CHAPTER 4. RADIATION INJURIES IN RADIOLOGY AND RADIOTHERAPY

Nowadays radiology and radiation oncology makes the greatest contribution to a dose received by a person from anthropogenic sources of radiation. Borders of radiological examinations are from 0,04 up to 1,0 m3v at the lowest and highest levels of health services. In radiotherapy the largest local total doses are 60-70 Gy.

4.1. Classification of radiation injuries

According to modern data the basic determined effects of the total irradiation are represented as follows (tab. 4.1):

Table 4.1. Biological effects of acute radiation exposures

Radiation dose	Effect
0,1 Gy to bone marrow	Risk of leukemia may be elevated.
0,1 Gy whole body	Elevated number of chromosome aberration: no detectable injury or symptoms.
1 Gy whole body	Mild radiation sickness – nausea, vomiting, fatigue are possible.
4 Gy whole body	Likely to result in death for 50% of exposed and untreated population.
10 Gy to skin	Erythema and blistering.
40 Gy or more, whole body	Death within 48 hours from shock and vascular damage.
60 Gy small volume	Used to treat cancer over 6 weeks.

On the whole, laws of radiation injury in an organism are defined by two factors:

1. Radiosensitivity of tissues, organs and systems essential for a survival of an organism.
2. Amount of the absorbed dose of radiation and its distribution in space and time.

These factors individually and combined determine the primary type of beam effects (local or the total), specificity and time of display (it is soon after an irradiation or in the remote terms) and their importance for an organism.

The best understanding of the basic displays of a radiation injury can be achieved by their comparison to the absorbed dose in “critical organs”. Critical organs are vital organs or systems are first affected by a certain radiation dose.

It is very important to distinguish deterministic and stochastic radiation effects.

Deterministic effect is clinically detected harmful biological effect caused by ionizing radiation concerning which there is a threshold. If the dose is lower than the threshold the effect is absent, if it is higher the effect severity depends on a dose.

Stochastic effect. Describes random, biological or clinical effects (tumorigenesis, inherited genetic effects) whose probability of occurrence in an irradiated (exposed) population is a direct function of dose. There is no relationship between dose and the severity of the effect. No threshold doses are assumed for stochastic effects.

For radiation protection, according to recommendations of International Commission on Radiological Protection (ICRP) it has been made an assumption, that stochastic effects have nonthreshold linear dependence.

Early radiation lesions are lesions occurring within first three months after irradiation. Late radiation lesions are lesions occurring later than three months after radiation exposure.

In radiobiological and clinical practice radiation reactions and radiation damages are distinguished.

Radiation reactions are such changes in tissues, which pass within 2-3 weeks after irradiation without special treatment. For example it is skin erythema.

Radiation damages are organic and functional changes in organs and tissues which demand special treatment.

4.2. Medical irradiation at radiotherapy

In radiotherapy of malignant tumours the absorbed doses of ionizing radiation are defined by clinical indications according to principles of radiation oncology and directed to achievement of the maximal selectivity of tumour lesions. As the used doses are large, as opposed to radiodiagnostics, beam influence on patients can be accompanied by non-stochastic (deterministic) effects from the side of healthy tissues (see by tab. 2).

4.3. Reactions and damages at radiotherapy

As it was specified in the previous chapters, the main principle of radiotherapy is to provide optimum influence of radiation on a tumour under condition of maximal possible sparing of surrounding organs and tissues. However it is hardly possible to avoid irradiation of healthy tissues completely, especially if tumours are deeply located. It should be mentioned, that the deviation of a dose in 5 % is considered to be critical, both for treatment of a tumour, and for influence on healthy tissues. Because of a small distinction interval between radio-sensitivity of a tumour and healthy tissues surrounding it, and despite development and perfection of radio-therapeutic techniques, radiation lesions of skin and other tissues may occur.

Table 4.2. Estimations of approximate threshold doses for clinically harmful non-stochastic effects in various tissues, based on reactions of patients on conventional fractionation x-ray or gamma irradiation

Organs	Damages in 5 years	A dose causing effect at 1 - 5 % of patients, Gy	The area of a field of an irradiation
Skin	ulceration, fibrosis	55	100 sm^2
Stomach	ulceration	45	100 sm^2
Thin bowel	ulceration, narrowing of the channel	45	100 sm^2
Large bowel	the same	45	100 sm^2
Liver	hepatic insufficiency	35	Entirely
Kidneys	sclerosis	23	Entirely
Bladder	ulceration, contraction	60	Entirely
Testicle	constant sterility	5-10	Entirely
Ovary	The same	2 - 3	Entirely
Capillaries	telangiectasia, a sclerosis	50 - 60	-
Heart	pericarditis, pancarditis	40	Entirely
Bones at adults	necrosis, crises	60	10 sm2
CNS (brain)	necrosis	50	Entirely
Spinal cord	necrosis	50	5 sm^2
Crystalline lens	a cataract	5	Entirely
Thyroid gland	hypothyroidism	45	-
Muscles at adults	An atrophy	100	Entirely
Bone marrow	hypoplasia	20	Locally
Lymph nodes	an atrophy	35 - 40	Locally
Lymphatic vessels	a sclerosis	50	Locally
Foetus	destruction	2	Entirely

It is necessary to admit, that a part of people (from 5 up to 10 %) are highly sensitive to ionizing radiation action, but it is impossible to diagnose individual radio-sensitivity beforehand. The necessity of studying of late radiation lesions is caused not only by frequency of their development, but by long torpid clinical manifest.

