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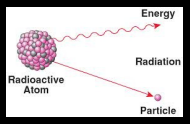
MEDICAL ASPECTS OF RADIATION INJURIES



Radiation Basics

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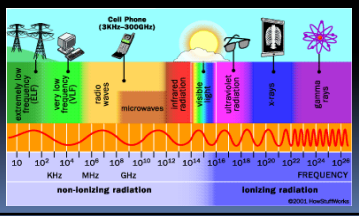
What is Radiation?

- Form of energy
- Emitted by nucleus of atom or orbital electron
- Released in form of electromagnetic waves or particles



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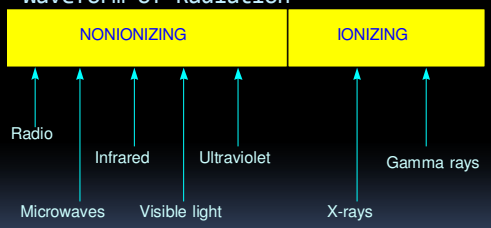
The Electromagnetic Spectrum

Waveform of Radiation



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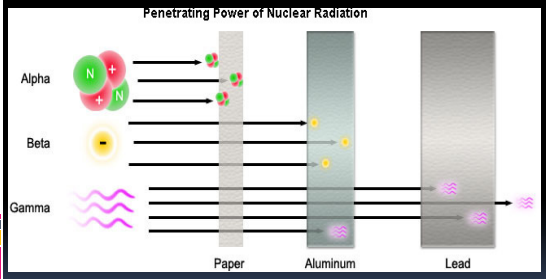
Types of Radiation



Source: FEMA IS-3

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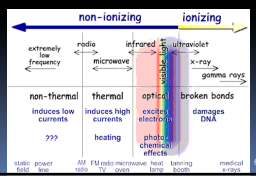
Difference between ionizing and nonionizing radiation

- Energy levels:
  - Ionizing radiation has enough energy to break apart (ionize) material with which it comes in contact (knock off e-)
  - Non ionizing radiation does not



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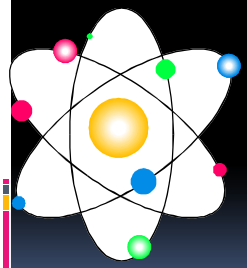
Types of Ionizing Radiation



- Important in healthcare:
- Diagnosing - X-Rays, PET Scans, Nuclear Medicine
- Therapy - Radiation Treatment, Nuclear Medicine

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Sources of Radiation Exposure

- Naturally occurring sources – ground, atm
- Environmental radiation – power plants
- Medical procedures (patient) – x-ray, chemo
- Occupational sources (worker) - airports

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X-Ray

- Penetrating electromagnetic waves – can cause internal damage
- Can pass through soft tissue, but not bone
- Originate in outer part of atom
- Used in medical procedures (diagnostic, CT, fluro)
- Energy inversely proportional to wavelength
  - The shorter the wave, the stronger the energy

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Exposures to Radiation

- Tanning beds/sun tanning
- X-ray
- Mammogram
- CT scan
- Nuclear medicine
- Dental X-ray
- Bone scan
- Angioplasty

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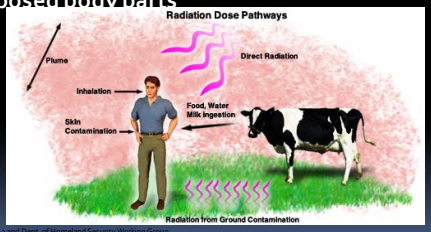
Radioactive Contamination

- **Internal contamination requires medical decorporation**
- **90% of external contamination can be cleansed by removing clothing and washing exposed body parts**



Source: FEMA IS-3 and Dept. of Homeland Security Working Group on Radiological Dispersal Device (RDD) Preparedness

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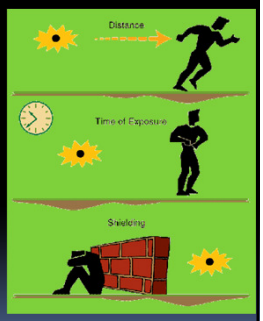
Reducing Radiation Exposure

3 steps for protection:

1) Keep your DISTANCE
2) Limit your TIME exposed
3) SHIELD yourself from exposure



Source: REMM http://www.remm.nlm.gov/

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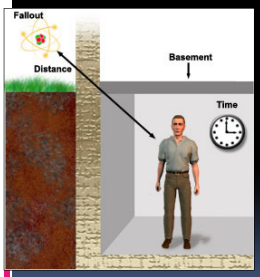
Protection from Radiation



Source: FEMA IS-3 (left) & Detroit News (right)

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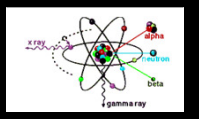
RADIATION INJURIES

- Ionizing radiation: Radiation that occurs when atoms have 1 or more electrons ejected owing to interactions with x- or gamma rays or with alpha or beta particles or neutrons.
- Penetrating radiation: x-, gamma rays, neutrons
- Non-penetrating radiation: alpha, beta

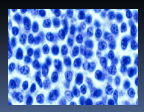


RADIATION INJURIES

- Humans affected externally and/or internally by radiation.
- 1 Roentgen = 1 rad = 1 rem =10 mGy = 10 mSv.

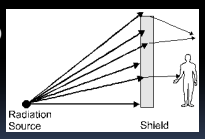
RADIATION INJURIES

- Radiobiological principles
  - Radiation targets water molecules in cells H_2O ionized → Resulting free radicals are highly reactive and rapidly interact with other cellular molecules (DNA, mRNA, proteins).



