Effects of childhood exposure:

An Issue from CT scans to Fukushima

9th Annual
Warren K. Sinclair Address

Fred A. Mettler Jr. MD, MPH
Warren at UNSCEAR meetings
Even small details are interesting to Warren
Acknowledgements

Disclosures
Task group of UNSCEAR

- Radiation effects after childhood exposure
- Publication expected 2013-14

- F. Mettler
- Roy Shore (RERF)
- Sandy Constine (Univ of Rochester)
- Dietmar Nosske (Bfs, Munchen)

- Note: Prior work of Dave Brenner, John Boice et.al.
There has been an Alarming Increase in the Number of Things I Know Nothing About

Bushberg, Siebert, Leidhold, Boone
Meetings in villages heavily contaminated by Chernobyl

I don’t care about myself. What about my children…??

Has anybody written a report on children we can look at ??
Outline

What are the questions
Data sources
Developmental anatomy and physiology
Dosimetry variations
Induced malignancies
Deterministic effects
Scams, scares and good things
A few radiation protection points
“Children are 3-5 times more sensitive to radiation than adults”

• Is this actually true?
• Is it true for all effects?
• If they are, why is that?
• Could they be less sensitive to some effects?
Childhood irradiation data sources

Atomic bomb survivors (LSS)
35,382 or 41% were 0-20 years old at exposure

Radiotherapy for benign conditions (thousands)

Childhood cancer survivor study
14,359 5-year survivors treated 1970-1986
Childhood irradiation data sources

Accidents
27% of those evacuated at Chernobyl were 0-17 years old

Future sources
13% at Fukushima were 0-14

CT scanning of children. In US (5 million annually). Mostly European studies
Aspects of developmental anatomy and physiology that affect radiation response
Patterns of human growth

Growth period unusually long for mammals > 25% lifespan

ICRP
lymphoid

Brain, liver, kidney, heart, lung

Musculoskeletal, GI, skin,

gonads

% size attained of total postnatal growth

age (years)
Proportional changes
The Brain

Long period of development and sequence makes children susceptible to high dose effects

10% body weight at birth  2% body weight in an adult
.....and even less than 2% in some persons
Gray matter
what you think, feel and move with

White matter
(wiring)
Development of the wiring and communication pathways

20-100 billion neurons (= number of stars in our galaxy)
Linked by 150 trillion synapses
or 1500-10,000 synapses per neuron
Increase in gray matter

Neonate

8 months

Barkovich AJNR 2004
More synapses produced than are ever needed. “Pruning occurs” with experience. Half of synapses are removed by puberty and pruning occurs into the 20’s
Cortical gray matter

Peaks at 1-2 years of age
Remains high until about 12 then declines
40% a year until age 16

Loss of neocortical neurons in adults
85,000 per day ~31 million per year ~1/sec

~ 3,000 lost during this lecture
Development of insulation for the wiring occurs over the first several years of life.

180,000 km of myelinated fibers
Myelin development

Neonate 24 months

Barkovich AJNR 2004
During development of the brain, high doses of radiation can:

- Reduce the number of neurons and reduce IQ
- Interfere with myelin development or even remove the myelin insulation
Pulmonary
20 million alveoli at birth, 150 million by age 2
300-400 million by age 7

Before age 5 disproportion of narrow peripheral airways increases airway resistance affecting deposition and retention
Children’s pulmonary system is somewhat less sensitive than adults to high dose radiation

• Can grow new alveoli up to a certain point

• Children have less underlying disease and aging damage
Bone growth occurs at the ends of long bones affecting radionuclide distribution.
## Alimentary Tract

### Age-dependent $f_1$ ingestion values

ICRP Publications 67 and 69

<table>
<thead>
<tr>
<th>Element</th>
<th>$f_1$ value</th>
<th>3 months</th>
<th>5 y</th>
<th>15 y</th>
<th>adults</th>
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<td>0.3</td>
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<td>0.2</td>
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</table>
Marrow retraction with age

Children have more red bone marrow in extremities and are more resistant to localized marrow irradiation.
Dosimetry Issues

Ukrainian and Belarussian children in contaminated villages
Who is getting the most absorbed dose?

