Emergency Department Management of Radiation Casualties

Scope of Training

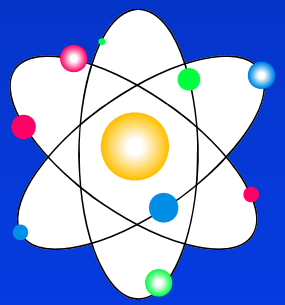
- Characteristics of ionizing radiation and radioactive materials
- Differentiation between radiation *exposure* and radioactive material *contamination*
- Staff radiation protection procedures and practices
- Facility preparation

Scope of Training (Cont.)

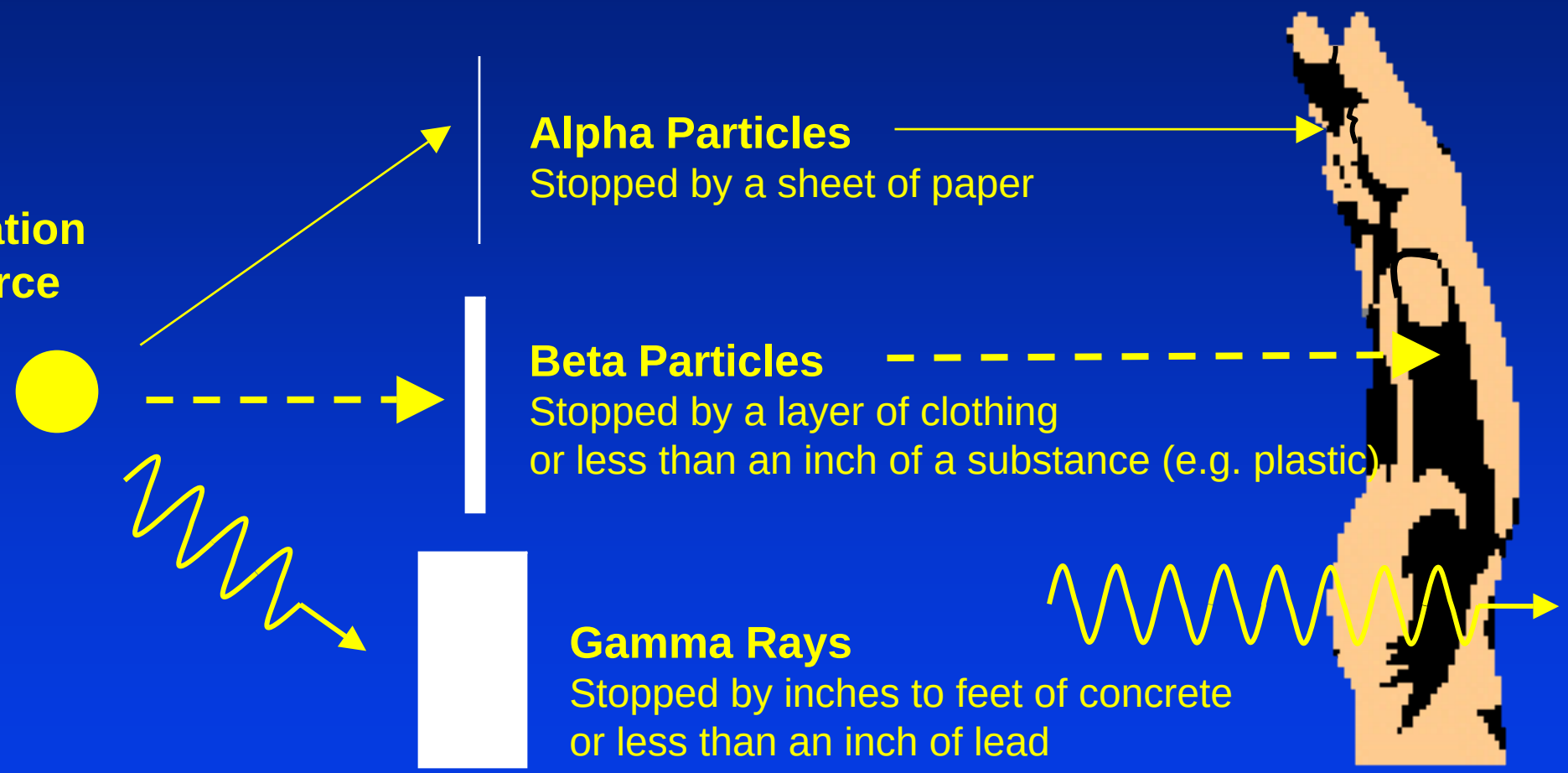
- Patient assessment and management of radiation contamination and injuries
- Psychosocial considerations
- Health effects of acute and chronic radiation exposure
- Facility recovery
- Resources

