Radiation injuries in radiology and radiotherapy

How the basic contribution to a dose received by the person from man-caused of sources of radiation: radiology and radiation oncology. Borders radiological examinations from 0,04 up to 1,0 мЗv at the lowest and highest levels of health services.

Classification of radiation injuries

On the modern data the basic determined effects of the total body irradiation are represented as follows (tab. 1):

Tab.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.

As a whole, laws of a radiation injury of an organism are defined by two factors:

1. Radiosensitivity of tissues, organs essential to a survival of an organism.
2. In size of the absorbed dose of radiation and its distribution in space and time.

Everyone and a combination with each other these factors define primary type of beam effects (local or the total), specificity and time of display (it is direct after an irradiation, 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 of an organism can be achieved by their comparison to the absorbed dose in “ critical organs ”. As critical organs understand the vital organ or the systems, the first leaving out of operation in a researched range of doses of radiation that causes destruction of an organism in the certain terms after an irradiation.

It is very important to distinguish effects of radiation determined and stochastic.

Effects of radiation determined - clinically revealed harmful biological effects caused ionizing by radiation concerning which existence of a threshold is supposed, are lower which effect is absent, and is higher - weight of effect depends on a doze.

Effects of radiation stochastic - the harmful biological effects caused ionizing by radiation, not having dosage a threshold of occurrence which probability of occurrence is proportional to a dose and which heaviness does not depend on a dose.

For the purposes of radiating protection, according to recommendations International Commission on Radiological Protection (ICRP) the assumption is accepted, that stochastic effects have nonthreshold linear dependence.

To early radiation injuries carry what arise within first three months after an irradiation. To late - after three months after the ending of beam influence.

In radiobiological and clinical practice distinguish radiation reactions and radiation damages.

It is accepted to name radiation reactions such changes in tissues, which next 2-3 weeks after an irradiation pass without special treatment. As an example can serve erythema skin.

Organic and functional changes of organs and tissues which demand special treatment concern to radiation damages.

Medical irradiation at radiotherapy

At radiotherapy of malignant tumours the absorbed doses ionizing radiations are defined by clinical indications according to principles of radiation oncology and directed on achievement of the maximal selectivity of lesion of tumours. As doses thus are used big, as against radiotherapy, beam influence on patients can be accompanied not stochastic (the determined effects) on the part of healthy tissues (see by tab. 2).

Table 2.

Estimations of approximate threshold dozes for clinically harmful not stochastic effects in the various fabrics, based on reactions of patients on conventional fractionation x-ray or gamma irradiations

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 sm2
Mucous a mouth	The same	60	50 sm2
Stomach	ulceration	45	100 sm2
Thin gut	ulceration, narrowing of the channel	45	100 sm2
Thick gut	The same	45	100 sm2
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
Uterus	necrosis, perforation	100	Entirely
Capillaries	telangiectasia, a sclerosis	50 - 60	-
Heart	pericarditis, pancarditis	40	Entirely
Bones at adults	necrosis, crises	60	10 sm2
Cartilage at adults	necrosis	60	Entirely
CNS (brain)	necrosis	50	Entirely
Spinal cord	necrosis	50	5 sm2
Eye	panophthalmitis, a haemorrhage	55	Entirely
Crystalline lens	A cataract	5	Entirely
Thyroid gland	hypothyroidism	45	-
Muscles at adults	An atrophy	100	Entirely
Bone marrow	hypoplasia	2	Entirely
Bone marrow	hypoplasia	20	Locally
Lymph nodes	An atrophy	35 - 40	Locally
Lymphatic vessels	A sclerosis	50	Locally

Foetus	Destruction	2	Entirely

Reactions and damages at radiotherapy

As it was specified at the previous lectures, main principle of radiotherapy provide necessity of optimum influence of radiation a tumour under condition of greatest possible sparing of surrounding organs and tissues. However completely to avoid an irradiation of healthy tissues, it is especial at deeply located tumors, practically it is not obviously possible. To tell enough, that the deviation in a brought dose on 5 % is considered critical, both for treatment of a tumour, and for influence on healthy tissues. Because of a small interval of distinctions in radiosensitivity of a tumour and healthy tissues surrounding it and now, despite of development and perfection of radiotherapeutic technics, there can be radiation injuries of skin and other tissues. It is necessary to notice, that a part of people (from 5 up to 10 %) are high-sensitivity to action ionising radiations in comparison with the majority of people, but to diagnose beforehand individual radiosensitivity it is not possible. Necessity of studying of late radiation damages it is caused not so much by significant frequency of their development, how many features long torpid clinical current.

Depending on display radiation reactions can be local and the total.

The total radiation reactions at radiotherapy

The total radiation reaction is a reaction of all organism to influence ionising radiations, is shown by the increased temperature, infringement of function of a gastroenteric path (a distortion of appetite, a nausea, vomitting and diarrhea), cardiovascular system (a tachycardia, a hypotonia) and changes in nervous and haematogenic systems.

