Radiation Poisoning

Radiation Safety

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Outline

Radiation Safety
- **Possible scenarios**
- **Radiation Basics**
- **Decontamination procedures**

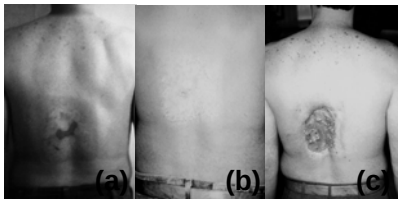
Medical Aspects of Radiation
- **Biologic effects**
- **Radiation sickness**

Possible Radiation Emergency Scenarios

- **Medical**
- **Terrorist use of nuclear materials**
- **Catastrophic event**

Medical Radiation Event

- 40 year old male underwent a coronary angiography, coronary angioplasty and secondary angiography due to complications, followed by a coronary artery by-pass graft.
- All procedures occurred on March 29, 1990



Appearance of skin injury post-procedure:
(a) 6-8 wks
(b) 16-21 wks
(c) 18-21 wks

Shope, T, *Radiographics*, 1996, 16, 1195-1199, 1996

Medical Radiation Event

- Radiation Oncology

Medical Radiation Event

- Acquisition protocols were not set properly resulting in excessive exposures
- Cedar Sinai (L.A.): 200 patients overexposed during 18 month period
- Providence St. Joe (L.A.): 34 patients overexposed during 20 month period
- Glendale Adventist Medical Center (L.A.): 10 patients overexposed during 10 months
- 8x national average for exposure

After Stroke Scans, Patients Face Serious Health Risks, The New York Times, August 1, 2010.

Terrorist Use of Nuclear Material

- Radiological Dispersal Device (i.e. “dirty bomb”)
- Combine radioactive material with explosive device
- Blast effect plus radioactivity

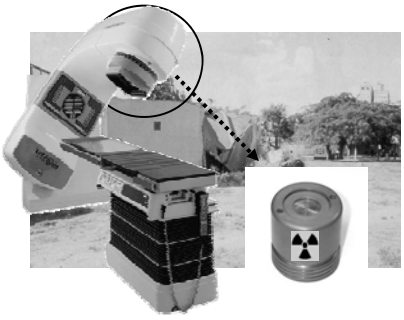
Terrorist Use of Nuclear Material

Improvised Nuclear Device or Nuclear Weapon

- **An actual nuclear detonation**
- **Allegation that 50 to 100 one kiloton suitcase nuclear weapons unaccounted for from former Soviet Union**
- **Various rogue or terrorist supporting states**

Catastrophic Event

- **Goiânia, Brazil**
- **1985: Private radiotherapy clinic closed down**
- **1987: teletherapy head stolen**
- **Unit dismantled, Cs-137 source capsule ruptured causing major contamination**
- **50.9 TBq (1375 Ci) caesium-137 teletherapy machine left in abandoned clinic**



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Catastrophic Event

Reactor Accidents

- **Three Mile Island - 1979**
- **Chernobyl – 1986**
- **Tokaimura, Japan – 1999 (uranium processing facility)**
- **Fukushima, Japan – 2011**

War Veterans

- **Operation UPSHOT-KNOTHOLE**
- **Exposures ranged from 0.4 – 31 mSv (equivalent to 5 – 390 chest x-rays)**

Goiânia, Brazil

- **112 000 people monitored**
- **249 people contaminated**
- **49 people 0.1 - 6.2 Gy**
- **4 people <u>died</u>**
  - **6 y old girl**
  - **18 y old man**
  - **22 y old man**
  - **38 y old mother**

Catastrophic Event

- Gilan, Iran
- 1996: Ir-192 source used for industrial radiography falls out of shielded container
- Manual worker picks up source and puts it in chest pocket

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Radiological Accident Statistics (1944-2000)

~ 400 reported accidents

~ 3000 exposed persons

> 100 deaths, more than half involving patients

In addition, orphan sources can be mixed up with scrap causing contamination problems

Illicit trafficking involves orphan sources but very few orphan source incidents are due to illicit trafficking events

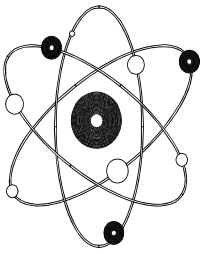
Gilan, Iran

- Resulting in severe radiation burns to the chest

The Basics of Radiation

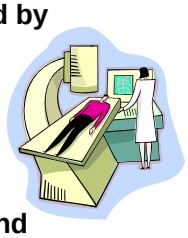
Ionizing radiation is electromagnetic energy or energetic particle emitted from a source.