Depending on manifestation of radiation response it can be local and the total.

Radiation poisoning. The radiation poisoning is a reaction of the whole organism to the influence of ionizing radiation, which declares itself by increased temperature, disorders of gastrointestinal tract function (dysorexia, nausea, vomiting and diarrhea), cardiovascular system (tachycardia, hypotonia) and changes in nervous and haematogenic systems.

The radiation poisoning is realized as a result of direct and indirect local action of ionizing radiation. As a result of direct lesion in the area of radiation exposure there is a suppression of hematopoiesis if it enters a zone of bone marrow irradiation and effect on peripheral blood cells (lymphocytes). Moreover, there is also a mediated damage to the organism realized as a result of radiotoxins influence: lipidic peroxides, quinone derivatives, protein radiotoxins (owing to disintegration of tumour cells and healthy tissues), histamine and choline. These connections cause intoxication and can cause hematosis suppression, that expresses in granulocytopenia, lymphopenia with the subsequent development of thrombocytopenia and, less often, anemia.

Total radiation response degree extensively depends on radiation dose and its fractionation regime as well as on individual radio-sensitivity of a patient. There is a certain dependence on body area and volume of the tissues, exposed to irradiation.

The most sensitive organs with regard to development of the radiation poisoning are the top part of the stomach, the head and the thorax.

The following the radiation poisoning are distinguished:

1. Mild: loss of appetite, nausea, unitary vomiting;
2. Moderately severe: constant nausea, vomiting during the first and second half of treatment, general weakness;
3. Severe: repeated vomiting during all the course of radiotherapy (both in the day of irradiation, and in days when irradiation was not performed).

Thus, leading clinical signs are nausea and vomiting.

Severe the radiation poisoning, leukopenia (is lower 3×10^9/l) demand a break in treatment. The radiation poisoning is convertible. All disturbed processes in organs and systems are gradually restored and get back to normal in 3-8 months.

Radioprotectors can be applied to prevent the radiation poisoning: mexamin hydrochloride 0,05 30 minutes prior to a session of radiotherapy; cystamine dihydrochloride 0,2-0,8 daily or every other day 1 hour prior to irradiation. In severe radiation poisoning at subtotal or total irradiation hemosorption is applied. Colony-stimulating factors of granulocyte, in particular – leukomax (recombinant human granulocyte-macrophage colony-stimulating the factor) - 3 mkg / kg up to 10 mkg / kg of weight per day are very effective. The maximal duration of treatment takes 10 days.

Such antiemetic drugs as aminazine (25 mg 1-3 times a day) and cerucalium (10 mg before a meal by 1-2 tablets 2-3 times a day) are indicated.

Medicines raising arterial pressure (in hypotonia) should be prescribed to the patients.

Complex use of the mentioned measures allows to carry out a full course of radiotherapy without the radiation poisoning manifestation. In cases, when, despite preventive measures, there are symptoms of the radiation poisoning, it is necessary to make a break in irradiation, however it is necessary to remember, that infringement of irradiation rhythm, especially in the first half of the course, has an adverse effect on results of treatment. Therefore the induced break in the absorbed dose of 20-30 Gy should not exceed 3 days. In a dose of 40-50 Gy, depending on character of disease, such breaks in radiotherapy can be increased till 10-14 days.

Local radiation lesions in radiotherapy (local side effect of radiotherapy).

Local radiation lesions may be early and late. Recovery of sublethally irradiated cells occurs within 100 days (within 3 months). If radiation lesions occur during this term they are called early radiation lesions. All disorders developed later, are late radiation lesions.

Reactions of a skin and subcutaneous cellular tissue are the most often since these tissues are first exposed to radiation influence atexternal irradiation. Most frequently skin reactions are observed when using opposite fields.

Radio-sensitivity of skin depends on several factors. So, there are individual fluctuations of radio-sensitivity of skin; the skin of women is less radiosensitive, than the skin of men. Skin possesses regional radio-sensitivity which decreases in the following order: neck, breast, belly, hips, back, and face. Skin is most sensitive in axillary and inguinal areas, in internal surface of hips and in neck area. In Basedow's disease, nephritis and diabetes the radio-sensitivity of skin rises. Inflamed and hyperemic skin becomes more radiosensitive.

Following skin radiation reactions are distinguished: erythema and radiodermatitis (dry and wet). Erythema is an expressed skin hyperemia in a zone of irradiation; it is accompanied by puffiness and moderate itch. In a basis of erythema development there is the expansion of skin capillaries.