RADIATION INJURIES

- Radiobiological principles
  - Severity of biological effects due to:
    - Dose
    - Dose rate
    - Shielding
    - Energy (degree affects penetration)

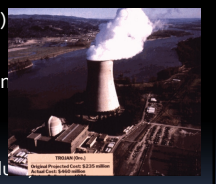


RADIATION INJURIES

- Radiation pathophysiology
  - Radiosensitivity varies directly with rate of cell proliferation (RBCs, G.I. Mucosa cells).
  - Radiosenstivity varies directly with number of future divisions (stem cells).
  - Radiosensitivity varies inversely with degree of morphologic and functional differentiation (exception: lymphocyte).

RADIATION INJURIES

- Types of radiation releases
  - Radiation dispersal device (RDD)
  - Nuclear reactor accident
  - Industrial/medical source accider
  - Nuclear weapon detonation
    - Thermal, blast, radiation trauma
    - Fallout (radioactive particles of du



RADIATION INJURIES

Gy	*Signs & Symptoms*
0.05-0.25	Asymptomatic.
0.50-0.75	Asymptomatic; few with decreased WBC, platelets.
0.75-1.25 some	Within 2 days, 10-20% with nausea, vomiting, fatigue; with mild WBC/platelet depression
1.25-2.0 lymphocytes	Symptomatic; most with hematologic changes; drop 50% within 48 hrs.
2.5-3.5 75%	Serious; 50% mortality if untreated; lymphocytes drop within 48 hrs.
5+	GI subsyndrome within 2 weeks; death occurs in most
50+	CV, GI, CNS subsyndromes with death within 24-72 hrs.

Biological Effects of Radiation

- **Somatic**
  - Affects cells originally exposed (cancer)
  - Affects blood, tissues, organs, possibly entire body
  - Effects range from slight skin reddening to death (acute radiation poisoning)
- **Genetic**
  - Affects cells of future generations
  - Keep levels as low as possible (wear lead)
  - Reproductive cells most sensitive

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Units of Measurement

- Effect of ionizing radiation is determined by:
  - Energy of radiation
  - Material irradiated
  - Length of exposure
  - Type of effect
  - Delay before effect seen
  - Ability of body to repair itself

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Radiation Units of Measurement

Roentgen (R) - expression of exposure to x-rays/gamma rays

Radiation Adsorbed Dose (rad) – amt of energy released to / absorbed by matter when radiation comes into contact with it

Radiation Equivalent Man (rem) - Injury from radiation (depends on amt of energy imparted to matter)

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Permissible exposure radiation doses

Body Part Exposed	Permissible Dose (rem per quarter)
Whole body	1.25
Hands, forearms, feet, ankles	18.75

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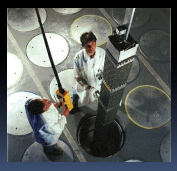
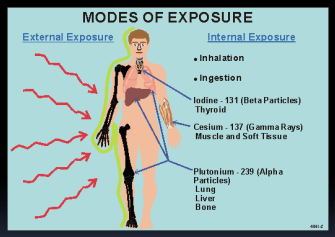
RADIATION INJURIES

- 3 Types of radiation exposure
  - Irradiation
  - Internal contamination
  - External contamination





Acute Radiation Syndrome

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Toxicity is Proportional to Dose

- **LD_{50} for humans (level of exposure that is lethal to 50% of people exposed to that dose):**
  - 3.5 to 4 Gy
    - Without supportive care
  - 4.5 to 7 Gy
    - With antibiotics, transfusions and other supportive care
  - >7-10 Gy
    - Possibly with hematopoietic cell transplantation
- **In a radiation incident, shielding may result in heterogenous body dosing**
  - A small portion of bone marrow that is shielded could reconstitute hematopoiesis

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RADIATION INJURIES

- Acute Radiation Syndrome (ARS)
  - Responsible for most deaths during first 60 days post-exposure.
  - Course affected by age, pre-existing health and nutritional status, concomitant illness/injury.
  - Composed of 3-4 subsyndromes which are sequential.

Acute Radiation Syndrome

- **There are 4 primary subsyndromes**
  - Cutaneous
  - Hematologic
  - Neurovascular
  - Gastrointestinal
- **Psychological consequences should be anticipated and addressed**

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RADIATION INJURIES

- Acute Radiation Syndrome (ARS)
  - Subsyndromes
    - Hematopoietic (1-5 Gy)
    - Gastrointestinal (6-30 Gy)
    - Cardiovascular (>30 Gy)
    - Neurologic (>30 Gy)

Acute Radiation Syndromes Dependent on Whole Body Radiation

- Hematopoietic system syndrome
  - 3 Gy - - - > 2 week latency - - - > systems fails - - - -> death at about 3 weeks post radiation
- Gastrointestinal system syndrome
  - 10 Gy - - - > 3 days latency - - -> system sloughs - - - > death in 2 weeks post radiation
- Cerebral system syndrome
  - 20 G - - -> 1 hour latency - - - -> death in 1 day

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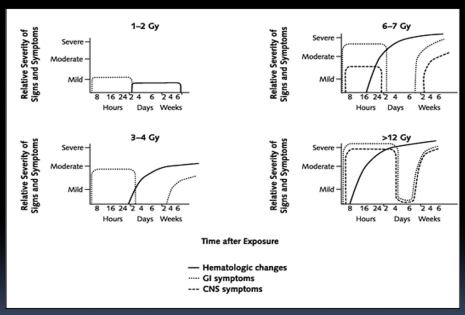
Acute Radiation Syndrome



