Radiation and the human body

Signs, symptoms
Detection and protection
Effects and response
Medical management

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Detroit, Michigan

Scope of event

<table>
<thead>
<tr>
<th>Event</th>
<th># Deaths</th>
<th>Most deaths from</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation Accident</td>
<td>None/Few</td>
<td>Radiation</td>
</tr>
<tr>
<td>Radioactive Dispersal Device</td>
<td>Few/Moderate Depends on size of explosion &amp; proximity of persons</td>
<td>Blast Trauma</td>
</tr>
<tr>
<td>Low Yield Nuclear Weapon</td>
<td>Large e.g. tens of thousands in an urban area even from 0.1 kT weapon</td>
<td>Blast Trauma, Thermal Burns, Radiation Exposure Fallout Depends on Distance</td>
</tr>
</tbody>
</table>
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

Types of cellular damage

- Ionizing Radiation
- Altered metabolism & function
- Cell death
- Reproductive cell death
- Mutation
Radiosensitivity of tissues

**High radiosensitivity**
- Bone marrow
- Lymphoid tissue
- Gastrointestinal epithelium
- Gonads
- Embryonic tissues

**Med radiosensitivity**
- Skin
- Vascular endothelium
- Lung
- Kidney
- Liver
- Lens (eye)

**Low radiosensitivity**
- Central Nervous System
- Muscle
- Bone and cartilage
- Connective tissue

Bone marrow

**Normal physiological situation**

- Resting stem cells
- Proliferating compartment: stem cell and progenitors
- Differentiating compartment: precursors
- Mature cells
- Blood

Stem cells: immature cells with autorenewal capability
Progenitors: primitive cells, high proliferative potential
Mature cells: no proliferative capability, *e.g.* red blood cells
Bone marrow

Effect of irradiation

- Resting stem cells
- Proliferating compartment: stem cell and progenitors
- Differentiating compartment: precursors
- Mature cells
- Blood

Activation → proliferation, differentiation → Depletion by absence of renewal → Depletion of proliferating compartment → BLOOD APLASIA

Irradiated bone marrow

Normal bone marrow

Irradiated bone marrow: lacks all precursor hematopoietic cells
Effects of radiation on lymphatic tissue

- Normal monkey lymph node
- Germinal centre of normal monkey lymph node
- Lymphoid cells depleted in cortex of irradiated canine lymph node
- Germinal centre of irradiated human lymph node

Lymphocyte effects

- Time after exposure (days): 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 150
- Lymphocytes (% of normal): 0, <1 Gy, 1–2 Gy, 2–5 Gy, >5–6 Gy

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Leukopoietic effects

![Graph showing neutrophils (% of normal) over time after exposure (days) for different radiation doses: <1 Gy, 1–2 Gy, 2–5 Gy, >5–6 Gy.]

Thrombopoietic effects

![Graph showing platelets (% of normal) over time after exposure (days) for different radiation doses: <1 Gy, 1–2 Gy, 2–5 Gy, >5–6 Gy.]

Effects of Radiological Agents
Erythropoietic effects

![Graph showing hemoglobin levels over time](image)

**The fetus**

Typical effects of radiation on an embryo:

- Intrauterine growth retardation (IUGR)
- Embryonic, fetal, or neonatal death
- Congenital malformations
### Effects of radiation according to gestational stage

<table>
<thead>
<tr>
<th>Gestational age</th>
<th>Stage</th>
<th>Radiogenic effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9 days</td>
<td>Preimplantation</td>
<td>All or none</td>
</tr>
<tr>
<td>10 days-6 weeks</td>
<td>Organogenesis</td>
<td>Congenital anomalies, growth retardation</td>
</tr>
<tr>
<td>6 weeks-40 weeks</td>
<td>fetal</td>
<td>Growth retardation, microcephaly, mental retardation</td>
</tr>
</tbody>
</table>

### Specific radiation effects on fetus: mental retardation, microcephaly

Mental retardation caused by radiation exposure in Hiroshima and Nagasaki
Considerations for pregnancy termination