In other equal conditions erythema develops after a unitary irradiation at a lowvoltage x-ray irradiation dose of 4 Gy and 7,5-8 Gy gamma ray radiation. At conventional fractionation of gamma rays radiation erythema develops after a dose of 30-35 Gy. 2-3 weeks after the end of irradiation the mentioned phenomena usually disappear or, according to a field of irradiation, there is a slight pigmentation with the subsequent desquamation, lasting for some months.

Dry radiodermatitis is a change of a skin in a zone of irradiation. Skin is dry, hyperemia accompanied by pigmentation, puffiness and itch. Dry radiodermatitis usually develops after a unitary irradiation in 8-12 Gy dose of gamma-rays radiation or 40-50 Gy fractional radiation.

In these cases recovery of irradiated skin is not always complete as uneven depigmentation or telangiectasis (resistant expansion of small hypodermic blood vessels) can develop.

Moist weeping radiodermatitis is characterized by formation of blisters with serous or serous-purulent contents accompanied by hyperemia and puffiness of the irradiated skin. Moist radiodermatitis usually develops after high total doses of irradiation (more than 50 Gy) or 12-16 Gy unitary (one-time) gamma-rays of radiation.

Epithelization is slow and skin after it remains dry, pigmented and atrophic.

Skin radiation reactions are always accompanied by loss of hair in a zone of irradiation.

Depending on severity of radiation reactions epilation can be constant and temporal, when hair grow, but it is, as a rule, defective (rare, dry and gray). The threshold absorbed dose of irradiation causing epilation, is close to 2,5-3 Gy on the head. At this and higher dose, approximately up to 6 Gy, the expressed epilation starts on the 14-17th day of illness. At the extremely high degree of lesion epilation occurs on the 8-9thday (fig. 4.1).

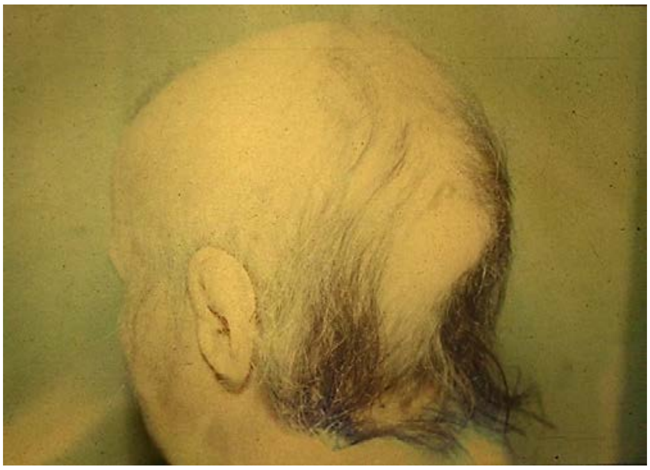

Fig. 4.1. Epilation. Loss of hair 3 weeks after external radiotherapy on the brain in total dose 30 Gy (a single dose 3 Gy) concerning cancer metastasises in a brain

Radiation histopathology of acute radiation dermatitis:

- Erythema is arteriolar constriction with capillary dilation and edema, with extravasation of leukocytes and erythrocytes.

- Dry desquamation is reflection of response of the germinative epidermal layer, diminished mitotic activity; swollen cells of the basal and parabasal layers; thin epidermis; desquamation of large macroscopic flakes of skin.
- Wet desquamation is an intracellular edema; vesicles coalesce to form bullae exterior to the basal laer, arrest of mitosis in proliferative layer, epidermis may slough, exposing the dermal surface, coated by fibrin.

Radiation reactions of mucous membranes (mucositis, radiation epitheliitis) develop when hollow organs are irradiated. They can simultaneously be observed with skin radiation reaction or separately. But as mucous skin reactions possess high radio-sensitivity its radiation reactions can arise in smaller dozes, than reactions of skin.

Following stages of radiation epitheliitis are distinguished:

– the stage I of epitheliitisis characterized by hyperemia and a slight mucous membrane edema. Then cornification of epithelium occurs and mucous becomes whitish, grown turbid and dry;

– the stage II is characterized by formation of solitary erosions (a stage of multifocal membranous epitheliitis);

– the stage III is characterized by extensive rejection of epithelium and formation of unbroken erosive surface (a stage of confluent membranous epithelitis).

Conjunctiva is the most radiosensitive mucous membrane. Between 17th and 21stdays after a dose of irradiation in 25-30 Gy conjuctiva becomes red in 2-3 days, then erosions and dyphththeria – like a strike incrustation appear owing to fibrin transudation. Usually, if overdoses were absent, all phenomena pass in 2-3 weeks after treatment. The mucous membrane of the mouth during irradiation becomes edematous, hyperemic and painful. Dryness in a mouth connected with suppression of salivary glands functions is often observed, as well as infringement of taste.

Irradiation of the larynx and pharynx cause changes in the mucous membrane and are clinically expressed in voice hoarseness, pains and difficulty at swallowing. The beam laryngitis arises usually in a dose of 40-45 Gy.