Source: Waselenko, J. K. et. al. Ann Intern Med 2004;140:1037

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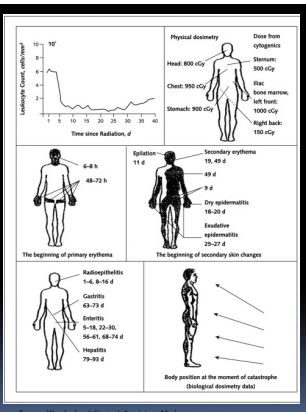

Source: Waselenko, J. K. et. al. Ann Intern Med 2004;140:1037

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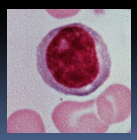
RADIATION INJURIES

- Acute Radiation Syndrome (ARS)
  - Hematopoietic
    - All blood stem cells undergo radiation-induced cell death (lymphocytes, granulocytes, thrombocytes, & RBC precursors)
    - Pancytopenia
    - Sepsis usual cause of death
    - Hemorrhage
    - Recovery: Months-years



RADIATION INJURIES

- Acute Radiation Syndrome (ARS)
  - Gastrointestinal
    - Targets: G.I. stem cells, lymphocytes in Peyer's patches
    - Mucosal lining sloughs, mucosal integrity damaged, mucosal hemorrhage, exudation, ulceration, third spacing, fluid/electrolyte imbalance, paralytic ileus, impaired nutritional absorption, bacterial translocation (sepsis)

Acute Radiation Syndrome-Gastrointestinal

Symptoms	Range of severity
Diarrhea - frequency	Twice/day >10 times/day
Stool - consistency	Bulky to watery
Blood in stools	Occult to gross hemorrhage
Abdominal pain/cramps	Minimal to excruciating
Nausea	Mild to excruciating
Vomiting	1 per day to >10 times per day

RADIATION INJURIES

- Acute Radiation Syndrome (ARS)
  - Cardiovascular/Neurologic
    - Mixed
    - Burning of skin within minutes
    - Pyrexia, ataxia, decreased higher cortical and motor function, hypotension, increased intracranial pressures within minutes to hours of exposure
    - Necropsy: Microvascular & endothelial damage, focal brain hemorrhage & necrosis, white matter edema, demyelination

Acute Radiation Syndrome-Neurovascular

Symptoms	Range of severity
Nausea	Mild to excruciating
Vomiting	1 per day to >10 times per day
Anorexia	Able to drink to requiring parenteral nutrition
Autonomic dysfunction	Low-grade fever to hypotension
Headache	Minimal to intense
Neurological deficits	No deficits to unarousable

Acute Radiation Syndrome-Cutaneous

Symptoms	Range of severity
Erythema	Minimal to severe
Altered sensation	Pruritis to severe pain
Edema	Asymptomatic to total dysfunction
Blistering	Rare to bullae with hemorrhage
Desquamation	Absent to confluent
Ulcer/necrosis	Epidermal only to muscle/bone
Hair loss	Thinning to complete
Onycholysis	Absent to complete

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Cutaneous Injuries from Open Sources

Source: IAEA

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RADIATION INJURIES

- Acute Radiation Syndrome
  - Four stages
  - 1: Prodrome
    - Initial symptoms: Important to observe, time, and document
    - Time of onset is inversely related to dose received
    - Anorexia, weakness, fatigability: Typical/nonspecific
    - CV/CNS S&S: Ominous
    - Nausea, vomiting, diarrhea (possible bloody): Important to note
      - Mild; >2 hr. & < 24 hr. = <2 Gy

RADIATION INJURIES

- Acute Radiation Syndrome
  - Four stages
  - 2: Latent period
    - Inversely related to dose
    - At lower doses: Essentially symptom free; mild fatigue; prone to infection and delayed wound healing.

RADIATION INJURIES

- *Prodromal/Latency Periods as a Function of Dose*

Dose Gy	Onset h	Duration h	Latency
0.5-2.0	6 or >	<24	3 wks or >
2.0-3.5	2-6	12-24	2-3 wks
3.5-5.5	1-2	24	1-2.5 wks
>5.5	< 1	48	2-4 days

RADIATION INJURIES

- Acute Radiation Syndrome
  - Four Stages
  - 3: Manifest Illness
    - Prodromal symptoms recur
    - Subsyndrome specific effects develop
    - Can last for several weeks
    - Requires intensive monitoring and care

RADIATION INJURIES

- Acute Radiation Syndrome
  - Four Stages
  - 4: Recovery
    - GI epithelium replaced
    - Hematopoietic elements return to normal
    - May take years to recover

RADIATION INJURIES

- Miscellaneous conditions
  - Skin
    - Initial transient erythema for few days
    - Secondary erythema progressing to blisters to ulcers
      - within 1 month
      - The greater the exposure the earlier the manifestations

RADIATION INJURIES

- Miscellaneous conditions
  - Pulmonary
    - Chernobyl
    - Acute radiation pulmonitis
    - Severe SOB + significant crepitus
    - Significant mortality from hypoxic coma within 2-4 wks later

RADIATION INJURIES

- Lymphocyte counts in Humans 24-48 Hours After Radiation Exposure

Lymphocyte Count (x1000/mm3)	*Dose Range (Gy)*
3.0	<0.25
1.2-2.0	1-2
0.4-1.2	2.0-3.5
0.1-0.4	3.5-5.5
<0.1	>5.5