Ionizing Radiation

- *Ionizing radiation* is radiation capable of imparting its energy to the body and causing chemical changes
- Ionizing radiation is emitted by
  - Radioactive material
  - Some devices such as x-ray machines



Types of Ionizing Radiation



Radiation Units

Measure of	Quantity	Unit
Amount of radioactive material	Activity	curie (Ci)
Ionization in air	Exposure	roentgen (R)
Absorbed energy per mass	Absorbed Dose	rad
Absorbed dose weighted by type of radiation	Dose Equivalent	rem

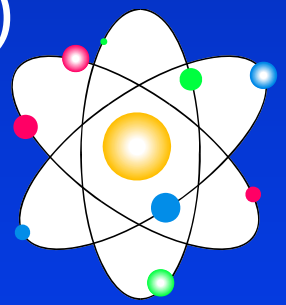
For most types of radiation **1 R ≈ 1 rad ≈ 1 rem**

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
Heart catheterization	45,000 mrem
Life saving actions guidance (NCRP-116)	50,000 mrem
Mild acute radiation syndrome	200,000 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 or wound contamination)



Half-Life (HL)

- **Physical Half-Life**

  Time (in minutes, hours, days or years) required for the activity of a radioactive material to decrease by one half due to radioactive decay

- **Biological Half-Life**

  Time required for the body to eliminate half of the radioactive material (depends on the chemical form)

- **Effective Half-Life**

  The net effect of the combination of the physical & biological half-lives in removing the radioactive material from the body

- Half-lives range from fractions of seconds to millions of years
- 1 HL = 50% 2 HL = 25% 3 HL = 12.5%

Examples of Radioactive Materials

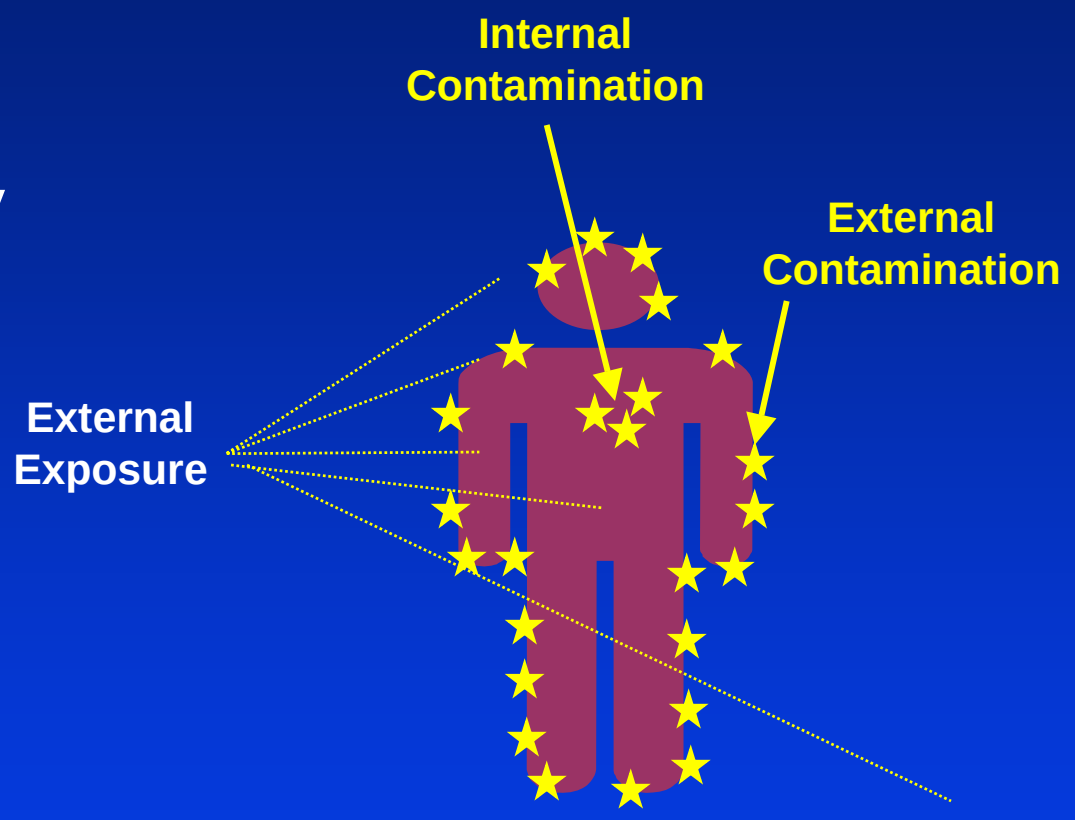
Radionuclide	Physical Half-Life	Activity	Use
Cesium-137	30 yrs	1.5×10^6 Ci	Food Irradiator
Cobalt-60	5 yrs	15,000 Ci	Cancer Therapy
Plutonium-239	24,000 yrs	600 Ci	Nuclear Weapon
Iridium-192	74 days	100 Ci	Industrial Radiography
Hydrogen-3	12 yrs	12 Ci	Exit Signs
Strontium-90	29 yrs	0.1 Ci	Eye Therapy 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	Smoke Detectors
Radon-222	4 days	1 pCi/l	Environmental Level