Reaction of bronchial tubes is expressed in dry cough, dyspnea, chest pains, and sometimes a moderate rise in body temperature. Radiations pneumonia develops quite often too.

Reaction of esophagus mucous is characterized by dysphagy (feeling of burning and difficulty at passage of food), retrosternal pains, pains in interscapular space, sialorrhea. Esophagitis can arise in a dose of 30-40 Gy.

Reaction in the urinary bladder mucous membrane is expressed by painful urination, pains in the bottom of the abdomen. It arises usually in a dose of 35-40 Gy.

The mucous of the uterus possesses rather high resistency. Epitheliitis in this organ can develop in a dose of above 60 Gy.

To prevent local radiation reactions of skin it is usually covered with vegetable and animal oils, indifferent creams. In erythema cod-liver oil, rosehip oil, sea-buckthorn oil, 0,5% prednisolone ointment are used. In development of dry radiodermatitis 0,5 % prednisolone ointment is used. Ointment is applied to the irradiated skin twice a day (in the morning after night sleep and in the afternoon after lunch sleep; it is needn’t to apply ointment before going to bed as it will be removed during the sleep). Treatment of wet radiodermatitis is performed more often in the open way without a bandage. Vitaminous preparations are widely used: pantenol-spray**,** "Olazolium", 5 % - 10 % dimexidum solution in radioepitheliitis.

For prevention and treatment of radioepitheliites it is necessary to avoid mechanical and thermal influence, 0,25 % - 1 % novocaine solution, oil irrigation (olive, sunflower, peach oil) should be applied.

To prevent radiation pneumonitis and to alleviate its course glucocorticosteroids are applied.

Treatment of radiation cystitises and rectitis is basically performed by washing the bladder and the rectum with antiseptic solutions (Furacillin 1:5000), the rectum is daily washed out with a warm chamomile tea solution. Before bedtime microclysters with vaseline oil, rosehip oil and a 5 % dimexidum solution are indicated.

Radiation damages. In early radiation damages, i.e. in such radiation injuries when independent recovery is impossible, more radiosensitive and well recycling structures suffer.

<u>Sharp necrosis</u> induced by radiation has a severe course. In 7-10 days erythema receives persistent character; it is accompanied by severe pains, deterioration of the general condition and rise in temperature. Peripheral lymph nodes increase. In the first days after irradiation bubbles with a clear liquid appear. After bubbles opening and epidermis rejection necrotic tissues becomes evident; it is covered with yellowish incrustation. After rejection of necrotized tissues the deep ulcer is found out. The process is accompanied by severe pains, however in some cases early radiation necroses can develop without the expressed pains or edemas. Sharp radiation necrosis is observed at large doses of fractionated irradiation (about 100 Gy and more) at single dozes more than 20 Gy-50 Gy.

Infringements of more radioresistant structures demanding more time for radiation damage realization at same doses of ionizing radiation lies in the basis of late radiation damages. Clinical displays of late radiation damage are consequences of gradual accumulation of changes in the small blood vessels and lymphatic vessels causing infringements of microcirculation and development of irradiated tissues hypoxia; its consequence is fibrosis and a sclerosis.

Destruction of cellular elements with their replacement with cicatricial tissues and sharp suppression of reparative opportunities of cells also play an essential role.

Late radiation damages are:

1. Atrophic processes (fig. 4. 2).
2. Hyperplastic processes.
3. Radiation fibrosis or indurative edema.
4. Radiation ulcers, late necrosis (fig. 4.3).
5. Radiation cancer.

Treatment of radiation damages. Treatment should be complex, combining the common actions with local influence on the damaged skin. The common medical actions are directed on increase of a vitality of an organism and activation of reparative process is reached by high-calorific meals, vitamin complexes, fresh fruit and vegetables.

Fig. 4.2. Atrophy of skin with sites of depigmentetion and angiectasia (dilation of blood vessels) in the field of the left clavicle 5 years after external radiotherapy concerning breast cancer in total dose of 50 Gy with usual fractions (2 Gy)

The daily toilet of an ulcer and its irrigation with solution of antibiotics is recommended. Later bandages with ointments containing sea-buckthorn oil are imposed. Sometimes Novocaine blockade of 0,25% solution is applied. When conservative treatment is inefficient at anatomic permissibility there arises a question on early surgical intervention with necrectomy or amputation of the struck segment of extremity not later, than in 2-2,5 months, i.e. in terms when necrosis areas are being outlined. The terms of severe lesions treatment are delayed to 0,5-1 year.