RADIATION INJURIES

- Mass Casualty Incidents
  - Standard MCI + Radiation Injuries: Standard Triage. ARS victims only tagged "DELAYED"
  - Radiation MCI only
    - 3 triage categories:
      - Radiation injury unlikely
      - Radiation injury probable
      - Radiation injury severe

RADIATION INJURIES

- **Radiation MCI categories:**
- Radiation injury unlikely
  - Absence of nausea, vomiting, diarrhea
- Radiation injury probable
  - Presence of symptoms, timing, severity, duration
- Radiation injury severe
  - Presence of hyperthermia, hypotension, prompt erythema, CNS dysfunction

RADIATION INJURIES CHERNOBYL TRIAGE

- ***FIRST DEGREE***
  - PRODROME: >3H
  - LYMPHS (3-6D): 600-1000
  - SKIN BURNS: SLIGHT
  - TBI DOSE: 1-2 Gy
  - SURVIVAL PROBABLE
- ***SECOND DEGREE***
  - PRODROME: 1-3H
  - LYMPHS (3-6D):300-500
  - SKIN BURNS: SLIGHT
  - TBI DOSE: 2-4 Gy
  - SURVIVAL: POSSIBLE
- ***THIRD DEGREE***
  - PRODROME: 1/2-1H
  - LYMPHS (3-6D):100-200
  - SKIN BURNS: SEVERE
  - ENTERITIS: ------
  - TBI DOSE: 4.2-6.3Gy
  - SURVIVAL: PROBABLE WITH THERAPY
- ***FOURTH DEGREE***
  - PRODROME: <1/2H
  - LYMPHS (3-6D):<100
  - SKIN BURNS: 40-90%
  - ENTERITIS: 7-9D
  - TBI DOSE: >6-12 Gy
  - SURVIVAL: UNLIKELY

RADIATION INJURIES

- Contamination issues
  - Decontamination performed
    - To reduce risk of contaminating personnel and environment
    - To reduce risk of internal contamination of victim

RADIATION INJURIES

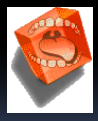
- Contamination issues
  - No medical personnel have ever received an exposure anywhere near the degree to cause radiation effects.

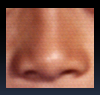
RADIATION INJURIES

- Contamination issues
  - 95% of decon occurs with:
    - Removal of patient's clothing
    - Soap & water

RADIATION INJURIES

- Contamination issues
  - Portals of entry for internal contamination
    - Wounds
    - Inhalation
    - Ingestion



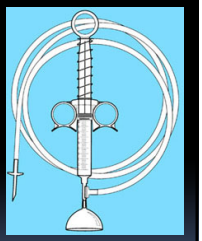


RADIATION INJURIES

- Decon procedures
  - Environmental/personal protection
  - Attend to medical problems first
  - Remove victim's clothes
  - Shower, soap/water
  - Tape and lift contaminant material
  - Water/bleach or citric acid or EDTA
  - Water/mild abrasive
  - Wrap/cover areas not deconned adequately and allow sweat/skin sloughing to decon

RADIATION INJURIES

- Decon procedures
  - Monitor effectiveness after every decon procedure
  - Contaminated wounds to be irrigated
  - Surgical debridement of wounds possible



RADIATION INJURIES

- Decon procedures for environs/personnel
  - Gowns, cap, gloves, mask, shoecovers
  - Decrease air flow
  - Cover floor, walls (plastic, brown paper rolls)
  - Contaminated clothes in plastic/paper bags
  - Avoid splashing
  - Monitor before moving out of area
  - Personal dosimeters
  - Drums to contain effluent
  - Restrict entry

RADIATION INJURIES

- Contamination issues
  - 4 means of reducing risk of internal contamination:
    - Reduce intake from inhalation, ingestion, or absorption from wounds
    - Decrease uptake through use of stomach/lung lavage, emetics, antacids
    - Reduce deposition of isotopes in an organ (KI)
    - Increase rate of elimination through chelating agents, diuresis, laxatives

RADIATION INJURIES

- Contamination monitors
  - Direct
    - Whole-body radiation counters, thyroid scanners, wound-monitoring instruments
  - Indirect
    - Bioassay sampling: Nasal swabs, urine/feces samples

RADIATION INJURIES

- DMAT functions
  - Obtain on-site Radiation Safety Officer
  - Team Commander remains above RSO
  - May work in warm/cold zones as long as no further radiation exposure
  - Obtain and train with standard radiation protocols
  - Treat Medical/Surgical matters first before Radiation matters
  - Recognize psychogenic factor

RADIATION INJURIES

- DMAT functions
  - Irradiated victims
    - Recognize no team danger
    - Treat based on exposure protocols
    - Assess and document signs/symptoms
    - Rule out contamination
    - Appropriate triage
      - No prodrome: Eventual release
      - CV/CNS prodrome: Palliative measures
      - Probable exposure: Eventual transport

RADIATION INJURIES

- DMAT functions
  - Contaminated victims
    - Recognize no team danger
    - Remember to treat conventional injuries first
    - Minimize internal contamination
    - Remove external contamination
    - Appropriate triage and transport

Radiological Event Scenarios

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Types of Radiological Incident

Incidents	*Description*	*Anticipated Deaths*
Radioactive source accident	Loss or theft of a radiological source (e.g. Goiania)	0-100s
Nuclear reactor accident	Release of radioactive gas or material (e.g. Chernobyl)	0-1,000s
Radiological dispersal device	Device or scheme for dispersing radioactive Isotope (e.g., dirty bomb or radioactive material in the food supply)	0-100s
Radiological exposure device (open source)	Radioactive material intended to expose people in the vicinity (e.g. Cesium source on a train)	100s-1,000s
Improvised nuclear device	Incorporates radioactive material intended to produce a low yield nuclear explosion	1,000s-1,000,000s
Military-grade nuclear device	Incorporates radioactive material intended to produce a fusion detonation	1,000,000s

Source: Weinstock et al. Blood 2008.

