Medical decision making and care of casualties from delayed effects of a nuclear detonation

Fred A. Mettler Jr. M.D., M.P.H.
New Mexico Federal Regional Medical Center
3 min  
10 min post detonation
Early deaths
Early survivors - ? delayed deaths
Medical issues and delayed health effects

- General issues regarding fallout vs health effects
- Acute radiation syndrome
- Beta burns
- Internal contamination
- Carcinogenesis
- In-utero effects
- Genetic effects
- Psychological effects
- Dosimetry and records
- Follow-up of exposed persons
Nuclear weapons

- Thermal radiation
- Air blast
- Initial and residual radiation
- A ground burst will inject a lot of radioactivity into the atmosphere
- Unless protected, lethality and delayed radiation injury from fallout will extend further than blast or fireball
Potential health effect sources vary over time

- **Early fallout**  gamma/beta external hazard
- **Delayed fallout**  alpha, beta, gamma external and internal hazard iodine, strontium, cesium

Very long term (yrs)

\[ ^3H, ^{14}C, ^{54}Mn, ^{55}Fe, ^{90}Sr, ^{95}Zr, ^{106}Ru, ^{125}Sb, ^{137}Cs, ^{144}Ce \]
The acute period is typically the focus
Gamma dose rate from fallout

- The dose rate decreases with a factor of 10 every 7 hours for early fallout.
- At 2 days it will be roughly $100^{th}$.
- Makes it sound as if there is little or no problem after 2 days.
The radiation exposure will continue although at much lower levels

It isn’t really over at some specific time point!!!
Operation
UPSHOT-KNOTHOLE
NEVADA PROVING GROUNDS

March - June 1953

Project 4.7
BETA-GAMMA SKIN HAZARD IN THE
POSTSHOT CONTAMINATED AREA

HEADQUARTERS FIELD COMMAND, ARMED FORCES SPECIAL WEAPONS
SANDIA BASE, ALBUQUERQUE, NEW MEXICO
Is it true that essentially all health risks will come from radiation received in the first week?

No
Bikini fallout data show health risks can be accumulated weeks and months later

<table>
<thead>
<tr>
<th>Period</th>
<th>Inhabited</th>
<th>Uninhabited</th>
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<tbody>
<tr>
<td>0-96 hrs</td>
<td>220 rads</td>
<td>3300 rads</td>
</tr>
<tr>
<td>96 h-1 wk</td>
<td>35</td>
<td>530</td>
</tr>
<tr>
<td>1 wk-1 mo</td>
<td>75</td>
<td>1080</td>
</tr>
<tr>
<td>1 mo-1 yr</td>
<td>75</td>
<td>1100</td>
</tr>
<tr>
<td>Total to 1 yr</td>
<td>405</td>
<td>6010</td>
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</tbody>
</table>
Same issue from Chernobyl fallout doses (mSv) in villages with ~ 15 Ci/km²

<table>
<thead>
<tr>
<th>Dose component</th>
<th>0-4 yrs</th>
<th>4-70 yrs</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>External</td>
<td>16-32</td>
<td>47-95</td>
<td>63-130</td>
</tr>
<tr>
<td>Internal</td>
<td></td>
<td></td>
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<tr>
<td>Cesium</td>
<td>0.8-2.3</td>
<td>13-26</td>
<td>15-27</td>
</tr>
<tr>
<td>Strontium</td>
<td>0.2-2.4</td>
<td>0.2-1.6</td>
<td>0.4-4</td>
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<tr>
<td>Total</td>
<td>17-35</td>
<td>60-120</td>
<td>78-160</td>
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</table>
Is it true that most health risks from fallout come from internal contamination?

No
~80% of Chernobyl fallout doses (~% of total) in villages with ~ 15 Ci/km². $^{137}$Cs come from external exposure.

<table>
<thead>
<tr>
<th>Dose component</th>
<th>0-4 yrs</th>
<th>4-70 yrs</th>
<th>Total</th>
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<tbody>
<tr>
<td>External</td>
<td>20</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Internal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cesium</td>
<td>1.4</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Strontium</td>
<td>1.4</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>75</td>
<td>100</td>
</tr>
</tbody>
</table>
Some other lessons from Chernobyl
Stylized NYC fallout mortality 12.5 Kt
Chernobyl 180 degree wind shift can occur in 12 hours: Delayed injuries can occur anywhere
World Trade Center from satellite

Normal wind direction
Even nearby fallout is heterogeneous. Very different health effects can occur with minor differences in distance.
Measurable fallout can extend for great distances

300 km

Millions of people will be exposed to some radiation and will want evaluation and be concerned about health effects
What do survival and medical decisions depend upon?