Types of Radiation Hazards

- ***External Exposure*** -

  whole-body or partial-body (no radiation hazard to EMS staff)

- ***Contaminated*** -
  - external radioactive material: on the skin
  - internal radioactive material: inhaled, swallowed, absorbed through skin or wounds



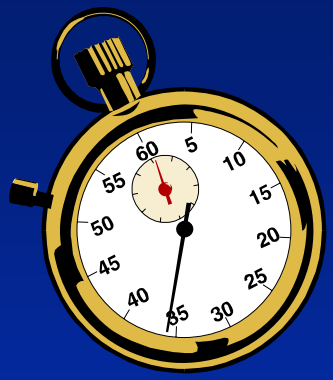
Causes of Radiation Exposure/Contamination

- **Accidents**
  - Nuclear reactor
  - Medical radiation therapy
  - Industrial irradiator
  - Lost/stolen medical or industrial radioactive sources
  - Transportation
- **Terrorist Event**
  - Radiological dispersal device (dirty bomb)
  - Low yield nuclear weapon

Scope of Event

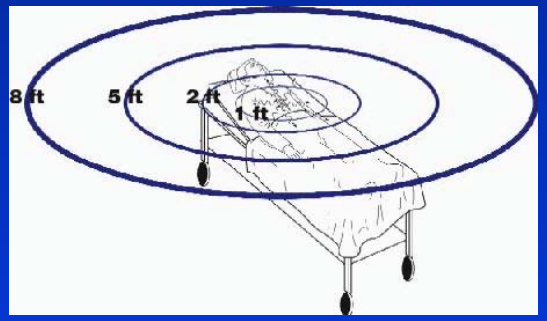
Event →	Number of Deaths →	Most Deaths Due to
Radiation Accident	None/Few	Radiation
Radioactive Dispersal Device	Few/Moderate (Depends on size of explosion & proximity of persons)	Blast Trauma
Low Yield Nuclear Weapon	Large (e.g. tens of thousands in an urban area even from 0.1 kT weapon)	Blast Trauma Thermal Burns Radiation Exposure Fallout (Depends on Distance)

Radiation Protection
Reducing Radiation Exposure



Time

Minimize time spent near radiation sources



To Limit Caregiver Dose to 5 rem

Distance	Rate	Stay time
1 ft	12.5 R/hr	24 min
2 ft	3.1 R/hr	1.6 hr
5 ft	0.5 R/hr	10 hr
8 ft	0.2 R/hr	25 hr

