

Physician and Hospital Responses to Radiological Incidents

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Experience of Authors

- Dr Wagner trained at Loyola and the DOE in Oak Ridge - Radiation Emergency Assistance Center/Training Site (REAC/TS)
- Drs Wagner and Henkin co-wrote the original manual for hospital management that was used by the State of Illinois
- Dr Wagner is has been consultant for Radiation Management Consultants since 1990 and trains and drills approximately 5 hospitals/year until 1998. Developed the plan for radiation accidents at Loyola
- Dr Henkin is a member of the Radiation Information Network of the American College of Nuclear Physicians
- Drs Wagner and Henkin are Board Certified by ABNM

Radiation and Terrorism

- Public perceptions of radiation
- The good news and the bad news
- Terrorism scenarios
- Types of radiation injuries
- Hospital response to radiation incidents

The Public Perceptions



The Bad News

- 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
- The objective of the terrorist is as much or more panic than it is physical harm

The Good News

- Nuclear Medicine and Radiation Therapy professionals are well trained in the fundamentals of radiation
- Respect radiation, but do not fear it
- Understand what radiation 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

What Can We Expect?

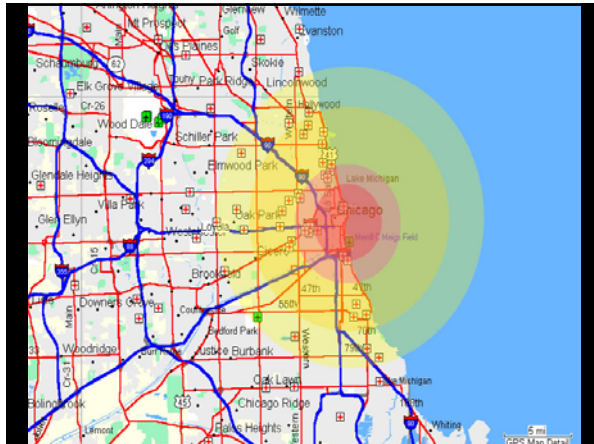
- Radiological/Nuclear Terrorism
 - A true nuclear detonation
 - A failed nuclear detonation
 - Radiation dispersal device
- Power Plant attacks

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

The Unthinkable

- Effects of a 1 megaton detonation in Chicago
 - 30% of all hospitals destroyed in 50 mile radius
 - Transportation and infrastructure compromised
 - Emergency vehicles and professionals unable to respond
 - Walking wounded with burns may have been fatally irradiated – unknown effects for days to weeks



Radiological Devices

- Not a “nuclear explosion”
- Consists of a bomb designed to disperse radioactive materials in air and water
 - Designed to create panic
 - Difficult to clean up, material spreads
 - Biological effects may take years to appear
- “A Dirty War” HBO/BBC Films 2005

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.

What do I Need to Know?

- **Fundamental Radiobiology**
 - Radiation effects are delayed
 - Burns if you see them are chemical or thermal in origin.
 - Dose limits
- **Key personnel**
- **Contamination control**
- **Focus on the medical problems**

1. Radiation - Fundamentals

- **Types of Radiation**
- **All radiation is part of the electromagnetic spectrum**
- **This spectrum ranges from infrared through radio/TV transmission and beyond**
- **Ranges of common exposures**

Radiation - Definition

- Energy that is transferred through space
- Examples
 - Microwaves
 - Radio waves
 - Visible Light
 - Nuclear radiation (Alpha, Beta, Gamma)
 - X-Radiation

Effectiveness of a Lead Apron

Isotope	Percent Stopped
Tc - 99m	78%
Ir - 192	14%
Cs - 137	6%

Don't wear one during an accident!

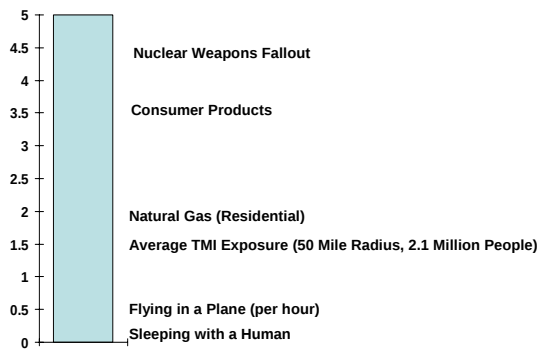
Measurement Units

- Roentgen – radiation dose measured in air
- Radiation Absorbed Dose (RAD) – a pseudo biologic unit
- Gray – 100 RADS
- Radiation Effective Dose Man (REM) – a biologically corrected dose
- Millrem - .001 REM

