Radiological Dispersal Device & Nuclear Detonation

EXPLOSION AND BLAST INJURIES

Scenario Presentation

Possible Scenarios

- Radiological Exposure Device
- Improvised nuclear device (IND)
- Nuclear weapon detonation
- Nuclear power plant accident
- Radioactive dispersal device (RDD) including the “Dirty Bomb” scenario

Photo Credit Sandia National Laboratories and Wikipedia
“Dirty Bomb”

- Conventional explosive + radioactive material =
  “dirty bomb”
- Dispersal pattern variable
- Combined blast and burn injuries
- External and internal contamination
- Potentially large population affected

Little Boy dropped on Hiroshima in August 6 1945

Simulation Target

Hypothetical Scenario in Downtown, Atlanta
Severe damage zone (0.5 mile radius):
- Near complete collapse
- Few, if any, buildings still standing
- 99% immediate fatalities

Moderate damage zone (1 mile radius):
- Some collapsed buildings, blown out building interiors, overturned automobiles, fires
- Significant thermal burns if outdoors
- 38% immediate fatalities, 14% expectant

Light damage zone:
- 2-3 mile radius
- 25% of windows are shattered
- Huge numbers of glass injuries
- 6% of casualties at risk of death
Dangerous Fallout Zone or Dangerous Radiation Zone:
- Extends 25 miles downwind of ground zero
- Reaches maximum extent at 1 hr
- Severely hazardous fallout will descend to the ground within a few hours and may shrink to a few miles in a couple of days (decay)
- Mostly visible to naked eye (grains of sand)
- Exposure rate > 10 R/h

Casualties (10 kT model)
- For large city with 2 million population
  - 230,000 immediate fatalities
  - 323,000 injured survivors
    - 90,000 will succumb without medical treatment
    - 73,000 will still succumb with medical treatment
    - 26,000 can be saved with medical treatment

Acute Injuries after a Nuclear Detonation
- Blast injuries
  - Blast wave can take several seconds to travel a few miles
  - Glass injuries (within a few miles)
    - Duck and Cover can protect people if they see the bright flash of light (can be seen up to 100 miles away)
    - May not be possible in a ground burst inside a city
- Thermal burns injuries
  - Primary flame (fireball up to few miles away)
  - Secondary fires
Acute Injuries after a Nuclear Detonation

- Radiation injuries
  - Prompt radiation (within first minute)
  - Latent (after first minute)
    - Emitted from the fallout
    - Composed of fission products and neutron activation products
  - Acute Radiation Syndrome
  - Beta burns

Acute Injuries after a Nuclear Detonation

- Combined injuries (estimated to occur in 60%)
- Flash blindness (up to 6 miles)
- Electromagnetic pulse (EMP)
  - No direct health effects
  - High voltage surge in conductors
  - Poorly characterized in an IND
  - Probably not beyond 2 miles of ground zero

Fig. 4.2 Nuclear terrorism incident damage and fallout pattern: Significant difference in fallout patterns can result from varying wind directions and speeds at varying altitudes. (Budnitz and Dillon, 2008)
Long Term Effects

- Delayed Effects of Acute Radiation Exposure (DEARE)
  - Pulmonary fibrosis
- Solid tumors
- Leukemias

MECHANISM OF DISEASE

Ionizing Versus Non-ionizing Radiation

- Ionizing radiation interacts with human body through direct and indirect effects:
  - Directly
  - Indirectly
- Non-ionizing radiation (microwaves, UV)
  - Does not ionize other atoms or lead to the formation of free radicals
Radiation Damage

- Deterministic
  - Threshold dose
  - Local radiation injury
  - Acute radiation syndrome
- Stochastic
  - Random
  - Oncogenensis
  - Teratogenesis

Radiation Physics 101

Radioactive Decay

- Atoms decay to reach a more stable state by emitting ionizing radiation in the form of particles or penetrating radiation (Gamma rays).
Different Types of Radiation

- Areas Persists: May persist on the skin.
- Beta Particles: Cause superficial damage, especially damaging to internal tissues if inhaled or ingested.
- Gamma Rays: Cause internal damage if inhaled or ingested, can cause cancer.
- Neutrons: Cause internal damage and can cause internal and external burns.

Types of Ionizing Radiation

Radiation Units: S.I. Versus USA

<table>
<thead>
<tr>
<th>Unit</th>
<th>Formula</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray (Gy)</td>
<td>100 x</td>
<td>RAD</td>
</tr>
<tr>
<td>Sievert (Sv)</td>
<td>100 x</td>
<td>REM</td>
</tr>
</tbody>
</table>
2 Different yet Possible
Overlapping Entities

- Exposure
  - Whole body
  - Partial body

- Contamination
  - External
  - Internal

Radiation Protection in Whole
Body Exposure

Time
Distance
Shielding
Pick the Appropriate Personal Protective Equipment (PPE)!