Ionizing radiation is able to strip electrons from atoms causing chemical changes in molecules.

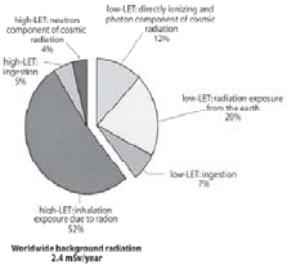


Ionizing Radiation

- Ionizing radiation is emitted by
  - -Radioactive material
  - -Machine generated (x-rays, LINACS)
- Biological effects from ionizing radiation are dependant on the energy and type of radiation



Natural Background

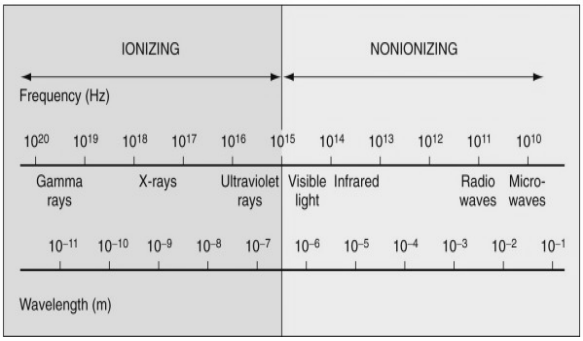


Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2, 2006

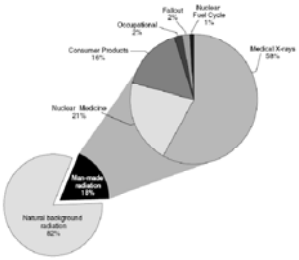
Primarily radon and gamma rays from the atmosphere

- Ground
  - ^{222}Rn
- Building Materials
- Air
- Food
  - ^{238}U and ^{232}Th from drinking water
- Universe
  - Gamma rays generated in supernova
- Elements within our own body
  - ^{14}C

Electromagnetic Radiation



Manmade Sources



Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2, 2006

Used in medicine, research, and industry

- X-ray equipment
- Radioactive materials

Assumes everyone receives two diagnostic x-ray exams per year

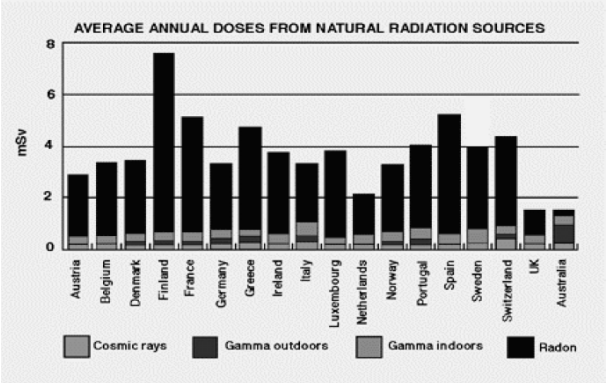
Key Point:

Every individual receives low levels of radiation every day of their life

Key Point:

Not all radiation is equal

Background Radiation Around the World



Particulate Ionizing Radiation

- **Alpha particles: two protons and two neutrons**
- **Beta particles: release gamma**
- **Neutrons: causes other substances to become radioactive**

Gamma or X-Ray (Photons)

- High energy rays
- Very penetrating
- Difficult to shield
- Can be produced from radioactive decay and a nuclear weapon explosion or reactor accident
- PPE will not protect against photon radiation

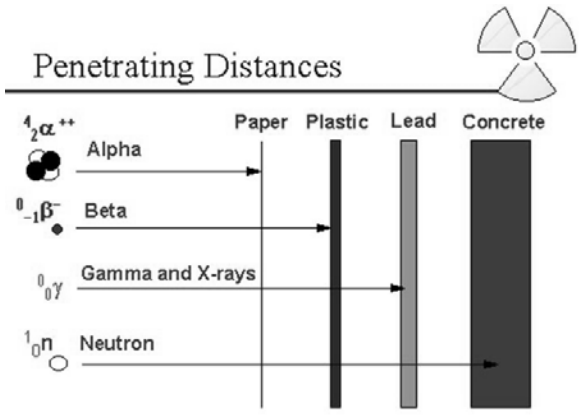
Radiosensitivity

Physical Factors

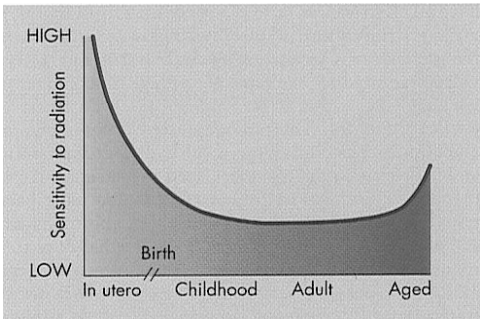
- Linear Energy Transfer (LET)
  - Measure of the rate at which energy is transferred from ionizing radiation to soft tissue.
- Relative Biologic Effect (RBE)
  - Ability to produce biologic damage
- Fractionation