1 µSv/hr
1000 kBq/m²
Polesskoe 1989
External radiation exposure is rarely uniform
Who is getting the most absorbed dose?

1 µSv/hr
1000 kBq/m²
Polesskoe 1989

Good answer but wrong
Who is getting the most absorbed dose?

1 µSv/hr
1000 kBq/m²
Polesskoe 1989

Correct answer
### Age-related correction factors for submersion and irradiation from the ground

<table>
<thead>
<tr>
<th>Age groups</th>
<th>≤1a</th>
<th>1-2a</th>
<th>2-7a</th>
<th>7-12a</th>
<th>12-17a</th>
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<td>&gt;200 keV</td>
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<tr>
<td>≤200 keV</td>
<td>1.8</td>
<td>1.7</td>
<td>1.5</td>
<td>1.3</td>
<td>1.1</td>
<td>1.0</td>
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<tr>
<td><strong>Irradiation from</strong></td>
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<td></td>
<td></td>
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<tr>
<td>the ground; &gt;200 keV</td>
<td>1.6</td>
<td>1.5</td>
<td>1.3</td>
<td>1.2</td>
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</tr>
</tbody>
</table>

D. Nosske
Age dependent conversion coefficients

![Bar graph showing effective dose per unit air kerma for toddlers, adolescents, and adults, with different radionuclides.

- **Uranium**
- **Thorium**
- **$^{40}$K**

- Toddlers (<4 y)
- Adolescents (4 - 14 y)
- Adults (>14 y)
Do kids get the dose we estimate?

Novozybkov 1989   200 kBq/m² cesium 137
Children are at increased risk due to radionuclides in breast milk or in Mom.
Technetium-99m and Iodine-131

Flourine-18 FDG
Children often get nuclear medicine scans with renal and bladder excretion.

Meckel’s scan $^{99m}$TcO$_4^-$

Renal scan $^{99m}$Tc-MAG3
Worries about radiation-induced malignancies
Accidental exposure and cancer

Alosha
Cesium-137 2.6 $\times 10^{12}$ Bq source 1988-1991
Are children really 3-5 more sensitive to cancer induction???

• The answer depends upon
  - what data you look at
  - how you look at the data
  - what model is used
  - what you do when there is no data
Lifetime attributable risk of radiation-induced cancer incidence (based on BEIR VII)

Cancer Incidence
Population average (male): 8.6%/Sv
Population average (female): 12.8%/Sv

Hricak et.al. Radiol 2010 258:3:889
Relative sensitivity of LAR by age at exposure in the BEIR VII model (male incidence)

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>40</th>
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<td>Colon</td>
<td>2.7</td>
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<td>2.0</td>
<td>1</td>
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<tr>
<td>Lung</td>
<td>3.0</td>
<td>2.5</td>
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<td>Bladder</td>
<td>2.6</td>
<td>2.2</td>
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<tr>
<td>Other (40%)</td>
<td>6.5</td>
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</tr>
<tr>
<td>Thyroid</td>
<td>38.3</td>
<td>25.3</td>
<td>16.7</td>
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<td>Leukemia</td>
<td>2.8</td>
<td>1.8</td>
<td>1.4</td>
<td>1</td>
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<tr>
<td>All</td>
<td>5.4</td>
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</table>
Mortality A-bomb survivors 1950-2003

![Diagram showing the modification of the excess relative risk (ERR) for all solid cancer by age at exposure and attained age.](image)

**FIG. 2.** Modification of the excess relative risk (ERR) for all solid cancer by age at exposure and attained age.

• If tissues are rather different in radiation sensitivity……..

• Why should most have similar age-at-exposure effects ?