**WHEN CARING FOR THESE PATIENTS**

**Respiratory Protection**

- Commonly available protective masks are generally sufficient pre-decontamination
- OSHA/NIOSH Hospital staff taking care of patients in the pre-decontamination and decontamination areas. PAPRs or HEPA filter negative pressure masks are described as minimum
Personal Protection

- Standard Precautions

Radiation Detection in the ED

- Victims should be surveyed with Geiger-Müller counters.

Radiation Detection in the ED

- Survey patient for radiological contamination and mark areas on body diagram.
- Remove contaminated clothes and label them.
- Except for an instance of highly-radioactive shrapnel, contamination should NOT deter medical staff from treating life-threatening injuries.
In Vivo Measurements

- Whole body counters
- Chest counters for Plutonium and Uranium
- Wound monitoring instruments

Whole Body Dosimetry

- Using whole body counters or scanners that are potentially available at nuclear medicine departments.
- It is crucial to know when the contamination occurs as well as which radionuclide is involved.

Diagnosis By Excretion (Bioassay) Sampling

- Collect urine or feces to measure excretion rates
- Challenging interpretation
  - Time when contamination occurred
  - Characteristics of inhaled or internalized radionuclides

www.bt.cdd.gov/radiation/clinicians/evaluation/index.asp
Internal Contamination
Acute Radiation Syndrome

**CLINICAL IMPACT AND CONSEQUENCES**

Clinical Consequences of Internal Contamination

- Acute and subacute
  - End organ damage
  - Acute Radiation Syndrome
  - Multiorgan failure
- Chronic
  - Solid tumors
  - Leukemias

**Management Strategies**

- Supportive care
- Decreasing absorption
- Decorporation and enhance elimination
- Long term monitoring
**Internal Contamination**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Exchanger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine</td>
<td>KI (potassium iodide)</td>
</tr>
<tr>
<td>Transuranics such as Plutonium &amp; Americium</td>
<td>Zn-DTPA, Ca-DTPA</td>
</tr>
<tr>
<td>Uranium</td>
<td>Bicarbonate</td>
</tr>
<tr>
<td>Cesium</td>
<td>Prussian Blue* [Ferrihexacyano-Ferrate (II)]</td>
</tr>
<tr>
<td>Rubidium</td>
<td></td>
</tr>
<tr>
<td>Thallium</td>
<td></td>
</tr>
<tr>
<td>Trifium</td>
<td>Water</td>
</tr>
</tbody>
</table>

**Transuranics**
- Used for Transuranics such as Plutonium and Americium
- First dose should be Calcium DTPA followed by Zinc DTPA
- Duration of therapy will be guided by urine or feces transuranic concentrations

**Cesium-137**
- 46 Goiania pts contaminated with Cs-137 treated with Prussian Blue
- Less than 1% is absorbed
- Exchanges a cation and binds Cesium or Thallium
- Decreases GI absorption and interrupts enterohepatic circulation
Radioactive Iodine Exposure

- Iodine Prophylaxis and Treatment
  - Potassium iodide (KI) is an effective, inexpensive thyroid-blocking agent

ACUTE RADIATION SYNDROME (ARS)
Acute Radiation Syndrome (ARS)

- Deterministic effect
- Prodrome phase
- Hematopoetic syndrome
- Gastrointestinal syndrome
- CV/CNS syndrome

Prodrone

- Vague Sx: nausea, vomiting, headache
- Help predict the dose: the higher the absorbed dose the earlier and the more frequent the Sx occur

Hematopoetic Syndrome (2-6 Gy)

15 June 2004 Annals of Internal Medicine Volume 140 • Number 12
Lymphocyte Depletion Kinetics

- Andrew's nomogram helps estimate the dose of radiation.
- WBC with differential every 6 hrs for first 24-48 hours.

Cytogenetics

- Rate of dicentric chromosomes in peripheral lymphocytes.
- Available at REAC/TS.
- Takes a few days.

Management of the Hematopoetic Syndrome

- Complications: infection and bleeding.
- Treatment is supportive:
  - Reverse isolation
  - IVF
  - Blood products
  - Antibiotics
  - Colony stimulating factors such as filgrastim or G-CSF (300 mcg/s/c per day)
  - Stem cell transplant
Population Monitoring

- The process to screen people for radioactive contamination or exposure to radiation, assist with decontamination, register, and prioritize for further follow up.
- Primary objective is to identify people who are in immediate danger.
- It is a local/state effort; similar to PODs.
  
  www.bt.cdc.gov/radiation/pdf/po
dulation-monitoring-guide.pdf

Community Reception Centers (CRC)

- The place to conduct "population monitoring"
- Primary services include:
  - external contamination screening, external decontamination,
  - prioritizing people for further care
- Benefits include:
  - providing needed services to affected and concerned people, reducing burden on hospitals, managing scarce medical resources, supporting public shelters
- Staffing:
  - Health physics (radiation safety), nursing/medical, and general staff

Thank You!