ODESSA NATIONAL MEDICAL UNIVERSITY

Department of Radiation Diagnostics, Therapy, radiation medicine and Oncology

METHODICAL RECOMMENDATIONS FOR STUDYING THE TOPIC:

" Basic properties of ionizing radiation. Features of the device of X-ray and radiological departments".

(for the 3th year students of the dentistry faculty)

Approved
at the methodical meeting of the department
"27" August 2021
Protocol №1
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"The main properties of ionizing radiation. Features of the device of radiological and radiological departments "- 2 years

1. Actuality of theme.

The ecological aspect - acquaintance with the nature of ionizing radiation convinces of the need to protect the environment from exceeding the natural level of radiation. Knowledge of the basic properties of ionizing radiation, units of measurement and methods of determining the dose of radiation, the structure of radiometers and dosimeters, the structure of X-ray and radiology departments are necessary for specialists in any field. Therefore, the main educational goals are related to the formation of professional skills for deontology, ecology, legal, psychological field of activity in medicine.

2. Objectives of the lesson:

2.1 General objectives:

1. Get acquainted with the structure of the atom.
2. Have a general idea of the laws of radioactive decay.
3. Know the primary physico-chemical and biological processes under the influence of ionizing radiation.
4. Assimilate information about the interaction of ionizing radiation with matter;

2.2 Educational:

1. Deontology - to provide information for interns' conversations with patients about the potential dangers of ionizing radiation.
2. Responsibility - to report information that implies the responsibility of a physician who uses ionizing radiation for diagnostic or therapeutic purposes.
3. Legal representations - the information in this lecture allows the doctor to avoid unfounded accusations of complications during the disease after medical or diagnostic procedures.

2.3. Specific goals:

- know:

1. What is the phenomenon of absorption of radiation of different types in matter.

2.Osnew properties of ionizing radiation, biological effect of ionizing radiation on healthy and pathologically altered cells.

2. Mayou have an idea of the basic properties of ionizing radiation, the biological effect of ionizing radiation on healthy and pathologically altered cells.

2.4. Based on theoretical knowledge on the topic:

- master the techniques / be able /:

1. Be able to predict the effect of the interaction of different types of ionizing radiation with matter.

2. Evaluate and calculate absorbed, exposure, equivalent, lethal, threshold, population doses.
3. Solve relevant clinical problems.
4. Interpret mechanisms of biological action of ionizing radiation on a healthy and pathologically altered cell from the standpoint of physiology, pathological anatomy and physiology, biology.

3. Materials for classroom independent training (interdisciplinary integration).

Names of previous disciplines	Acquired knowledge and skills
1. Physics.	Know the basics of nuclear physics (types of ionizing radiation, units of measurement, dosimetry). 1. Solve problems in nuclear physics. 2. Choose the right methods and techniques of protection against the main types of ionizing radiation. 3. Use the main types of radiometers and dosimeters. 4. Justify the use of a dosimeter or radiometer in different conditions.
2. Biology	Describe the structure of the cell, apply knowledge of the mechanism of cell division to explain the effects of ionizing radiation on cells, tissues, organs, etc., classify organisms by types and species, sketch the scheme of cell division and the cell itself, compare different types of organisms and cells, demonstrate basic knowledge .
3. Histology	Describe the structure of different types of cells and tissues, determine tissue types, apply knowledge to explain the effects of ionizing radiation, classify tissues, schematically depict the structure of cells, compare the effects of ionizing radiation on different types of tissues.
4. Normal physiology	Describe the main metabolic processes in the human body, determine the mechanisms of action of ionizing radiation and assess their harmful effects, have knowledge, compare the effects of various harmful factors on

	physiological processes

4. Content of the topic (text or thesis), graph of the logical structure of the lesson.

4.1 Physics of ionizing radiation.

The structure of the atom.

All substances consist of atoms. A substance consisting of atoms of the same species with the same chemical properties is called a chemical element.

The structure of the nucleus. The nucleus of an atom consists of protons and neutrons, together they are often called nucleons. A proton is a stable elementary particle and has a positive unit charge. The mass of the proton is equal to $1.6729 \cdot 10^{-}24$ g, which is 1836 times the mass of the electron. In the free state, the proton captures an electron, forming a hydrogen atom. A neutron - a nuclear particle - has no electric charge. The mass of the neutron is approximately equal to the mass of the proton.

Atoms whose nuclei contain the same number of protons but different numbers of neutrons are called isotopes of this element (isotope is a Greek word meaning the same place). Isotope atoms differ in their relative atomic mass, but have the same chemical properties.

An important characteristic of an atom is its relative atomic mass.