Total radiation reaction is realized owing to direct and indirect local action ionising radiations. As a result of direct defeat in a zone of beam influence there is an oppression haemopoiesis at hit in a zone of an irradiation of a bone brain and action on cells of peripheral blood (lymphocyte), and mediated defeat of the organism realized owing to influence of radiotoxins: the peroxides of lipidic derivative quinone, albuminous radiotoxins (owing to disintegration of cells of a tumour and healthy tissues), histamine, choline. These connections cause an intoxication and can cause depression haemopoiesis, that finds the granulocytopenia, lymphopenia with the subsequent development, a thrombocytopenia and, less often, anemias.

There is a certain dependence on area of a body and volume of the tissues, exposed to an irradiation. The most sensitive in the plan for development of the total reaction is the top part of a stomach, a head, a thorax.

On classification of experts the Word Health Organization distinguish next total radiation reactions:

1. Easy radiation reactions: loss of appetite, a nausea, unitary vomitting;
2. Average radiation reactions: a constant nausea, vomitting during the first and second half of treatment, general weakness;
3. Heavy reactions: repeated vomitting during all rate of radiotherapy (both in day of an irradiation, and in days when the irradiation was not carried out.

Thus, leading clinical attributes are the nausea and vomitting.

Heavy radiation reactions, leukopenia (is lower 3×10^9/l) demand a break in treatment. Total radiation reaction is convertible. All broken processes in organs and systems are gradually restored and in 3-8 months come to norm.

Radioprotectors can be applied to preventive maintenance of the total radiation reaction: mexamin hydrochloride 0,05 30 minutes prior to a session of radiotherapy; cystamine dihydrochloride on 0,2-0,8 daily or in a day 1 hour prior to an irradiation. At heavy reactions at carrying out of a subtotal or total irradiation it is applied hemosorption. Are very effective colony-stimulating factors granulocyte, in particular - leukomax (recombinant human granulocytemacrophage colony-stimulating the factor) - 3 mkg / kg up to 10 mkg / kg of weight day. The maximal duration of treatment - 10 days.

From antiemetic means appoint: aminazine of 25 mg 1-3 times day, cerucalium - 10 mg inside up to meal on 1-2 tablets 2-3 times day.

The patient, suffering cardiovascular diseases, it is necessary to appoint corresponding preparations and the means raising arterial pressure (at a hypotonia).

Complex application of the specified actions allows to carry out a full rate of radiotherapy without display of radiation reaction more often. When, despite of measures of preventive maintenance, there are symptoms of the total radiation reaction, it is necessary to make a break in an irradiation, however thus it is necessary to remember, that infringement of a rhythm of an irradiation, is especial in first half of course, has an adverse effect on results of treatment. Therefore the compelled break at the absorbed dose 20-30 Gy should not exceed 3 days. At a dose 40-50 Gy, depending on character of disease, such breaks in radiotherapy can be increased till 10-14 days.

Local radiation injuries at radiotherapy

Depending on duration of time after an irradiation local injures share on early and remote. Restitution sublethal the irradiated cells occurs within 100 days. (within 3 months), it is necessary to count the radiation injures developed in this term early. All damages developed later, are late (remote).

Local radiation reactions

Skin. Reactions of a skin and subcutaneous cellulose tissue are the most often since these tissues first of all are exposed to influence of radiation at an external irradiation. Most frequently reactions of a skin are observed at use of opposite fields. Radiosensitivity of a skin depends on lines of factors. So, there are individual fluctuations of radiosensitivity of a skin, a skin of women a little radiosensitive, than the skin of men. The skin possesses also regional radiosensitivity which decreases in the following order a neck, a breast, a belly, hips, a back, a face. The skin axillary and inguinal is most sensitive area, an internal surface of hips, cubital a bend, area of a neck. At Basedov illnesses, at greenstones, a diabetes radiosensitivity of a skin accordingly raises. Inflamed, hyperemic the kin becomes more radiosensitive.

Distinguish the following radiation reactions of a skin: erythema and radiodermatitis (dry and wet). Erythema - expressed hyperemia skin in a zone of an irradiation, it is accompanied by puffiness, a moderate itch. In a basis of development erythema expansion of capillaries of a skin.

With other things being equal erythema after a unitary irradiation develops at a dose 4 Gy a low-voltage x-ray irradiation, 7,5-8 Gy gamma - ray radiations. At conventional fractionation a single dose of gamma-rays - radiation erythema develops after a dose 30-35 Gy. After 2-3 weeks after the ending of an irradiation the specified phenomena usually disappear or, according to a field of an irradiation, there is an easy pigmentation with the subsequent peeling, kept some months.

