

Disorders due to ionizing radiation

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IONISING RADIATION

DEFINITION

Radioactivity is the property of unstable nuclides of disintegrating spontaneously.

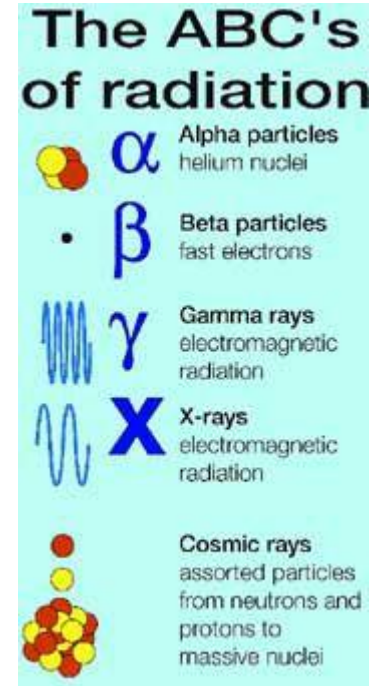
Ionizing radiation - radiation having sufficient energy to pull away electrons from atoms that they hit, so to produce ions.

IONISING RADIATION

TYPES OF IONIZING RADIATION:

Alpha particle: a nucleus consisting of 2 neutrons and 2 protons. **Shielding:** from 4 cm to 8 cm of air or a sheet of paper

Beta particle: a negatively charged particle emitted from the nucleus with mass and charge equal to an electron. **Shielding:** from 4 cm to 10 cm of air depending of the energy of the beta particle, a thin piece of aluminium or 1 cm of plexiglas, protective glasses, layer of clothing



Gamma radiation: is electromagnetic radiation emitted by the nucleus during a nuclear reaction. Gamma rays have no mass and no charge. **Shielding:** several cm thick piece of lead or concrete

Neutron radiation: neutron is a corpuscular radiation, has no electrical charge, produced by nuclear fission, it disappears when fission is stopped. **Shielding:** fission neutrons are very high energy with high initial speed, so are highly penetrating. Neutron radiation is attenuated by light materials such as water or by concrete. Neutrons can be captured by boron.

RADIATION SOURCES

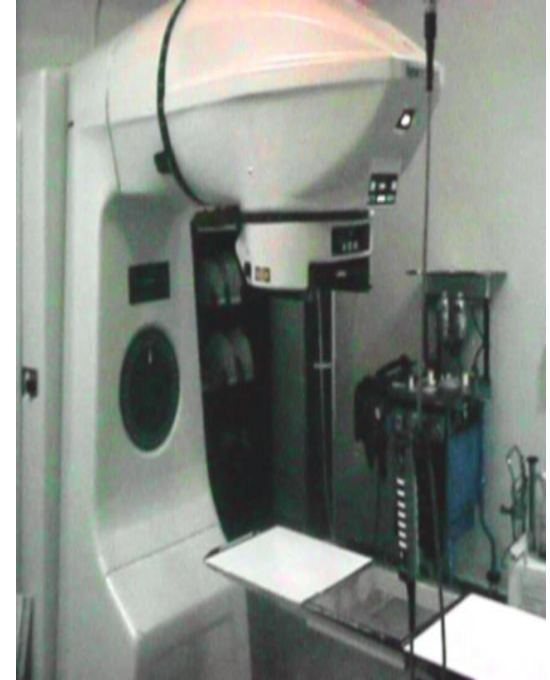
➤ Nuclear industry (nuclear reactor, nuclear weapons, radioactive wastes)

➤ Uranium industry (Rn decay products)

➤ Non-nuclear industrial and research facilities (sterilization, radiography, gauging: **Co-60**, Cs-137, Ir-192, Am-241)

➤ Medical facilities (radiology, radiotherapy, nuclear medicine)

sealed or unsealed source (particle accelerator, X-ray generator, Co-60, Cs-137, I-131)



RADIATION UNITS

Activity (A) = the unit Becquerel - Bq (s^{-1}) = rate of decay per second

Absorbed dose (D) = the unit Gray - Gy (J.kg^{-1}) = quantity of radiation absorbed per unit of mass

