

Effects of ionising radiation

Ionizing radiation effects are either deterministic - occur whenever their threshold is exceeded, or stochastic - the probability increases with ionizing radiation dose, that the effects will manifest.

Deterministic effects of ionizing radiation

These are the biological effects of ionizing radiation, which are manifested after exceeding the so-called *threshold doses*. It is not the same for all organs, the susceptibility of cells to radiation damage is described by the term *radiosensitivity*. Other effects of ionizing radiation are called stochastic (causing cancer or hereditary genetic changes), for which there is no threshold dose, although their risk also increases progressively with the dose.^[1]

Characteristics of deterministic effects

Characteristic effects are threshold, certain and non-random. They arise after exposure to a threshold dose for a certain tissue. The dose-response curve has a sigmoidal shape, so the probability of developing an impairment increases significantly with increasing dose. Manifestations of damage arise shortly after receiving the threshold dose (so-called early effects). The exception is radiation cataract and chronic radiodermatitis, which develop after a repeated dose of radiation. Most sensitive to ionizing radiation are stem cells, lymphatic tissue, bone marrow, intestinal epithelium and male genital epithelium.

Clinical correlates

Diseases related to the deterministic effects of ionizing radiation include acute radiation syndrome, radiation dermatitis, radiation cataracts, fertility disorders, and damage to the embryo and fetus.

Acute radiation syndrome (radiation sickness)

It occurs after whole-body, one-time irradiation with a dose of more than **1 Gy** (x-ray, gamma, neutron). The clinical picture manifests itself in four stages:

1. **the stage of early prodromal symptoms** - the result of the activation of regulatory mechanisms (autonomic system), the main symptom is vomiting, then loss of appetite, nausea, salivation, diarrhea, apathy, sweating, headache, hypotension;
2. **asymptomatic stage** - clinical symptoms subside;
3. **stage of disease manifestation** (critical stage);
4. **stage of recovery**.



International symbol for radioactivity

In general, the higher the dose, the faster the phases change (except for the recovery phase, which is prolonged in case of survival).

Forms of radiation sickness

■ Mild form of radiation sickness

A mild form occurs after a dose of **1-2 Gy**. Prodromes in 3 hours or later, latency period lasts **20-30 days**. There is general fatigue, weakness, recovery takes several weeks. There is a decrease in leukocytes and platelets in the peripheral blood.

■ Hematological (medullary) form

The medullary form occurs after a dose of **2-6 Gy**. There is a significant decrease in blood cell precursors. Its course is moderate to severe. Early prodromes (1-3 h after exposure). **Latency is between 7-28 days**. Severe lymphopenia, significant granulocytopenia and thrombocytopenia occur. The critical stage comes when high fever, infection, sepsis or bleeding occur. Radiation pneumonitis may even develop.

■ GIT form

The GIT form occurs after a dose of **6-10 Gy or more**. Its course is very severe and even fatal. Necrosis of the cells of the intestinal lining occurs. Early symptoms appear within 30 minutes after exposure (vomiting, severe diarrhea, altered consciousness). Very severe lymphopenia occurs. The critical stage is manifested by high fevers, severe diarrhea, bleeding manifestations, vomiting, hematemesis, disruption of the internal environment, dizziness, hypotension.

■ Neuropsychic form

The neuropsychic form occurs after doses of **30-50 Gy**. Its course is fatal, early symptoms within 10 minutes, no symptom-free period. Brain edema, heart failure dominates. Death comes within hours.

Investigative methods

A blood count is taken, where first the lymphocytes decrease (1-2 Gy - decrease by 50% in 48 h). Neutrophils initially rise, then fall. Cytogenetic analysis of chromosomal aberrations in blood lymphocytes.

Treatment

- **Mild forms** - we monitor, symptomatic treatment.
- **More severe forms** – prophylaxis – ATB, antifungals, antivirals.
- **Neuropsychic form** – palliative treatment.

See the Radiation sickness page for more detailed information.

Radiation dermatitis

Acute radiation dermatitis

After one-time local (and whole-body) irradiation, or contamination of the skin with beta emitters. The dose size is about **3-9 Gy**. The most sensitive is the skin on the front of the neck, in the elbow and popliteal fossa.