Dry desquamation - change of a skin in a zone of the irradiation, shown by a fine peeling epidermis, dryness, pigmentation on a background hyperemia, puffiness. It is accompanied by an itch. Dry desquamation usually develops after a unitary irradiation in a doze 8-12 Gy gamma-rays radiations or 40-50 Gy fractional.

In these cases recovery of an irradiated skin not always full - non-uniform depigmentation, sometimes develop telangiectasis (proof expansion of fine hypodermic blood vessels).

Wet desqumation is characterized by formation the blisters with serous or serous-purulent contents on a background hyperemia and puffinesses of the irradiated skin. Wet desqumation usually develops after high total doses of an irradiation (more than 50 Gy) or 12-16 Gy unitary (one-time) gamma-rays of radiation. Epithelization there is slowly then remains dry is more often, pigmented atrophy a skin.

Radiation reactions of a skin are always accompanied by loss of hair in a zone of an irradiation. Depending on weight of radiation reactions epilation it happens constant and time when

hair grow, but they are, as a rule, defective (rare, dry and gray-haired). The threshold absorbed dose of an irradiation causing epilation, is close to 2,5-3 Gy on a head.
At this dose and higher, approximately up to 6 Gy, expressed epilation begins on 14-17 day of illness. At the biggest degree of weight of defeat epilation arises for 8-9 day.

Radiation Histopathology of skin

- Erythema – arteriolar constriction with capillary dilation and edema, with extravasation of leukocytes and erythrocytes.
- Dry desquamation – reflection of response of the germinative epidermal layer, diminished mitotic activity; cells of the basal and parabasal layers swollen; thin epidermis; desquamation of large macroscopic flakes of skin.
- Wet desquamation – intrasellular edema; vesicles coalesce to form bullae exterior to the basal laer, eepidermis may slough, exposing the dermal surface, coated by fibrin.

Acute radiation dermatitis

- Cells of the basal layer are decreased in number and lose cohesion and intracellular brindging.
- Intrasellular and extrasellular vacuolation are present.
- Arrest of mitosis in proliferative layer.
- Shortened life – span of progenitor cells.
- Thickened dermal collagen and elastic fibers.

Radiation reactions of mucous membranes (mucositis, radiation epithlitis) develop at an irradiation hollow organs. They can simultaneously be observed with radiations reaction of a skin or separately. But as mucous skin reactions possess the big radiosensitivity on them radiations reactions can arise at smaller dozes, than reactions of skin.
Distinguish the following stages radiations epithelitis. At I stages epithelitis are available hyperemia and an easy edema mucous. Further occurs cornification epithelium and mucous it is represented whitish, grown turbid, dryish.

At II stage there is a tearing away become horny epithelium and formation of single erosion with necrotic is for a short while (a stage multifocal uptake filmy epithelitis).

At III stage there is an extensive tearing away epithelium and formation continuous erosive surfaces (a stage drain filmy epithelitis).

From mucous membranes most radiosensitive conjunctiva. Reactions here are characterized by that between 17 and 21-st days after a dose of an irradiation at 25-30 Гр mucous reddens in 2-3 days after that there are erosion and a strike owing to transudation fibrin. Usually, if not was overdoses, all phenomena pass in 2-3 weeks after treatment. The mucous membrane of a mouth during an irradiation becomes fluid, hyperemic and painful. Are quite often marked xerostomia (dryness in a mouth, connected with suppression of function salivary желез), infringement of flavouring sensations.

At an irradiation of a throat and drinks of change on the part of a mucous membrane are clinically expressed in fugacious the phenomena: hoarseness of a voice, pains and difficulty at swallowing. The beam laryngitis arises usually at furnace to a dose 40-45 Gy.

Reaction on the part of bronchial tubes is shown dry attack-like by cough, a short wind, pains in a thorax, sometimes moderate rise in temperature of a body. The radiations pneumonia quite often develops.

Reaction mucous a gullet is characterized dysphagy (feeling of burning and difficulty at passage of food), pains behind a brest and in nterscapular space, sialorrhea. Esophagitis can arise at furnace to a doSe 30-40 Gy.

Reaction on the part of a mucous membrane of a bladder is shown, painful urination, pains in the bottom of a stomach. Arises usually at furnace to a dose 35-40 Gy.

The mucous membrane cervix of the uterus and bodies of a uterus possesses rather high resistency. Epithlitis these bodies can develop at furnace to a doze from above 60 Gy.

For the prevention of local radiation reactions of a skin of it usually process vegetative and animal oils, indifferent creams. At occurrence erythema apply vitaminized cod-liver oil, sea buckthorn oil, 0,5 % prednisolone ointment. At development dry desqumation use ointment 0,5 % prednisolone.10 % Streptocid and other ointments. Ointment is rendered on an irradiated skin with 2 times day (in the morning after night dream and in the afternoon after lunch dream; before dream to grease does not follow, since fat for a night is erased). Treatment wet desqumation carry out more often in the open way without a bandage. It is widely used vitaminous preparations: pantenol-spray**,** **"**", at radioepithelitis a solution dimexidum 5 % - 10 %.