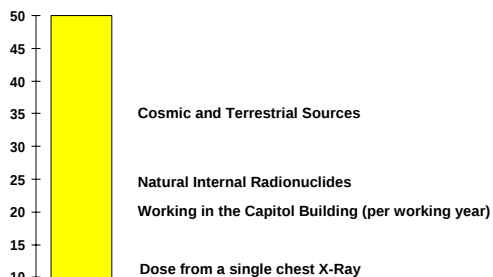
We Live in Radioactive World

- Naturally occurring radioactive elements abound
- Cosmic radiation
- Man-made radiation accounts for less than 1% of total radiation
- Average human dose 150 to 170 mR/year
- Dose varies by geographic location

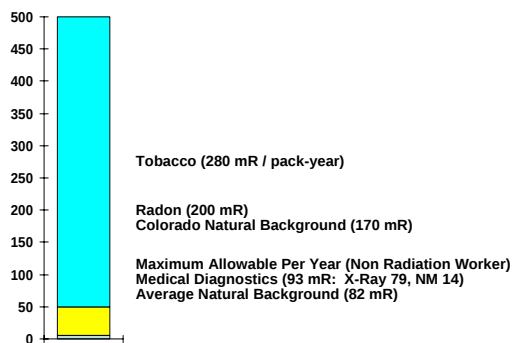
Low Level Radiation 0 - 5 mR



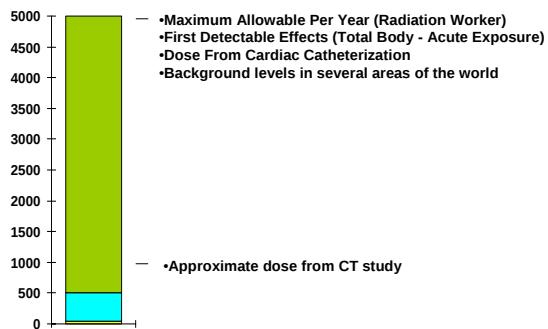
Low Level Radiation 5 - 50 mR



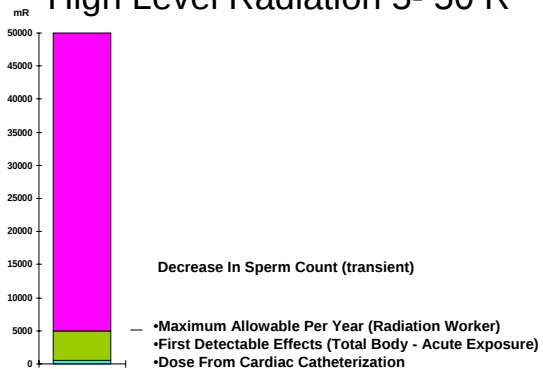
Low Level Radiation 50 - 500 mR

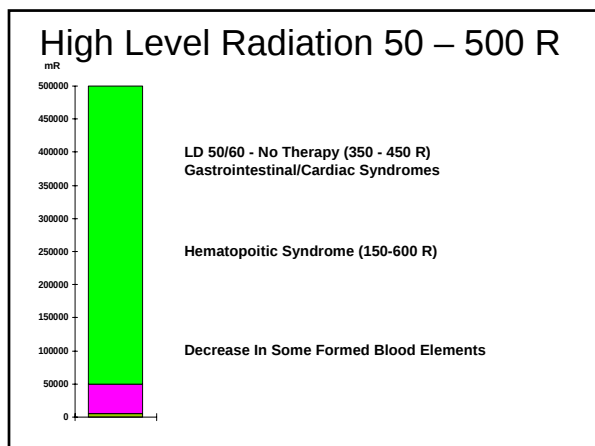


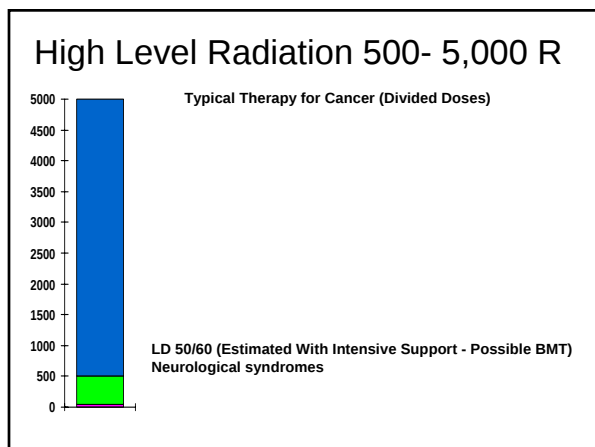
Low Level Radiation 500 - 5,000 mR



High Level Radiation 5- 50 R







Exposure vs Contamination	
Exposure	Contamination
Standing near a septic tank	Falling in a septic tank
X-Ray Procedure	Nuclear medicine procedure
Medical Supply or Food Irradiator	Power plant or research lab