The treatment of late radiation lesions should be planned with consideration to clinical form of a lesion. In atrophic dermatitis it is recommended to apply steroid

Fig. 4.3. Late radiation ulcer on skin 7 years after lowvoltage x-rays radiotherapy squamous cell skin cancer in total dose 75 Gy

and vitaminized oils. In treatment of hypertrophic processes and fibrosis absorbing preparations, such as dimexidium, lidasa and glucocorticoid are applied. Purposeful medicinal electrophoresis of dimexidium, heparinum and proteolytic enzymes quite often gives good therapeutic effect. This technique yields good results in treatment of late radiation ulcers as well as necrosis. This technique yields good results in treatment of late radiation ulcers as well as necrosis. However the basic method of treatment of such lesions is radical excision of the damaged tissues with the subsequent skin defect replacement by transplantation.

Radiation protection of patients in radiotherapy. In radiotherapy of malignant tumours the absorbed doses of ionizing radiations are defined according to clinical indications in compliance with principles of radiation oncology and are directed to the achievement of the maximal selectivity of tumours defeat. As the used doses by radiotherapy are large, the radiation influence on patients can is accompanied by the determined effects on the part of healthy tissues. Patients, suffering from malignant tumors, cannot cause the essential contribution to genetically significant dose due to a disease character and a patient’s age. Taking in account the latent period the risk of a new tumour development after therapeutic irradiation is practically insignificant.

At the same time, in radiotherapy the determined lesions have special value taking into account, that a 5 % deviation in a used dose is considered to be critical both for treatment of a tumour and for influence on normal tissues.

Thus the principle of justification of the practice and optimization of protection is used according to ICRP. When carrying out radiotherapy all possible measures of radiation complications prevention in the patient should be taken.

The most important for patients protection in radiotherapy is the exact leading of correctly appointed dose of radiation to a zone of tumour lesion with minimally possible irradiation of healthy tissues.

In this connection great demands of dosimetric maintenance of radiotherapy are made. Therefore the equipping of radiological departments by radiological simulators, dosimetric and planning systems is provided.

The x-ray computer tomographs allowing with great accuracy to transfer geometrical parameters of irradiated structures in computer systems for radiation therapy planning have great value.

The control of correctness of the beam fields of irradiation is established with the help of special device – a radiotherapy simulator which allows to carry out fluoroscopy and radiography with the exact localization of irradiation field and the choice of radiation direction taking in account the target volume.

For performance of complex dosimetric calculations digital copies of x-ray computer tomograms are transferred to the computer system of irradiation planning. To use a computer in irradiation planning, the program of the warranty, including the test program should be prepared to be confident that the computer system of planning of irradiation works with stable accuracy.

Planning of irradiation in radiation therapy with the use of open radionuclide sources is based on the metabolism of a radiopharmaceutical and its physical characteristics. On the basis of this information, knowing weights of organs and tissues calculations of radiation doses both in target volume and organs at risk are performed.

In external irradiation the position of the patient should be reproducible. The patient should be in convenient position; if necessary immobilization means are used. These means are applied to reproduce the position of the patient at each irradiation session; they have special value when it is difficult for a patient to keep the necessary position for irradiation.

It is necessary to calculate duration of irradiation and check it up beforehand and independently.

For protection of normal tissues absorbing materials are frequently placed in a radiation beam: multi-leaf collimator, blocks, wedge filters, the trellised diaphragms. JGRT technique is also used.

The control of a radiation beam characteristics and direct measurements over the patient are carried out with the help of corresponding dosimeters. In the external irradiation dose measurements should give radiation doses in certain points under certain conditions with a margin error ± 3 %. Measurements of deep doses, factors of easing wedge filters and prefixes for blocks should be carried out with a margin error 0,5-2 %. Activity of the used radionuclide it is necessary can have a margin error ± 5 %.

There are programs of quality assurance of the equipment for radiotherapy, including reception tests and periodic operational tests for check of an invariance of entry conditions.

Radiation protection of personnel during radiotherapy. Beam treatment methods depending on a degree of radiating danger can be arranged in the following order: therapy with the help methods of introduction of radioactive preparations, brachytherapy and external beam radiotherapy.

4.4. Medical irradiation in radiology

The most widespread kind of radiation used in diagnostic purposes is x-ray. The data of research results show, that over 50 % of the population receives doses of irradiation during x-ray examination.

Of all methods of beam diagnostics only x-ray and radionuclide «in vivo» researches are connected to the influence of ionizing radiation on a patient's organism (tabl.4.2).

Nuclear medicine considerably less contribution to a collective effective dose of population irradiation, than x-ray researches (in 10 times and more), that is connected with lower frequency of radionuclide researches application in clinical practice. At the same time, real effective doses on one patient in some kinds of radionuclide researches can exceed doses of irradiation from many kinds of x-ray researches.

Table 4.2. Doses used for radiologic investigations

Type of research	Dose (mSv)
Chest film	0,1-0,2
Fluoroscopy of chest	3
Fluoroscopy of stomach or intestine	10
Film of leg or arm	0,1
Film of vertebrae	1,6
Pelvic CT	15-25
Chest CT	3
Head CT	0,2-0,4
Nuclear medicine study (average level for one research)	4,5

Thus doses can induce stochastic effects: malignant tumors and hereditary effects.

Risk of malignancies: lifetime probability of radiation induced fatal cancers – 5% per 1000 mSv in nominal population of all ages.