For preventive maintenance and treatments radioepithelitis avoid mechanical and thermal influences, process 0,25 % - 1 % a solution Novocaine, oil irrigation (olive, sunflower, peach oil).

With the purpose of preventive maintenance and also to facilitate current beam pneumonitis, steroid hormones are applied.

Treatment of radiation cystitises and rectitis reduced basically to washing a bladder and a direct gut antiseptic solutions (Furacillin 1:5000), a direct gut daily wash out a warm solution infusion camomiles. Oils of a dogrose are appointed to night, a solution dimexidum 5 % by microclyster.

Radiation damages

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

Sharp radiation necrosis differs rough current. In 7-10 days erythema gets proof character, it is accompanied by strong pains, deterioration of the common condition and rise in temperature. Peripheral lymph nodes increase. In the first days after an irradiation there are bubbles with a light liquid. After opening bubbles and tearing away epidermis are found out necrosis tissues which surface is covered a with not removed yellowish raid. After tearing away necrotizing tissues the deep ulcer is found out. All process is accompanied by strong pains, however in some cases early radiation necrosis can develop and without the expressed pains and a hypostasis. Sharp radiation necrosis it is observed at the big doses fractionated irradiations (about 100 Gy and more) at single dozes more than 20 Gy-50 Gy.

In a basis of late radiation damages infringements of more radioresistant structures demanding at the same doses ionizing radiation of greater time for realization of radiation damage lay. Clinical displays of late radiation damage are consequence of gradual accumulation of changes in the fine blood and lymphatic vessels causing infringements of microcirculation and development hypoxia of irradiated tissues, consequence of that is them fibrosis and a sclerosis. In this process also plays an essential role destruction of cellular elements with replacement by their cicatricial tissues, and also sharp oppression reparative opportunities of cells.

To late beam damages carry:

1.Atrophic processes
2. Hyperplastic processes
3. Radiation fibrosis or indurative edema
4. Radiation ulcers, late necrosis
5. A 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 reparative process is reached by a high-calorific meal, purpose of a complex of vitamins, fresh fruit and vegetables. The daily toilet of a ulcer and processing by a solution of antibiotics is recommended, and further impose bandages with ointments, including containing sea-buckthom oil.

Sometimes apply Novocaine blockade of 0,25 % by a solution. When conservative treatment is inefficient at anatomic permissibility there is a question on early surgical intervention with necrectomy or amputation of the struck segment of finiteness not later, than in 2-2,5 months, i.e. in terms when restriction of a zone necrosis is just planned. Terms of treatment of heavy local defeats are delayed from 0,5 till 1 year.

Treatment of late damages should be under construction in view of the clinical form of damage. At atrophic dermatitis it is recommended to apply steroid and vitaminized oils. At treatment of hypertrophic processes and fibrosis are applied absorbing preparations, such as dimexidium, lidasa and glucocorticoid. Purposeful medicinal electrophoresis dimexidium, heparinum and proteolytic enzymes quite often gives good therapeutic effect. This technique yields good results and at treatment of late radiation ulcers and necrosis. However the basic method of treatment of such damages should be counted radical excision the damaged tissues with the subsequent skin-plastic replacement of defect.

Radiating protection of patients at radiotherapy.

At radiotherapy of malignant tumours the absorbed doses ionizing radiations are defined according to clinical indications according to principles of radiating oncology and directed on achievement of the maximal selectivity of defeat of tumours. As doses thus are used big, as against radiology, radiation influence on patients is accompanied by the determined effects on the part of healthy tissue, however thus tolerance, i.e. the limiting beam loading which is not resulting in irreversible changes a tissue should not be exceeded. Medical use of sources ionizing radiations from consideration of frequency of stochastic effects can be excluded, as it in most cases takes place only at malignant tumors. The persons, suffering such diseases, by virtue of character of diseases and age in which they develop, cannot cause the essential contribution to genetically significant dose. In view of the latent period inherent induced by radiation in tumours, is practically insignificant and risk of occurrence of a new tumour as a result of a therapeutic irradiation already available tumors. At the same time, in radiotherapy the determined defeats have special value if to take into account, that the deviation in a brought dose on 5 % is considered critical both for treatment of a tumour, and for influence on normal tissue.

Thus the principle of a substantiation and optimization is used according to ICRP. At carrying out of radiotherapy all possible measures for prevention of radiation complications at the patient should be accepted.

The most important for protection of the patient in radiotherapy is exact leading correctly appointed doze of radiation on a zone of tumoral defeat at minimally possible irradiation of healthy tissues.

In this connection are demanded much of dosimetric maintenance of beam treatment. For what equipment of radiological branches by radiological simulators, dosimetric and planning systems is provided.

