FUNDAMENTALS OF RADIATION ACCIDENT MANAGEMENT

“Day of Disaster”
Vertically Integrated Curriculum for Medical Students

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Professor of Radiology and Director NM
How Likely is a Radiation Accident?

- Nuclear Power plants in Illinois – 5 in Northern Illinois, about 100 in country.
- Transfer of high level waste to permanent facility in Yucca Mountain – highway accidents
- Now due to open in 2017
- Research Labs
- Industrial sources
- Terrorist attacks (radiological or nuclear devices)
- Earthquakes!
Current Sites of High Level Waste

- Alaska
- Hawaii

Sites storing spent nuclear fuel, high-level radioactive waste, and/or surplus plutonium destined for geologic disposition.

Symbols do not reflect precise locations.
The Public Perceptions

Konstanze Halt
Nuclear Terror
Almost nothing creates more terror than radiation

- It’s invisible to touch, taste, and smell
- Most people have unrealistic ideas about radiation
- Most physicians don’t even understand it
- Little if any training in radiation and radiobiology
Nuclear Medicine and Radiation Therapy professionals are well trained in the fundamentals of radiation

- Respect it, but don’t fear it
- Understand what it can and cannot do
- There have been industrial radiation accidents that we have learned much from
- It is easily detected in contrast to biological and chemical agents
Chemical Terrorism
- Aerosolized ricin (castor bean toxin)
- Blistering agents
  - Phosgene
  - Mustard gas
- Poisons – Cyanide
- Neurotoxins – Sarin (Tokyo – 1995)

Effects are generally quick onset
What Can We Expect?

- Biologic Terrorism
  - Smallpox
  - Anthrax (Post 9/11/2001)
  - Plague
  - Botulism
  - Tularemia
  - Ebola

- Experience with H1N1
- Symptoms may take days to appear
What Can We Expect?

- Radiological/Nuclear Terrorism
  - A true nuclear detonation
  - A failed nuclear detonation
  - Radiation dispersal device
  - Radiation poisoning
- Power Plant attacks (unlikely)
A Nuclear Detonation

- Least likely scenario (fortunately)
- Most likely from a stolen nuclear weapon
- Results would be devastating, both psychologically and in terms of damage
Red
100% lethal zone – all buildings destroyed
Pink
50% lethal – severe building damage – fires
Yellow
10% lethal – mild-moderate damage – fires
Light yellow
Fallout area – no wind

Effects of a modern thermonuclear weapon detonated over Chicago
Failed Nuclear Detonation

- Most likely from an improvised nuclear device (IND)
- Beyond the scope of an individual terrorist – would need 10-15 people
- Greatest barrier is availability of weapons grade material
- Would create a critical mass or explosion, but not the same degree as a true nuclear detonation.
- Nuclear material needs to stay in contact for a longer period of time to allow flux to form
Radiological Dispersal Device

- The most likely scenario
- Simply a bomb loaded with radioactive materials
- Uses stolen hospital or industrial materials
- Acute effects are limited to psychological and traumatic injury
- Long term effects would be on contamination of large areas
- Huge expense for cleanup
Chernobyl Comparison

Co-60 food irradiation pencil in a RDD

Radiation Levels

• Inner ring – same as permanently closed around Chernobyl
• Middle ring – same as permanently controlled area around Chernobyl
• Outer ring – same as periodically controlled zone around Chernobyl
Cancer Deaths

Co-60 food irradiation pencil in a RDD

Increase risk of cancer

- Inner ring – 1 per 100 people
- Middle ring – 1 per 1,000 people
- Outer ring – 1 per 10,000 people

Cancer affects 1 in 4 individuals (25%)

Expected Cancer deaths per million 250,000

- Inner ring – 260,000 (excess 1% lifetime risk)
- Middle ring – 251,000 (excess 0.1% lifetime risk)
- Outer ring – 250,100 (excess 0.01% lifetime risk)

Cleanup could exceed $2 Trillion
The Weather
Direction of the wind can make all the difference.

Aerial photograph shows the smoke from 9/11 traveling south.