Biologic Factors

- Oxygen Effect
  - Tissue is more sensitive in the presence of oxygen
- Recovery
- Age



Radiation Sensitivity and Age



Law of Bergonie and Tribondeau

- Stem cells are radiosensitive. The more mature a cell, the more resistant to radiation it is.
- The younger the tissue and organs, the more radiosensitive they are.
- When the level or metabolic activity is high, radiosensitivity is also high.
- As the proliferation rate for cells and the growth rate for tissue increase, the radiosensitivity also increases.

Radiation Doses and Dose Limits

Flight from Los Angeles to London	5 mrem
Annual public dose limit	100 mrem
Annual natural background	300 mrem
Fetal dose limit	500 mrem
Barium enema	870 mrem
Annual radiation worker dose limit	5,000 mrem

Measures of Radiation Exposure

- Rad = Radiation Absorbed Dose: measures amount of energy actually absorbed by a material (i.e. tissue)
- Rem = Roentgen Equivalent Man: measures biologic damage of radiation; takes into account dose and type of radiation involved
- In most situations, 1 Rem = 1 Rad
- 1 Gray (Gy) = 100 Rads
- 1 cGy = 1 Rad
- 1 Sievert = 100 Rems
- 1 millisievert = 0.1 Rem

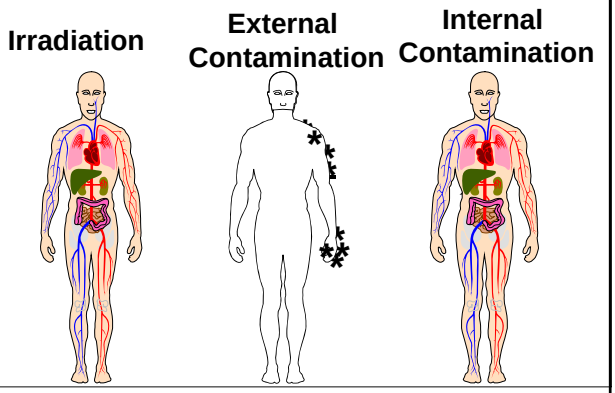
Radiation Doses and Dose Limits

Heart catheterization	45,000 mrem
Life saving actions guidance (NCRP-116)	50,000 mrem
Mild acute radiation syndrome	100,000 mrem
$LD_{50/60}$ for humans (bone marrow dose)	350,000 mrem
Radiation therapy (localized & fractionated)	6,000,000 mrem

Radioactive Material

- ***Radioactive material*** **consists of atoms with unstable nuclei**
- **The atoms spontaneously change (decay) to more stable forms and emit radiation**
- **A person who is *contaminated* has radioactive material on their skin or inside their body (e.g., inhalation, ingestion, shrapnel, or wound contamination)**
- **A person *exposed* to radiation may, or may not, be contaminated.**
- **Not all radioactive materials are equal**

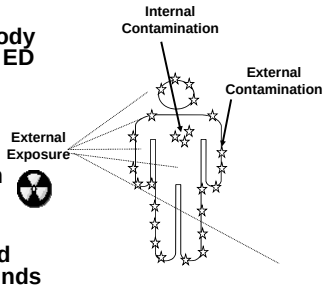
Radiation Exposure Types



Types of Radiation Hazards

- ***External Exposure*** **-**

  whole-body or partial-body (no radiation hazard to ED staff)
- ***Contaminated*** **-**
  - **external radioactive material: on the skin**
  - **internal radioactive material: inhaled, swallowed, absorbed through skin or wounds**