Threshold dose for developmental effects is approximately 0.1 Gy

Normal rate of preclinical loss >25%.
At 0.1 Gy, this increases by only 0.1-1%

A fetal absorbed dose >0.5 Gy at 7-13 weeks: substantial risk of IUGR and CNS damage

0.25-0.5 Gy at 7-13 weeks: parental decision to terminate with physician’s guidance

Review points 1

• Most deaths from radiation poisoning are likely to come from radiation accidents or low-yield nuclear weapons
• Hazards are from external exposure, and from external and internal contamination
• Measurable effects on the bone marrow and the fetus (in a pregnant woman) can be seen even after low, non-fatal, doses of radiation
• Fetal exposure is of particular concern, since effects can be permanent
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Acute Radiation Syndrome

Timescale of radiation effects

<table>
<thead>
<tr>
<th>Time scale</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fractions of seconds</td>
<td>Energy absorption</td>
</tr>
<tr>
<td>Seconds</td>
<td>Changes in biomolecules (DNA, membranes)</td>
</tr>
<tr>
<td>Minutes</td>
<td>Biological repair</td>
</tr>
<tr>
<td>Hours</td>
<td>Change of information in cell</td>
</tr>
<tr>
<td>Days</td>
<td>Cell death</td>
</tr>
<tr>
<td>Weeks</td>
<td>Organ death</td>
</tr>
<tr>
<td>Months</td>
<td>Clinical changes</td>
</tr>
<tr>
<td>Years</td>
<td>Mutations in a Germ cell</td>
</tr>
<tr>
<td>Decades</td>
<td>Somatic cell</td>
</tr>
<tr>
<td>Generations</td>
<td>Leukaemia or Cancer</td>
</tr>
<tr>
<td></td>
<td>Hereditary effects</td>
</tr>
</tbody>
</table>

Effects of Radiological Agents 10
Radiation effects

**Early**
(deterministic only)

- **Local**
  - Radiation injury of individual organs: functional and/or morphological changes within hrs-days-weeks

- **Common**
  - Acute radiation disease
  - Acute radiation syndrome
    - $L_{D_{50/60}} \sim 3.5 \text{ Sv}$
    - $L_{D_{100/60}} > 5 \text{ Sv}$

- **Deterministic**
  - Radiation Dermatitis
  - Radiation Cataracts
  - Teratogenic
    - (D > 0.1 Sv)

- **Stochastic**
  - Probability increases with dose
    - tumors
    - leukemia
    - genetic effects

**Late**
Deterministic effects at low doses

<0.1 Gy, whole body  No detectable difference in exposed versus non-exposed subjects

0.1-0.2 Gy, whole body  Detectable increase in chromosome aberrations. No clinical signs or symptoms

>0.12 Gy, whole body  Sperm count decreases to a minimum at about day 45

0.5 Gy, whole body  Detectable bone marrow depression with lymphopenia

Acute radiation syndrome (ARS)

Acute radiation syndrome (ARS): Combination of clinical syndromes occurring in stages, hours to weeks after exposure, as injury to various tissues and organs is expressed

ARS threat from:
- Discharged medical irradiators
- Industrial radiography units
- Commercial irradiators
- Terrorist detonation
- Nuclear fuel processing
- Nuclear reactors
Acute radiation syndrome (ARS)

- ARS is the most notable deterministic effect of ionizing radiation
- Signs and symptoms are not specific for radiation injury, but collectively highly characteristic of ARS
- **Symptoms** appear in phases, hours to weeks after exposure
- **Extent and severity** of symptoms is determined by:
  - total radiation dose received
  - how rapidly dose delivered (dose rate)
  - how dose is distributed (whole versus partial body irradiation)

Phases of ARS

- **Initial or prodromal phase**
  - early symptoms seen
- **Latent phase**
  - apparent recovery
- **Manifest illness phase**
  - full extent of syndrome
- **Recovery phase (or death)**
Exposure levels at which healthy adults are affected by radiation

