

Radiation incidents

Ionising radiation

- Ionising radiation (invisible, odourless and tasteless) is a form of energy emitted spontaneously by radioactive materials
- Natural radiation is all around us: in air, from cosmic rays; in the earth and building materials; and in food and water – and all of this makes up the **background radiation** to which we are all exposed all the time, from conception to death
- Man-made sources of radiation and radioactive materials are used in medicine (diagnostic imaging, radiotherapy), research, widely in industry (nuclear power stations, mining, food irradiation), industrial radiography (eg of pipes, buildings, baggage), and for many other uses including nuclear fuel and nuclear weapons
- Alpha particles, beta particles, gamma rays, X-rays and neutrons are all forms of ionising radiation
- Alpha and beta particles and gamma rays are produced as radioactive materials decay; X-rays are generally man-made
- **Alpha** particles are heavy and highly charged, and interact strongly with atoms. As a result, they lose momentum rapidly, can travel only very short distances and cannot penetrate human skin. Alpha emitters are hazardous only when inhaled, ingested, injected or absorbed (eg through a wound)
- **Beta** particles are also charged, but interact less strongly than alpha particles, so travel further and penetrate more: they can penetrate the dermis. Clothing, including standard PPE, provides some protection against them. They can cause radiation skin injury on prolonged exposure but are hazardous to internal organs only when inhaled, ingested, injected or absorbed (eg through a wound)
- **Gamma** rays and **X-rays** are uncharged, so do not interact directly with atoms, and travel many metres in air. They easily penetrate the human body, causing organ damage. Their effects can be attenuated by concrete or lead shielding
- **Neutrons** are uncharged, travel far and penetrate everything (except thick layers of concrete and water), and are highly damaging, but only likely to be present in the very early stages of a nuclear detonation or accident

Exposure and contamination

- An **exposure** occurs when all or part of the body is irradiated
- Three key factors affect exposure: **duration, distance and shielding**. If the exposure time is halved, the dose is halved. The inverse square law applies to distance: doubling the distance between the source and the body reduces the dose by a factor of 4; trebling the distance between the source and the body reduces the dose by a factor of 9, and so on
- A person is **contaminated** when radioactive material is deposited on skin and/or clothing (**external contamination**), or into the body (**internal contamination**) by inhalation, ingestion (hand-to-mouth, food, drink), or absorption via a wound
- In the same way that a patient who has had a CT scan or X-ray presents no risk to others, radiation safety precautions are **NOT** needed for patients who have been exposed to radiation but not contaminated
- External contamination – usually dust or particulate matter – is readily removed by **decontamination**
- Even if a patient is contaminated, the risk of long term health effects for a health professional who uses standard precautions is likely to be tiny, if not trivial
- **Radiation is readily detectable with equipment, and contamination is easily measurable. Medical physics, nuclear medicine departments, and front line services have equipment for detecting beta and gamma radiation, and people trained to use it**
- **In a radiation incident:**
 - Triage and treat life-threatening injury before decontamination; if the patient's clinical condition permits, decontaminate first, and then treat
 - If trauma cases require surgery, perform as soon as possible (and certainly within 48 hours) if dose more than 1 Sievert, or await marrow recovery

Measuring radioactivity and radiation

- Radioactivity (and contamination by radioactive material) is measured in becquerels (1Bq = 1 disintegration per second)
- The **absorbed dose** of radiation (the amount of energy absorbed by per unit mass of tissue) is measured in gray (Gy); 1Gy = 1 joule/kg of tissue
- Different types of radiation have different effects on human tissue (gray for gray, alpha particles and neutrons are more damaging than beta particles, gamma rays or X rays in terms of the risks of cancer or of heritable genetic defects), so the absorbed dosage is multiplied by a radiation weighting factor to account for this. This gives the **equivalent dose** (of an organ or tissue), measured in Sievert (Sv). For X-rays and gamma rays, and beta particles, the weighting factor = 1, so: 1 gray = 1 sievert = 1000 milli sievert
- Some organs are more radiosensitive than others (eg bone marrow is more sensitive than thyroid), and exposures are rarely uniform. Weighting the equivalent doses received by different organs and tissues during an exposure to allow for each organ's radiosensitivity, and then summing the results, gives the **effective dose**
- An estimate of the **whole body dose** is helpful in estimating long term cancer risk

Radiation doses and dose limits

- Chest X-ray: 20 micro sievert
- Average annual background radiation in UK: 2.2 milli sievert (2,200 micro sievert)
- Annual effective dose limit for member of the public: 1 milli sievert (1,000 micro sievert)
- Annual effective dose limit for radiation worker: 20 milli sievert (20,000 micro sievert)
- Acute radiation sickness (whole body single dose): 1 sievert and above
- LD50/60 (dose killing 50% of those exposed within 60 days if whole body dose): ~4.5 sievert

Acute radiation syndrome (ARS)

Think of radiation exposure

- In any newly diagnosed bone marrow depression (leucopenia: infection; thrombocytopenia: bleeding gums, nosebleeds, bruising), *or*
- 'Burns', erythema, or bullae with no history of heat or chemical exposure, *or*
- Sudden, rapid, hair loss **especially** if there is a relevant occupational history or unexplained nausea / vomiting +/- diarrhoea 2-4 weeks before onset, *and*
- When dealing with **ANY** incident involving a bomb or other intentionally placed explosive device