The x-ray computer tomographs allowing with the big accuracy to transfer geometrical parameters of irradiated structures in computer system of planning of an irradiation have great value.

The control of correctness of the beam fields of an irradiation is established with the help special radiodiagnosis the device - a radiological simulator of an irradiation which allows to carry out fluoroscopy and rontgenography for exact localization of a field of an irradiation and a choice of a direction of a beam of radiation in view of volume of a target.

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

Planning of an irradiation at beam therapy with use open radionuclid sources is based on the account of a metabolism of a radiopharmaceutical preparation, and also its physical characteristics. On the basis of this information, knowing provisional values of weights of bodies and tissues, calculations of doses of radiation both in volume of a target, and in bodies and the tissues representing interest are carried out.

At an external remote irradiation of the patient it is necessary to stack so that stacking was reproduced. The patient should be in convenient position; means immobilization are if necessary used. These means apply to reproduction of position of the patient at each session of an irradiation; they have special value when it is difficult for patient to keep desirable position of an irradiation itself.

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

For protection of normal tissues frequently place in a beam of radiation absorbing materials: figured blocks, wedge filters, the trellised diaphragms compensating filters.

The control of characteristics of a beam of radiation and direct measurements over the patient are carried out with the help of corresponding dosimeters. At an external irradiation dose measurements should give dozes of radiation in the 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 used radionuclid it is necessary to know with 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.

Radiating protection at carrying out of radiotherapy

Radiating protection of the personnel at carrying out of radiotherapy. On a degree of radiating danger methods of beam treatment can be arranged in the following order: intracavitary therapy with the help of traditional methods of introduction of radioactive preparations, therapy with the help hose devices and remote therapy.

RADIATION PROTECTION PRINCIPLES

There are four basic radiation protection principles that can be employed to reduce exposure to ionizing radiation   These principles are based on consideration *of four radiation protection factors* that alter radiation dose, time, distance, shielding, and quantity.

Time

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. Many radiation monitoring devices measure exposure in milliroentgens (mR) per hour. An exposure rate of 60 mR/hr means that for each minute spent in a radiation field, a person will receive a 1-mR exposure (60 mR/hr - 5- 60 min/hr = 1 mR/min)   Obviously, the longer a person remains in a radiation field, the more radiation that person will accumulate.

A *rotating team approach* can be used to keep individual radiation exposures to a minimum as long as patient care is not compromised and if personnel are available

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 addition, some specialty centers for radiation accident management have constructed shielded surgical tables for protection. Such measures are, however, not recommended in the community hospital.

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.

Medical irradiation at beam diagnostics

Radiological diagnostics. The most widespread kind of radiation used in the diagnostic purposes, X-rays are.

The data of results of research show, that over 50 % the population receives doses of an irradiation by X-ray examinations.

From all methods of beam diagnostics only radiological and radionuclid « in vivo » researches are connected to influence ионизирующего radiations on an organism of the patient.

radionuclid diagnostics gives considerably smaller contribution to a collective effective doze of an irradiation of the population, than radiological researches (in 10 times and more), that is connected to smaller frequency of application radionuclid researches in clinical practice. At the same time, real effective dozes on one patient at some kinds radionuclid researches can exceed dozes of an irradiation from many kinds of radiodiagnosis. As a rule, effective dozes at use of radiological researches exceed doses from short-leave radionuclids (^{113m}In; ^{99m}Tc), but at introduction such radionuclid as ^{67}Ga they it is much less.

Table 3

Doses from medicine procedures

Type of research	Dose (mSv)
Chest film	0,1-0,2
Fluoroscopy of chest with image-enchanced	3
Fluoroscopy of chest non-image-enchanced (“conventional”)	5
Fluoroscopy of stomach or intestine with image-enchanced	10
Fluoroscopy of stomach or intestine with non-image-enchanced (“conventional”)	20
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 a 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.

Effects on the embryo. Effects of radiation

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, including (possibly) none at all. 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 effect's on embryo:

(for those exposed in utero in the period between 8 and 15 weeks after conception)

Δ downward shift of IQ distribution:

30 IQ points for 1000 mSv

Δ dose required to shift from normal Ig to severely mentally retarded:

1000 mSv or more
Δ dose required to shift from low IQ to severely mentally retarded:
a few hundred mSv.

From all methods of beam diagnostics only X-ray and radionuclid « in vivo » researches are connected to influence ionizing radiations on an organism of the patient. Nuclear medicine gives considerably smaller contribution to a collective effective doze of an irradiation of the population, than X-ray researches (in 10 times and more), that is connected to smaller frequency of application radionuclid researches in clinical practice. At the same time, real effective doses on one patient at some kinds radionuclid researches can exceed doses of an irradiation from many kinds of X-ray examinations. As a rule, effective doses at use of X-ray researches exceed does from short time "live" radiopharmaceutical preparations (^{113m}In; ^{99m}Tc), but at introduction such ^{67}Ga they it is much less.