Examples of Radioactive Materials

Radionuclide	Physical Half-Life	Activity	Use
Cesium-137	30 yrs	1.5×10^6 Ci	Industrial radiography
Cobalt-60	5 yrs	15,000 Ci	Cancer Therapy
Plutonium-239	24,000 yrs	600 Ci	Nuclear Weapon
Iridium-192	74 days	100 Ci	Industrial Radiography
Hydrogen-3	12 yrs	12 Ci	Exit Signs
Strontium-90	29 yrs	0.1 Ci	Eye Therapy Device
Iodine-131	8 days	0.015 Ci	Nuclear Medicine Therapy
Technetium-99m	6 hrs	0.025 Ci	Diagnostic Imaging
Americium-241	432 yrs	0.000005 Ci	Industrial radiography
Radon-222	4 days	1 pCi/l	Environmental Level

Medical Aspects of Radiation

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ARS - Phases

1. Prodromal Phase - occurs in the first 48 to 72 fours post-exposure and is characterized by nausea, vomiting, malaise and anorexia. At doses below about 500 rads last 2 to 4 days. The earlier the symptoms, the worse the exposure

2. Latent Phase - follows the prodromal phase and lasts for approximately 2 to 2 1/2 weeks. During this time, critical cell populations (leukocytes, platelets) are decreasing as a result of bone marrow insult. The time interval decreases as the dose increases.

Acute Radiation Syndrome (ARS)

- **Group of symptoms that develop after total body irradiation (> 100 rads)**
- **May occur from either internal or external radiation**
- **Four important factors are:**
  - **High Dose**
  - **High Dose Rate**
  - **Whole Body Exposure**
  - **Penetrating Radiation**

ARS - Phases

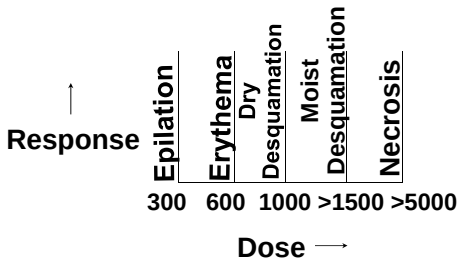
3. Illness Phase - period when overt illness develops

4. Recovery or Death Phase - may take weeks or months

Prodromal Phase and Prognosis

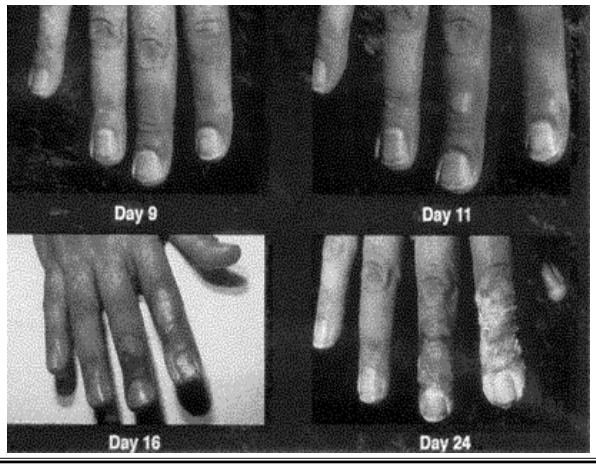
- If time to emesis is <4 hours: exposure at least 3.5 Gy
- If time to emesis is < 1 hour: exposure at least 6.5 Gy

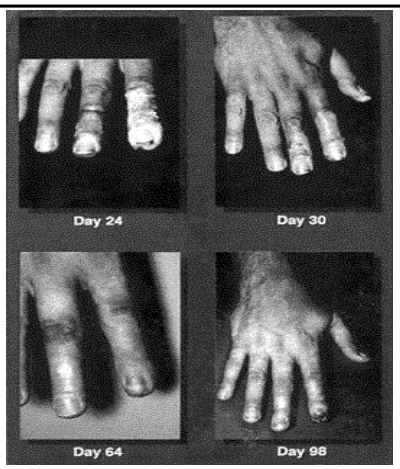
ARS - Skin



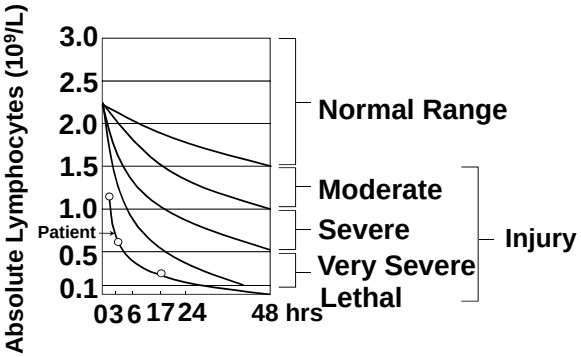
Acute Radiation Sickness

- Skin/hair
- Gastrointestinal tract
- Hematopoietic system
- Central nervous system