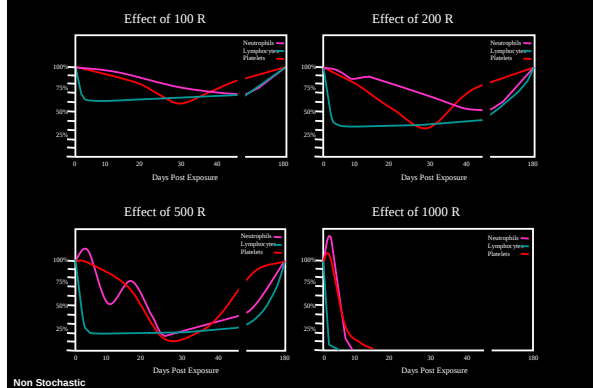
Contamination In Perspective

- 1 mCi = 3,700,000 CPM
- Bone Scan uses 25 mCi
- Typical levels of contamination < 10,000 CPM

Radiation Injuries

- Dependent on dose
 - Non-Stochastic effects (Dose related)
 - Decrease in sperm count – 15 R
 - Hematological effects – 150 R
 - Gastrointestinal effects, epilation – 300 R
 - CNS effects – 1000 R
 - Stochastic Effects (Non-dose related)
 - Increase in cancer risk
 - Genetic abnormalities

Behavior of Blood Elements after Exposure



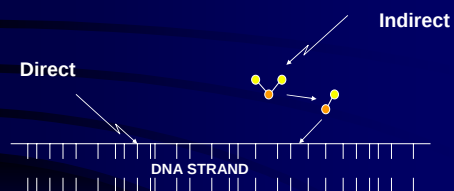
Burns From Radiation

- Generally do not appear immediately
- Healing is extremely poor
- Not likely to be seen in the acute setting

2. Introduction to Radiobiology

- Mechanism of Cellular Injury
- Comparison of Tissue Sensitivities
- Dose Effect Relationships
- Genetic Effects
- Carcinogenic Effects
- Embryonic and Fetal Effects
- How to Limit Exposure

Mechanism of Cellular Injury



Comparison of Tissue Sensitivities

Most Sensitive

Bone Marrow
Skin
GI Tract
.....
.....
Muscle
Nervous Tissue

Least Sensitive

Rapid Cell Turnover

Slow or No Cell Turnover

Biological Effects of Radiation Depend on:

- Total Dose Received
- Rate of Exposure
- Total or Partial Body

Radiation In Perspective Genetic Effects

- The risk of a spontaneous genetic disorder is 10.7%.
- 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!

Source - SNM Review

Stochastic

Radiation In Perspective Carcinogenic Effects

- The lifetime risk of getting cancer is 25%
- The lifetime risk of dying from cancer is 16%
- There are 160,000 deaths per million per year from cancer
- Estimates for carcinogenesis from 1 Rad of acute radiation range from 10 to 500 excess deaths per million.
- The increased risk is between 1 in 2000 and 1 in 100,000!

Stochastic

Source BEIR - 1980

Radiation In Perspective Embryonic and Fetal Effects

- 50% of all human pregnancies do not reach viability.
- Prenatal death from radiation may occur at doses as low as 10 Rads.
- Permanent growth retardation, malformations and behavioral changes have not been observed at doses lower than 25 Rads.

Stochastic

Source - Animal Data

Methods of Decreasing Exposure to Staff

- Time – linear relationship
- Distance – geometric relationship
- Shielding – half value layers

Symptoms and Syndromes Associated with High Level Exposure

- Prodrome - One to two days
- Latent period - Variable, hours to weeks
- Manifest illness - Severity proportional to exposure
- Recovery - Months to years

Non-stochastic

3. Hospital Preparation For Radiation Accident Management

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

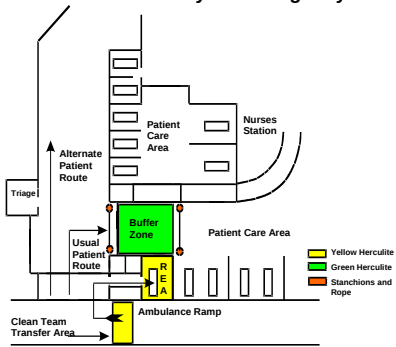
Key Personnel - Immediate

- Emergency Room nurses
- Emergency physician
- Nuclear medicine technologist or radiation technologist
- Security
- Public Relations
- Housekeeping