<table>
<thead>
<tr>
<th>Health effects</th>
<th>Acute dose (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood count changes</td>
<td>0.50</td>
</tr>
<tr>
<td>Vomiting (threshold)</td>
<td>1.00</td>
</tr>
<tr>
<td>Mortality (threshold)</td>
<td>1.50</td>
</tr>
<tr>
<td>(LD_{50/60}) (minimal supportive care)</td>
<td>3.2-3.6</td>
</tr>
<tr>
<td>(LD_{50/60}) (supportive medical treatment)</td>
<td>4.8-5.4</td>
</tr>
<tr>
<td>(LD_{50/60}) (autologous bone marrow or stem cell transplant)</td>
<td>&gt;5.4</td>
</tr>
</tbody>
</table>


Radiation doses and dose limits

- Flight from Los Angeles to London: 0.05 mSv
- Annual public dose limit: 1 mSv
- Annual natural background: 3 mSv
- Fetal dose limit: 5 mSv
- Barium enema: 8.7 mSv
- Annual radiation worker dose limit: 50 mSv
- Heart catheterization (skin dose): 450 mSv
- Life saving actions guidance (NCRP-116): 500 mSv
- Acute radiation syndrome: 2,000 mSv
- \(LD_{50/60}\) for humans (bone marrow dose): 3,400 mSv
- Radiation therapy (localized, fractionated): 70,000 mSv
Factors which decrease the $LD_{50/60}$

- Coexisting trauma or combined injury
- Chronic nutritional deficit
- Coexisting infection
- Contribution of high-LET radiation

Manifestations of ARS

Hematopoietic syndrome (HPS) affects the marrow and blood

Gastrointestinal syndrome (GIS) affects the guts

Neurovascular syndrome (NVS) affects the brain
Principal syndromes contributing to death after acute whole body radiation exposure

<table>
<thead>
<tr>
<th>Whole body dose (Gy)</th>
<th>Syndrome</th>
<th>Time of death (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-10</td>
<td>Hematopoietic (HPS)</td>
<td>30-60</td>
</tr>
<tr>
<td>10-30</td>
<td>Gastrointestinal (GIS)</td>
<td>10-20</td>
</tr>
<tr>
<td>&gt;30</td>
<td>Neurovascular (NVS)</td>
<td>1-5</td>
</tr>
</tbody>
</table>

Phases of hematopoietic syndrome

Prodromal phase: symptoms are nausea and vomiting lasting only a few hours, with time of onset from later than one hour to about 24 hours after exposure

Latent phase: lasts up to a month. Relatively asymptomatic except for some fatigue and weakness

Manifest illness phase: characterized by neutropenic fevers, systemic and localized infections, sepsis, and hemorrhage
Gastrointestinal syndrome (8–30 Gy)

Pathophysiology of the GI Syndrome

Depletion of the epithelial cells lining the lumen of the gastrointestinal tract
Intestinal bacteria gain free access to body
Hemorrhage through denuded areas
Loss of absorptive capacity

Phases of GI syndrome

Prodromal period: Severe nausea and vomiting, watery diarrhoea and cramps. Occurs within hours after exposure
Latent phase: Asymptomatic for hours to days, severe tiredness, weakness
Manifest illness phase: Return of severe diarrhoea, vomiting with fever; progression to bloody diarrhoea, shock and death without aggressive medical intervention
Systemic effects of GI syndrome

- Malabsorption ➔ malnutrition
- Fluid and electrolyte shifts ➔ dehydration, acute renal failure, cardiovascular collapse
- GI bleeding ➔ anaemia
- Sepsis
- Paralytic ileus ➔ vomiting, abdominal distention

Neurovascular syndrome (NVS)

At 30 Gy and above

- Endothelial cell damage
- Endothelial cells form the lining of larger blood vessels and the walls of capillaries
Neurovascular syndrome (NVS)

Prodromal period
• Burning sensation within minutes of exposure
• Nausea and vomiting within the first hour
• Loss of balance, confusion with prostration
• Hypotension, hyperpyrexia

Latent period
• Apparent improvement lasting several hours
• May be lucid and in no pain, but weak

NVS overt clinical picture

Rapid onset
Watery diarrhoea
Respiratory distress
Gross CNS signs
Wide pulse pressure
Hypotension
### ARS Neurovascular Syndrome