- Deep tissue dose and damage
- Skin injury extent
- Combined injury from blast/thermal
What do we do about early survivors who got external whole body radiation exposure?

Possibly hundreds of thousands of persons
How much dose did they get?
How do we tell?
Who needs treatment?
Sorting methodology will need to be applied to fallout and prompt radiation areas to determine need for delayed care (Chernobyl lessons)

• Any test will need to process tens or hundreds of thousands of people and be rapid

• Nausea, vomiting, diarrhea

• Complete blood count with differential

• Chromosome aberrations especially PCC and automated (maybe ???)
Whole body radiation dose/effect

- 10mGy (1 rad)  1/1000 chance of cancer
- 100 mGy (10 rads)  1/100 chance of cancer
- 1 Gy (100 rads)  Prodromal symptoms
- 3.5 Gy (350 rads) LD50 (without treatment)
- 6.5 Gy (600 rads) LD50 (with treatment)
- >12 Gy (>1200 rads)  Not survivable

Some deaths in decades

Many deaths in weeks - months

Deaths in weeks
Treat the patient not the estimated dose?
Acute Radiation Syndrome
from whole body penetrating radiation

[Diagram showing the progression of radiation effects from subclinical to gastrointestinal with points for OK, NEED Rx, and palliation.]
Hematological Response to 300 rads

- Lymphocytes and Neutrophils (x 1000)
- Hemoglobin (g)
- Thrombocytes (x 1000)

Graph showing changes over time in Hemoglobin, Neutrophils, Lymphocytes, and Thrombocytes.
Have bone marrow transplants been useful to treat whole body exposure?

• 34 patients as of 2002
• 1 survived 8.7 Gy (recovered native marrow) = survival less than 4%
• Several died as a result of complications
• 4 Chernobyl patients (6-8 Gy) survived without transplant
• CSF etc will be in huge demand
Gastrointestinal changes – days to many months

Large ulcerations
Acute causes of death at various times following whole body exposure

- 10 Gy: Bone Marrow
- 5 Gy: GI etc.

About 100% Lethality

Other organ failure

Months:
- 0-1
- 0.5-1.5
- 4-8
Belarus industrial irradiator accident

24 hours post exposure

90 days-
pulmonary
failure death
Deaths at 6-15 months
Multi-organ failure
Bottom line on external exposure and ARS (a factor of ~ 2-3)

- ARS treatment will be needed both for prompt radiation as well as fallout victims
- LD 50/30 ~ 3-3.5 Gy without medical treatment
- LD50/30 ~ 6-8 Gy with intensive medical treatment
- The issue of long term issue of multi-organ failure has not been overcome
How effective is medical treatment?

Current medical treatment can only improve things by a factor of ~2-3.

If ... we have the best ICU care, beds, transport and staff.

...... Which we won’t.
Protective actions can reduce doses and consequences by factors of up to 1000 or more
Issue of combined agents

Chemical agents have immediate effects that must be dealt with first.

There is not likely to be synergism between radiation and chemical or biological agents.

Do plans deal with medical care for multi-agent attacks?
Radiation injury to the skin

- Will occur as a result of both beta and gamma radiation
- Skin doses can be much higher than deep tissue dose
- Can seriously and adversely affect survival when occurring with ARS (depressed marrow etc)
- Skin injury was *the* major cause of mortality in Chernobyl ARS patients so will thermal burns, glass
Beta burns

- Fresh fission products from reactor core or from recently exploded weapon

- Beta/gamma ratio is often 3-20

- Skin injury if a large enough area will be a major cause of mortality
Skin injury with acute radiation exposure often take days to weeks to appear

- 2-6 Gy
  - Transient erythema 2-24 h
- 3-5 Gy
  - Dry desquamation 3-6 wks
- 3-4 Gy
  - Temporary epilation 3 wks
- 10-15 Gy
  - Erythema 18-20 days
- 15-20 Gy
  - Moist desquamation
- 25 Gy
  - Ulceration/ slow healing
- 30-50 Gy
  - Blistering, necrosis at 3 wks
- 100 Gy
  - Blistering, necrosis at 1-3 wks
Cells already dead

Radiation damaged cells

Long-term arteriolar occlusion
Late Skin and Soft Tissue Changes cause problems for months to years

- Epilation - permanent or temporary
- Pigmentation
- Atrophy
- Fibrosis with limitation of range of motion
- Necrosis

- Dose calculation notoriously inaccurate and treatment based on clinical appearance and temporal changes
BETA BURNS
ON 13 YEAR OLD
MARSHALLENSE BOY
45 DAYS AFTER
EXPOSURE
13 YEAR OLD MARSHALLESE BOY
6 MONTHS AFTER EXPOSURE
Chernobyl fireman-acute fatal beta burns
Combined Effects of Simultaneous Whole-Body Irradiation and Burns on Rats