Normal wind direction (arrow) is northeast.
Polonium 210
- 5 million times more toxic than hydrogen cyanide
- Oral LD$_{50}$ – 50ng
- Inhaled LD$_{50}$ – 10ng
- 1 gram – can poison 100 million – 50% will die
- 1 gram in same place self heats to 500° C
- Estimated cost - $10 million to poison this man (10 times as much needed was used)

Alexander Litvinenko, 2006
Types of Radiation

- **Alpha (microns)**
  - Helium Nucleus
  - Positively charged (+2)
  - More common in the heavier elements
  - No practical medical use (yet)
  - Safe as long as it remains outside of body

- **Beta (millimeters)**
  - Negatively charged (negatron or electron)
  - Positively charged (positron)
  - Useful in therapeutic medicine (Radiation Therapy or Nuclear Medicine)
  - Long term – large amounts can cause burns on skin

- **Gamma or X-Ray (centimeters)**
  - No charge
  - Useful in medical imaging
  - Large amounts required to cause biological changes
Estimated exposure in a uniform area where the dose rate is 20 mR/hour

<table>
<thead>
<tr>
<th>Time</th>
<th>Exposure</th>
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</thead>
<tbody>
<tr>
<td>15 minutes</td>
<td>5 mR</td>
</tr>
<tr>
<td>30 minutes</td>
<td>10 mR</td>
</tr>
<tr>
<td>1 hour</td>
<td>20 mR</td>
</tr>
<tr>
<td>2 hours</td>
<td>40 mR</td>
</tr>
</tbody>
</table>
Behaves according to inverse square law
## Shielding Effectiveness of a Lead Apron

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Percent Stopped</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tc - 99m</td>
<td>78%</td>
</tr>
<tr>
<td>Ir – 192</td>
<td>14%</td>
</tr>
<tr>
<td>Cs – 137</td>
<td>6%</td>
</tr>
</tbody>
</table>

Don’t wear one during an accident! (Weighs about 10 – 15 lbs)
The risk of a spontaneous genetic disorder is 10%.

10 Rads of Acute Gonadal Radiation will increase this risk by 0.005% to 0.075%.

The increased Risk is between 1 in 1,300 to 1 in 20,000!
The lifetime risk of getting cancer is 40%.
The lifetime risk of dying from cancer is 22%.
Carcinogenesis from 10 Rads of Acute radiation is estimated at 1 per hundred people exposed.
The increased risk for 1 Rad of radiation therefore is estimated at 1 in 1000!
Assumption: Using linear no threshold model – worst case scenario.

Source: BEIR VII – 2006
ACS - 2006

Stochastic
Dose Limits

- Normal
  - 100 mR – members of the public
  - 5,000 mR – radiation professionals

- Do they apply during emergencies?

- Urgent actions guidelines
  - 50 R or less total body
  - 75 R to an extremity
  - Lifesaving – may exceed these doses

- LD 50/60 – 350 – 450 R Total body
Effects of High Level Exposure

- Not seen on initial presentation
- Symptoms and Syndromes
  - Prodrome - One to two days
  - Latent period - Variable, hours to weeks
  - Manifest illness - Severity proportional to exposure
  - Recovery - Months to years
- Burns
  - Thermal or Chemical - acute
  - Radiation burns - delayed
Behavior of Blood Elements after Exposure

Effect of 100 R

Effect of 200 R

Effect of 500 R

Effect of 1000 R

Days Post Exposure

Days Post Exposure

Days Post Exposure

Days Post Exposure

Non Stochastic
Radiation Protection Drug Shows Promise In Animal Tests

CBLB502 is a polypeptide derived from the whip like tails of the Salmonella bacterium and it binds to a cell receptor called TLR5 to trigger appropriate apoptosis-suppressing signal.

The drug protected the mice against the effects of radiation on organs of the digestive tract and in blood cell producing bone marrow (protected against "gastrointestinal and hematopoietic acute radiation syndromes") and improved their survival.
Management of Exposure and Contamination

- Concepts
  - Exposure vs. Contamination
  - Local vs. Total Body
- Treatment of Exposure
- Contamination: Internal vs. External
- Treatment of Contamination
<table>
<thead>
<tr>
<th>Exposure</th>
<th>Contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing near a septic tank</td>
<td>Falling into a septic tank</td>
</tr>
<tr>
<td>X-Ray Procedure</td>
<td>Nuclear medicine procedure</td>
</tr>
<tr>
<td>Medical Supply or Food Irradiator</td>
<td>Power plant or research lab</td>
</tr>
</tbody>
</table>
Treatment of Exposure Localized