Clinical picture

Transient early erythema appears – after local irradiation skin swelling occurs due to the release of histamine (after doses of 3–80 Gy).

1. **radiation dermatitis grade I** (erythematous) – doses 3–10 Gy
 - erythema – inflammatory exudate in the corium, temporary hair loss and pubescence (above **6 Gy**, epilation is permanent).
2. **radiation dermatitis II. degrees** (desquamative) – after 12–25 Gy
 - an early erythema occurs, blisters appear after 2-3 weeks of latency, infection is usually added, wetting begins;
 - during the following weeks the skin is renewed.
3. **radiation dermatitis III. degrees** (necrotic form) – doses above 30 Gy, affect deeper layers
 - vascular changes, necrosis, ulcers occur, they take a long time to heal, the new skin is atrophic.



Hands of a disabled radiologist (early 20th century)

Treatment is in the hands of professional dermatology and plastic surgery (burn clinic in Vinohrady)

Chronic radiation dermatitis

It occurs after repeated external exposures, when the total local dose reaches **30-50 Gy**. It used to be common for radiologists on their hands.

Clinical picture

1. **atrophic form** – skin dry, thin, smooth, hairless, numerous telangiectasias, brittle nails.
2. **hypertrophic form** - hyperpigmented, thickened skin, foci of hyperkeratosis (tumors can arise from them - mainly spinalioma).

Other disabilities

▪ Radiation cataract

It occurs after a single exposure to a dose of **1.5-2 Gy**, the latency period is min. **6 months**. Clinically significant opacity develops over several years or after repeated exposure to the eye. Punctate or reticulate opacities typically present at the posterior pole of the lens.

▪ Fertility disorders

Men are more sensitive to radiation – transient oligospermia after doses of 0.1–0.3 Gy. A dose above **3 Gy** can already lead to permanent aspermia, and the decrease occurs only after **6-8 weeks** after exposure. Diagnosis consists of examining a spermiogram. In **women**, susceptibility increases with age, doses above 3 Gy cause sterility, and premature menopause occurs.

▪ Effects in pregnancy

Irradiation during the first two weeks leads to an early abortion or, on the contrary, the child survives and is completely healthy (either all or nothing). **4-8 week** is the period of organogenesis, when **malformations** can occur (the critical dose is **50 mGy**). **8-15** a week is reserved for the maturation of the CNS. During this period, after irradiation, there is a decrease in intelligence, mental retardation (threshold dose is **120-200 mSv**).

More detailed information can be found on the Teratogens, Congenital developmental defects pages.

Stochastic effects of ionizing radiation

Stochastic effects of ionizing radiation are such effects that we do not know with certainty that they will manifest themselves after exposure, they manifest themselves only **with a certain probability**. This includes an increase in the risk of cancer and hereditary diseases. For doses of ionizing radiation below 100 mSv, the dependence of the additional risk is not entirely clear (different probability models of risk habituation are assumed – linear, linear-quadratic, threshold, increased risk model), for doses above 100 mSv, the increase in risk is linearly dependent on the dose. ^[2]

Additional risk of cancer

From doses exceeding 100 mSv, the risk of fatal cancer increases linearly. The nominal coefficient of occurrence of fatal cancer is $5 \cdot 10^{-2} \text{Sv}^{-1}$. However, this coefficient is dependent on gender and age. ^[2]

Additional risk of hereditary diseases

No additional risk could be demonstrated in first-generation offspring. However, the methodology of the studies conducted may be flawed, so the research is still ongoing. ^[2]

Links

Related Articles

- Ionizing radiation
- Radiotherapy

External links

- European Society of Radiology (<https://www.myesr.org/article/1792>)

References

1. SMEDLEY, Julia – DICK, Finlay – SADHRA, Steven. *Oxford Handbook of Occupational Health*. - edition. OUP Oxford, 2013. 915 pp. ISBN 9780199651627.
2. HORÁKOVÁ, Ivana. *Základy radioační ochrany obecné* [lecture for subject Mimořádný specializační e-kurz – Radiační ochrana, specialization Radiační ochrana pro indikující lékaře, Radiační hygiena Institut postgraduální vzdělávání ve zdravotnictví]. Praha. 2020-04-15. Available from <<https://moodle.creativeconnections.cz/course/view.php?id=94>>.