Risk of hereditary effects: probability of hereditary effects for all generations: 1,2% per 1000 mSv. Probability of hereditary effects for two first generations: 0,3% per 1000 mSv. Probability of hereditary effects in the first l generation: 0,2% per 1000 mSv.

Radiation effects on the embryo. Effects of radiation in utero are generally referred to as effects on the embryo. They can occur at all stages of embryonic development, from zygote to foetus and may include lethal effects, malformations, mental retardation and cancer induction. The first three may be the possible outcome of deterministic effects during embryonic development, particularly at the period of formation of organs.

Evidence of effects on brain growth and development has emerged after observations of severe mental retardation in some children exposed in utero at Hiroshima and Nagasaki. The effects from high-dose, high-dose-rate exposure in utero, particularly linked to the period between 8 and 15 weeks after conception, seem to indicate a downward shift in the intelligence quotient (IQ) distribution. For low radiation doses, this potential effect on the embryo is undetectable in the newborn.

Studies of in utero exposures have given conflicting evidence of carcinogenesis in the child, from relatively high risk to essentially small undetectable risk. There is no biological reason to assume that the embryo is resistant to carcinogenesis but on the basis of current data such effects cannot be quantified with any certainty.

Risk of effects on an embryo: (for those exposed in utero in the period between 8 and 15 weeks after conception). Downward shift of IQ distribution: dose required to shift from normal IQ to severely mentally retarded: 1000 mSv or more.

*Measures on restriction of medical irradiation in radiology. Physical radiation protection principles.*There are four basic physical radiation protection principles that can be employed to reduce exposure of ionizing radiation. These principles are based on consideration *of four radiation protection factors* that alter radiation dose, time, distance, shielding, and quantity.

Time is an important factor in radiation protection. This principle states that the shorter the time spent in a radiation field, the less radiation will be accumulated. Depending on the activity present, radioactive material will emit a known amount of radiation per unit time. Obviously, the longer a person remains in a radiation field, the more radiation that person will accumulate.

Distance. The second radiation protection factor is *distance,* and the principle is the farther a person is from a source of radiation, the lower the radiation dose. This principle is known as the inverse square law. By measuring the radiation exposure rate at a given distance from a source of radiation and then doubling the distance from the source, the intensity of the radiation is decreased by a factor of four. For example, a source of radiation that measures 8 mR/hr at 2 feet from a source would measure only 2 mR/hr at 4 feet. Conversely, when the distance from the source of radiation is reduced by half, for example, from 2 feet to 1 foot, the exposure rate increases from 8 mR/hr to 32 mR/hr, a factor of four.

Shielding. The third radiation protection factor is shielding. The principle follows that the denser a material, the greater is its ability to stop the passage of radiation. In most cases, high-density materials such as lead are used as shields against radiation. Portable lead or concrete shields are sometimes used when responding to accidents where contamination levels are very high.

In emergency management of the contaminated patient, shielding is limited to standard surgical clothing with slight modifications. Surgical clothing will protect the individual against contamination, and also will stop the passage of all alpha and some beta radiation. However, it does not stop penetrating gamma radiation. In the hospital emergency department shielding is actually limited to anti-contamination measures, and the principles of time and distance are used to reduce radiation exposure.

Quantity. The fourth radiation protection factor is *quantity*. Because the exposure rate from a given radioactive material is directly related to the amount or quantity of the material present, the principle involves limiting the quantity of radioactive material in the working area to decrease radiation exposure. Any technique that reduces the amount of radiation or radioactive material in the treatment area is very useful.

At work with the closed sources of radiations there is a potential danger of radioactive pollution of integuments, overalls and working surfaces due to infringement of tightness of sources. It is necessary for taking into account at carrying out of a sanitary – radiation control. Check of tightness of the closed sources is necessary for carrying out on a regular basis by the developed techniques (smear dry and damp materials with the subsequent radiometric in the well counter). Also the regular control over radioactive impurity of hands, overalls, toolkit and working surfaces is necessary. At work with the closed sources of the small sizes there is its danger loss. In such cases it is necessary to have a dosimeter - radiometer with which help it is possible to start searches of the lost source immediately.

At work with the closed sources of special requirements to furnish of rooms do not show. The closed radioactive preparations, not suitable for whatever reasons to further use, are considered as radioactive waste products and when due hereunder surrender on a burial place.

The purpose of protection against radiation is elimination of the determined radiation injuries and decrease in somatic and genetic risk for patients and the personnel.

According to ICRP for maintenance of normal operation of sources of radiation it is necessary to be guided by the following main principles of radiation safety:

1. Justification of the practice. No practice involving exposure to radiation should be adopted unless it produces a benefit that outweighs the harm it causes or could cause.
2. Optimization of protection. Radiation doses and risks should be kept as low as reasonably achievable economic and social factors being taken into account; constraints should be applied to dose or risk to prevent an unfair distribution of exposure or risk.
3. Limitation of individual risk. Exposure of individuals should not exceed specified dose limits above which the dose or risk would be deemed unacceptable.