Measures on restriction of a medical irradiation at radiology.

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:

- Non overflow allowable limits of individual doses of an irradiation of the person from all sources of radiation (a principle of normalization);
- Prohibition of all kinds of activity on use of sources of radiation at which received for the person and a society the benefit does not exceed risk of the possible harm caused by an additional irradiation (a principle of a substantiation);
- Maintenance on possible a low and achievable level in view of economic and social factors of individual doses of an irradiation and number of irradiated persons at use of any source of radiation (a principle of optimization).

Principles of the control and restriction of radiating influences in medicine are based on reception necessary and the helpful information or therapeutic effect at minimally possible levels of an irradiation. Thus limits of doses are not established, but principles of a substantiation of purpose of radiological medical procedures and optimization of measures of protection of patients are used.

Radiating safety of patients and the population should be provided at all kinds of a medical irradiation (preventive, diagnostic, medical, research) 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 purpose 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 under medical indications when are absent, or it is impossible to apply, or other alternative methods of diagnostics are insufficiently informative.

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

Rules of carrying out of all kinds radiological diagnostic researches should guarantee 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 body knowing questions of public health services, within the limits of the established allowable levels of an irradiation at the obligatory written approval surveyed after granting of data by it about possible consequences of an irradiation.

At carrying out of radiotherapy all possible measures for prevention of beam complications at the patient should be undertaken.

For radiological medical researches and radiotherapy the equipment registered by republican state body, knowing should be used by questions of public health services.

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

Doses of an irradiation of the patient from carrying out of everyone radiological researches and procedures of radiotherapy should be brought in a personal sheet of the account of doses of the medical irradiation, being by the obligatory appendix to his out-patient card.

The medical personnel has no right directly or indirectly to influence increase in an irradiation of the patient with a view of reduction of own professional irradiation.

At introduction to the patient of a radiopharmaceutical preparation with the therapeutic purpose the doctor should recommend him time abstention from reproduction of posterity. Introduction of radiopharmaceutical means with the purpose of diagnostics and therapies to pregnant women is not supposed. At introduction with the purpose of diagnostics or therapy of radiopharmaceutical preparations to feeding mothers feeding of the child by a breast should be temporarily suspended. Term of the termination of chest feeding depends on a kind and quantity of an entered preparation and is defined by separate instructions.

Protection of patients at radiological researches. In « Sanitary rules and norms. Hygienic requirements to the device and operation of x-ray cabinets, devices and to carrying out of radiological researches », it is underlined 2004, that the system of maintenance of radiating safety at carrying out of medical radiological researches should provide practical realization of three basic principles of radiating safety - normalizations, substantiations and optimization.

The principle of normalization is realized by an establishment of hygienic specifications (allowable limits of dozes) irradiations.

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

The principle of a substantiation at carrying out of radiological researches is realized in view of the following requirements:

- Priority use of alternative (not radiating) methods;
- Carrying out X-ray researches only under clinical indications;
- A choice of the most sparing methods of radiological researches;
- The risk of refusal of radiological research should exceed obviously risk from an irradiation at its carrying out.

At achievement of the saved up doze of a medical diagnostic irradiation of the patient 500 mSv measures on the further restriction of his irradiation if radiology procedures are not dictated by vital indications should be accepted.

At reception by persons from the population of an effective doze of radiation for a year more than 200 mSv, or the saved up doze more than 500 mSv from one of sources of an irradiation, or 1000 mSv from all sources of an irradiation the special medical inspection organized by controls of public health services is necessary.

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

- Correct definition of a position at radiography. For example, the picture of a skull in a front - back projection causes 50-100 doze on a crystalline lens of an eye in comparison with a hind-forward projection. Further, the front-back picture easy instead of hind-forward gives 5-fold increase in a doze on dairy to iron.

- Collimation of X-rays beam.
- 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.
- Use of preservation of the image (at carrying out of researches, at surgical interventions). Introduction of hardware-software complexes on processing and archivings of videoimages allows to lower a doze of an irradiation of patients considerably also.
- Wide application digital radiography will allow to reduce essentially a doze of radiation at radiography.
- Usage fluoroscopy with image-enchanced. In this case the fluorescent screen is combined with an electronic device that converts the visible light into an electron stream that amplifies the image (makes it brighter) by converting the electron pattern back into visible light. This system allows the radiologist to see the image clearly without necessitating dark adaptation of the eyes, as is necessary in "conventional" (non-image-enhanced) fluoroscopy. The dose is decrease for this technology (see tab.).

Radiation protection of the personnel at radiology researches. That personnel which directly works with sources of radiation is most subject to an irradiation or is in a zone of radiation (for example, the nurses supporting small children).

