RADIATION INJURIES

FUNDAMENTALS OF RADIATION PHYSICS:

NONIONISING AND IONISING RADIATION:

- Radiation is energy emitted from a source
- Nonionising radiation does not carry enough energy to remove an electron from an atom → UV, visible light, infrared, microwave, radiowaves
- Ionising radiation → has sufficient energy to displace electrons from atoms, causing them to be charged or ionised as they pass through matter → alpha, beta, gamma particles, neutrons, x-rays
- Types of ionising radiation are outlined below:

Table 11-1 Types of Radiation

Type (Symbol)	Charge	Penetration	Shield	Hazard	Source
Alpha	+2	Few centimeters in air	Paper, keratin layer of skin	Internal contamination only; requires special detection devices	Heavy radioisotopes (e.g., plutonium, uranium, radon)
Beta	+1	~8 mm into skin	Clothing	External (skin) and internal contamination	Most radioisotopes decay by beta followed by gamma emission
Neutron	0	Variable	Material with high hydrogen content	Whole-body irradiation	Nuclear power plants, particle accelerators, weapons assembly plants
Gamma and x-rays	0	Several centimeters in tissue	Concrete, lead	Whole-body irradiation	Most radioisotopes decay by beta followed by gamma emission

BIOLOGIC EFFECT OF IONISING RADIATION:

- Effect occurs at the cellular level → high levels may directly cause cell death, but more commonly, lower levels interrupt the cell's reproductive process by damaging its mitotic capability, making the cell unable to divide
- Short-lived cells, such as bloods cells, are quickly depleted, and injury may become evident before new cells are generated
    - Longer-lived cells, such as the lens of the eye, regenerate slowly and injury may not become apparent for years after exposure
    - In general, poorly differentiated cells and cells with a short life span and high turnover rate are most vulnerable to the detrimental effects of radiation
    - Rapidly proliferating cells, such as HAEMATOPOIETIC, GI AND REPRODUCTIVE SYSTEMS, are more radiosensitive than the more slowly dividing cells of the nervous and musculoskeletal systems

MEASURING RADIATION:

UNITS OF MEASURE:

- Can be measured as activity, exposure or dose → see below

Table 11-2 Radiation Units of Measure			
Description	**Conventional Units**	**SI Unit**	**Conversion**
Activity	Curie	Becquerel	1 Bq ~2.7 x 10^{11} Ci
Units of activity describe the amount of radioactivity present.			1 Ci ~3.7 x 10^{10} Bq
Exposure	Roentgen	Coulomb per kilogram	1 R = 2.58 x 10^{4} cP/kg
Units of exposure measure the amount of x-ray or gamma radiation that produces a given number of ionizations in air.			
Absorbed dose	rad	Gray	1 rad = 0.01 Gy
Units of absorbed dose can be applied to any type of radiation and reflect the energy imparted to matter.			1 Gy = 100 rad
Dose equivalent	Roentgen equivalents man	Sievert	1 rem = 0.01 Sv
Units that provide a common scale of measure for the different types of radiation.			1 Sv = 100 rem

- Allowed annual dose of radiation is 3.0 millisieverts (mSv) and the annual dose above background radiation that is considered safe is 1mSv/year
- See below for dose levels:

Table 11-4 Selected Approximate Levels of Radiation Exposure	
Natural background radiation	300 mrem/y (U.S. average)
Chest x-ray (effective dose)	10 mrem
Abdominal x-ray	100 mrem
Lumbar spine x-ray	70 mrem
CT head	200 mrem
CT chest	800 mrem
CT abdomen or pelvis	1000 mrem
Air travel London–New York	4 mrem each way
Annual radiation dose limit (public)	100 mrem
Lethal dose in 50% of exposed subjects within 60 d (4.5 Gy)	450,000 mrem (450 rad*)

LETHAL DOSE OF RADIATION:

- LD 50/60 from exposure to ionising radiation is defined as the dose of ionising radiation that will result in the deaths of 50% of exposed population at 60 days → 4.5gray, 450 rad
    - This value assumes intensive medical therapy is provided, including antibiotics, blood products and reverse isolation

CLINICAL EFFECTS OF RADIATION:

LOCAL RADIATION INJURY:

- Majority of accidents result in partial-body exposure with local radiation damage
- In contrast to whole-body irradiation, partial-body irradiation rarely causes systemic manifestation and the extent and course of cutaneous involvement is dose-dependent → transient erythema, hyperesthesia and itching initially → progresses to ulceration or desquamation by 4 weeks
- Similar to thermal burns, but they differ in that cutaneous radiation injury may be associated with waves of transient erythema as well as delayed onset of pain, followed by a more prolonged and severe pain

WHOLE-BODY IRRADIATION/ACUTE RADIATION SYNDROME:

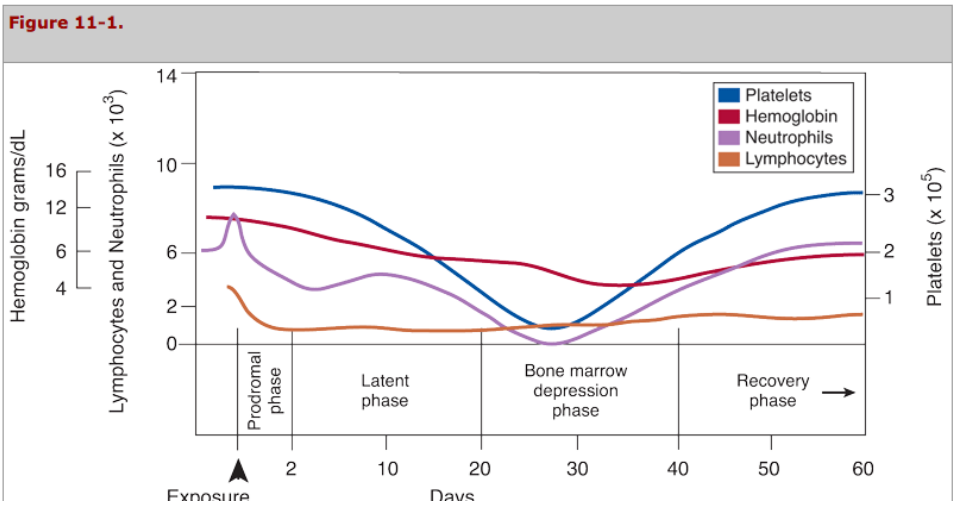
- Develop when a significant portion of the body is exposed to a high level of penetrating radiation over a short period of time (typically <24 hours) → collectively referred to acute radiation syndrome → a whole body gamma dose of >2 gray (200 rad) is primary cause

Table 11-5 Acute Radiation Syndrome

Approximate Dose	Onset of Prodrome	Duration of Latent Phase	Manifest Illness
>2 Gy (200 rad)	Within 2 d	1–3 wk	Hematopoietic syndrome with pancytopenia, infection, and hemorrhage; survival possible
>6 Gy (600 rad)	Within hours	<1 wk	GI syndrome with dehydration, electrolyte abnormalities, GI bleeding, and fulminant enterocolitis; death likely
>20–30 Gy (2000–3000 rad)	Within minutes	None	Cardiovascular/central nervous system syndrome with refractory hypotension and circulatory collapse; fatal within 24–72 h

- There are FOUR DISTINCT PHASES seen in unfolding of acute radiation syndrome (ARS):
    - PRODROMAL PHASE → transient period of self-limiting symptoms, the acuity of onset and duration of this phase are directly related to the dose received. Characterised by AUTONOMIC RESPONSE → anorexia, N+V, diarrhoea (high doses)
    - LATENT PHASE → symptom-free period that follows the resolution of the prodromal phase → shorter latent phase relate to higher levels of dose received
    - MANIFEST ILLNESS PHASE → this is divided into three dose-dependent SUBSYNDROMES (in ascending order of severity, haematopoietic, GI and CVS/CNS syndromes)

- MANIFEST ILLNESS:
  - HAEMATOPOIETIC SYNDROME:
    - First organ system to manifest injury at doses above 1.5 to 2 Gy
    - Radiation destroys circulating lymphocytes and damages stem cells in the bone marrow and lymphatic system → the rapid decline in lymphocytes is a hallmark of the haematopoietic syndrome and is one of the best early indicators of the extent of radiation injury



Typical haematologic course after sublethal exposure to total-body irradation

    - This syndrome results in pancytopaenic and immunosuppression with subsequent HAEMORRHAGE AND INFECTION as the principal causes of morbidity and mortality
  - GI SYNDROME:
    - Doses above 6-7 Gy
    - Onset of nausea, vomiting and often diarrhoea within hours of exposure then latent period of up to one week → reappearance of GI symptoms then occurs with severe nausea, vomiting, diarrhoea and abdominal pain → DAMAGE OF INTESTINGAL MUCOSAL BARRIER WITH MASSIVE FLUID LOSSES RESULTING IN PROFOUND VOLUME LOSS AND ELECTROLYTE DISTURBANCES →
    - Denuded mucosa allows enteric flora to disseminate into the bloodstream and results in FULMINANT ENTEROCOLITIS
    - Few documented cases in humans, all of which have been fatal
  - CARDIOVASCULAR AND CNS SYNDROME:
    - Doses of 20-30 Gy
    - Presents with immediate prostration, nausea, vomiting and explosive bloody diarrhoea as well as hypotension
    - Alterations in consciousness, including lethargy, disorientaiton, ataxia and convusions occur within hours after exposure
    - Hypotension is persistent and refractory to all treatment
    - Lymphocyte count promptly falls to near-zero levels
    - UNIVERSALLY FATAL within 24-72 hours → predominantly due to circulatory collapse