Distance

Maintain maximal practical distance from radiation source

Shielding

Place radioactive sources in a lead container

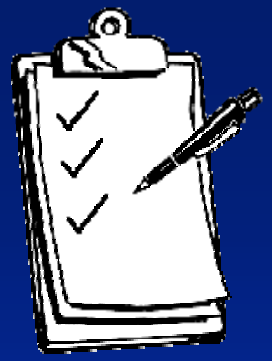
Protecting Staff from Contamination

- 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

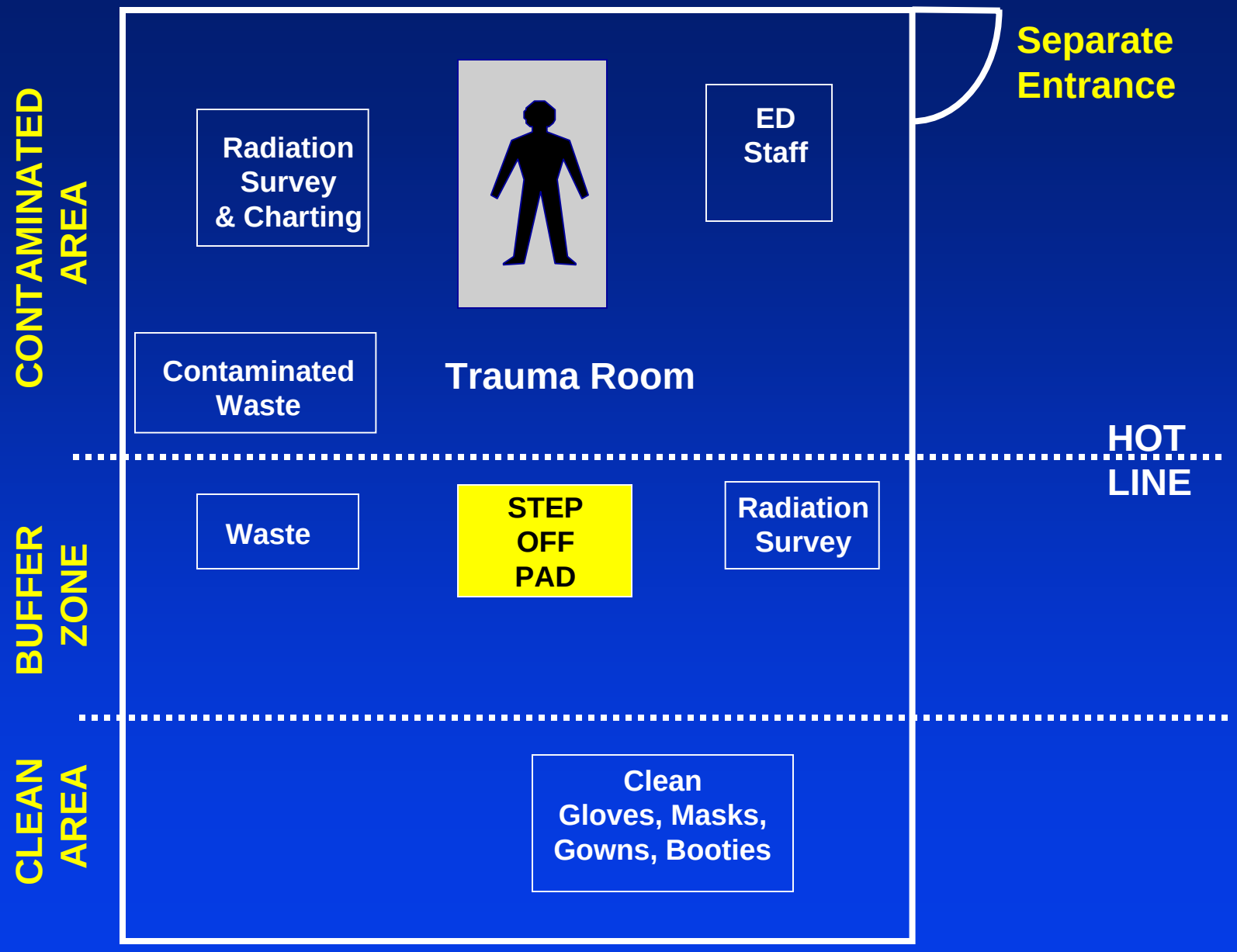
- Contamination is easy to detect and most of it can be removed
- It is very unlikely that ED staff will receive large radiation doses from treating contaminated patients

Facility Preparation



- Activate hospital plan
  - Obtain radiation survey meters
  - Call for additional support: Staff from Nuclear Medicine, Radiation Oncology, Radiation Safety (Health Physics)
  - Plan for decontamination of uninjured persons
  - Establish triage area
- Plan to control contamination
  - Instruct staff to use universal precautions and double glove
  - Establish multiple receptacles for contaminated waste
  - Protect floor with covering if time allows