Equivalent dose (H) - the unit Sievert - Sv (J.kg^{-1}) = absorbed dose in terms of estimated biologic effect relative to an exposure of 1 roentgen of x-ray or gamma radiation; take into account the biological efficiency of different radiation by a radiation weighting factor

$$H = D \times W_r$$

Type of radiation	weighting factor W_r
Beta and gamma	1
Neutron	5-20
Alpha	20

EXTERNAL BIOLOGIC EXPOSURE

- **External biologic exposure to x-rays, gamma rays and proton and neutron radiation results in high absorption and damage**
 - **beta particles penetrate skin poorly**
 - **alpha particles do not penetrate at all**
- Skin contamination with beta particles can result in acute radiation dermatitis (ARD)**

INTERNAL BIOLOGIC EXPOSURE

Internal biologic exposure to alpha or beta particles by inhalation, ingestion or diffusion through the skin (tritium) or through a wound can result in serious acute or delayed injury.

In any radiological accident the most important step is the assessment of the absorbed dose.

In some cases it requires a reconstruction of the accident.

In the case of internal contamination, which may occur by inhalation, ingestion, or wounded skin, physical measurement includes thyroid monitoring, whole body counting, gamma camera measurement, and blood and excreta analysis.

In the case of external contamination, physical measuring equipment such as surface contamination monitor can be used and swab samples have to be taken from body surfaces and orifices and measured.

Health effects caused by ionizing radiation

- ❑ Deterministic effects

- ❑ Stochastic effects

DETERMINISTIC EFFECTS (THRESHOLD EFFECTS – EARLY AFFECTS)

Deterministic effects are caused by cell killing

- ✓ **threshold dose is high**
- ✓ **latency time is generally short**
- ✓ **effect is certain if dose is high enough**
- ✓ **severity of effects increases with dose**
- ✓ **dose response curve is sigmoid**

DETERMINISTIC EFFECTS

- **acute radiation syndrome**
- **acute and chronic radiation dermatitis**
- **cataract**
- **sterility**
- **radiation in pregnancy**

ACUTE RADIATION SYNDROME - ARS

ARS is consequent to heavy external exposure of all or part of the body to ionizing radiation.

The clinical presentation and severity of illness are determined by the dosage, body distribution and duration of exposure.

The most radiosensitive are tissues with the most rapid cellular turnover: **reproductive, haematopoietic and gastrointestinal tissues.**

ACUTE RADIATION SYNDROME - ARS

PATIENTS PASS THROUGH 4 PHASES:

1) PRODROMAL MANIFESTATION OF THE ARS

prodromal symptoms are not very specific - fatigue, anorexia, nausea, headache, vomiting