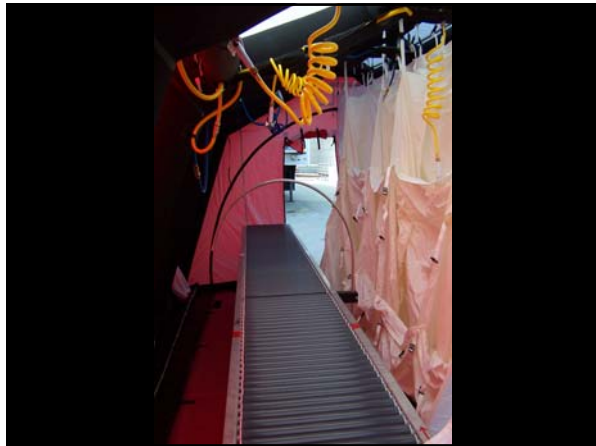
Key Personnel - Long Term

- Surgeon (Trauma and Burns)
- Radiation technologist
- Nuclear physician, radiologist and/or radiation therapist
- Oncologist (If suspecting possible BMT)
- Internist (Other medical conditions)
- Legal counsel

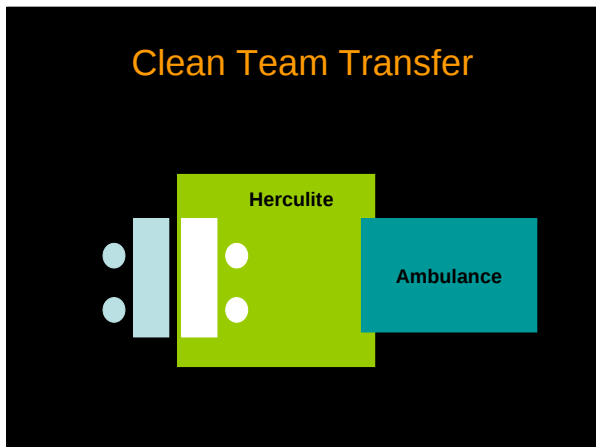
Loyola Emergency Room Layout





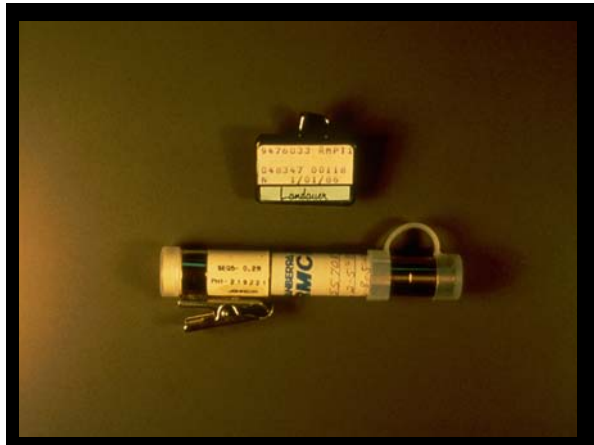


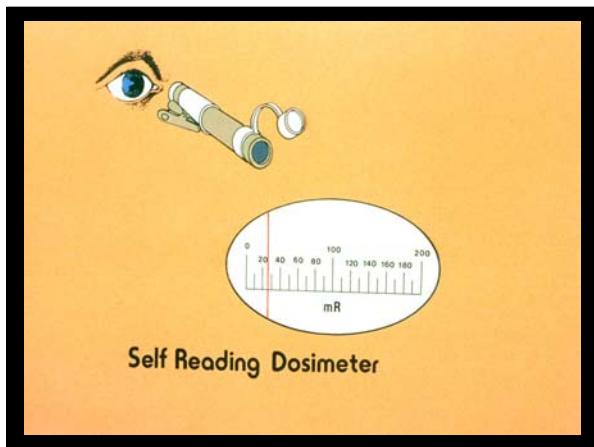




Necessary Equipment

- Masks, Gowns and Gloves
- Dosimetry
- Specimen Kit
- Decontamination Kit
- Herculite
- Decontamination Cart





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 | • Decontamination |
| • Triage | • Final Survey |
| • Remove Clothing | • Patient Exit |
| • Medical Management | • Staff Exit |
| • Radiological Assessment | |
| – Document areas of Contamination | |
| – Obtain Samples | |

4. Management of Exposure and Contamination

- Concepts
 - Exposure vs. Contamination
 - Local vs. Total Body
- Treatment of Exposure
- Contamination: Internal vs. External
- Treatment of Contamination

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.