• Or do they ?????
Leukemia (huge difference)

Richardson et al. Rad Res 172:368-382 2009
Thyroid cancer after radioiodine exposure

Marked age-at-exposure effect
Childhood thyroid cancer as a result of Chernobyl radioiodine exposure

![Bar chart showing cases of childhood thyroid cancer by age at exposure (0-4 yrs, 5-9 yrs, 10-14 yrs) from 1987 to 1997.](image-url)
Subjects of Regional Radiation Medical Network

1. Many primary radiation hospitals were located within 30km radius. These hospitals were subject to evacuation, so didn’t work.

2. Fukushima Medical Univ. was not suitable for WBC measurement on March 15, because the air dose rate was 20 μSv/h.

3. Majority of health care professionals in the Primary-Secondary Radiation Hospitals had little knowledge about the radiation injuries and the radiation risk, so got an excess fear.

4. Appropriate instructions for the administration in stable iodine was not conducted.
Passing Pills
Japanese towns near the Fukushima Daiichi power plant and their access to potassium iodide for combating effects of radiation.

**EVACUATION ZONES**

**March 12**
- Government expands evacuation zone from 6.2 to 12.4 miles.
- 78,000 evacuated.

**April 22**
- Elevated radiation found outside 12.4-mile zone. 10,000 more ordered to evacuate.

**April 22**
- People told to be prepared to evacuate. 28,500 left.

Source: Japan's Nuclear Safety Commission

- **Towns where potassium iodide pills were distributed and taken by residents.**
- **Towns where pills were distributed but not taken.**
- **Towns where pills were not distributed.**
Most around Fukushima did not get KI
Breast cancer (3-4 fold difference)

FIG. 3. Estimated excess relative risk per Sv with 90% confidence limits, by 5-year intervals of age ATB, e. The panels show a fitted exponential function on the left, $\text{ERR}_{1\text{Sv}} = a \times \beta e^{-z}$, and an isotonic regression on the right constrained only to be monotone non-decreasing in e.
Age at exposure response is similar in most radiation-induced breast cancer studies.
Breast cancer
(different results of age-at-exposure effect by model)

Preston et.al. 168(1)2007
Relative sensitivity of LAR by age at exposure in the BEIR VII model (male incidence)

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ERR for cancer incidence in atomic bomb survivors estimated at attained age of 80 years

Shuryak, Sachs, Brenner. JNCI 2010 102(21) 1028
### Relative sensitivity of LAR by age at exposure in the BEIR VII model (male incidence)

<table>
<thead>
<tr>
<th>Tissue</th>
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Colon cancer (Incidence vs mortality)

• A-bomb incidence

  ERR no effect, EAR effect (attained age model)

• A-bomb mortality

  ERR no effect, EAR +/-
ERR for cancer incidence in atomic bomb survivors estimated at attained age of 80 years

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<table>
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<tr>
<th>Condition</th>
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</table>
Other National Academy reports

“There is no convincing evidence that prostate cancer is a radiogenic disease”
Do we have a “procrustean” problem?
“procrustean”

• 1. A early form of a crustacean

• 2. The lower layer of the earth’s mantle or crust

• 3. A mythical Greek robber

• 4. The outermost layer of a baguette
“procrustean”

1. A early form of a crustacean
2. The lower layer of the earth’s mantle or crust
3. A Greek robber
4. The outermost layer of a baguette
Procrustus and approaches to dealing with data
Not long enough.....
Too long....
There is little or no data for some tumor types.

...are we cutting off legs that were never there?
This is OK if you realize it….but don’t assume the model is really the truth
# Sensitivity to cancer induction

**Children vs adults**

<table>
<thead>
<tr>
<th>Site</th>
<th>More</th>
<th>Same</th>
<th>Less</th>
<th>No data on AAE</th>
<th>Evidence</th>
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<td>ERR</td>
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<td>Colon (mortality)</td>
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<td>ERR?</td>
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<tr>
<td>Liver</td>
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<td>Lung</td>
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<tr>
<td>Skin (non-melanoma)</td>
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<td>Ovary</td>
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</table>