<table>
<thead>
<tr>
<th>Radiation dose (Gy)</th>
<th>Symptoms</th>
<th>Life threatening injuries</th>
<th>Death of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Loss of consciousness</td>
<td>5–12 days</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Neurovascular damage</td>
<td>2–5 days</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Triage of injured persons
Mass casualties, contaminated but uninjured people, and “worried well”

- A nuclear terrorism incident will create large numbers of contaminated people who are not injured, and worried people who may not be injured nor contaminated
- These people must be prevented from overwhelming Emergency Departments
- A triage site should be established outside the ED to intercept such people and divert them to appropriate locations.
  - Triage site should be staffed with medical and security personnel
  - Precautions should be taken so that people cannot avoid the triage center and reach the ED

Radiological triage: Quick “frisk”

112,000 persons monitored in Goiânia at Olympic stadium
Measurements of severity

- Prodromal effects
  - Time of onset
  - Degree of symptoms

- Hematological changes
  - Lymphocyte counts
  - Biological dosimetry

- Physical dosimetry
  - Attendant readable

Radiation dose under 5 Gy

- No *immediate* life-threatening hazard exists

- Prodromal symptoms of moderate severity
  - Onset >1 hour
  - Duration <24 hours
Fatal radiation

- Nausea and vomiting within minutes (during the first hour)
- Within hours (on the first day):
  - Explosive bloody diarrhoea
  - Hyperthermia
  - Hypotension
  - Erythema
  - Neurological signs

Triage categories of radiation injuries according to early symptoms

<table>
<thead>
<tr>
<th></th>
<th>Unlikely</th>
<th>Probable</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nausea</td>
<td>—</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Vomiting</td>
<td>—</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>—</td>
<td>—/+</td>
<td>—/+ to +++</td>
</tr>
<tr>
<td>Hyperthermia</td>
<td>—</td>
<td>—</td>
<td>—/+ to +++</td>
</tr>
<tr>
<td>Hypotension</td>
<td>—</td>
<td>—</td>
<td>+ to ++</td>
</tr>
<tr>
<td>Erythema</td>
<td>—</td>
<td>—</td>
<td>—/+ to ++</td>
</tr>
<tr>
<td>CNS Dysfunction</td>
<td>—</td>
<td>—</td>
<td>—/+ to ++</td>
</tr>
</tbody>
</table>
Guide for management of radiation injuries on the basis of early symptoms

| No vomiting | < 1 Gy | Outpatient with 5-week surveillance |
| Vomiting 2-3 h after exposure | 1-2 Gy | Surveillance in a general hospital (or outpatient for 3 weeks) followed by hospitalization |
| Vomiting 1-2 h after exposure | 2-4 Gy | Hospitalization in a hematological department |
| Vomiting earlier than 1 h, other severe symptoms, like hypotension, hyperthermia, diarrhoea, oedema, erythema, CNS symptoms | > 4 Gy | Hospitalization in a well equipped hematological or surgical department with transfer to a specialized centre for radiopathology |

Medical management of Acute Radiation Syndrome
Infection management: General principles

- Prophylaxis
  - Barrier/isolation
  - Gut decontamination
  - Antiviral agents
  - Antifungal agents
  - Pneumocystis prophylaxis
  - Early cytokine therapy
  - Close wounds
  - Avoid invasive procedures

- Direct therapy for infections
  - Culture specific antibiotics
  - Therapy for leukopenia
    - Cytokine administration

Isolation

Treat ARS patients with estimated whole-body dose >2 Gy in isolated rooms. Warn nursing personnel of the need for rigorous environmental control including:

- Laminar flow isolation
- Strict hand washing before and after patient care
- Surgical scrubs for staff
- Gowns, caps, gloves, masks for staff
- Double bagging of all disposables
Prevention of infection

- Reduction of microbial acquisition
  - Contact control (e.g. careful, frequent hand washing)
  - Low-microbial content food
  - Acceptable water supply
  - Air filtration to reduce aspergillus infection
- Reduction of invasive procedures (e.g. nasogastric tubes, catheters)

Cytokines
Advantages of cytokine therapy

- Bone marrow
  - increase production of white cells
  - stimulate production of colony forming units
  - decrease maturation time
- Mature cells
  - increase viability
  - prime neutrophils/macrophages
  - stimulate additional cytokine release
- Can act in synergy to increase hematopoiesis