Treatment Area Layout



Detecting and Measuring Radiation

- **Instruments**
  - Locate contamination - GM Survey Meter (Geiger counter)
  - Measure exposure rate - Ion Chamber
- **Personal Dosimeters - measure doses to staff**
  - Radiation Badge - Film/TLD
  - Self reading dosimeter (analog & digital)

Patient Management - Priorities

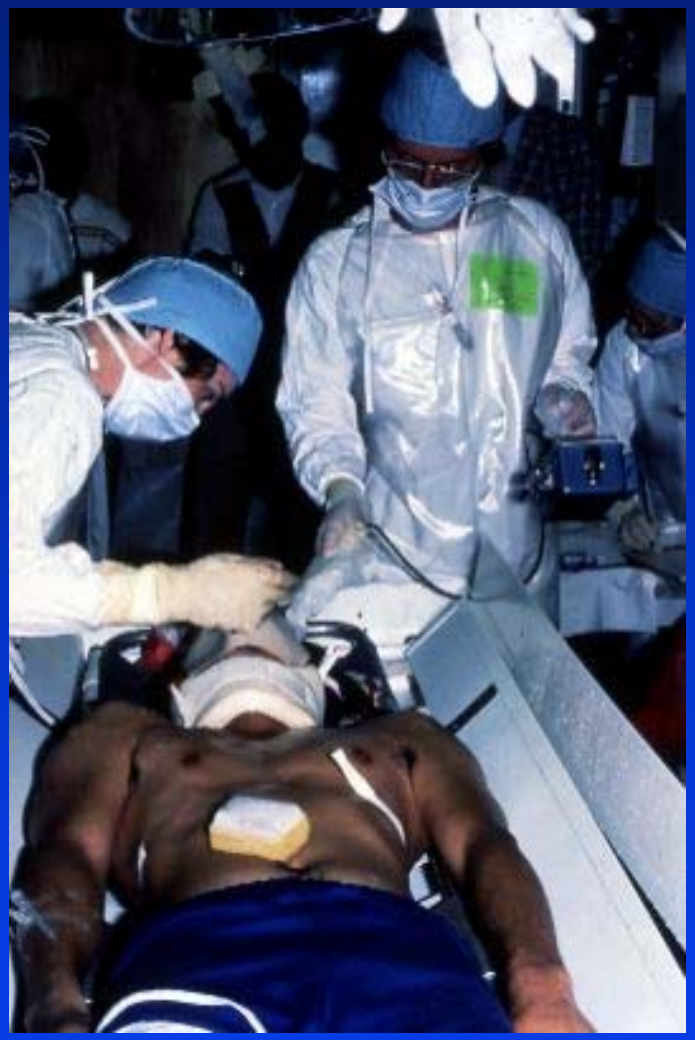
Triage

- Medical triage 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

Patient Management - Triage

Triage based on:

- Injuries
- Signs and symptoms - nausea, vomiting, fatigue, diarrhea
- History - Where were you when the bomb exploded?
- Contamination survey



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
- 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

Patient Management - Decontamination

- Carefully remove and bag patient's clothing and personal belongings (typically removes 95% of contamination)
- Survey patient and, if practical, collect samples
- Handle foreign objects with care until proven 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.)

- Protect non-contaminated wounds with waterproof dressings
- Contaminated wounds:
  - Irrigate and gently scrub with surgical sponge
  - Extend wound debridement for removal of contamination *only* in extreme cases and upon expert advice
- Avoid overly aggressive decontamination
- Change dressings frequently
- Decontaminate intact skin and hair by washing with soap & water
- Remove stubborn contamination on hair by cutting with scissors or electric clippers
- Promote sweating
- Use survey meter to monitor progress of decontamination

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.
- 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.