All three principles apply to the protection of workers and the public. However, to protect patients during the medical use of ionizing radiation only justification and optimization apply. Dose limits are not applicable to medical exposure, but guidance levels which show what is achievable by good practice may be established for use by medical practitioners. Dose limits are also inapplicable to interventions, which are concerned with reducing exposure.

The dose limits for practices are intended to ensure that no individual is committed to unacceptable risk due to radiation exposure. For the public the limit is 1 mSv in a year, or in special circumstances up to 5 mSv in a single year provided that the average does over five consecutive years does not exceed 1 mSv per year.

Principles of control and restriction of radiation influence in medicine are based on reception necessary and the helpful information or therapeutic effect at minimally possible levels of an irradiation. Radiating safety of patients and the population should be provided at all kinds of a medical irradiation by achievement of the maximal benefit of radiological procedures and all-round minimization of radiating damage at the unconditional superiority of benefit for irradiated above harm.

The medical irradiation of patients with the aim of reception of the diagnostic information or therapeutic effect is carried out only to destination the doctor and with the consent of the patient. The final decision on carrying out of corresponding procedure is accepted by the doctor – radiologist.

The medical diagnostic irradiation is carried out on medical indications when other methods are impossible, or they are insufficiently informative.

All used methods of radiology and radiotherapy should be authorized by state public health services. In the description of methods it is necessary to reflect optimum modes of performance of procedures and levels of irradiation of the patient at their performance.

Rules of all kinds of radiological diagnosing researches should guarantee the absence of the determined radiation effects.

The irradiation of people with the purpose of reception of the scientific medical information can be carried out under the decision of the republican state public health services, within the limits of the established allowable levels of irradiation at the obligatory written approval surveyed after granting of data about possible consequences of irradiation.

In carrying out of radiotherapy all possible measures for prevention of beam complications in a patient should be taken.

For radiological medical researches and radiotherapy the equipment registered by republican state should be certified.

The medical personnel engaged in radiological diagnostics and therapy is obliged to provide protection of a patient, supporting individual doses on possible low level of irradiation. The dose received by a patient and personnel is subjected to registration.

Doses of irradiation of a patient received during radiological researches and procedures should be registered in a personal sheet of the doses account of medical irradiation, being the obligatory appendix to his out-patient card.

The medical personnel has no right to increase irradiation of a patient directly or indirectly to reduce own professional irradiation.

Introducing radiopharmaceuticals with therapeutic purposes to a patient the doctor should recommend him/her temporary abstention from reproduction. Introduction of radiopharmaceuticals to pregnant women with the purpose of diagnostics and therapy is not supposed. At introduction of radiopharmaceuticals to breast feeding mothers with the purpose of diagnostics or therapy breast feeding should be temporarily suspended. The terms of breast feeding termination depends on a kind and quantity of preparation used and is defined by separate instructions.

Protection of patients at radiological researches. The principle of limitation of individual risk is realized by establishment of hygienic specifications (allowable limits of doses).

For practically healthy persons the annual effective doze of preventive medical radiological procedures and scientific researches should not exceed 1 mSv.

The principle of justification of the practice of radiological researches is realized in view of the following requirements:

- priority use of alternative (not radiating) methods;
- carrying out of x-ray researches only under clinical indications;
- choice of the most sparing methods of radiological researches;
- the risk of radiological research refusal should exceed obvious risk from irradiation itself.

When the accumulated dose of medical diagnostic irradiation of the patient comprises 500 mSv specific measures on further restriction from irradiation should be taken if radiological procedures are not dictated by vital indications.

If patients receive more than 200 mSv of the effective irradiation dose per year, or accumulated dose is more than 500 mSv from any irradiation source, or 1000 mSv from all the sources of irradiation the special medical inspection should be organized by public health services.

The dose of radiation received by the patient is influenced by following factors:

– correct position during radiography. For example, the picture of the skull in a front -back projection causes 50-100 dose on a crystalline lens of the eye in comparison with a hind-forward projection;
– collimation of x-ray beams;
– sensitivity of the screen, amplifiers and detectors of the image;
– combinations: a x-ray film - the screen strengthening have the major value;
– now the strengthening foil containing materials from group rare-earth of metals (for example, gadolinium lanthanum) is standard. It is (at identical image sharpness) more sensitive, than a foil from tungstate calcium;
– digital systems considerably reduce a dose of radiography;
– use of image preservation (during researches and surgical interventions); Introduction of hardware-software complexes on processing and archivings of videoimages allows to lower a dose of irradiation of patients considerably;
– usage fluoroscopy with imaging intensifier. This technology helps to reduce the dose (see tab. 4.2).

*Radiation protection of the personnel during radiology researches.*The personnel who works with sources of radiation directly or is in a zone of radiation (for example, the nurses supporting small children) is most subjected to irradiation.