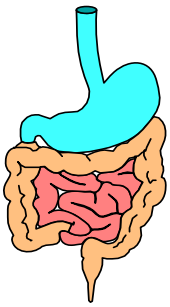

Day 24
Day 30
Day 64
Day 98

ARS - Hematopoietic Syndrome



ARS - Gastrointestinal Syndrome

- Radiation > 600 rads
- Damages intestinal lining
- Nausea and vomiting within the first 2 - 4 hours
- May develop diarrhea
- Associated with sepsis and opportunistic infections
- At 10 days could develop bloody diarrhea resulting in death

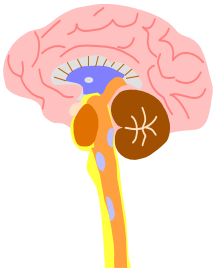


ARS Blood Counts

- 48 hour absolute lymphocyte count > 1200: good prognosis; 300 - 1200: significant radiation exposure; <300: probably lethal
- Absolute granulocyte counts: should be followed with higher-level exposures; nadir occurs at 8 to 30 days post-exposure
- Other parameters: platelet counts, reticulocyte counts, numbers of dicentric chromosomes in blood and bone marrow

ARS - Central Nervous System

- Seen with radiation dose > 1,000 rads
- Microvascular leaks Õ edema
- Elevated intracranial pressure
- Death within hours



Evaluation & Treatment - Hospital Care

- Activate hospital plan
- Establish triage area (separate entrance)
- Plan to control contamination (don't count on patients already being decontaminated)
  - Prepare area by cover/marking floor, control ventilation
  - Prepare staff by issuing protective clothing
  - Prepare for surveying; call radiation safety officer
  - Establish area for storage of waste
  - Plan for decontamination of non-traumatized patients

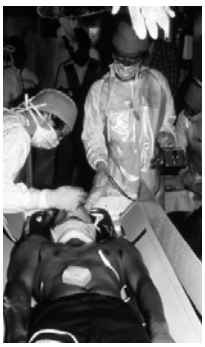
Prehospital Care

- Information is critical: type of exposure, internal vs. external vs. whole vs. partial body, radioactive materials involved
- Decontamination if time permits
  - remove and bag clothing
  - soap and water cleansing of exposed skin
  - retain wash water
- Emphasis on treating life-threatening injuries

Patient Management: Triage

Triage based on:

- Injuries
- Signs and symptoms - nausea, vomiting, fatigue, diarrhea
- History - Where were you when the bomb exploded/ how close?
- Contamination survey with G-M meter



Patient Management: Priorities

Triage

- **Medical treatment is the highest priority**
- **Radiation exposure and contamination are secondary considerations**
- **Degree of decontamination dictated by number of, and capacity to treat, other injured patients**

Staff Protection Levels of PPE

- **Level A – IDLH environments, fully encapsulated, requires SCBA**
- **Level B – Chemicals or substances with inhalation hazard, requires SCBA or SAR**
- **Level C – Known contaminants, requires air-purifying respirator**

Protecting Staff from Contamination

- **Use universal precautions**
- **Survey hands and clothing with radiation meter**
- **Replace gloves or clothing that is contaminated**
- **Keep the work area free of contamination**

Key Points

- **Most contamination is easy to detect and most of it can be removed**
- **It is very <u>unlikely</u> that ED staff will receive large radiation doses from treating contaminated patients**

Decon Agents - 1

- **Dry Removal**
- **Soap / Shampoo**
- **Household Bleach 1:10 (Sodium Hypochlorite)**
- **Waterless Cleansers**

Decon Agents - 2

- Povidone-Iodine
- Lava Soap
- Cornmeal / Tide 50:50
- Vinegar (^{32}P) or Club Soda
- Toothpaste

Patient Management: Decontamination

- Carefully remove and bag patient's clothing and personal belongings (typically removes 75-95% of contamination). This may have been done at the scene.

- Survey patient and, if practical, collect samples (skin/wound swabs)

Decontamination

- Irrigate open wounds and cover with sterile dressing
- Soap and water showering (including hair)
- Effective for mixed radiation/chemical contamination
- Refer for any surgery

Patient Management: Decontamination

- Handle foreign objects with care until determined non-radioactive with survey meter
- Decontamination priorities:
  - Decontaminate wounds first, then intact skin
  - Start with highest levels of contamination

- Change outer gloves frequently to minimize spread of contamination

Patient Management: Decontamination (cont.)