* Little relation to radiation exposure

Shore et. al. UNSCEAR draft
### Sensitivity to cancer induction
**Children vs adults**

<table>
<thead>
<tr>
<th>Site*</th>
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<th>Same</th>
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<th>Evidence</th>
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<td>weak</td>
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<td>strong</td>
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<td>Pancreas*</td>
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</tbody>
</table>

* Little relation to radiation exposure

Shore et. al. UNSCEAR draft
Tumor site and differential sensitivity based on the epidemiological data

- Children more sensitive: 7 (30%)
- Same as adults: 5 +/- (22%)
- Less than adults: 2 (11%)
- No good data on age at exposure: 5 (22%)
- Poorly or not related to radiation: 4 (17%)

- Actually only a few tumor types have strong age-at-exposure data
Deterministic effects/
Tissue reactions

Data primarily from radiotherapy
and accidents
Accidental exposures

Orphan industrial radiography source  $10^{12}$ Bq (26 Ci) $^{192}$Ir

Jammet et al., Ricks 1980.
Erythema from accidental CT scan overexposure
Issues that drove Jacoby’s parents crazy

- Initial radiologist said “there is no problem or risk”
- Parents saw erythema and were skeptical
- Hospital medical physicist reported a “fatal cancer risk of 39% due to the exposure”
- Dicentric analysis 5 Gy to several hundred Gy
Beta burns on 13 year old Marshallese boy 45 days after exposure

13 year old Marshallese boy 6 months after exposure
Brain
Costa Rica accident: 60% overexposure for leukemia treatment
Childhood cancer survivor study

- 5 year survival
- Leukemia, lymphoma, CNS, bone, Wilm’s, neuroblastoma, soft tissue sarcoma
- Diagnosis 1970-1986
- 20,696 eligible
- 14,370 participants
- Surg, chemo, xrt 43%
- Chemo + xrt 12%
- Surg + xrt 12%
- Xrt 1%
IQ reduction variation with age

Merchant et.al. JCO 2009
Schizophrenia and Childhood Radiation ??

- Inconclusive studies
  - A bomb prenatal
    Imamura et.al 1999
  - Childhood radiotherapy
    Ross et. al. 2003
  - Chernobyl
    Loganovsky et.al. 2000

- Tinea capitus
  46 year followup 20,000+
  subjects. Association not supported
  Sadetzki et.al. Rad Res 176 670-677 2011
Cataracts and subcapsular opacities

- Radiotherapy of children
  
  total body irradiation $<$40Gy = $<$10% severe cataracts
  Tinea capitus pre-cataract changes not severe at doses $>$ 0.2 Gy

- Chernobyl
  
  Increase 2-3 fold opacities in 12-17 males.
  ? dosimetry and observer bias
Subcapsular opacities? 1.5-2 fold more sensitive

**Fig. 5.** Odds ratio per Sv for posterior sub-capsular opacity (PS) vs. age at exposure.

Nakashima et. al. Health Phys. 2006 (90(2);154-160
Cataracts

Jacoby at 4.5 years later has no evidence of lenticular opacities or cataract
Breast hypoplasia after benign hemangioma radiotherapy

Fact: Humans are unique among mammals with breast ducts etc present at birth. Most mammals develop these with pregnancy.
Heart
Heart disease in childhood cancer survivors

Cumulative incidence (%) for congestive heart failure by different levels of cardiac radiation:
- No cardiac radiation
- <500 cGy cardiac radiation
- 500 to <1500 cGy cardiac radiation
- 1500 to <3500 cGy cardiac radiation
- ≥3500 cGy cardiac radiation

Mulrooney et.al. BMJ 2009 339:4606
Is there an age-at-exposure effect?

Atomic bomb survivors
  Shimizu et.al. For heart disease no significant modification by age-at-exposure

Childhood cancer survivors
  Mulrooney et.al. 14,000 + survivors. Risk for cardiac outcomes slightly higher for “diagnosis” at young ages.