At the decision of a question on protection of the medical personnel it is necessary to observe the following rules:

1. At carrying out of radiological researches it is necessary to work quickly, as much as possible to limit as a diaphragm a working beam of radiation.
2. To use protective clothes.
3. To be at carrying out of procedures on sufficient distance from sources of radiation.
4. The great value has definition of indications, a choice of a method and algorithm of research. The question is a necessary ratio of benefit and harm.

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 device works.

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

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

Radiation protection of patients at nuclear medicine. Carrying out of nuclear medicine procedures is connected to a small dose of the radiation, unable to cause not stochastic radiation injuries, however, as well as in x-ray diagnostics, the opportunity of stochastic effects is not excluded.

As well as in x-ray diagnostics the regulation dose on patients and the personnel is carried out at nuclear medicine. However protection of patients on the basis of physical principles of protection from ionizing radiation in conditions nuclear medicine « in vivo » diagnostics is possible only due to reduction of quantity entered in an organism radionuclides. Decrease dose is achieved by use of modern hardware and methodical opportunities at preservation of the necessary diagnostic information. So, sodium iodine ($Na^{131}I$), causing rather big дозовое influence, now for diagnostics practically is not applied. Contra-indications to carrying out radionuclid « in vivo » researches were above specified.

Radiating protection of the personnel at nuclear medicine. Radiating protection against an external irradiation. At storage, packing and introduction of radiopharmaceutical preparations in quantity of several tens MBq the dozes received by the personnel from an external irradiation, can appear big. Protection against external radiation of open radioactive sources should be provided not only at their packaging, but also in chambers where there are patients by whom radionuclid are entered in the medical purposes. The choice of means of protection is influenced with many factors, main from which are: 1) physical characteristics of radiation; 2) time of action of radiation for the personnel; 3) distance between a source of radiation and a workplace; 4) a degree of shielding and radiating properties of a protective material. The account of sets of these factors allows to calculate and carry out radiating protection of the personnel against external radiation in practice and to provide non overflow the basic dose limits. 3 principles of radiating protection follow from the listed factors: protection by time, distance and shielding.

Radiating protection against an internal irradiation. A problem of protection at an internal irradiation more difficult, than at external as when radionuclid is inside an organism, to change conditions aside amplifications of protection it is practically impossible.

Quantity radionuclid, arrived in an organism, as well as ways of its receipt, depend on lines of factors, in particular, from activity of a preparation, character of spent works, use of protective adaptations, observance of requirements of radiating safety and the organization of a sanitary - radiation control. Rules regulate quantities of activity radionuclid on a workplace (protection by quantity). Receipt of radioactive substances in an environment is warned by protective actions which basic purpose - to not allow uncontrolled receipt radionuclid in a zone of a presence of the personnel. To these actions concern: automation of operations with open sources, use of the hermetically sealed protective chambers, containers and exhaust cases, and also use of means of an individual defence.

The complex of protective measures at work with radioactive substances in an open kind should provide prevention of air pollution, working surfaces, integuments and clothes of the personnel in working and adjacent rooms. Protective measures should be applied as well against possible pollution of an environment - air, water and ground.

To number of the basic preventive actions on maintenance of radiating safety of the personnel working with open radioactive sources, the following concern: 1) accommodation and a lay-out of premisesб 2) furnish of premises; 3) protective and auxiliaries; 4) rational systems of ventilation and the water drain; 5) gathering and distance of radioactive waste products; 6) a choice of technological modes; 7) the rational organization of workplaces of the personnel; 8) observance of rules of personal hygiene.

Requirements to furnish of premises. In furnish of the premises intended for work with open radioactive sources, it is necessary to combine requirements of effective deactivation and preventive maintenance of visual exhaustion. For premises of constant stay of the personnel are recommended light tone of painting of walls.

Walls and ceilings of premises become covered special non-adsorbing materials. Floors become covered non-adsorbing materials, for example, plastic compounds.

For convenience of cleaning and deactivation corners of premises are brief. Edges{*territories*} of coverings of floors should have the elementary structures.

Requirements to protective and to auxiliaries. In premises for works with radionuclid protection against external radiation provides a set of filters. For each manipulation with open radioactive sources it is necessary to have the special equipment corresponding to a kind used radionuclid and its activity. This equipment should include mobile filters, remote toolkit (a nipper, captures, holders, tweezers), trays, pallets, ditches, etc. Remote tools and local shielding provide reliable enough protection against external radiation бета-and scales - sources with activity up to several hundreds MBq.

The equipment and working furniture should have smooth surfaces, a simple design and adsorbing the coverings facilitating distance of radioactive sustances.

Bowls and sinks for washing the polluted utensils and toolkit, and also 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. Drainage pipes of bowls - sinks should to incorporate to the basic sewer directly, whenever possible. Drains should be accessible to the periodic radiating control.

Requirements to ventilation and water drains.

The organization of workplaces. At the organization of workplaces of the personnel accommodation of the equipment, the equipment and remote tools, and also control facilities should be carried out in view of zones of availability for working and maintenance of rational alternation of working poses on the basis of anthopometrical and psychophysiological parameters.