Following rules should be obeyed to protect medical personnel:

1. Performing radiological researches it is necessary to work quickly and limit a beam of radiation by a diaphragm.
2. To use protective clothes.
3. To be on sufficient distance from sources of radiation.
4. The great value has definition of indications, a choice of a method and algorithm of research.

Are very important for maintenance of radiating safety of the device of the signal system and the signs on safety warning the personnel and patients that the given room carries out radiological research and the x-ray machine works.

Protection of the personnel is provided, first of all, by shielding and reduction of stay time in a zone of irradiation. The personnel should limit the radiation beam by a diaphragm as much as possible, use standard protective means: screens, aprons, skirts, gloves.

Reduction of irradiation time is achieved by thorough training before a research, a choice of an optimum method, reduction of time of the research, careful selection of the patients subject to inspection.

Radiation protection of patients in nuclear medicine. Nuclear medicine procedures are connected to a small dose radiation, unable to cause non-stochastic radiation lesions, however, as well as in x-ray diagnostics, the probability of stochastic effects is not excluded.

As well as in x-ray diagnostics the regulation of doses for patients and personnel is carried out in nuclear medicine. However protection of patients on the basis of physical principles of protection from ionizing radiation in conditions of nuclear medicine «in vivo» diagnostics is possible only due to reduction of entering in an organism radionuclides quantity.

Decrease of doses is achieved by use of modern hardware and methodical opportunities while preserving necessary diagnostic information. So, sodium iodine ($Na^{131}I$), causing rather important dose influence, is not practically used in diagnostics. Contra-indications for carrying out of nuclear medicine researches are specified above.

Radiation protection of the personnel in nuclear medicine. Radiation protection against external irradiation. At storage, packing and introduction of radiopharmaceutical preparations in quantity of several tens of MBq the doses received by the personnel from external irradiation, can appear high.

Protection against external radiation of open radioactive sources should be provided not only when packaging, but also in wards with patients to whom radionuclides are injected in the medical purposes. The choice of means of protection depends on many factors, the main of which are: 1) physical characteristics of radiation; 2) time of radiation action to personnel; 3) distance between a source of radiation and a workplace; 4) a degree of shielding and radiating properties of a protective material. All these factors allow to calculate and carry out radiation protection of the personnel against external radiation in practice and help not to exceed the basic dose limits. Principles of radiation protection follow from the listed factors: protection by time, distance, shielding and quantity.

Radiation protection against internal irradiation. A problem of protection from internal irradiation is more difficult, than from external as when radionuclide is inside an organism, it is practically impossible to change conditions to amplify protection.

Radionuclide quantity, arrived in an organism, as well as the ways of its distribution, depend on factors, in particular, on activity of preparation, character of the works, use of protective adaptations, observance of requirements of radiation safety and the organization of a sanitary - radiation control. Rules regulate quantity of radionuclide activity on a workplace (protection by quantity). Distribution of radioactive substances in the environment is warned by protective actions which basic purpose is not to allow uncontrolled radionuclide distribution in a zone of personnel presence. These actions are: automation of operations with open sources, use of the hermetically sealed protective chambers, containers and use ofself-defense means.

The complex of protective measures during the work with open radioactive substances should provide prevention of air pollution, working surfaces, integuments and clothes of the personnel in working and adjacent rooms. Protective measures should be also applied against possible pollution of the environment – air, water and ground.

Basic preventive actions on maintenance of radiating safety of the personnel working with open radioactive sources are:

1. Placing and planning of premises.
2. Buffing of premises.
3. Protective and additional devices.
4. Rational systems of ventilation and water drain.
5. Gathering and removal of radioactive waste.
6. A choice of technological modes.
7. The rational organization of workplaces for personnel.
8. Observance of personal hygiene rules.

Requirements to buffing of premises. Walls and ceilings of premises should be covered with special non-adsorbing materials. Floors should be covered with non-adsorbing materials, for example, plastic compounds. For convenience the corners must be round to make cleaning easier.

In rooms intended for working with radionuclides a set of shields provides protection against external radiation. For each manipulation with open radioactive sources it is necessary to have special equipment corresponding to a kind of the used radionuclide and its activity. This equipment should include mobile shields, toolkit (a nipper, holders, tweezers), trays, pallets, ditches, etc. Tools for remote actions and local shielding provide reliable enough protection against external radiation of radionuclides.

The equipment and working furniture should have smooth surfaces, a simple design and non adsorbing coverings for facilitating the washing. Sinks for washing of the polluted utensils and toolkit as well as washstands should be supplied with cranes with cubital or pedal management. Washing of toilet bowls in toilets is carried out by pedal descent of water.

At the organization of workplaces of the personnel the equipment and remote tools should be carried out in view of zones of availability for working and of rational working poses on the basis of anthropometrical and psychophysiological parameters.

The equipment, utensils and tools in working premises should be marked. In working rooms with open radionuclides the following is forbidden: stay of the personnel without necessary individual protective means, foodstuff, tobacco products, drink, smoking, cosmetic accessories, domestic clothes, and other subjects not connected with work.