RADIATION EVENT MANAGEMENT:

ADVANCE PLANNING → CRUCIAL. All pre-hospital providers should have plan for evacuation of victims from a radiation disaster

PREHOSPITAL EMERGENCY MEDICAL MANAGEMENT:

- Emergency responders should establish incident command to identify the hazard
- Personal protective equipment, respiratory protection provided as per protocol
- Lifesaving medical interventions are administered and transportation of seriously injured victims is not delayed, even if the patient is contaminated
- If patient stable → remove clothing and decontaminate and perform radiation monitoring
- NOTIFY LOCAL ED → if contamination is unknown,patient should be assumed to be contaminated and undergo decontamination measures

TRIAGE AND TREATMENT PHILOSOPHIES:

- Triage as per acute medical condition and not specifically on radiation exposure
- Radioactive contamination is never immediately life-threatening, thus surveying or decontamination should never supersede lifesaving medical intervention

PATIENT MANAGEMENT AND TREATMENT:

DECONTAMINATION OF EXTERNALLY CONTAMINATED PATIENTS:

- A patient is externally contaminated when radioactive materials are physically deposited onto the patient's skin or clothing
- The radiation dose from external contamination to either the patient or the medical staff is rarely significant → spreading the contamination in the environment and the potential of internalisation are the main hazards with external contamination
- For those surveying positive for radiation → wounds and body orifices should be irrigated first because of the potential for systemic absorption

TREATMENT OF LOCAL RADIATION INJURY:

- ED care of localised cutaneous radiation injury is limited to analgesia, routine burn care and if indicated → surgical referral.
- These patients should be monitored closely fro haemorrhage, infection and necrosis

TREATMENT OF WHOLE-BODY IRRADIATION:

- In most cases, the patient who has been exposed to an external source of penetrating radiation IS NOT RADIOACTIVE OR CONTAMINATED
- Treatment of the irradiated patient in the ED is directed toward alleviating the symptoms of the prodromal phase

    - 5HT3 antagonists (ondansetron) are most effective at controlling GI symptoms. Do not give prophylactically as time of onset of vomiting is important in determining radiation dose
    - In those with documented high doses → comfort care should be prioritised as medical care will be futile
        - Survival is possible for those with lower radiation doses resulting in the haematopietic form of ARS (bone marrow transplant may assist)
- Biologic dosimetry:
    - Time of onset of all symptoms, especially nausea and vomiting should be carefully observed
    - The earliest lab indicator of biologic damage from radiation is marked decrease in peripheral lymphocytes → often within 8 hours of exposure
- The ultimate long-term goal is to provide support during the period of deficient defenses against infection and haemorrhage until marrow recovery occurs
    - Supportive treatment may include IV fluids, blood produces, TPN as well as prophylactic antibiotics and antifungals
    - Anaemia, granulocytopaenia and thrombocytopaenia can be expected within one month after significant radiation exposure
        - Haematopoietic colony-stimulating factors and stem cell transplants are being used to combat bone marrow suppression

INTERNALLY CONTAMINATED PATIENTS:

- Radioactive material gains entry into the body by three principal routes → inhalation, ingestion or absorption from contaminated mucous membranes or abraded skin
- Identification of the specific radionuclide is important for determining the method of treatment (see below):

Table 11-9 Commonly Treated Forms of Internal Contamination

Radionuclide	Treatment	Mechanism of Action	Usual Administration*
Iodine	Potassium iodide	Blocks thyroid uptake	130 milligrams PO for adults
Plutonium	Ca-DTPA or Zn-DTPA	Chelation	1 gram in 250 mL NS or 5% dextrose in water over 60 min
Tritium	Water	Dilution	Oral: 3–4 L a day for 2 wk
Cesium	Prussian blue	Decrease GI uptake	1 gram in 100–200 mL water three times a day for several days
Uranium	Bicarbonate	Alkalinization of urine	2 ampules in 1 L NS at 125 mL/h

- Once radioactive material crosses into the extracellular fluid, incorporation has occurred and elimination is more difficult → decorporation include blocking agents, isotopic dilution, chelation

PRENATAL EXPOSURES:

- After 2 weeks' gestation, organogenesis begins and the embryo is at risk of congential malformations → the risk of injury is greatest for the particular organ system that is under development at the time of radiation exposure
    - After 7 weeks, major organogenesis is complete (except CNS)
    - Data derived from Japanese atomic bomb survivors suggest the most common in utero injuries are related to the CNS → particularly microcephaly and mental retardation