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Threat Planning by the U.S. Government

1) 10-Kiloton Improvised Nuclear Device
2) Aerosol Anthrax
3) Pandemic Influenza
4) Plague
5) Blister Agent
6) Toxic Industrial Chemicals
7) Nerve Agent
8) Chlorine Tank Explosion
9) Major Earthquake
10) Major Hurricane
11) Radiological Dispersal Devices
12) Improvised Explosive Devices
13) Food Contamination
14) Foreign Animal Disease (Foot and Mouth Disease)
15) Cyber Attack

Source: U.S. National Planning Scenarios, http://publicintelligence.net/

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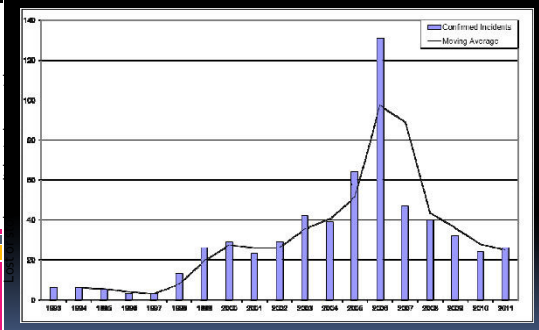
Many Radiation Sources are Poorly Secured



Source: IAEA 2006 Illicit Trafficking Database Report

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Radiation "Accidents" Worldwide (1944 – Jul 2011): "Classification by Device"

Radiation Devices			**324**
	Sealed Sources	212	
	X-ray Devices	86	
	Accelerators	25	
	Radar Generators	1	
Radioisotopes			**103**
	Diagnosis and Therapy	48	
	Transuranics	27	
	Fission Products	11	
	Tritium	2	
	Radium Spills	1	
	Other	14	
Criticalities			**20**
	Critical Assemblies	8	
	Reactors	6	
	Chemical Operations	6	
		Total	**447**

Source: REAC/TS Registry

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Isotope Ingestion

- Alexander Litvinenko
  - Fell ill November 1, 2006
  - Died November 23, 2006
  - Ingestion of 1 mg of Po

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Open Source Exposure

- Taiwanese graduate student
  - October 1994 - February 1996
  - Survived attempts by fellow student to poison with ^{32}P and other chemicals
- Taiwan scientist rivalry
  - In 2003, a nuclear scientist planted Iridium-192 pellets in the office of a business rival
  - Sickened the rival and 74 other people

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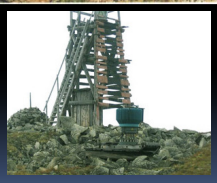
Open Radiation Sources

- Goiania, Brazil – 1987
  - ^{137}Cs source taken from vacant clinic
  - Opened to sell metals to recycler
  - Glowing blue Cesium handled by adults and children
  - 28 cases of radiation sickness
  - 112,000 people screened
- Russia - 2002 & 2003
  - 1,000 nuclear generators used to power remote lighthouses
  - Generators are unguarded and frequently stolen or vandalized by scrap metal hunters
  - Multiple incidents resulting in exposed cores and injuries



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Open Radiation Sources

- **Juarez, Mexico – 1984**
  - ^{60}Co pellets from junked radiotherapy device
  - Recycled into steel and used for construction
  - Over 200 people exposed from Mexico to Illinois
  - 1 fatality, 4 injuries
  - 109 homes demolished as part of decontamination

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Miscalibrated Radiotherapy Devices

- **Houston, TX – 1980 (7 fatalities)**
- **Columbus, OH – 1974-76 (10 fatalities, 78 injuries)**
- **Epinal, France – 2004-05 (1 fatality, 13 injuries)**
- **Panama City, Panama – 2000-01 (17 deaths, 11 injuries)**

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Radiological Dispersal Device (RDD)

- **Chechen Rebels, 1995**
  - Planted cesium and explosives device in a playground
  - Notified local TV station
  - Never detonated
- **Chechen Rebels ,1998**
  - Dirty bomb recovered next to a railway line

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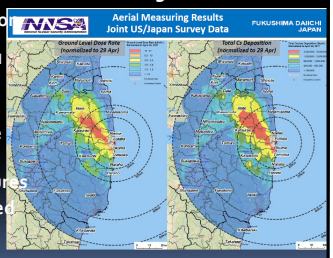
The Fukushima Disaster

- Japan Earthquake on March 11, 2011 resulted in a massive tsunami
- Tsunami wave topped 33 foot sea wall hobbling the Fukushima Daiichi Nuclear Power Station
  - Reactors overheated and melted
  - Hydrogen gas explosions destroyed reactor buildings
  - Spent fuel rods in open pools of water became exposed
- Worst nuclear disaster since Chernobyl in 1986
- No serious radiation exposures
- Surrounding areas evacuated
- What did RITN do?



