbody>
</table>
Photon Summary

- High energy photons readily penetrate the dermis with only partial deposition in the upper layers of the skin.
- Low energy photons do not readily penetrate the dermis with maximal deposition in the upper layers of the skin.
- High levels of photons are needed to create a significant radiation wound.
  - Low energy are “better” because they do not penetrate deeply causing “other types” of radiation injury.
- Lovelace studies utilized pure photon exposures.
Particle Radiation

- Photons are different wavelengths of energy
- Particles have a physical mass
  - Alpha particles
    - Helium nuclei
  - Beta particles
    - Electrons
Alpha Wounds

• Not likely to result in moderate to deep wounds (full thickness)
  – Particles do not penetrate past the very top layer of the skin
    • Protects the under lying tissues from injury
  – Low every, low travel lengths
• Very dangerous if internal
  – Ingestion, open wound, inhalation
Beta Wounds

- Will result in wounds
  - Particles deposit their energy in the first several layers resulting in compared to photons
- But...
  - Spectrum of energy
  - Damage at deeper depths
  - Results in complex wounds
Beta Wounds

- Because particles are present, lower doses than photons are needed

<table>
<thead>
<tr>
<th>Dose (Gy)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>2–6 Gy</td>
<td>transient erythema 2–24 h</td>
</tr>
<tr>
<td>3–5 Gy</td>
<td>dry desquamation in 3–6 weeks</td>
</tr>
<tr>
<td>3–4 Gy</td>
<td>temporary epilation in 3 weeks</td>
</tr>
<tr>
<td>10–15 Gy</td>
<td>erythema 18–20 days</td>
</tr>
<tr>
<td>15–20 Gy</td>
<td>moist desquamation</td>
</tr>
<tr>
<td>25 Gy</td>
<td>ulceration with slow healing</td>
</tr>
<tr>
<td>30–50 Gy</td>
<td>blistering, necrosis in 3 weeks</td>
</tr>
<tr>
<td>100 Gy</td>
<td>blistering, necrosis in 1–3 weeks</td>
</tr>
</tbody>
</table>
Linear Energy Transfer (LET)

- Amount of energy a particle transfers to material (skin) per unit distance
  - Comes down to the energy of decay
- High LET – low penetration
  - All energy deposited in a short distance
- Low LET – high penetration
- Not directly transferable to gamma rays
- LET explains why injury is not always proportional to dose
Particle Summary

• Alpha particles are mono-energetic
  – low in energy with a high LET
• Beta particles are poly-energetic
  – Continuous energy spectrum
  – Some high LET, some low LET
Summary

• Know your source
  – Pure gamma rays will require a large dose to create a dermal wound
    • High energy will penetrate and result in secondary radiation effects
    • Low energy will result in mostly superficial dermal wounds
  – Alpha particles are less likely to result in dermal wound
  – Beta particles are the biggest concern
    • Penetration at all dermal levels depending on the energy
    • Lower doses can result in dermal injuries similar to high gamma doses
  – Isotopes with multiple routes of decay (beta and gamma) will result in
    wounds from both types of radiation
    • Beta will be more pronounced due to dermal interactions
• Understand your model
  – What are you trying to accomplish?
    • Full thickness – needs a higher energy OR a higher total dose
    • Partial thickness – needs a lower energy OR a lower total dose
    • Combined injury – radiation + other types of injury
Thank You
www.lovelacebiomedical.org