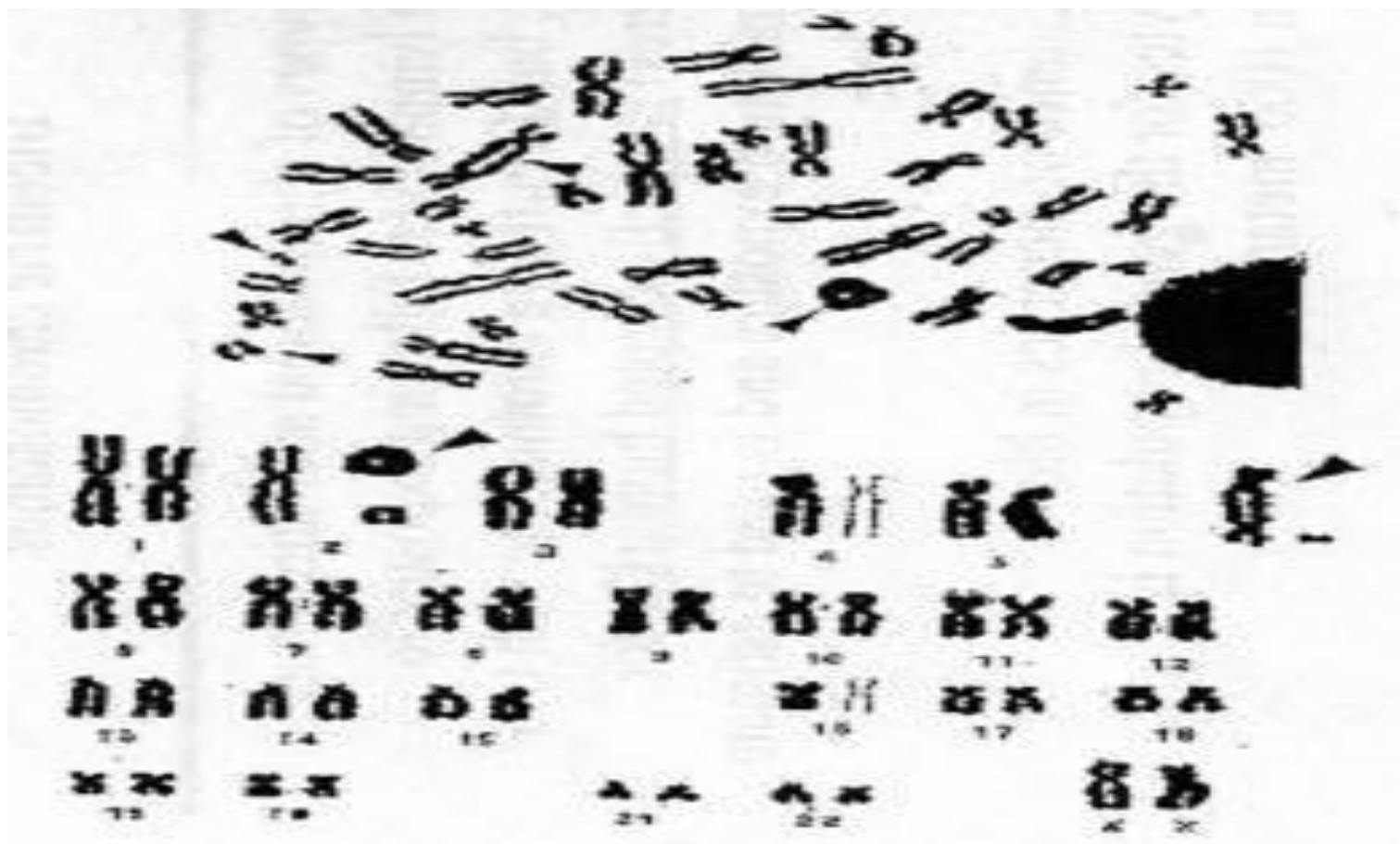
2) LATENT PHASE OF THE ARS - no symptoms

3) CRITICAL PHASE OF THE ARS - main illness

4) RECOVERY PHASE OF THE ARS OR DEATH

Diagnosis is confirmed by clinical findings a laboratory analysis: samples of blood to be taken in the hospital for cytogenetic analysis, for analysis peripheral blood count, and biochemical analysis.

CYTOGENETIC ANALYSIS



ACUTE RADIATION SYNDROME OF MILD DEGREE **EXPOSURE TO DOSES 0,25 – 2 Gy**

Nausea, vomiting, fatigue, headache and abnormal laboratory findings may be seen

Slight lymphopenia occurred within a few days, followed by mild granulocytopenia and thrombocytopenia at 4 weeks

Therapy: only symptomatic, haematological surveillance

Prognosis: excellent

Time of recovery: several weeks

Incidence of death: none

HAEMATOPOIETIC FORM

EXPOSURE TO DOSES 3 – 6 Gy

ARS OF MODERATE DEGREE

Prodromal phase: headache, anorexia, nausea, vomiting begin within 2 – 6 hours

After latency period 1 - 3 weeks occurs bone marrow aplasia - severe leukopenia, thrombocytopenia, anaemia, haemorrhage, purpura, infection, epilation, hair loss, secondary erythema