No risk at doses < 5 Gy. Risk significantly increased only at doses > 15 Gy
Musculoskeletal

Pigmentation and muscle atrophy

Atrophy on right

Osteochondroma
Ovary

2.5-5 Gy

- <14 years: OK
- 15-40 years: 30-40% sterility
- >40 years: 90% sterility
Testes

• Sensitive especially during puberty

• Case of child abuse. Texas 1972-73
  – Petroleum engineer two 1Ci $^{137}$Cs sources
  – Divorce issues. Partial custody 12 yr old son
  – Put in sock, pillow, headphones, underwear
  – Exposed over months
  – Injuries not diagnosed for a year or more
  – 16 surgeries. Effectively castrate

Collins and Gaulden 1980
Uterine ovarian damage

CCSS  Children of women who received more than 5 Gy uterine dose were small for age

(Green et.al 2009)

No effect from male exposure on stillbirth and neonatal death. At uterine doses > 10 Gy there was an increase in adverse effects from uterine (not hereditary) damage  (Signorello, Boice et.al.2010)

1-2.5 Gy uterine dose before menarche increased adult risk of stillbirth or neonatal death  (Signorello, Boice et.al 2010)
### Deterministic effects

#### Child vs adult sensitivity

**Radiotherapy dose levels !!!!**

<table>
<thead>
<tr>
<th>Tissue</th>
<th>More</th>
<th>Same</th>
<th>Less</th>
<th>?</th>
<th>Data</th>
<th>Comment</th>
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<td>X</td>
<td></td>
<td></td>
<td>strong</td>
<td>more consequence</td>
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<td></td>
<td></td>
<td>weak</td>
<td>2-fold for opacities</td>
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<tr>
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<td>strong</td>
<td>myocyte issues</td>
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<tr>
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<td>X</td>
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<td>strong</td>
<td>Hypoplasia</td>
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<tr>
<td>Lung</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>weak</td>
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<tr>
<td>Tissue</td>
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<td>Same</td>
<td>Less</td>
<td>?</td>
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<tr>
<td>Ovaries</td>
<td></td>
<td></td>
<td>X</td>
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<td></td>
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<tr>
<td>Uterus</td>
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<td></td>
<td></td>
<td></td>
<td>Moderate</td>
<td>decrease perfusion</td>
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<tr>
<td>Marrow</td>
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<td>X</td>
<td></td>
<td>Moderate</td>
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<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Musculoskel</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Strong</td>
<td>Hypoplasia</td>
</tr>
<tr>
<td>Testes</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>During puberty</td>
</tr>
<tr>
<td>Bladder</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Strong</td>
<td>&lt; capacity</td>
</tr>
<tr>
<td>Kidney</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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## Deterministic effects
### Dose levels below radiotherapy

<table>
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<th>Less</th>
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<th>Data</th>
</tr>
</thead>
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<tr>
<td>Cataract</td>
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<td>Weak</td>
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<tr>
<td>Hypothyroid</td>
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<td>X</td>
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<tr>
<td>Autoimmune</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nodules</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Strong</td>
</tr>
</tbody>
</table>
Hereditary effects
What about the children of the exposed children?
<table>
<thead>
<tr>
<th>Condition</th>
<th>Survivors (2,198)</th>
<th>Controls (4,544)</th>
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</thead>
<tbody>
<tr>
<td>Birth defect</td>
<td>3.37%</td>
<td>3.13%</td>
</tr>
<tr>
<td>Cancer</td>
<td>0.30%</td>
<td>0.23%</td>
</tr>
</tbody>
</table>

Byrne, Teratology 59:210, 1999
Recent childhood cancer survivor studies

4,699 children. No relation between ovarian or testicular dose to congenital abnormalities (Signorello et.al. 2011)

No increase in cancer in offspring (Madanat-Harjuola et.al. 2010)
Scams, scares and some good things
“Children of Chernobyl” Then vs now……
Now, over twenty years later traces of plutonium are still being detected in the placenta of mothers, and children are still being born with documented cases of life threatening diseases including "Chernobyl heart" disease.

http://www.world-heart.org/doc/9078
Japan Says Children Exposed to Radiation

Survey of Youths Near Stricken Plant Raises Concerns Over Long-Term Health

BY YUKA HAYASHI

TOKYO—Nearly half of the children surveyed in three towns near the stricken Fukushima Daiichi nuclear plant received low-grade internal exposure to radiation during the early days of the accident, the government said Thursday, fueling concerns about long-term health effects on local residents.