Percent Lethality

- **Burns**
- **Radiation**
- **Combined**

Legend:

- Red: Burns
- Yellow: Radiation
- Blue: Combined

<table>
<thead>
<tr>
<th>Radiation (R)</th>
<th>Lethality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td></td>
</tr>
</tbody>
</table>
Chernobyl reactor worker
- healed beta burns- 2 decades later
Gamma from prompt radiation as well as from fallout will also cause skin and underlying tissue injuries.
Long term cataracts 2-5 years

Issue present but of relatively minor significance
Internal exposure – complex issue

38 elements and about 300 radionuclides

- Americium (bone)
- Californium (bone)
- Cerium (GI,lung)
- Curium (bone)
- Iodine (thyroid)
- Plutonium (bone)
- Polonium (lung)
- Strontium (bone)
- Tritium (whole body)
- Uranium (bone)

Deaths very unlikely from internal exposure

Except for radiiodine in young persons relatively minor clinical significance.
Radiation carcinogenesis: Long term problem
Small overall percentage impact

86,572 A-bomb survivors with average dose of 23 rem (0.23 Sv)

7,578 cancer deaths total 334 excess (4.6% increase)

•UNSEAR 2000
Causes of death in atomic bomb survivors

Non cancer deaths

Expected
cancer deaths

Radiation excess
deaths

Non cancer deaths
Radiation-induced thyroid cancer in a child from Chernobyl
Childhood Thyroid Cancer after Chernobyl

The graph shows the number of cases (Cases) of childhood thyroid cancer from 1987 to 1997, categorized by age groups:
- 0-4 yrs
- 5-9 yrs
- 10-14 yrs

Age at exposure is indicated on the x-axis, and the number of cases is indicated on the y-axis.
• **High risk**: non-CLL leukemia, breast, lung, stomach colon, thyroid (children)

• **Moderate risk**: esophagus, skin

• **Little risk**: lymphoma, pancreas

• **No detectable risk**: cervical, endometrial, prostate, CLL
Latent periods (years) for various tumors

<table>
<thead>
<tr>
<th>Site</th>
<th>Mean</th>
<th>Minimum</th>
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<tbody>
<tr>
<td>Thyroid</td>
<td>20</td>
<td>~ 5</td>
</tr>
<tr>
<td>Breast</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>Skin</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Bone</td>
<td>20</td>
<td>2-3</td>
</tr>
<tr>
<td>Leukemia</td>
<td>7</td>
<td>2</td>
</tr>
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</table>
Fetal Radiation Risk

• There are radiation-related risks throughout pregnancy which are related to the stage of pregnancy and absorbed dose.

• Radiation risks are most significant during organogenesis and in the early fetal period, somewhat less in the 2nd trimester and least in the third trimester.
Radiation-Induced Malformations

- Malformations have a threshold of 100-200 mGy (10-20 rads) or higher and are typically associated with central nervous system problems.
Percent severe mental retardation as a function of radiation dose and fetal age

<table>
<thead>
<tr>
<th>EGA</th>
<th>Fetal</th>
<th>dose</th>
<th>in rads</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0-7</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8-15</td>
<td>0.8</td>
<td>4.3</td>
<td>8.0</td>
</tr>
<tr>
<td>16-25</td>
<td>0.6</td>
<td>1.2</td>
<td>0</td>
</tr>
<tr>
<td>25+</td>
<td>1.3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Hiroshima and Nagasaki ICRP 49
55歳
百合子さんは毎日この場所にすわったまま一日を過ごします。
55 years old
Yuriko spends her days sitting right here.
Hereditary effects of radiation
Hereditary effects have not been seen in humans in spite of 3 generations of study in atomic bomb survivors.

Hereditary effects are not apparent in children of radiation therapy patients.

Risk not exactly known but estimated to be less than 1/10th of radiogenic cancer risk.
Psychosocial issues

- Persist for decades
- Occur regardless of dose level
- Remain major issues in A-bomb and Chernobyl populations
Ethical Issues

Planners usually worry about the acute period (days-week) and leave long term effects to others. Who are the others??

Many serious health effects will not be immediately evident and will last for decades

Examples: A-bomb, Downwinders, Chernobyl etc
Record keeping

• Always a big problem
• Registry of exposed persons ??
• Dose often expressed as effective dose rather than organ dose
• Doses usually not individual and subject to large uncertainties
• Privacy issues (HIPPA)
• Bias in reporting of health effects
An unsolved issue?

Who is responsible for planning and providing intermediate or long term medical care and or follow-up?

Assumedly a large portion will be absorbed in the current health care system and by having the government print additional money.
Long term - Relocate or stay?
Contaminated village  5 years later
Good luck