- The damage is already done
- Reconstruct the accident to determine dosage
- Effects depend on area exposed
- Surgical management may be needed for burns or long term complications.
The damage is already done!
- Provide supportive care
- Reconstruct accident to estimate the exposure level (biologic dosimeters)
- Reverse isolation may be needed
- Fluid and electrolyte maintenance
- Follow blood levels of platelets and WBC’s
- If exposure is high, consider BMT (consult)
Contamination In Perspective

- 1 mCi = 37,000,000 DPS (Becquerels)
- Bone Scan uses 25 mCi
- Typical levels of contamination < 10,000 CPM
Contamination
Internal vs External

- **External** (Done acutely)
  - Remove contaminated clothing
  - Wash affected areas
  - Avoid harsh agents that may compromise skin

- **Internal** (Done later)
  - Decontamination efforts require knowledge of the chemistry and biologic properties of the contaminant
  - Requires that specimens were obtained initially
Saturate the organ
- Stable iodine competes with radioactive iodine

Dilute the isotope
- Tritum behaves like water. Exchange the fluid compartment in the body.

Displace the isotope
- Calcium competes with Strontium in binding with bone matrix

Bind or chelate the isotope
- DTPA, EDTA, desferoxamine, penicillamine, Prussian blue. Use caution! Non specific.
Radiation Accidents

- Worst one in history?
  - Chernobyl
- What is the second worst accident?
  - Fukushima
- ...and the third?
In The News 3/12/2011

For battered Japan, a new threat: nuclear meltdown

Japan struggles with nuclear accident and tsunami aftermath

Fukushima Plants
Fukushima, Japan

- Earthquake
  - Level 9.0 – plant designed to withstand 8.3
  - Tidal wave – 30 feet
  - Primary power loss
  - Backup power generators lost from tidal wave

- Power Plants
  - Shut down
  - Fuel remains heated (and radioactive)
  - Spent fuel pools – cooling stopped
  - Saltwater used as emergent cooling
Aerial Measuring Results
Joint US / Japan Survey Data

Total Cesium Deposition (Bq/m²)
Normalized to April 29, 2011

- 3,000,000 - 30,000,000
- 1,000,000 - 3,000,000
- 600,000 - 1,000,000
- 300,000 - 600,000
- < 300,000

No Aerial Data
Fukushima Daiichi

Employees in protective clothing and respirators checking the radiation level of a child's hand.

http://www.iaea.org
Earthquakes in the US?
Thieves break into a warehouse containing medical equipment
Steal materials for scrap metal
Includes an old therapy source – Cs\textsuperscript{137}
Powder mixed with phosphor – sparkles
Residents of town find it amusing – later become sick
Doctor from nearby town arrives
Goiania, Brazil, in 1987

- Over 32,000 checked for contamination
- 247 people demonstrated contamination
- 6 people died
- Topsoil removed from the town and currently stored above ground in canisters.
- Cs\textsuperscript{137} half life ~ 30 years
Monitoring people for contamination at Olympic Stadium
Waste Containers
Hospital Preparation For Radiation Accident Management

- Key Personnel
- Layout of a Radiation Emergency Area
- Necessary Equipment
- The Plan
Key Personnel - Immediate

- Emergency Room Nurses
- Emergency Physician
- Nuclear Medicine Technologist or Radiation Technologist
- Security
- Public Relations – do not talk to the media!
- Housekeeping
Key Personnel

- Surgeon (Trauma and Burns)
- Radiation Technologist
- Nuclear Physician, Radiologist and/or Radiation Therapist
- Oncologist (If suspecting possible BMT)
- Internist (Other medical conditions)
- Legal Counsel
What Injuries Can We Expect?