Use of cytokines for treatment of ARS

- G-CSF and GM-CSF increase the rate of hemopoietic recovery in patients after radiation exposure and may obviate need for BMT, when stem cells are still viable. Interleukins (IL-1 and IL-3) act in synergy with GM-CSF
- Successfully used for radiation victims after Goiânia, San Salvador, Israel, Belarus and Istanbul accidents
Conventional therapy for thrombocytopenia

- Transfusion of platelets remains the primary therapy to maintain adequate platelet counts
- Requirement for platelet support depends on patient's condition. In irradiated patients with or without other major medical problems, platelets should be maintained at greater than 20,000/μL. If surgery is needed, platelet count should be greater than 75,000/μL

Therapy for anemia

- Transfusion of peripheral red blood cells (PRBCs) remains the primary therapy to maintain hemoglobin above 8 g/dl; PRBC transfusions should be irradiated
- Erythropoietin (Epo) anemia therapy: use of Epo after radiation injury is not recommended even though probably safe, as anemia is not generally life-threatening in this situation
Effect of shielding, dose inhomogenity and GM-CSF on bone marrow recovery

Indications for BMT

Physicians should consider allo-BMT if:
• a fully matched sibling donor is available
• the patient has an absolute lymphocyte count (ALC) <100/μl
• the radiation dose is unknown or likely to be 8-12 Gy
• no other injuries preclude survival or transplantation (e.g. severe burns)
• irradiation is not continuing from an internal source
Limitations of BMT

- Identification of histocompatible donors
- HLA typing in lymphogenic patients
- Need for additional immunosuppression
- Risk of graft versus host disease (GvHD)

BMT: Medical lessons learned from other radiological accidents

The Chernobyl and Soreq experiences show BMT has only a limited role in treatment of victims of radiation accidents, benefits very few exposed individuals and might be considered only for those:
- receiving doses in the range of 8-12 Gy
- uniformly distributed
- without serious skin injuries
- without severe internal contamination and conventional injuries
Criteria for choice of therapy

I

Therapeutic recommendations:

If the lymphocyte count during first week is 200-500 cells/µL, spontaneous recovery is possible.
Therapy: Isolation, antibiotics, supportive therapy including platelet infusion. Growth factors (cytokines) can be used.

Criteria for choice of therapy

II

If the lymphocyte count in the first week is below 200 cells/µL, stem cells are probably irreversibly damaged.
Therapy: Isolation, antibiotics, supportive therapy including platelet infusion. Additional growth factor (cytokine) therapy is the method of choice.
Criteria for choice of therapy

III

If the lymphocyte count in the first week is below 100 cells/µL, consider treatment with growth factors and BMT. Observe HLA compatibility at allogenic BMT. This therapy may be recommended for patients exposed to whole-body radiation doses exceeding 9 Gy.

Therapeutic support for severely irradiated patients: gastrointestinal syndrome

- Nausea, vomiting and diarrhoea associated with prodromal effects of radiation exposure most likely related to neurohumoral factors. Nausea and vomiting can be prevented/ameliorated by new generation of 5-HT3-receptor antagonists such as ondansetron and granisetron.
- Diarrhoea associated with prodromal and subacute phases of gastrointestinal injury most likely affects gastrointestinal motility and transport. Anticholinergics, metamucil, amphogel, and loperamide can be used.
Gastrointestinal syndrome

Generally, exposure to doses of 8-30 Gy causes reproductive death of mucosal crypt stem cells.

In spite of considerable medical advances in the treatment of radiation injury, no patient with full-scale gastrointestinal syndrome has yet survived!

The GI system and possibly lungs can limit survival probability, assuming patient survives bone marrow damage.

Review points 2

- Acute radiation syndrome is a complex of acute injury manifestations occurring after extensive exposure to high doses of ionizing radiation.
- Phases of acute radiation syndrome: prodromal, latent, manifest illness, recovery.
- Different ranges of whole body dose produce different manifestations of injury.
- Dose ranges producing the most characteristic manifestations: hematological, gastrointestinal, cardiovascular/central nervous system syndromes.
Review points 3

- Radiation doses in the cardiovascular/central nervous system syndrome range are *uniformly fatal* regardless of therapy.
- Doses in gastrointestinal syndrome range, which also produce life-threatening pulmonary effects, are usually fatal.
- Doses in the hematopoietic syndrome range are survivable. *Therapeutic goal:* lessen the severity of thrombocytopenia and neutropenia while minimizing and treating infection.