The government in late March tested 1,150 children in the three towns located primarily outside the government mandatory evacuation zone of 20 and 30 kilometers, and said that all of them cleared its health standard. After Fukushima parents and radiation experts demanded more details, the government revealed this week that 45% of the children were exposed to radiation, albeit at low levels.

While the government has released reports on radiation exposure for workers at the Fukushima complex, this is the first time officials have made public the results for tests to detect internal exposure on residents near the reactors.

Internal radiation—which enters the human body through breathing in contaminated air or consuming contaminated food or drinks—can have a greater health effect than what is known as external radiation, in which the radiation is confined to the surrounding environment.

Since the accident, the government has tested 215,000 residents for external exposure. Some initially showed elevated levels, but once clothes were removed and showers were taken, none had showed results high enough to warrant health concerns, according to a Nuclear and Industrial Safety Agency statement. The government has promised to do further tests in the coming weeks on potentially affected populations.

A spokesman for NISA, the main nuclear regulatory body, said Thursday that the doses the Fukushima children received were below the levels at which health effects become a concern. Children, particularly younger ones, are more susceptible to the effects of radiation, facing higher risks than adults of developing thyroid cancer later in life, experts say.

One independent expert, Yoshihisa Hoso, a professor at the Research Institute for Radiation Biology and Medicine at Hiroshima University, said in an interview that, assuming the results reported are accurate, “I think the possibility of these children developing thyroid cancer is extremely low.”

However, he raised some questions about the government’s testing methodology, saying that officials didn’t conduct the tests quickly enough after the initial exposure to measure radioactive elements known to disintegrate rapidly, such as iodine 131 and tellurium. NISA officials couldn’t be reached late Thursday to comment.

The latest news follows a series of reports raising concerns about the protection against radiation exposure provided by the government to local residents during the days and weeks following the accident. For example, government officials had data a few days after the accident indicating that Iitate—one of the three towns where the children were tested—had become what they later called a “hot spot” with elevated levels of contamination.

The tests were conducted between March 24 and 30 on the thyroid glands of children in Iitate, Kawamata and Iwaki—three municipalities located outside the government’s 20-kilometer evacuation zone set the day after the March 11 earthquake and tsunami struck the plant.

The move came after the government confirmed in late March that its radiation protection system had failed, as the government had said. The tests showed a total dose of exposure of 1.5 millisieverts per hour—well below the government’s annual guideline of 0.2 millisieverts per hour that the government considers a health risk.

“They told me my son will be fine,” Yuka Sato, a 25-year-old mother from Iitate said. The exposure level of her 12-month-old child was below the 0.2 microsievert guideline, she said, adding, “I am still worried about his health in the future.”
Christopher Busby Foundation for Children of Fukushima
Calcium Lactate 800mg
Magnesium Oxide 300mg
Sodium selenate 50 micrograms
Sodium molybdate 25 micrograms
plus cellulose etc bulking agents etc

Price: $5800  Add to Cart
Radiation Detox Clay Bath

LL's Magnetic Clay bath kits are packaged in bulk and will administer 10 one cup baths per kit. Included in each kit are 5lbs of bulk formula, 8 pages of graphic step-by-step instructions, 15 pH testing strips, fiberglass drain screen, flat drain stopper, and herbal formula pack.

Price: ₪4800

Available, Shipping Time: more than 8 days
Launching the products and tests, Busby warns in his video of a public health catastrophe in Japan caused by the Fukushima explosions, and claims that radioactive caesium will destroy the heart muscles of Japanese children.