- Trauma
  - Blunt
  - Blast
  - Piercing
  - Crush
  - Lacerations
- Burns (chemical and thermal)
- Contamination – Internal and external
Necessary Equipment

- Personal Protection
  - Masks, Gowns and Gloves
  - Dosimetry
- Specimen Kit
- Decontamination Kit
- Herculite
- Decontamination Cart
Necessary Equipment

- Specimen Kit
  - Cotton tipped applicators
  - Specimen Containers - urine, stool, tissue, bandages, etc.
  - Scissors
  - Nail clippers
  - Labels and markers

- Decontamination Kit
  - 4 x 4’s and “Buff Puffs”
  - “Chucks”
  - Normal saline
  - Betadine
  - Phisohex
  - Peroxide
  - Wash Basins
  - Johnson’s Baby Shampoo
Sequence of Events in Management

- Patient Arrival
- Triage
- Remove Clothing
- Medical Management
- Radiological Assessment
  - Document areas of Contamination
  - Obtain Samples

- Decontamination
- Final Survey
- Patient Exit
- Staff Exit
Remember your A, B, C’s of emergency care.

- **Airway**
- **Breathing**
- **Circulation**
  
  ... 
  ... 
  ... 
  **Radiation**

Don’t be ashamed to follow the list. Don’t be afraid to ask questions.
Dosimetry

- Remove your own badge
- Use a provided badge
- Only needed in areas of suspected contamination
- Wear on inside of protective clothing
Clean Team Transfer

- Herculite
- ER Cart
- Stretcher
- Ambulance
Loyola Emergency Room Layout

- Triage
- Alternate Patient Route
- Buffer Zone
- Usual Patient Route
- Patient Care Area
- Nurses Station
- Patient Care Area
- Clean Team Transfer Area
- Ambulance Ramp

Legend:
- Yellow Herculite
- Green Herculite
- Stanchions and Rope
The question of radiation causes fear
Many people may arrive for evaluation
Take care of the injured first
How to manage a large group of worried otherwise healthy people?
- Identify an area to house them (Olympic Stadium)
- No eating or drinking
- Obtain patient information and contact number
- Systematically look for contamination
- Obtain samples (hands, nose and mouth swabs), CBC with differential if concern of large exposure
How to Decontaminate

- Identify area by survey – document cts/min
- Steps
  - Wash with WARM water
  - Dry
  - Resurvey
- 4 x 4’s to basin to patient to garbage
- Repeat until background activity
- If contamination is stubborn, dry a different solution.
- Do NOT use harsh agents
- If all else fails, bandage the area and check later
Potassium Iodide

- Who gets it?
- Dosage
  - Adults – 2 tabs (130 mg)
  - Children 3-12 – 1 tab (65 mg)
  - Infants – 3 yrs – ½ tab
Rad. Resident Duties

- Make sure Nucmed MD and Rad Safety notified
- Check that GM counter is available and working
- Put on protective clothing - no lead apron!
- Prevent spread of contamination outside of REA
- If possible wait for Nuclear Med physicians and Radiation Safety to arrive. If not….
  - Survey patient for areas of contamination
  - Obtain samples of material for later analysis
  - Decontaminate patient
- Do not perform unless patient is stable!
History:

53 yo male contractor working in a nuclear power plant during a scheduled outage. At 10:40 AM he slips and falls 30 feet. A health physicist and first aid are on the scene in several minutes. The patient is semiconscious and groaning with a contusion on his forehead and a bump on his posterior skull.
Case: Contaminated Fall

Time Line:

10:40 AM Accident occurs
10:45 AM HP and first aid on scene
10:50 AM Control room calls EMS
10:55 AM Control room calls hospital
11:03 AM EMS arrives
11:07 AM EMS departs
11:45 AM EMS arrives at hospital (Not the closest hospital)
Case: Contaminated Fall

En Route to Hospital:

Falling BP and chest pain
Pt had history of MI x 2
Sublingual nitroglycerine given
No feeling in either foot, motion intact
Case: Contaminated Fall

Hospital Response:

Good room setup
Proper gowning and dosimetry issued
First survey showed 1500 cpm on forehead
All needed medical equipment in place
Patient stabilized and transferred to the initial hospital that was passed.
Patient Disposition:

Patient died 3 hours later
- Ruptured liver and spleen
- Subdural hematoma
- Hemorrhage and shock
Case: Contaminated Fall

Review:

• The “Golden Hour” was missed.
• Patient should have gone to closest facility
• M.D. was untrained, but E.R. nurses instructed.
• Bioassay samples were not obtained.
Where Can I Get More?

http://www.acr.org/

http://orise.ornl.gov/reacts/

http://www.ready.gov