Treatment of Exposure Total Body

- 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 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

Internal Contamination

- Saturate the organ - Stable iodine competes with radioactive iodine
- Dilute the isotope - Tritium 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.

Case: Evaporator Discharge

History:

An evaporator, designed to decrease the volume of radioactive sludge that accumulates from cleaning contaminated equipment is shut down for maintenance. The worker begins on the evaporator that is still in operation.







Case: Evaporator Discharge

Treatment:

Treated as a burn victim
Fluid replacement (Parkland formula)
Morphine for pain
Foley catheter - to watch urine output
NG tube - for nausea
Chest X-Ray
Clinical Labs

Case: Evaporator Discharge

Samples Obtained:

✓Nasal Smears	✓Skin
✓Oral Swabs	✓Eschar
✓Nostrils	✓Dressings
✓Ears	✓Clothing

Case: Evaporator Discharge

Bioassay Data:

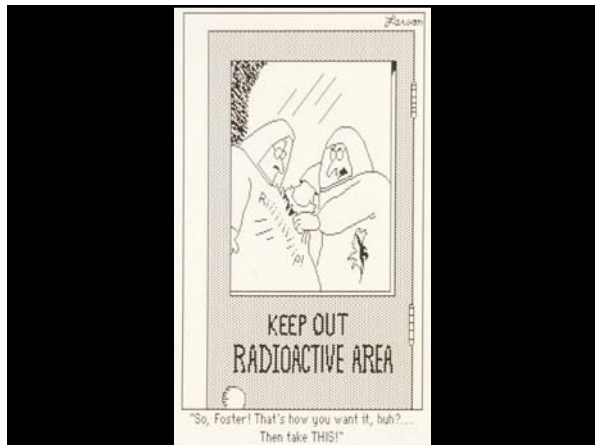
Small quantities of Co-58, Co-60 and Mn-54
Primarily cleared through stool
Traces of Co-58 and Co-60 found in urine

Case: Evaporator Discharge

Sludge Analysis:

228 F Degrees
pH: 11.0

Isotopes: Mn-54
Co-58
Co-60
Cr-51
Fe-59



Case: Contaminated Fall

History:

53 y/o 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

Enroute 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.

Case: Contaminated Fall

Patient Disposition:

Patient died 3 hours later

Autopsy Findings

- 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.

Case: Embedded Contamination

History:

A mechanic, repacking a valve at a power plant slipped and injured his left 4th finger. He had a 1 x 0.5 cm laceration. Bleeding was venous and was easily controlled with pressure.

Survey at the site determined that there was 4000 cpm embedded in the tissue and the material was Co-58 and Co-60.

Case: Embedded Contamination

Decontamination:

The wound was washed with soap and water x 3. No significant decrease in contamination was noted. The patient was then transferred to the nearest hospital for management of the wound.

Case: Embedded Contamination

Hospital Preparation:

The responding hospital prepared to the fullest extent. This included herculite floor coverings, gowning, dosimetry, etc.

Case: Embedded Contamination

Hospital Decontamination:

Decontamination efforts began with betadine and water but had no effect. Other solutions also had no effect.

4000 cpm remained in the distal finger.

Case: Embedded Contamination

Decision Point:

- Can the material be left in or should it be removed?
- M.D. asked health physicist what to do in presence of patient.
- Result: Loss of patient-physician confidence.
- The patient was not consulted.
- The wound was closed and a consult was called.

Case: Embedded Contamination

Radiobiologic Data:

Material was insoluble so it wouldn't migrate.
Lifetime dose calculated to finger would be 254 Rads.
No total body dose.

Follow up:

- Patient followed monthly for one year with total body scans.
- Leaving it present would result in three to four years of extra exposure to finger.

Case: Embedded Contamination

Patient Disposition:

The patient was continually conscious of the presence of contamination. Despite assurances of safety at the levels involved, he decided he wanted it to be surgically removed.

Surgical debridement left a minor deformity of the distal finger.

What's My Role?

- Learn the institutional protocols
- Do not wait for the disaster to train
- Know who and where your resources are
- Do not contribute to panic with uninformed statements
- Refer questions to the scene commanders