Therapy: Antibiotics, bone marrow transplantation

Prognosis: good

Time of recovery: 1- 12 months

Incidence of death: 60 - 80 %

Cause of death: haemorrhage - infection

GASTROINTESTINAL FORM

EXPOSURE TO DOSES 6 - 10 Gy

SEVERE AND VERY SEVERE DEGREE OF ARS

Prodromal phase - early symptoms begin within 30 minute or 1 hour (anorexia, nausea, vomiting)

After latency period within 4-6 days occurs radiation induced enterocolitis - fever, diarrhoea, disturbance of electrolyte balance, later severe lymphopenia, granulocytopenia, thrombocytopenia, purpura, **haemorrhage, infection**.

Treatment: parenteral nutrition, bone marrow transplantation

Incidence of death: 80 - 100 %

Cause of death: enterocolitis, haemorrhage, infection

CENTRAL NERVOUS SYSTEM FORM

EXPOSURE TO DOSES 50 Gy

LETHAL DEGREE OF ARS

Symptoms begin immediately or within 1/2 hour - anorexia, vomiting, fever, apathy, lethargy, somnolence (vasculitis, meningitis, encephalitis, brain edema), tremor, convulsions, coma, disturbance of electrolyte balance, massive fluid and blood loss

Treatment: symptomatic, sedatives

Prognosis: death within hours

Incidence of death: 100 %

Cause of death: circulatory collapse, cerebral edema

ACUTE RADIATION DERMATITIS - ARD

- Single external exposure of isolated skin and body parts to ionizing radiation will result in ARD.**
- Time of onset of clinical signs of skin injury (local radiation injury) depending on the dose received.**
- Early and transitory erythema begin within 48 or 1 hour after exposure depending on the dose received.**
- Latency period lasting more than 1 or 3 weeks.**

ACUTE RADIATION DERMATITIS - ARD

DOSE

No signs	0 - 3 Gy
Epilation and hair loss	>3 Gy
Secondary erythema	3 - 10 Gy
Dry desquamation	10-15 Gy
Wet desquamation, blisters	15 - 20 Gy
Ulceration	>20 Gy
Necrosis	>25 Gy

Therapy: conservative, surgery required for secondary complications (necrosis, gangrene) necrectomy, skin transplantation, amputation

CHRONIC RADIATION DERMATITIS

Caused by repeated doses of external exposure of skin

Clinical findings: the skin is dry, smooth, shiny, thin and there are signs of teleangiectasia, atrophy or hypertrophy and diffuse pigmentation