Since 1961, 1/12 of the atom of the carbon isotope ^{12}C has been recommended as the unit of atomic mass.

The mass number is determined by the number of protons and neutrons (nucleons) in the nucleus of the atom. To denote this type of atom, the symbol of the chemical element is usually given the ordinal number of the element Z at the bottom left, and the mass number A at the top. leads to the emergence of electannual charges of opposite signs. This ability has only those radiations whose energy is greater than the binding energy of the electron in the atom.

Radioactivity. Many atomic nuclei have the ability to spontaneously (without any external influence) disintegrate and emit particles, turning into atomic nuclei of another type. This phenomenon is called radioactivity. Only five types of their radioactive transformations are known: alpha, beta decay, neutron decay, spontaneous (spontaneous) fission, and the isomeric transition of the excited nucleus to the ground state by the release of gamma quanta. Alpha and beta distributions are the most common forms of radioactive conversion of nuclei.

Alpha distribution. Heavy radioactive nuclei with Z> 82 are characterized by involuntary transformation with the release of an alpha particle, which is a nucleus of helium 2 He, consisting of two protons and two neutrons. Radioactive transformation with the release of alpha particles can be recorded as follows:

AND **A-4 4**

- × → —— Y + - No.

Z Z - 2 2

As a result of the alpha decay, the mother element X is transformed into a child element Y, which is located in the periodic table two cells earlier than the mother.

Beta decay. During beta decay, radioactive nuclei emit either electrons or positrons. A positron is an elementary particle whose mass is equal to the mass of an electron having a single positive charge (antiparticle of an electron). During beta decay with the release of an electron, one of the neutrons in the radioactive nucleus is converted into a proton. The mass number of the atom remains unchanged. Beta transformation with electron emission can be expressed by the formula:

AND **AND**

- × → - Y + e⁻

Z Z +1

When the nucleus decays with the release of a positron, one of the protons in the nucleus is converted into a neutron and the charge of the nucleus decreases by one.

Gamma radiation. Gamma rays are electromagnetic radiation with very short wavelengths. Most nuclei that occur during radioactive transformations are formed in excited states. During the transition of excited nuclei to lower energy levels, which are accompanied by the release of gamma rays, the energy of gamma quanta is in the range of 10 KeV-5 MeV.

Law of radioactive decay.

The activity of a radioactive substance can be characterized by the number of atoms decaying per unit time, and this number is proportional to the total number of atoms of the radioactive element present in the sample. If N is the number of radioactive atoms, then the number of atoms d decaying in time dt will be determined from the ratio

$$dN = -\lambda N dt$$

where λ is the coefficient of proportionality, called the decay constant. The negative value of the derivative indicates that the number of radioactive atoms decreases over time. The decay constant λ is the probability of an atom decaying per unit time by the fraction of atoms of a given radioactive substance decaying per unit time. The value of 1 / λ determines the average lifetime of radioactive atoms of this isotope.

Units of activity. An important characteristic of a radioactive substance is its activity. The activity of a given radioactive source is the number of atoms decaying per unit time (rasp / s). In practice, a special unit of curie (Ki) is widely used. This is the value of the activity of the drug of this isotope, in which in one second there are 3, 700-10^{1o} acts of decay.

Derivative units - milikuri (mki) and microcuri - (mkki).

Interaction of ionizing radiation with matter

X-ray and gamma radiation, alpha and beta particles, fluxes of neutrons and other nuclear particles, and cosmic rays also belong to the group of radiation

sightings. Absorption of radiation of different types in matter will lead to the same phenomenon-ionization. Charged particles (alpha, beta, etc.) ionize atoms (or molecules) of the medium; electrically neutral radiation (gamma rays, neutrons) ionizes the atoms of the environment as a result of secondary processes.

Alpha particles. When passing through the substance, alpha particles cause strong ionization. The electric field of the alpha particle, interacting with the outer electronic shell of atoms, accelerates electrons and pulls some of them out of this shell. This forms a free electron and a positively charged atom or molecule. In addition to the energy expended on ionization, the alpha particle loses energy when neutral atoms and molecules are broken. The trajectories of alpha particles in matter are rectilinear. When passing alpha particles in the air, an average of 32.5 eV is spent on the formation of one pair of ions.

Beta particles. Beta particles emitted by radioactive atoms have a fairly high velocity. Passing through matter, the velocity of beta particles slows down as a result of interaction with its atoms. The interaction of electrons and positrons with matter is almost the same. The only difference is that at the end of the path the positron disappears when interacting with an electron and the formation of two gamma quanta.

