Radiation Risk: Is it Real?

Fergus Coakley MD, Professor of Radiology and Urology, Vice Chair for Clinical Services, Chief of Abdominal Imaging, UCSF
Objectives

- Describe the standard model used in calculating low dose radiation risk

- List the evidence basis for and against the standard model
Estimated radiation risk

- 10 mSv: 1 in 2000 risk of fatal cancer
  - Delayed and obscured

- Contrast: 1 in 20,000-100,000 fatal risk
  - Immediate and obvious

- What is the basis of this risk estimate?

  *BEIR VII and www.fda.gov*
### Raw data: Solid cancer deaths

<table>
<thead>
<tr>
<th>Dose</th>
<th>Number</th>
<th>Deaths</th>
<th>Excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5 mSv</td>
<td>36,479</td>
<td>3,013</td>
<td>-42</td>
</tr>
<tr>
<td>5-20 mSv</td>
<td>16,921</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-50 mSv</td>
<td>9,390</td>
<td>2,795</td>
<td>85</td>
</tr>
<tr>
<td>50-100 mSv</td>
<td>6,538</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-200 mSv</td>
<td>5,467</td>
<td>504</td>
<td>18</td>
</tr>
<tr>
<td>200-500 mSv</td>
<td>6,308</td>
<td>632</td>
<td>77</td>
</tr>
<tr>
<td>0.5-1 Sv</td>
<td>3,202</td>
<td>336</td>
<td>73</td>
</tr>
<tr>
<td>1-2 Sv</td>
<td>1,608</td>
<td>215</td>
<td>84</td>
</tr>
<tr>
<td>2+ Sv</td>
<td>679</td>
<td>83</td>
<td>39</td>
</tr>
</tbody>
</table>
Dose-response curve
Response curve at low doses

Excess risk

Radiation dose

Linear non-threshold: Standard model
Response curve at low doses

Excess risk

Radiation dose

Linear threshold
Response curve at low doses

Excess risk

Radiation dose

Supralinear non-threshold
Response curve at low doses

Excess risk

Radiation dose

Protective - “hormesis”
Why choose the LNT model?

- Biological argument for LNT:
  - Single photon can cause carcinogenic DNA break
  - Cancer risk therefore proportional to dose
  - “…a true dose threshold demands totally error-free DNA damage response and repair”

1 hit - 1 cancer

n hits - n cancers

Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2; 2006: 245
Problems with LNT

- Atomic bomb data at low dose
- 15 country nuclear worker study
- Canadian fluoroscopy results
- HDRA data
- Radon paradoxes
- Latency and adaption
A-bomb data at low doses

- Large error bars, but do not look linear…

15 country study

- Conducted by IARC – International Agency for Research on Cancer
- 407,391 nuclear industry workers

Canadian fluoroscopy results

- 31,710 women treated with fluoroscopy for TB at Canadian sanatoriums between 1930-52


**BREAST CANCER RISK VERSUS BREAST DOSE**
Radon paradox

- Careful statistical analysis suggests radon protects against lung cancer!

Environ Health Perspect 1998; 106(S1): 363-368
HBRA radiation paradox

- High background radiation areas:
  - Natural doses of up to 260 mSv/year
- Little to no evidence of raised cancer risk

Sun Q, Carr Z. Summary of HBRA epidemiological studies International Congress Series 2005; 1276: 147-150
Latency and adaptation

- **Latency:** Animal and human data indicate the interval between radiation and cancer increases at low doses.

- **Adaptation:** Similar evidence indicates adaptive responses with DNA repair at low doses.

Evidence of adaptation

- 1920s work on fruit flies: Mutation rate proportional to dose at higher doses
- Modern studies: Mutation response is non-linear at low doses

Muller HJ. Radiation Biology 1954; Vol 1 Chap 8: 475-626.

## Problems with BEIR VII

<table>
<thead>
<tr>
<th>Cancer</th>
<th>Relative risk/Sv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leukemia</td>
<td>5.6</td>
</tr>
<tr>
<td>Female breast cancer</td>
<td>2.4</td>
</tr>
<tr>
<td>Multiple myeloma</td>
<td>2.2</td>
</tr>
<tr>
<td>Ovary</td>
<td>1.9</td>
</tr>
<tr>
<td>Urinary tract</td>
<td>1.8</td>
</tr>
<tr>
<td>Colon</td>
<td>1.6</td>
</tr>
<tr>
<td>Lung</td>
<td>1.5</td>
</tr>
<tr>
<td>Esophagus</td>
<td>1.5</td>
</tr>
<tr>
<td>Stomach</td>
<td>1.2</td>
</tr>
</tbody>
</table>

_Holland Frei, Cancer Medicine, Volume 8_
To estimate the risk of leukemia, the BEIR VII model is linear-quadratic, since this model fitted the data substantially better than the linear model.

Leukemia = 16% of A-bomb cancer deaths

http://www.rerf.or.jp/radefx/late_e/leukemia.html
DREF and DDREF:

- “Dose-rate effectiveness factor is the factor by which the effect caused by a specific type of radiation changes at low doses or low dose rates”
- “Dose and dose-rate effectiveness factor is a judged factor by which the radiation effect, per unit of dose, caused by a given high or moderate dose of radiation received at high dose rates is reduced when doses are low or are received at low dose rates”

- DDREF = 1.5 for doses < 500 mSv

BEIR VII; Glossary and p. 250
Problem with BEIR VII “fixes”…

- Scientifically and logically inconsistent with LNT model
- LNT = “shooting fish in a barrel”
My opinion…

- LNT extrapolation is suspect:
  - Is speeding a better analogy than “shooting fish in a barrel”?

http://www.arrivealive.co.za

Risk of casualty MVA

Speed - mph

http://www.arrivealive.co.za
Expert skepticism of LNT

- Health Physics Society (6000 radiation protection scientists) position paper:
  - “Below 10 rad (100 mSv) risks of health effects are too small to be observed or are non-existent”

- Online poll of radiation protection professionals (RADSAFE):
  - Voted 118 to 12 against LNT

- French Academy of Medicine report:
  - LNT is “without any scientific validity”

Cohen BL. J Am Phys and Surg 2008; 13: 70-76*
Expert skepticism of LNT

- Lauriston Taylor (former president of the Health Physics Society): The abuse of the LNT is "a deeply immoral use of our scientific heritage"

- Zbigniew Jaworowski (former UNSCEAR chairman): "The no-threshold principle, however, belongs to the realm of administration and is not a scientific principle"
Conclusions

- LNT model is the current standard method for calculating low dose radiation risk
- Substantial evidence that LNT model overestimates risk at low dose
- Patients should be counseled accordingly