Treatment of Internal Contamination

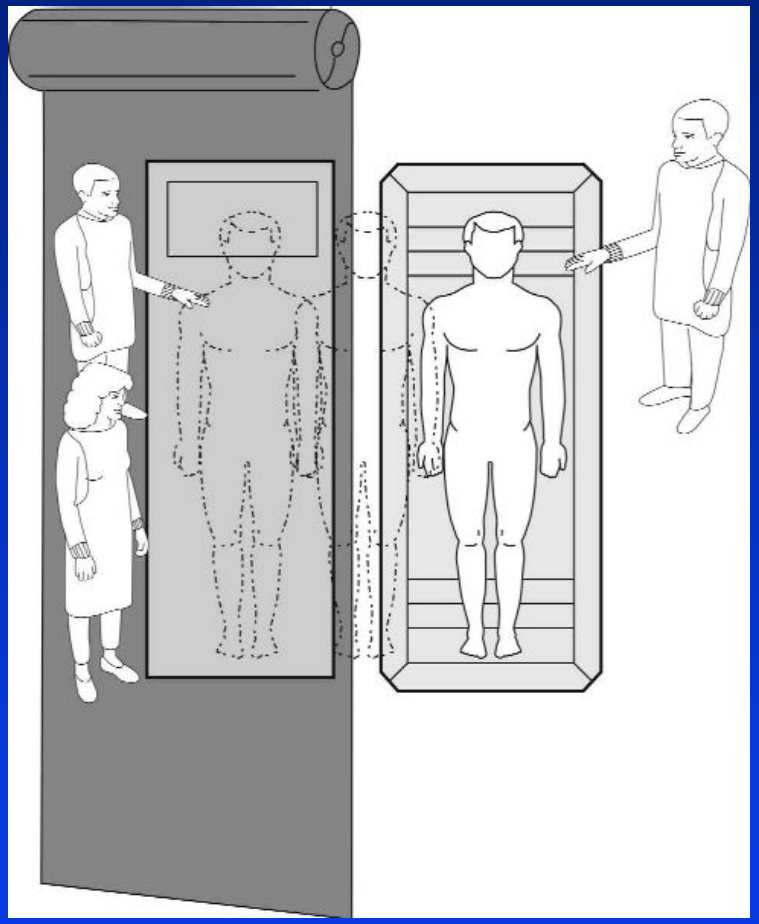
- Radionuclide-specific
- Most effective when administered early
- May need to act on preliminary information
- NCRP Report No. 65, Management of Persons Accidentally Contaminated with Radionuclides

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

Patient Management - Patient Transfer

Transport injured, contaminated patient into or from the ED:

- Clean gurney covered with 2 sheets
- Lift patient onto clean gurney
- Wrap sheets over patient
- Roll gurney out of treatment room



Facility Recovery

- Remove waste from the Emergency Department and triage area
- Survey facility for contamination
- Decontaminate as necessary
  - Normal cleaning routines (mop, strip waxed floors) typically very effective
  - Periodically reassess contamination levels
  - Replace furniture, floor tiles, etc. that cannot be adequately decontaminated

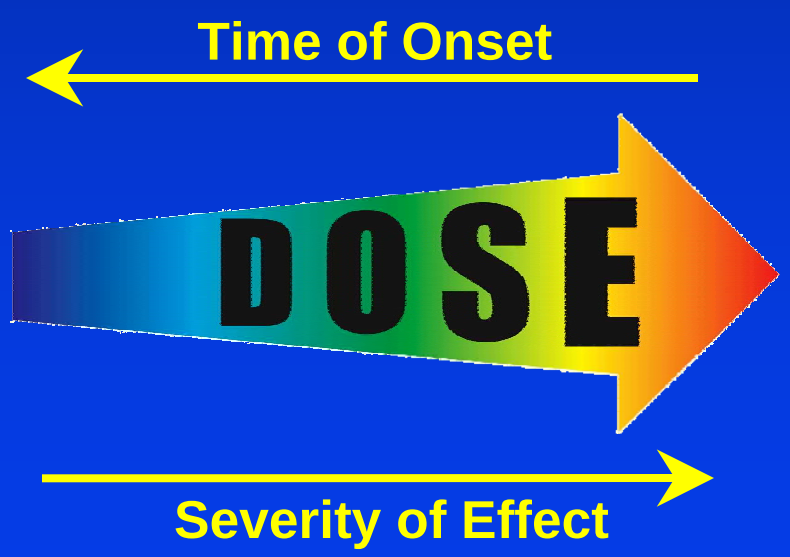
- Decontamination Goal: Less than twice normal background…higher levels may be acceptable

Radiation Sickness
Acute Radiation Syndrome

- Occurs only in patients who have received very high radiation doses (greater than approximately 100 rem) to most of the body
- **Dose ~ 15 rem**
  - no symptoms, possible chromosomal aberrations
- **Dose ~ 50 rem**
  - no symptoms, minor decreases in white cells and platelets

Acute Radiation Syndrome (Cont.)
For Doses > 100 rem

- **Prodromal stage**
  - nausea, vomiting, diarrhea and fatigue
  - higher doses produce more rapid onset and greater severity
- **Latent period (Interval)**
  - patient appears to recover
  - decreases with increasing dose
- **Manifest Illness Stage**
  - Hematopoietic
  - Gastrointestinal
  - CNS



Acute Radiation Syndrome (Cont.)

