Risks and Realities of Radiation Dose in Medical Imaging
BEIR VII
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Where does Table 12D come from?
Cumulative estimate from 3 risk models
Contains numerous assumptions, opinions

Theory:
Based on Linear No Threshold Hypothesis

Source of Data:
Based almost exclusively on Atomic Bomb Survivors Study
Limited input from Medical Radiation Studies

Risk models:
Excess Relative Risk (ERR)
Excess Absolute Risk (EAR)
Lifetime Attributable Risk (LAR)

Parameters:
Dose & Dose Rate Effectiveness Factor (DDREF)
Relative Biological Effectiveness (RBE)
Latency period

100,000
women
aged 30

Single
dose of 100 mGy

Over their lifetime
Sources of data used in BEIR VII

Atomic bomb survivor Studies

“In the presence of available data, it is neither sound statistical interpretation nor prudent risk evaluation to take the view that the risk should be considered zero in some low-dose range…”

BEIR VII Committee

Data from Table 4, Preston et al, 2007

# solid cancers adjusted to per 100,000 people

“Based on fitting with lower threshold, best estimate of threshold was 40 mGy with upper bound of 65 mGy (90% CI). However model not significantly better than LNT.”

(Radiation Effects Research Foundation)

Sources of data used in BEIR VII

Medical Radiation Studies

Focus on therapeutic studies

“…most of the information comes from studies of populations with medium to high doses”

Lung Cancer – 9 studies, 40,000 subjects
average dose ~ 1 Gy

Breast cancer – 11 studies, 20,000 subjects
average dose ~ 300 mGy
Medical Radiation Studies
Cancer Incidence from radiation exposure to the lungs
9 studies, >40,000 subjects

ERR
Excess risk relative to background risk

Average Dose to the Lung (Gy)

-1
-0.5
0
0.5
1
1.5
2
0 5 10 15 20 25

ERR per Gy

Howe (1995)
Fluoroscopy
1178 cancers
1176 controls
25,000 controls

Calculation of ERR - Medical Radiation Studies
Cancer Incidence from radiation exposure to the lungs
9 studies, >40,000 subjects

ERR
Excess risk relative to background risk

Average Dose to the Lung (Gy)

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Weighted value

Calculation of EAR - Medical Radiation Studies
Cancer Incidence from radiation exposure to the breast
6 studies, >30,000 subjects

EAR
Excess absolute above background risk

Average Dose to the Breast (Gy)

Weighted value
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-5
0
5
10
15
20
25
0 0.2 0.4 0.6 0.8 1

EAR per Gy
Calculation of EAR - Medical Radiation Studies
Cancer Incidence from radiation exposure to the breast 6 studies, >30,000 subjects

EAR
Excess absolute above background risk

Breast Cancer Risk after Radiotherapy in Infancy
Pooled analysis of 17,202 Infants – Mean follow-up of 45 Years

Lundell et al, Radiation Research 1999; 151: 626-632
Risk Models

- Excess Relative Risk (ERR)
  - Excess risk expressed relative to background risk

- Excess Absolute Risk (EAR)
  - Excess risk expressed as difference between total risk and background risk

- Lifetime Attributable Risk (LAR)
  - Uses one of the above to calculate lifetime risk of cancer

Same Data – 2 different Risk Models
Comparison of LAR using ERR and EAR

Risk Models

Excess Relative Risk (ERR) vs.
Excess Absolute Risk (EAR)

Which model is correct?

Final Risk model = x.ERR + (1-x).EAR
where x is determined by committee!
Modifying Parameters

- Dose & Dose Rate Effectiveness Factor (DDREF)
  - Range of values 1.1 – 2.5
- Relative Biological Effectiveness (RBE)
  - Range of values 1 - 4
- Latency period
  - Range 2 – 10 years
- Ethnicity, Environment (diet, lifestyle)
  - Convert cancer risk in Japanese subject in 1940’s to American subject in 2011

Risk Models

- Lifetime Attributable Risk (LAR)
  - Uses different final risk models for different organs
  - Assumptions about modifying parameters
  - Risk models then applied to cancer rates for U.S. population
  - Cancer incidence in Table 12D is based on this parameter!

| TABLE 12-5A: Lifetime Attributable Risk of Solid Cancer Incidence |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Cancer Site     | Lifetime Attributable Risk | Male | Female | Combined and Analytical Model (BEIR VII) | Risk Transport |
| Breast          | 23               | 280  | 34.15-350  | 32              | 270  | 41.15-390  |
| Colon           | 28               | 150  | 26.04-360  | 160             | 170  | 26.04-360  |
| Lung            | 28               | 130  | 11.02-290  | 80              | 90   | 11.02-290  |
| Stomach         | 28               | 130  | 14.02-390  | 150             | 160  | 14.02-390  |
| Prostate        | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |
| Ovary           | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |
| Uterus          | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |
| Bladder         | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |
| Thyroid         | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |
| Risk of cancer  | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |
| Risk of cancer  | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |
| Risk of cancer  | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |
| Risk of cancer  | 28               | 6    | 0.0 (0.0-80) | 50              | 60   | 0.0 (0.0-80) |

...range of plausible values for LAR is labeled a “subjective confidence interval” to emphasize its dependence on opinions in addition to direct numerical observation (BEIR VII, page 278)
Risk Models

• Lifetime Attributable Risk (LAR)
  • “Because of the various sources of uncertainty it is important to regard specific estimates of LAR with a healthy skepticism, placing more faith in a range of possible values” (BEIR VII, page 278)

Based on Table 12D BEIR VII, and risk estimates for 56,900,000 patients

For comparison: 9,700,000 people will die of cancer

IF they all lived in Minnesota, (bkg rad = 3 mSv)
we would expect 576,000 deaths from background radiation

IF they all lived in Colorado, (bkg rad = 4.5 mSv)
we would expect 863,000 deaths from background radiation

Differences in residence = 287,000 cancers, or ~20 CT scans/patient

BEIR VII:

What it does say:

• All estimates are based on multiple models and assumptions
• Regard specific estimates with a healthy skepticism
• Confidence intervals are “subjective” and partly based on opinion

Don’t quote cancer estimates from BEIR VII as if they were a proven scientific fact !!!
If you believe I’m wrong and BEIR VII is correct, here are a few suggestions to keep you safe!!

• Don’t stand close to anyone - stay single, no close friends!
  - we all are radioactive, even your dog
  - if you want a pet, pick a goldfish!
• Don’t fly on airplanes (cosmic rays)
• Don’t live or visit mountain areas (radon / cosmic rays).
• Don’t breath too much air (radon is in the air).
• Don’t eat fruits and vegetables (they contain radioisotopes)