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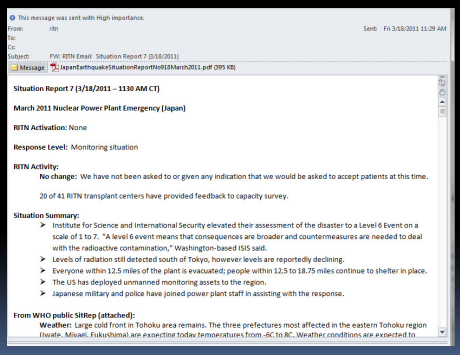
RITN Daily Situation Reports



This message was sent with High importance.

From: ritn Sent: Fri 3/18/2011 11:29 AM
To:
Cc:
Subject: FW: RITN Email: Situation Report 7 (3/18/2011)
Message JapanEarthquakeSituationReportNo918March2011.pdf (395 KB)

Situation Report 7 (3/18/2011 – 1130 AM CT)

March 2011 Nuclear Power Plant Emergency (Japan)

RITN Activation: None

Response Level: Monitoring situation

RITN Activity:

No change: We have not been asked to or given any indication that we would be asked to accept patients at this time.

20 of 41 RITN transplant centers have provided feedback to capacity survey.

Situation Summary:

- Institute for Science and International Security elevated their assessment of the disaster to a Level 6 Event on a scale of 1 to 7. "A level 6 event means that consequences are broader and countermeasures are needed to deal with the radioactive contamination," Washington-based ISIS said.
- Levels of radiation still detected south of Tokyo, however levels are reportedly declining.
- Everyone within 12.5 miles of the plant is evacuated; people within 12.5 to 18.75 miles continue to shelter in place.
- The US has deployed unmanned monitoring assets to the region.
- Japanese military and police have joined power plant staff in assisting with the response.

From WHO public SitRep (attached):

Weather: Large cold front in Tohoku area remains. The three prefectures most affected in the eastern Tohoku region (Iwate, Miyagi, Fukushima) are expecting today temperatures from -6C to 8C. Weather conditions are expected to

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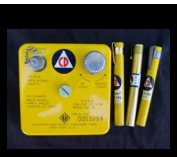

Dosimetry

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Biodosimetry Tools

- **Definition**
  - Biodosimetry is the use of biological markers to estimate dose
  - Dosing after radiological and nuclear events is complicated by a variety of factors, including shielding
- **Standard approaches**
  - Time to vomiting
  - Lymphocyte depletion kinetics
  - METREPOL – Combines clinical data and blood cell counts
  - Dicentric chromosomes in peripheral blood lymphocytes
- **Research approaches**
  - Proteomics
  - Markers of DNA damage

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Time to vomiting as a marker of dose

Estimation of External Radiation Dose Related to Onset of Vomiting*

Vomiting Post Incident	Estimated Dose	Degree of ARS
Less than 10 minutes	> 8 Gy	Lethal
10-30 minutes	6-8 Gy	Very Severe
Less than 1 hour	4-6 Gy	Severe
1-2 hours	2-4 Gy	Moderate
More than 2 hours after	Less than 2 Gy	Mild

* For acute external exposures only. Gray (Gy) is the SI unit of measurement for radiation absorbed dose.

Adapted from: Berger ME, Leonard RB, Ricks RC, Wiley AL, Lowry PC. *Hospital Triage in the First 24 Hours After a Nuclear or Radiological Disaster.* REAC/TS (Radiation Emergency Assistance Center/ Training Site); http://www.orau.gov/reacts: 2004.

Source: CDC Radiological Terrorism Emergency Management Pocket Guide for Clinicians Pocket Guide, www.bt.cdc.gov/radiation/pocket.asp

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Lymphocyte Depletion Kinetics

Estimating dose from a single Absolute Lymphocyte count (ALC).
SERIAL MEASUREMENTS MORE ACCURATE and are strongly recommended
Using AFRRI BAT tool on REMM is also more accurate.
Instructions: 1) Determine the ALC for that patient, 2) read down by the number of hours after the incident and 3) read across for estimate of whole body dose.
(Table adapted by Scarce Resources Group from AFRRI dose calculator on REMM (www.remm.nlm.gov)

		Absolute Lymphocyte Count (ALC) Value × 10 to the ninth (single value)											
		1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
		Estimate of whole body dose from radiation exposure □ Below 2 Gy ■ 2-6 Gy ■ Above 6 Gy												
Hours after exposure	24	0	0	1.8	2.5	3.3	4.2	5.2	6.3	7.7	9.3	>10	>10	>10
	48	0	0	0	1.5	2.0	2.5	3.1	3.8	4.6	5.6	6.9	8.7	>10
	72	0	0	0	0	0.9	1.8	2.2	2.7	3.2	3.9	4.8	6.1	8.2
	96	0	0	0	0	0	0	1.7	2.1	2.5	3.1	3.8	4.8	6.5

Table from: Coleman CN, Weinstock DM, Casagrande R, et al. Triage and treatment tools for use in a scarce resources-crisis standards of care setting after a nuclear detonation. Disaster Med Public Health Prep. 2011;5(Suppl 1):S111-S121.