Hematopoietic Component - latent period from weeks to days

- **Dose ~ 100 rem**
  - ~10% exhibit nausea and vomiting within 48 hr
  - mildly depressed blood counts
- **Dose ~ 350 rem**
  - ~90% exhibit nausea/vomiting within 12 hr, 10% exhibit diarrhea within 8 hr
  - severe bone marrow depression
  - ~50% mortality without supportive care
- **Dose ~ 500 rem**
  - ~50% mortality with supportive care
- **Dose ~ 1000 rem**
  - 90-100% mortality despite supportive care

Acute Radiation Syndrome (Cont.)

Gastrointestinal and CNS Components

- **Dose > 1000 rem - damage to GI system**
  - severe nausea, vomiting and diarrhea (within minutes)
  - short latent period (days to hours)
  - usually fatal in weeks to days
- **Dose > 3,000 rem - damage to CNS**
  - vomiting, diarrhea, confusion, severe hypotension within minutes
  - collapse of cardiovascular and CNS
  - fatal within 24 to 72 hours

Treatment of Large External Exposures

- Estimating the severity of radiation injury is difficult.
  - Signs and symptoms (N,V,D,F): Rapid onset and greater severity indicate higher doses. Can be psychosomatic.
  - CBC with absolute lymphocyte count
  - Chromosomal analysis of lymphocytes (requires special lab)
- Treat symptomatically. Prevention and management of infection is the primary objective.
  - Hematopoietic growth factors, e.g., GM-CSF, G-CSF (24-48 hr)
  - Irradiated blood products
  - Antibiotics/reverse isolation
  - Electrolytes
- Seek the guidance of experts.
  - Radiation Emergency Assistance Center/ Training Site (REAC/TS)
  - Medical Radiobiology Advisory Team (MRAT)

Localized Radiation Effects - Organ System Threshold Effects

- **Skin - No visible injuries < 100 rem**
  - Main 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

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

Chronic Health Effects from Radiation

- Radiation is a weak carcinogen at low doses
- No unique effects (type, latency, pathology)
- Natural incidence of cancer ~ 40%; mortality ~ 25%
- Risk of fatal cancer 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%

What are the Risks to Future Children? Hereditary Effects

- Magnitude of hereditary risk per rem is 10% that of fatal cancer risk
- Risk to caregivers who would likely receive low doses is very small - 5 rem increases the risk of severe hereditary effects by ~ 0.02%
- Risk of severe hereditary effects to a patient population receiving high doses is estimated as ~ 0.4% per 100 rem

Fetal Irradiation

No significant risk of adverse developmental 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 childhood cancer risk. (~ 0.6% per 10 rem)

Key Points

- Medical stabilization is the highest priority
- Train/drill to ensure competence and confidence
- Pre-plan to ensure adequate supplies and survey instruments are available
- Universal precautions and decontaminating patients minimizes exposure and contamination risk
- Early symptoms and their intensity are an indication of the severity of the radiation injury
- The first 24 hours are the worst; then you will likely have many additional resources

Resources

- Radiation Emergency Assistance Center/ Training Site (REAC/TS) (865) 576-1005 www.orau.gov/reacts/
- Medical Radiobiology Advisory Team (MRAT) Armed Forces Radiobiology Research Institute (AFRRI) (301) 295-0530 www.afrri.usuhs.mil
- Books:
  - Medical Management of Radiation Accidents; Gusev, Guskova, Mettler, 2001.
  - Medical Effects of Ionizing Radiation; Mettler and Upton, 1995.
  - The Medical Basis for Radiation-Accident Preparedness; REAC/TS Conference, 2002.
  - National Council on Radiation Protection Reports Nos. 65 and 138
- Article: "Major Radiation Exposure - What to Expect and How to Respond," Mettler and Voelz, New England Journal of Medicine, 2002; 346: 1554-61.
- Websites:
  - www.acr.org - Disaster Preparedness for Radiology Professionals
  - www.afrri.usuhs.mil - Medical Management of Radiological Casualties Handbook; Jarrett, 2003, and Terrorism with Ionizing Radiation Pocket Guide

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