- the nails are brittle and striated
- may occur skin keratoses or cancers

Therapy: conservative, surgery required for skin cancers

CHRONIC RADIATION DERMATITIS AND FINGER LOSS

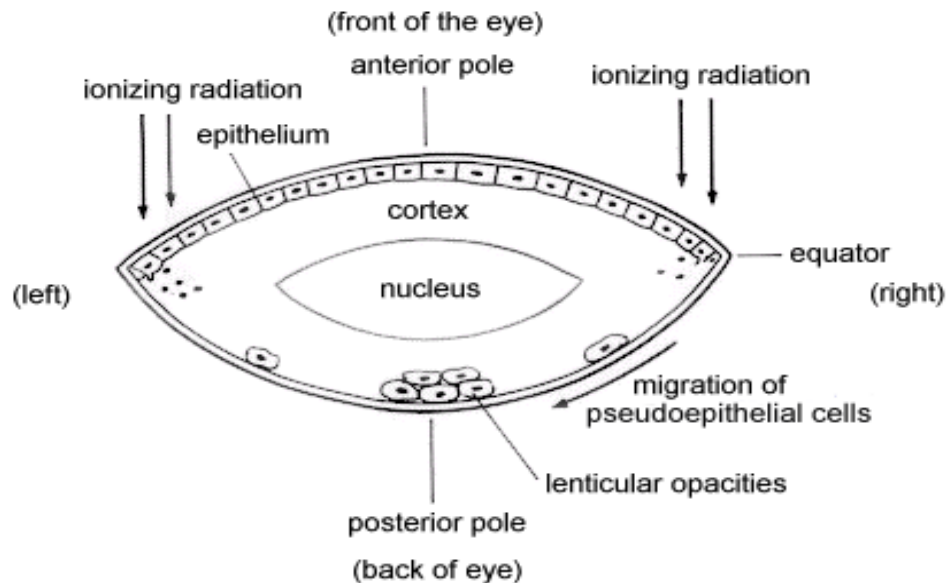


CATARACT

- single dose about 1,5 Gy is developing the cataract within 6 months
- **HOWEVER EYE EXAMINATION IS NEEDED IMMEDIATELY** – to differentiate from senile cataract (the findings are **NONSPECIFIC**)
- repeated doses with cumulative exposure about 4 or 6 Gy are developing the cataract within 2 years

Diagnosis: slit lamp examination of eyes: posterior opacities of the lens

Treatment: cataractic lens extraction, intraocular lens implantation



normal



cataract

STERILITY

Temporary sterility is developing after single external irradiation of testes - dose 0,1- 0,5 Gy

**Permanent sterility is developing after single irradiation of testes - dose range 2 - 6 Gy
of ovary - dose about 3 Gy**

Diagnosis: in men sperm counts (spermiogram)

STOCHASTIC EFFECTS

NON THRESHOLD EFFECTS – LATE EFFECTS

- **no threshold dose exist;**
- **probability of damage increases with dose;**
- **dose response curve is linear;**
- **there is a latency period several years for cancer and hundreds of years for hereditary effects**

STOCHASTIC EFFECTS

CANCER

- individual risk for cancer is low even after high dose;
- population risk may be considerable
- about 1000 children have got thyroid cancer after Chernobyl (dose less than 300 mGy)
- background cancer mortality is 20%

LUNG CANCER

➤The lung cancer associated with exposure to radon decay products in URANIUM MINERS

➤Inert gas radon diffuses out of the rock containing uranium into the mine atmosphere, where it decays into radioisotopes of Po, Bi, Pb (radon decay products) which are inhaled as free ions or attached to dust particles.

➤No cell type of lung carcinoma is pathognomonic

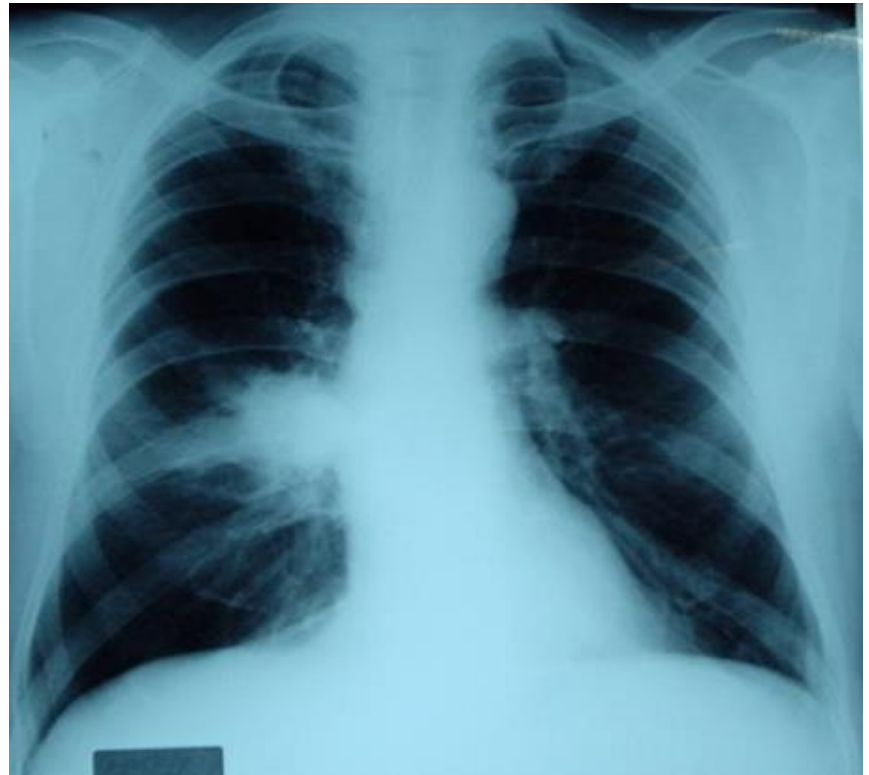
➤latency period is 15 - 40 years and more

LUNG CANCER DUE TO RADON is the most common occupational cancer in Czech Republic - the incidence of lung cancer is decreasing among uranium miners – in 1981- 113 cases, in 2007 only 15 cases.