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Biodosimetry Metrics

Table 5. Biodosimetry Based on Acute Photon-Equivalent Exposures*

Dose Estimate	Victims with Vomiting	Time to Onset of Vomiting	Absolute Lymphocyte Count†						Rate Constant for Lymphocyte Depletion‡	Dicentrics in Human Peripheral Blood Lymphocytes§	
			Day 0.5	Day 1	Day 2	Day 4	Day 6	Day 8		Per 50 Cells	Per 1000 Cells
Gy	%	h	←			$\times 10^9$ cells/L		→	k‡	n	
0	–	–	**2.45**	**2.45**	**2.45**	**2.45**	**2.45**	**2.45**	–	0.05–0.1	1–2
1	19		**2.30**	**2.16**	**1.90**	**1.48**	1.15	0.89	0.126	4	88
2	35	4.63	**2.16**	**1.90**	**1.48**	0.89	0.54	0.33	0.252	12	234
3	54	2.62	**2.03**	**1.68**	1.15	0.54	0.25	0.12	0.378	22	439
4	72	1.74	**1.90**	**1.48**	0.89	0.33	0.12	0.044	0.504	35	703
5	86	1.27	**1.79**	1.31	0.69	0.20	0.06	0.020	0.63	51	1024
6	94	0.99	**1.68**	1.15	0.54	0.12	0.03	0.006	0.756		
7	98	0.79	**1.58**	1.01	0.42	0.072	0.012	0.002	0.881		
8	99	0.66	**1.48**	0.89	0.33	0.044	0.006	<0.001	1.01		
9	100	0.56	1.39	0.79	0.25	0.030	0.003	<0.001	1.13		
10	100	0.48	1.31	0.70	0.20	0.020	0.001	<0.001	1.26		

* Depicted above are the 3 most useful elements of biodosimetry. Dose range is based on acute photon-equivalent exposures. The second column indicates the percentage of people who vomit, based on dose received and time to onset. The middle section depicts the time frame for development of lymphopenia. Blood lymphocyte counts are determined twice to predict a rate constant that is used to estimate exposure dose. The final column represents the current gold standard, which requires several days before results are known. Colony-stimulating factor therapy should be initiated when onset of vomiting or lymphocyte depletion kinetics suggests an exposure dose for which treatment is recommended (see Table 7). Therapy may be discontinued if results from chromosome dicentrics analysis indicate a lower estimate of whole-body dose.
† Normal range, 1.4–3.5 × 10^9 cells/L. Numbers in boldface fall within this range.
‡ The lymphocyte depletion rate is based on the model $L_t = 2.45 \times 10^9$ cells/L $\times e^{-k(Dt)}$, where L_t equals the lymphocyte count ($\times 10^9$ cells/L), 2.45 × 10^9 cells/L equals a constant representing the consensus mean lymphocyte count in the general population, k equals the lymphocyte depletion rate constant for a specific acute photon dose, and t equals the time after exposure (days).
§ Number of dicentric chromosomes in human peripheral blood lymphocytes.

Waselenko, J. K. et. al. Ann Intern Med 2004;140:1037-1051

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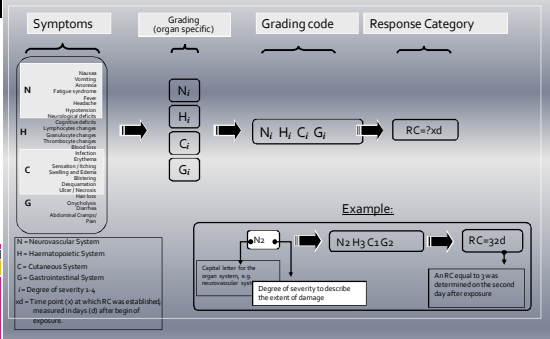
METREPOL Dosimetry Approach



Source: REMM

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Clinical Care Based on RC

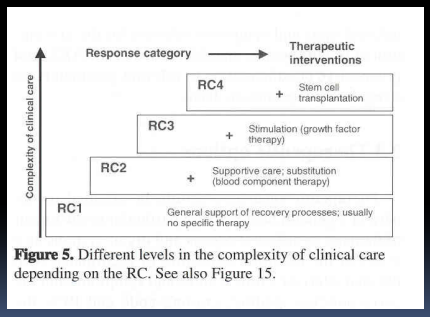

Figure 5. Different levels in the complexity of clinical care depending on the RC. See also Figure 15.

Source: Fliedner TM et al. Brit J. Radiology 78:1-8, 2005

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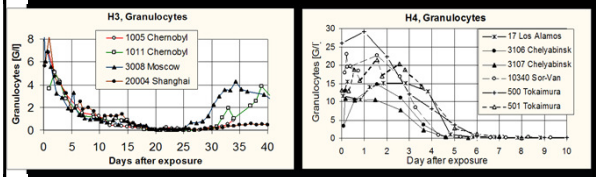
Severe but reversible (H3) versus irreversible (H4) toxicity



- Decline between day 4 and 10
- Abortive recovery (shoulder)
- Nadir days 20 to 30
- Initial granulocytosis
- Nadir by day 6

Source: British Journal of Radiology

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Biodosimetry Tools

- **AFRRI Biodosimetry Assessment Tool (BAT)**
  - Downloadable software
- **Radiation Event Medical Management (REMM)** www.remm.nlm.gov
  - Web-based software
  - Provides suggested treatments based on estimated dose
  - Standardized admission and treatment order templates

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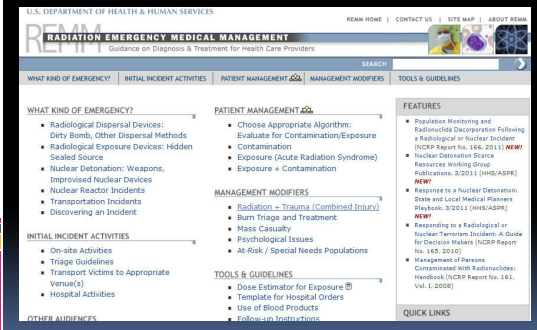
www.remm.nlm.gov