Overview

- All nuclear and other major sites in the UK have emergency plans and exercise and update them regularly
- On average, there is one serious radiation incident – resulting in death or major radiation injury – in the world each year
- Incidents at major sites will be recognised and managed according to existing plans. However, in the last 50 years there have been more than 200 incidents involving lost, stolen or misused ('orphan') sources (eg Lilo, Georgia, 1996-97, 11 trainee border guards exposed to 12 hidden, abandoned, sources had signs and symptoms of radiation injury, but the cause remained unrecognised by doctors for months). The first sign of a problem may be the presentation of a case to an emergency department
- Other concerns include the possibility of exposure from a 'dirty bomb' (conventional explosive used to disperse radioactive material), a low yield improvised nuclear device (IND), or a deliberately hidden source of radiation

Acute radiation syndrome

- Many radiation accidents cause partial body injury (early erythema followed by bullae, and, if severe, ulceration and necrosis, often of the hands) and may not be associated with ARS
- ARS follows a **large, usually** external exposure of **all** (or most) of the body to **penetrating** radiation (gamma rays, high-energy X-rays, neutrons) in a **short** time (seconds)
- Symptoms of ARS occur in a four-phase sequence: prodromal phase → latent period → illness → recovery/death
- As the radiation dose increases, the prodromal and latent periods shorten, and the severity of illness, and mortality, increase. Major trauma and radiation exposure interact synergistically on mortality
- Initial symptoms of ARS are non-specific, and rarely immediately life-threatening; treatment of other injuries takes priority
- If, in the first 6 hours after a suspected exposure, there are no symptoms of exposure (eg nausea, vomiting), serious ARS is unlikely

Symptoms and signs

Dose: less than 1 sievert	Dose: 1 sievert – 8 sievert	Dose: more than 6 sievert – 20 sievert	Dose: more than 20 sievert
<p><i>Usually asymptomatic</i></p> <ul style="list-style-type: none"> • Symptoms mild (or absent) • Episodic nausea, vomiting in first 48 hours in 1%-10% • Mildly depressed WBC at 2-4 weeks • No foetal effects if effective dose less than 100 milli sievert (100,000 micro sievert) • Counselling needed if pregnant and effective dose more than 100 milli sievert (100,000 micro sievert) 	<p><i>Haematopoietic syndrome</i></p> <ul style="list-style-type: none"> • Anorexia, nausea, vomiting, fatigue: 1-4 hours after exposure, timing and severity dose-related • Latent period: 2 days-4 weeks • Bone marrow depression: leucopenia – infection; low platelets – bleeding, bruising • Serial lymphocyte counts in first 48 hours predict severity • 3-4 sievert: hair loss at 2-3 weeks • LD 50/60 is ~4.5 sievert without treatment 	<p><i>Gastrointestinal syndrome</i></p> <ul style="list-style-type: none"> • Early nausea, vomiting, diarrhoea, anorexia, fatigue • Latent period: hours-1 week • Severe gastrointestinal symptoms (fever, abdominal pain, cramps, watery diarrhoea, haemorrhage, electrolyte imbalance, dehydration) coupled with bone marrow depression • LD100 is about 10 sievert, death usually within 2 weeks 	<p><i>CNS/CVS syndrome</i></p> <ul style="list-style-type: none"> • Almost immediate projectile vomiting, explosive bloody diarrhoea, headache, collapse, confusion, loss of consciousness, agitation, burning sensation on skin • May be lucid interval (hours) • Neurological and cardiovascular symptoms predominate: convulsions, coma, hypotension, shock • Death within 2-3 days

Management

- Stabilise airway, breathing, circulation, and initiate Rx of any life-threatening conditions (trauma, thermal burns, lung injury)
- Assume all patients are contaminated until you know that they are not: make sure that you, and the area you work in, are protected from possible contamination (see PPE, and radiation facts); reassign pregnant staff; do not handle unfamiliar objects or embedded fragments (eg shrapnel) directly: use tongs or forceps and place in lead-lined container; remember distance & inverse square law
- Assess contamination using contamination meter. If present, decontaminate, and presume patient may also be internally contaminated
- Removing patient's clothing (bag, label and store it securely) can reduce external contamination by as much as 90%
- Symptomatic treatment for nausea, vomiting (cyclizine, ondansetron), diarrhoea, pain (opiates), and erythema; monitor and replace fluid loss
- To help assess the dose of radiation received: obtain and record as much information as possible about type and extent of exposure (what? where? when? for how long?); record date, time of onset, and severity of all symptoms and signs; record (body-map, or photograph) sites of any erythema or local injury
- Samples: baseline FBC with serial absolute lymphocyte counts 3-4 hourly for first 12 hours after acute exposure, then 6 hourly for 48 hours; HLA typing (BEFORE transfusing – use irradiated blood products if ARS possible); pregnancy test; nasal swabs or nose blows x 2; chromosome analysis (7ml venous blood taken 24 hours post exposure into lithium heparin tube); if contamination confirmed, 24 hour urine and faeces
- Seek expert advice early on formal dose assessment and management of internal contamination (medical physics, nuclear medicine, HPA RPD, MoD); infection-prevention regimes, G-CSF and GM-CSF, stem cell/platelet transfusions (haematology, oncology, INM)
- If dose more than 1 sievert and surgery required, do as early as possible (and certainly within 48 hours of exposure) or wait for marrow recovery

See also

- Radiation facts, decontamination, personal protective equipment, emergency contacts