He also alleges that the Japanese government is trucking radioactive material from the Fukushima site all over Japan, in order to "increase the cancer rate in the whole of Japan so that there will be no control group" of children unaffected by the disaster, in order to help the Japanese government prevent potential lawsuits from people whose health may have been affected by the radiation. The pills, he claims, will stop radioactive contaminants attaching themselves to the DNA of Japanese children.

But Gerry Thomas, professor of molecular pathology at the department of
Post-Fukushima 'anti-radiation' pills condemned by scientists

Green party distances itself from Dr Christopher Busby, a former spokesman promoting products following Japanese nuclear disaster.

George Monbiot and Justin McCurry in Tokyo
guardian.co.uk, Monday 21 November 2011 11.59 EST
Article history

Dr Christopher Busby, director of environmental consultancy Green Audit, who published a YouTube video to launch his products. Photograph: Yann Forget
Infant mortality and Chernobyl

Contaminated oblasts vs Ukraine as a whole
A 35% Spike in Infant Mortality in Northwest Cities Since Meltdown

Is the Dramatic Increase in Baby Deaths in the US a Result of Fukushima Fallout?

By JANETTE D. SHERMAN, MD
and JOSEPH MANGANO

U.S. babies are dying at an increased rate. While the United States spends billions on medical care, as of 2006, the US ranked 28th in the world in infant mortality, more than twice that of the lowest ranked countries. (DHHS, CDC, National Center for Health Statistics. Health United States 2010, Table 20, p. 131, February 2011.)
A recent article on the Al Jazeera English website cites a disturbing statistic: infant mortality in certain U.S. Northwest cities spiked by 35 percent in the weeks following the disaster at the Fukushima Daiichi nuclear power plant. The author writes that "physician Janette Sherman MD and epidemiologist Joseph Mangano published an essay shedding light on a 35 per cent spike in infant mortality in northwest cities that occurred after the Fukushima meltdown, and [sic] may well be the result of fallout from the stricken nuclear plant." The implication is clear: radioactive fallout from the plant is spreading across the Pacific in sufficient quantities to imperil the lives of children (and presumably the rest of us as well).
Are Babies Dying in the Pacific Northwest Due to Fukushima? A Look at the Numbers

By Michael Meyer | Tuesday, June 21, 2011 | 34 comments

A recent article on the Al Jazeera website raised concerns about certain U.S. Northwest cities seeing increased infant deaths since the Fukushima Daiichi nuclear power plant incident. Epidemiologist Joseph Marks has analyzed infant mortality in northwest cities and found that a spike in deaths may well be the result of fallout from the nuclear disaster. Radioactive fallout from the plant could have imperiled the lives of children across the region, leading to higher death rates.

The chart above illustrates the trend in infant deaths over time, with a notable increase coinciding with the Fukushima incident. The data suggests a significant correlation between the two events.
Good things

CHILDSMART

S - Shielding appropriate?
M - Marking of films, ID etc. appropriate?
A - Area collimation appropriate? Field size and location.
R - Restriction of child motion appropriate?
T - Technical settings appropriate? Shortest exposure time, kV up.
Great Idea !!

- Donald Frush et. al. AJR 2002
- Color by size
- Protocol/dose by size
It really took media attention to accelerate changes in CT scanner design, but it happened...........

CT scans for young kids raise concerns

1930 to 1959. Because 95 percent of Swedish men ages 18 and 19 are tested before military service, researchers were able to track information about the education and cognitive test results of these former pediatric patients.

The researchers found that the proportion of boys who attended high school decreased in relation to increasing doses of ionizing radiation — the type that penetrates the body — to the front and back of the brain.

The more radiation they were exposed to, the more impaired their learning ability and logical reasoning. Spatial recognition was unaffected. Because the dosages overlap those of CT scans, the findings raise questions about the long-term developmental effects of CT scans, which increasingly are used to assess minor head injuries, Swedish researchers wrote. Although they had data only about radiation exposure before the age of 18 months, they said the findings raised questions about exposure and young children in general.