- Cease decontamination of skin and wounds
  - When the area is less than twice background, or
  - When there is no significant reduction between decon efforts, and
  - Before intact skin becomes abraded.

Special Considerations

- High radiation dose and trauma interact synergistically to increase mortality
- Close wounds on patients with doses > 100 rem
- Wound, burn care and surgery should be done in the first 48 hours, or delayed for 2 to 3 months (> 100 rem)

Emergency Surgery	Hematopoietic Recovery No Surgery	Surgery Permitted
24 - 48 Hours	~3 Months	After adequate hematopoietic recovery

Patient Management: Decontamination (cont.)

- Contaminated thermal burns
  - Gently rinse. Washing may increase severity of injury.
  - Additional contamination will be removed when dressings are changed.
- Do not delay surgery or other necessary medical procedures or exams…residual contamination can be controlled

Patient Management: Psychological Casualties

- Terrorist acts involving toxic agents (especially radiation) are perceived as very threatening
- Mass casualty incidents caused by nuclear terrorism will create large numbers of worried people who may not be injured or contaminated
- Provide psychological support to patients and set up a center in the hospital for staff

Patient Management: Psychological Casualties

- Establish triage (monitoring and counseling) centers to prevent psychological casualties from overwhelming health care facilities
- Staff counseling centers with physicians with a radiological background, health physicists with instrumentation and psychological counselors

Potassium Iodide

- Blocks thyroid uptake of Iodine-131 (a beta emitter)
- Treat within 4 Hours (no utility >12 hours)
- Has no protective effect on anything else
- Soviets administered KI 72 hours after Chernobyl, and had thousands of cancers
- KI or NaI, 300 mg tablet
- SSKI (1 g / ml), 5 - 6 drops in water

NCRP Report No 65, p 83-86, 104

Patient Management : Treatment of Internal Contamination

- Radionuclide-specific, and time sensitive
- Most effective when administered early
- May need to act on preliminary information
- NCRP Report No. 65, Management of Persons Accidentally Contaminated with Radionuclides

Radionuclide	Treatment	Route
Cesium-137	Prussian blue	Oral
Iodine-125/131	Potassium iodide	Oral
Strontium-90	Aluminum phosphate	Oral
Americium-241/ Plutonium-239/ Cobalt-60	Ca- and Zn-DTPA	IV infusion

Radiostrontium Contamination Therapy

- Al Phosphate (100 ml) reduces absorption as much as 85%
- Ba Sulfate is also effective
- Na Alginate inhibits uptake by 80–90% (10g po)

Prussion Blue

- Blocks intestinal absorption of Cs-137

DPTA chelation

- Plutonium
- Americium
- curium

Penicillamine

- Radioactive heavy metal poisoning (lead)

Other adjuncts

- Filgrastim and sargramostim to treat neutropenia

Localized Radiation Effects – Organ System Threshold Effects

- **Skin - No visible injuries < 100 rem**
  - Prompt - erythema, epilation >500 rem
  - Moist desquamation >1,800 rem
  - Ulceration/Necrosis >2,400 rem
- **Cataracts**
  - Acute exposure >200 rem
  - Chronic exposure >600 rem
- **Permanent Sterility**
  - Female >250 rem
  - Male >350 rem

Fetal Irradiation

No significant risk of adverse health effects below 10 rem

Weeks After Fertilization	Period of Development	Effects
<2	Pre-implantation	• Little chance of malformation • Most probable effect, if any, is death of embryo
2-7	Organogenesis	• Reduced lethal effects • Teratogenic effects • Growth retardation
7-40	Fetal	• Impaired mental ability • Growth retardation with higher doses
All		• Increased risk of childhood cancer

Chronic Health Effects From Radiation

- **At low doses, radiation is a weak carcinogen**
- **Risk of fatal cancer due to radiation exposure is estimated as ~ 4% per 100 rem**
- **A dose of 5 rem increases the risk of fatal cancer by ~ 0.2%**
- **A dose of 25 rem increases the risk of fatal cancer by ~ 1%**

Key Points

- **Early symptoms are an indication of the severity of the radiation dose**
- **Pre-planning to ensure adequate supplies of PPE and survey instruments**
- **Rescue and treatment protocols vary little for radiation contamination**
- **Treatment of medical/surgical emergencies takes priority**
- **Donning PPE and decontaminating patients minimizes exposure risk**
- **Treatment requires a unified effort**