The quantity radionuclid on a workplace should be minimal. The number of operations at which losses radionuclid are possible, should be finished with a minimum. At work with open radioactive sources it is necessary to use plastic films, a filtering paper and other subsidiary materials of single using for restriction of pollution of workplaces, the equipment and premises. Works should be carried out on trays, pallets and the ditches executed from non-adsorption of materials.

The equipment, utensils and tools in working premises should be marked.

In premises for works with open radionuclids are forbidden: stay of the personnel without necessary individual protective means; storage of foodstuff, tobacco products, domestic clothes, cosmetic accessories and other subjects which are not having the attitudes to work; reception peep, smoking, using cosmetic accessories.

The ICRP recommends that any exposure above the natural background radiation should be kept as low as reasonably achievable, but below the individual dose limits The individual dose limit for radiation workers is 50 mSv in one year, and for members of the general public, is 1 mSv per year These dose limits have been established based on a very conservative approach by assuming that there is no threshold dose below which there would be no effect It means that any additional dose will mean a proportional increase in health effects This relationship has not yet been established in the low dose range where the dose limits have been set There are many high natural background radiation area around the world where the annual radiation dose received by members of the general public is several times higher than the ICRP dose limit for radiation workers Still, there is so far no evidence of any detectable health effects

The ICRP (the International Commission on Radiological Protection) and (the International Atomic Energy Agency IAEA recommend the individual dose must be kept as low as reasonably achievable, and consideration must be given to the presence of other sources which may cause simultaneous radiation exposure to the same group of the public. Also, allowance for future sources or practices must be kept into consideration so that the total dose received by an individual member of the public does not exceed that dose limit. In general, the average annual dose received by radiation workers is found to be considerably lower than the individual dose limits This demonstrates that good radiation protection practice can result in low radiation exposure to workers.

At what level is radiation harmful?

The effects of radiation at high doses and dose rates are reasonably well documented A very large dose delivered to the whole body over a short time will result in the death of the exposed person within days. Much has been learned by studying the health records of the survivors of the bombing of Hiroshima and Nagasaki We know from these that some of the health effects of exposure to radiation do not appear unless a certain quite large dose is absorbed At lower doses and dose rates, there is a degree of recovery in cells and tissues.

However, at low doses of radiation, there is still considerable uncertainty about the overall effects. It is presumed that exposure to radiation, even at the levels at natural background, may involve some risk of cancer. However, this is yet to be established. To determine what level of exposure would cause cancer would mean observing millions of people over several generations. Such an analysis would be complicated by the impossibility of isolating a part of the population as a control group which had not been exposed to radiation. In addition, thereare thousands of substances in our every day life besides radiation that can also cause cancer, including chimney soot, tobacco smoke, ultraviolet light, asbestos, some chemical dyes, fungal toxins in food, viruses, and even heat Only in exceptional cases is it possible to identify conclusively the cause of a particular cancer.

There is also experimental evidence from animal studies that exposure to radiation can cause genetic effects. However, the studies of the survivors of Hiroshima and Nagasaki give no indication of this for humans. Again, if there were any hereditary effects of exposure to low-level radiation, they could be detected only by careful analysis of a large volume of statistical data, and they would have to be distinguished from those of a number of other agents which might also cause genetic disorders, but whose effect may not be recognized until the damage has been done (thalidomide, once prescribed for pregnant women as a tranquilizer, was one for example).

With all the knowledge so far collected on effects of radiation, there is still no definite conclusion as to what level of exposure harm to health begins

Risks and benefits. We all face risks in everyday life It is impossible to eliminate them all, but it is possible to reduce them The use of coal, oil, and nuclear energy for electricity production, for example, is associated with some sort of risk to health, however small In general, society accepts the associated risk in order to derive the benefit from the introduction of such a practice Any individual exposed to carcinogenic pollutants will carry some risk of getting cancer Attempts are made in the nuclear industry to reduce such risks to as low as reasonably achievable

Radiation protection sets examples for other safety disciplines with two unique rules

- First, there is the assumption that any level of radiation above zero will carry some risk of harm to health.
- Second, to protect future generations from the activities that we conduct today.

The use of radiation and nuclear techniques in medicine, industry, agriculture, energy, and other scientific and technological development areas has brought tremendous benefits to human society. The benefits in the field of medicine for diagnosis and treatment in terms of human lives saved are enormous Radiation is a major tool in the treatment of certain kinds of cancer Three out of every four patients hospitalized in the industrial countries benefit from some form of nuclear medicine The impacts in the area of agriculture have been very striking in bringing improved variety and yield of crops. The beneficial impacts in other fields are similar.

No human activity or practice is devoid of associated risks. Radiation should be viewed from the perspective that the benefit from it to mankind is less harmful than many other agents.