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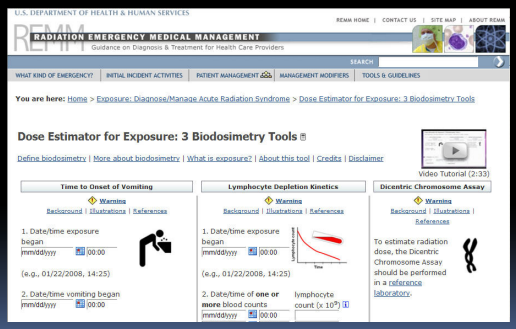
Biodosimetry Tools



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Data Collection Protocol

- Incorporated into standard NMDP data collection system
- Will feed consistent information for review after an event
- Will track progress of victims
  - Online data entry
  - Real-time feedback of data

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Mitigation and Treatment

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Suggested Treatments Based on Dose

- All treatments are based on extrapolation:
  - Radiation accident victims
  - Animal studies
  - Patients with cancer
- FDA approval requirements limit guidelines and inclusion of certain agents in the Strategic National Stockpile

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Suggested Treatments Based on Dose

Hematopoietic Subsyndrome Treatment

Consensus Guidance for Treatment, Based on Exposure Dose and Event Size [1]

- View recommendations by clicking on whole-body dose (Clear)
  1. Click on a whole-body dose (Gy)
  2. View consensus treatment guidance based on
     - Number of casualties
     - With or without injury/burn

  or,
- Show recommendations for all doses/scenarios (Clear)

Consider Treatment	Whole-body Dose (Gy) What is Gy (Gray)? 1	2	3	4	5	6	7	8	9	10	Event Size, ± Injury/Burn (Small event: ≤ 100 victims; Mass event: > 100 victims)
					↓						
NOTE: All potential treatments may not be feasible in a large size event.											
Prophylactic Antibiotics†					✓						Small/no injury
					✓						Mass/no injury
					✓						Small/injury + burn
					✓						Mass/injury + burn
Cytokines/ Bone Marrow Growth Factors‡					✓						Small/no injury
					✓						Mass/no injury
					✓						Small/injury + burn
					✓						Mass/injury + burn, if resources available
Stem-cell Transplantation											Small/no injury

Source: REMM, www.remm.nlm.gov

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Mitigation and Supportive Care

- Blood products - irradiated and leukoreduced
- Antibiotics
- G-CSF
  - Improved survival in irradiated nonhuman primates
  - Maximal benefit may require administration <24 hours after exposure
  - Significant potential to reduce resource utilization
  - Limited supply in the Strategic National Stockpile
- Potassium iodide
- Decorporating agents
- Template order sets and doses (www.remm.nlm.gov)

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Summary

- There are a variety of incident scenarios
- Hematologists, oncologists, and stem cell transplant experts may be called upon to care for casualties
- Have a plan and get involved!

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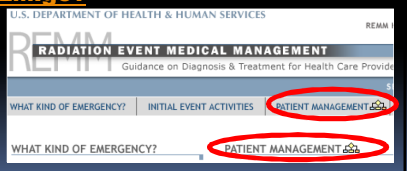
For treatment guidelines, references:

www.RITN.net

www.REMM.NLM.gov



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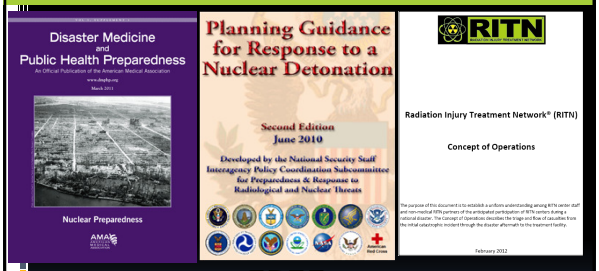
Fantastic Resources at a Price You Can't Beat



FREE

http://www.dmphp.org/content/vol5/Supplement_1/index.dtl
http://www.remm.nlm.gov/PlanningGuidanceNuclearDetonation.pdf
http://www.ritn.net/About/

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RADIATION INJURIES

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  - Virtual Naval Hospital: External Contamination. www.vnh.org/BUMEDINST6470.10A/ExtContamination.html
  - Virtual Naval Hospital: Wound Contamination. www.vnh.org/BUMEDINST6470.10A/WoundCont.html
  - Virtual Naval Hospital: Internal Contamination. www.vnh.org/BUMEDINST6470.10A/IntCont.html
  - Virtual Naval Hospital: Neutron Exposure. www.vnh.org/BUMEDINST6470.10A/NeutronExp.html
  - Fong F, Schrader DC: Radiation Disasters and Emergency Department Preparedness. Emergency Clinics of North America 14:349-370, 1996.

BAD DAY

There's a saying that if Mike Wallace with a crew from "60 Minutes" is waiting for you when you get to work, you're going to have a bad day. If Jack Bauer shows up and puts a gun to your head, they may need to update that saying...

- "There are no bad days, only challenging moments."

ATTITUDE

A Sense of Humor Can Help Make Even the Toughest Job Easier


"Call it a clan, call it a network, call it a tribe,
call it a family. Whatever your call it,
whoever you are, you need one!!!"

Thanks !