Uranium-mine



Bronchogenic carcinoma in uranium miners



LEUKEMIA

Incidence of leukemia is increased following exposure to gamma and neutron radiation

➤ **occured after explosion in Hiroshima, Nagasaki or after radiation accident in Chernobyl (USSR)**

➤ **latency period is 2 -18 years**

➤ **leukemia is reported as occupational disease in uranium miners in Czech Republic**

Basal cell carcinoma in uranium miners



Epidermoid carcinoma (spinalioma) in uranium miners



INTERNAL CONTAMINATION

INTERNAL CONTAMINATION can result in serious acute or delayed injury.

Diagnosis is confirmed by analysis for radionuclide content in urine, blood and stools and by physical measurement – thyroid monitoring, whole body counting, gamma camera measurement.

Therapy: NON - SPECIFIC PROCEDURES can be applied:

- Lavage of the stomach or wound
- Administration of laxatives for cleaning gastrointestinal tract (sodium or magnesium sulphate)
- Surgical excision for removing radionuclide from a wound

ANTIDOTES

Indicated in the case of internal contamination by:

➤ **Radioiodine-131** = Potassium iodide (KI) oral

➤ **Plutonium, Americium, Transuranics, Lanthanides, Manganese, Iron, Cobalt, Zirconium, Ruthenium, Yttrium:**

➤ **DTPA (DiethyleneTriaminePentaAcetic acid - Ca (Zn) salt**

➤ **Cesium-137:** Radiogardase-Cs (Prussian blue)

➤ **Strontium, Radium:** Barium sulphate (Micropaque susp) and magnesium sulphate

➤ **Uranium nitrate:** Isotonic sodium bicarbonate

Antidotes



Antidotes



Antidotes



PREVENTION

Monitoring of occupational exposure with personnel or area monitoring devices.

Shielding with lead or other effective barrier to contain emissions.

Protective clothing and breathing gear must be used correctly whenever these are needed.

The system of radiation safety and the prevention in the Czech Republic is on an advanced level.

In the course of 30 years there have been 163 cases of occupational diseases - lung cancer was excluded from this statistics:

- ✓ acute and chronic dermatitis (92)**
- ✓ cataract (10)**
- ✓ haematological changes (18)**
- ✓ skin cancer (34)**
- ✓ leukemia (6)**
- ✓ other cancer (3)**

PREVENTION

The most frequently diagnosed condition was the radiation induced dermatitis (92 cases), mostly in health care workers.

Described occupational diseases were caused by higher exposures in previous years or developed as a consequence of radiological accidents.

Recently the medical personnel receives the effective dose of about 1-2 mSv per year.

HEALTH SYSTEM OF SPECIAL MEDICAL CARE PROVIDED TO PERSONS IRRADIATED IN RADIATION ACCIDENTS IN THE CZECH REPUBLIC

In the Czech Republic there are three specialized Health Centres for treatment of persons damaged by ionising radiation:

- **Persons with acute radiation syndrome who receive the whole body dose above 1 Gy are admitted and treated at the [Haematological Department in Hradec Králové](#).**
- **Persons with local radiation injury and persons with open wound contaminated by radionuclides, who need surgical treatment, are admitted and treated at the [Burn Unit of the Department of Plastic Surgery in Prague 10](#).**
- **Persons with local radiation injury who do not need surgical treatment or receive the whole body doses under 1 Gy or need antidote treatment after internal contamination with radionuclides, are admitted and treated at our [Department of Dermatology in Prague 2](#).**