But Nelson said the types of radiation used then are different from today's CT, and that there are differences in the way various types of radiation are absorbed by the brain.

"If the child has significant head trauma as determined by the examining physician would not hesitate to do a CT," Nelson said. "The benefits far outweigh the risks."

CT is the preferred test when a doctor suspects that a child has sustained a brain injury. The signs are unequal eye pupil size, weakness or lack of movement in extremities and abnormal reflexes or unconsciousness for several minutes. But it's not always required. If a child knocked out briefly, he or she should be observed and usually won't need a CT scan, Nelson said.

If a CT is recommended, Nelson suggests that parents ask the doctor or radiologist "whether the CT facility is using the proper reduced-dose protocols for children based on the size of the child.

He noted that many hospitals and medical facilities use radiation dosing guidelines for adults, which "deliver two to three times more radiation than is needed for a proper pediatric CT."
Join with us.
Take the image gently pledge.
Today.

IMAGE WISELY™
Radiation Safety in Adult Medical Imaging
## Dosage Card (Version 1.5.2008)

### Multiple of Baseline Activity

<table>
<thead>
<tr>
<th>Weight kg</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Weight kg</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>32</td>
<td>3.77</td>
<td>7.29</td>
<td>14.00</td>
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</tbody>
</table>

**NORTH AMERICAN CONSENSUS GUIDELINES FOR ADMINISTERED RADIOPHARMACEUTICAL ACTIVITIES IN CHILDREN AND ADOLESCENTS**
A few radiation protection points
The issue of effective dose for different ages

Effective doses (mSv) for CT scans

<table>
<thead>
<tr>
<th>Age</th>
<th>Newborn</th>
<th>≤ 1 y</th>
<th>2 - 5 y</th>
<th>6 - 10 y</th>
<th>11 - 15 y</th>
<th>&gt; 15 y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranium</td>
<td>3.3</td>
<td>2.7</td>
<td>2.0</td>
<td>2.1</td>
<td>0.89</td>
<td>1.0</td>
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<tr>
<td>Thorax</td>
<td>1.6</td>
<td>1.6</td>
<td>2.3</td>
<td>3.0</td>
<td>3.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Abdomen</td>
<td>4.4</td>
<td>5.1</td>
<td>6.6</td>
<td>7.5</td>
<td>7.5</td>
<td>14</td>
</tr>
</tbody>
</table>
Is there really such a thing as an effective dose for a newborn or a 5 year old?
Disparate radiation criteria and "limits" cause intense anxiety among parents
Incoherence in drinking liquids

\[ \text{Guidelines for Drinking-water Quality} \]

\[ \text{CODEX ALIMENTARIUS} \]

\[ = 10 \text{ Bq L}^{-1} \text{ for } ^{137}\text{Cs} \]

\[ = 1000 \text{ Bq L}^{-1} \text{ for } ^{137}\text{Cs} \]

100 x more

A. Gonzales
Incoherence in non-edible vs. edible

10 x more

= 1000 Bq kg$^{-1}$ for $^{137}$Cs

= 100 Bq kg$^{-1}$ for $^{137}$Cs

A. Gonzales
Parents in Fukushima are angry over rule changes which mean that school children can be exposed to 20 times more radiation than was previously permissible.

Photograph: Carlos Barria/Reuters
Sign in park in Fukushima City expresses apologies from city for declaring one-hour park-usage time limit due to radiation level on soil and equipment.
Summary

• Children are not just small adults

• Children’s tissues morph into adults at different rates and at different times

• Some differences in radiation effects with age are explainable, others are not
Summary

• Children are at more risk than adults for some effects, similar risk for some effects and more resistant for others

• Modeling may be procrustean, but it can obscure the fact that in some areas we have precious little data often due to high background noise and little or no radiation effect
Last disclosure

This lecture has been previously tested on childhood audiences with variable results
Indifference
Suspicion
I hope you enjoyed it more

Thank you

Questions ?