BEIR VII: What It Does and Doesn’t Say
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Using BEIR VII report, estimated radiation-related incident cancers
Estimated that 29,000 future cancers could be related to CT scans performed in the U.S. in 2007.....and would translate into about 14,500 cancer deaths.
Arch Intern Med. 2009;169(22):2078-2086

"Boy I'm lucky I never had one of these done! I was always skeptical of this procedure. It was my intuition that told me don't go there!....."USA Today

Where does the estimate of 29,000 cancers come from?

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

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

Analysis of Radiation Risks in Atomic Bomb Survivor
Data is based on the Linear No Threshold Hypothesis

Low Dose

• LNT introduced by Muller in 1902s as a model for the mutagenic effect of x-rays in fruit flies (later proved invalid)
• Muller served as consultant on 1st BEIR committee in 1956 and urged their adoption of this model

Sources of data considered in BEIR VII

• Atomic bomb survivor Studies
• Medical Radiation Studies
• Occupational Radiation Studies
• Environmental Radiation Studies

Sources of data used in BEIR VII

Atomic bomb survivor Studies

• 120,000 survivors
  93,000 present at time of bombings
  27,000 from locale, but absent at time of the bombing (excluded from analysis)
• Monitored over 60 years & includes both sexes and all ages of exposure – mean dose = 200 mSv
• Dose range
  37,000 0-5 mSv
  32,000 5-100 mSv
  17,000 100 mSv – 2000 mSv

This is the primary source of data for all risk models used in BEIR VII

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 45 mGy with upper bound of 45 mGy (90% CI) However model not significantly better than LNT"
Sources of data used in BEIR VII
Atomic bomb survivor Studies

Data from Table 4, Preston et al, 2007

# Solid Cancers

12000.00
17000.00
22000.00
27000.00
32000.00
37000.00

0 500 1000 1500 2000 2500 3000 3500
Radiation dose to Colon (mGy)

1 10 100 1000 10000
# Solid Cancers

(Radiation Effects Research Foundation)

Data from Table 4, Preston et al, 2007

# Solid Cancers

12000.00
17000.00
22000.00
27000.00
32000.00
37000.00

0 500 1000 1500 2000 2500 3000 3500
Radiation dose to Colon (mGy)

1 10 100 1000 10000
# Solid Cancers

(Radiation Effects Research Foundation)

“Based on fitting with lower threshold, best estimate of threshold was 40 mGy with upper bound of 85 mGy (90% CI). However model not significantly better than LNT.”

BEIR VII Committee

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

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

Mattson et al (1997)
Benign breast disease
10 cancers
1,216 controls

Howe (1995)
Fluoroscopy
1178 cancers
25,000 controls

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

(17,202 infants)

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

Mortality from Breast Cancer after Irradiation during Fluoroscopic Examinations in Patients being treated for Tuberculosis
Miller AB et al, NEJM 1989; 321: 1285-1289

31,710 women treated between 1930 - 1952
"Risk was statistically significant for all those who received more than 700 mGy of radiation"
Sources of data used in BEIR VII

Occupational Radiation Studies

- U.S. – 9 studies
- U.K. – 6 studies
- Canada – 1 study
- France – 1 study

Six large combined cohort studies
Combined study population > 500,000 subjects with 30-40 years of follow-up
Cumulative dose levels: 30-60 mSv

“...in most cases, rates for all causes and all cancer mortality in the workers were substantially lower than the reference populations.”

Effect explained as “healthy worker effect”

“Because of uncertainty in occupational risk estimates... the committee has concluded that the occupational studies are not suitable for the projection of population-based risks.”

Sources of data used in BEIR VII

Environmental Radiation Studies

- Populations living near nuclear facilities
  “...no increased risk...with radiation exposure”
- Populations exposed to atomic bomb testing
  “...some studies (4 out of 10) show some effect”
- Chernobyl
  High incidence of thyroid cancer
  “...no evidence of an increase in any solid cancer type to date”
- Natural background (China / India)
  “...did not find higher disease rates in geographical areas with high background levels...”

Breast Cancer Mortality

Study of 67,979 women who worked with radiation in Nuclear Weapons facilities before 1980 (relative to unmonitored women in same facilities)

Expected mortality = 18,106 deaths / Observed mortality = 13,671 deaths

Relative Risk


Sources of data used in BEIR VII

Cancer Mortality in High Background Radiation Area of Yangjiang, China, 1979-1995

- Estimated cancer risk associated with the low level radiation exposure of 6.4 mSv / year
- 20-year study in 125,079 subjects
- Excess Relative Risk
  ERR/Sv = 0.10 (-0.67 to 0.69)
- Conclusion: the mortality of all cancers in Yangjiang was generally lower than that in control group, but not significant statistically.

(Tao et al, Zhonghua Yi Xue Za Zhi, 1999; 79: 487-492)

Most radioactive place in the world - Ramsar, Iran (due to Radium-226)
Background radiation = 100-260mSv / year
No epidemiological evidence of adverse effects
Residents demonstrate a marked increase in DNA repair.
Co-60 Contamination in Taiwan Buildings


180 buildings, schools and small businesses (> 1600 apartments)

~10,000 residents affected, many for ~20 years

<table>
<thead>
<tr>
<th>Cohort</th>
<th># People</th>
<th>Cumulative dose 1983-2003 (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>1,100</td>
<td>4000</td>
</tr>
<tr>
<td>Medium</td>
<td>900</td>
<td>420</td>
</tr>
<tr>
<td>Low</td>
<td>8,000</td>
<td>120</td>
</tr>
</tbody>
</table>

(Chen et al. Dose Response 2007; 5:63-75.)

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

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!

Same Data – 2 different Risk Models

Comparison of LAR using ERR and EAR

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!

...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 radionuclides)