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Review points 4

- Cytokine therapy: is a powerful tool for treating patients with life threatening but survivable radiation injury.
- Consideration of peripheral stem cell transfusion and BMT should be reserved for patients with potentially survivable damage but whose bone marrow *does not respond* to cytokines.
Review points 5

- Because aggressive control of infectious agents is necessary, use selective gut decontamination, prompt therapy of neutropenic fever, prophylactic antiviral and antifungal agents, and stringent nursing environmental control
- Aggressive fluid, blood product, and symptomatic therapies are indicated

Local and chronic effects
Psychological effects
Reducing radiation exposure
Localized radiation effects:
Organ system threshold effects

- **Skin - No visible injuries < 1 Sv**
  - Erythema, epilation >5 Sv
  - Moist desquamation >18 Sv
  - Ulceration/Necrosis >24 Sv

- **Cataracts**
  - Acute exposure >2 Sv
  - Chronic exposure >6 Sv

- **Permanent Sterility**
  - Female >2.5 Sv
  - Male >3.5 Sv

Special considerations

- High radiation dose and trauma interact synergistically to increase mortality
- Close wounds on patients with doses >1 Sv
- Wound, burn care and surgery should be done in the first 48 hours or delayed for 2 to 3 months (>1 Sv)

<table>
<thead>
<tr>
<th>Emergency Surgery</th>
<th>Hematopoietic Recovery</th>
<th>Surgery Permitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 - 48 Hours</td>
<td>~3 Months</td>
<td>After adequate hematopoietic recovery</td>
</tr>
</tbody>
</table>
Chronic health effects from radiation

- Radiation is only 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 Sv
- A dose of 0.05 Sv increases the risk of fatal cancer by ~ 0.2%
- A dose of 0.25 Sv increases the risk of fatal cancer by ~ 1%

Psychological effects

- 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
- Establish centers to provide psychological support to such people
- Set up centers in the hospitals to provide psychological support for staff
Radiation protection: Reducing radiation exposure

**Time**
Minimize time spent near radiation sources

<table>
<thead>
<tr>
<th>Distance</th>
<th>Rate</th>
<th>Stay time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ft</td>
<td>12.5 R/hr</td>
<td>24 min</td>
</tr>
<tr>
<td>2 ft</td>
<td>3.1 R/hr</td>
<td>1.6 hr</td>
</tr>
<tr>
<td>5 ft</td>
<td>0.5 R/hr</td>
<td>10 hr</td>
</tr>
<tr>
<td>8 ft</td>
<td>0.2 R/hr</td>
<td>25 hr</td>
</tr>
</tbody>
</table>

**Distance**
Maintain maximal practical distance from radiation source

**Shielding**
Place radioactive sources in a lead container

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Protecting staff from contamination

**Universal precautions:**
- Survey hands and clothing with a 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 EMS staff will receive large radiation doses from treating contaminated patients
**Decontamination techniques**

**Monitoring a Contaminated Patient**

![Monitoring a Contaminated Patient](image)

**Contaminated Patient after removal of outer clothing and shoes**

![Contaminated Patient](image)

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**Treatment of internal contamination**

- Is 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

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Treatment</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cesium-137</td>
<td>Prussian blue</td>
<td>Oral</td>
</tr>
<tr>
<td>Iodine-125/131</td>
<td>Potassium iodide</td>
<td>Oral</td>
</tr>
<tr>
<td>Strontium-90</td>
<td>Aluminum phosphate</td>
<td>Oral</td>
</tr>
<tr>
<td>Americium-241/Plutonium-239/Cobalt-60</td>
<td>Ca- and Zn-DTPA</td>
<td>IV infusion, nebulizer</td>
</tr>
</tbody>
</table>
**Prussian blue therapy for cesium decorporation**

![Schematic representation of PB action in the body](image)

**Review points 6**

- 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