The interaction of fast electrons with matter consists of three main processes: elastic scattering by atomic nuclei, scattering by electrons of atomic shells, and inelastic collisions with atomic nuclei. Elastic scattering of electrons on atomic nuclei is accompanied only by a change in the direction of their motion. Due to the small mass of the electrodes, they often deviate at large angles. The trajectory of the electron due to multiple scattering is so tortuous that if it is pulled in a straight line, its full length will be 1.5-3 times the thickness of the layer of matter passed through the electron.

The interaction of beta particles with the electrons of atomic shells leads to the excitation or ionization of the atom and determines mainly the energy loss of beta particles when passing through matter.

The third process of interaction of fast electrons with matter is inelastic collisions with atomic nuclei. The energy lost by the electron during braking in the electric field of the nucleus is converted into inhibitory X-rays. However, the loss of energy for bremsstrahlung during the passage of beta particles in matter plays a paramount role. The attenuation of beta rays when passing through matter is due to all three mechanisms of interaction.

Gamma radiation. Gamma rays are one of the most penetrating. The penetrating power of gamma radiation depends on its energy and the properties of the passage substance. Weakening of gamma radiation in matter occurs as a result of various processes of their interaction with particles of matter. The main processes that cause the attenuation of the beam are the photoelectric effect, the Compton phenomenon and the formation of pairs. The Compton effect is a collision of a quantum with an electron, in which a quantum transfers part of its energy to an electron and turns into another quantum with less energy. The electrons involved in the Compton effect spend the energy they acquire on the ionization of counter atoms. Because the resulting quanta propagate in all

directions, the Compton phenomenon leads to the weakening of the gamma ray beam.

Neutron radiation. The most intense neutron fluxes are created during a nuclear explosion and during the distribution of heavy nuclei in the reactor. The maximum energy spectrum of the distribution neutrons is 1 MeV, the average energy is about 2 MeV. Free neutrons can be obtained by knocking them out of atomic nuclei. In particular, neutrons can be recovered by bombarding nuclei or alpha particles with gamma rays.

Interaction of neutrons with biological tissue. The type of interaction of neutrons with tissue depends on both the energy of neutrons and the chemical composition of the tissue. Approximately the chemical composition of soft biological tissue can be determined by the formula of the imagined tissue "molecule" (C5H40O18N) x. It is characteristic of living tissue that it consists in general of light elements. The lightest of the elements - hydrogen, the number of atoms ranks first among all tissue elements.

All ionization in the tissue when irradiated with thermal neutrons is due to its origin exclusively to nuclear reactions and mainly to radiation capture. As a result of the capture of a thermal neutron by hydrogen, deuterium is formed and a gamma quantum with an energy of 2.23 MeV is emitted. In the reaction to nitrogen-14, protons with an energy of 0.62 MeV and radioactive carbon-14 are formed. These reactions:

1 2 14 14

$$H + n \rightarrow H + \gamma \text{ and } N + n \rightarrow C + p$$

1 ***1 7 6***

play a leading role in the absorption of thermal neutrons and gamma quanta formed by the reaction, and protons create the main ionization in the tissue. Slow neutrons lose their energy due to the disruption of molecules, their fission, and eventually turn into thermal neutrons.

The basis of primary radiation-chemical changes of molecules can be two mechanisms:

1. Direct action, when a given molecule experiences a change directly when interacting with radiation;
2. Indirect action - a changing molecule does not directly absorb the energy of incident radiation, but receives it by transmission from another molecule.

Excellent properties of ionizing radiation.

- How do ionizing rays differ from others?

Ionizing radiation has common properties, 2 of which are the ability to penetrate different thicknesses of materials (opaque to visible light) and the ability to ionize air and cause ionization and excitation of many atoms and molecules of living cells (hence they are called ionizing rays). especially close attention. These differences are due to high energy. For example, the energy of light is 0.5 eV (electron volts), andα- particles have energy up to 10 MeV. Due to this and other factors, these rays have a strong biological effect .. But

penetrating abilityα- very small particles. These rays are easily trapped by a thin layer of paper. Therefore, when exposed to external radiation, they do not pose a danger to humans. This danger becomes great with the penetration of emitters into the body (incorporation of radionuclides). Hard R-rays,**γ**-rays are able to penetrate the entire human body, lingering only partially. But the specific ionization of these rays is much less than corpuscular. And neutrinos (we do not use them in diagnosis and treatment) can pass without delay through the globe.

All types of ionizing radiation have the following properties:

1) great energygia;

2) high penetrating power;

3) ionizeCha ability - the ability to form many pairs of ions when interacting with atoms of the environment;

4) photochemical ability to activate molecules of silver bromide or other chemical compoundsbow;

5) luminescent ability to cause the glow of some substances;

6) thermal action - the ability of the ionizing radiation energy of the converterkeep warm;

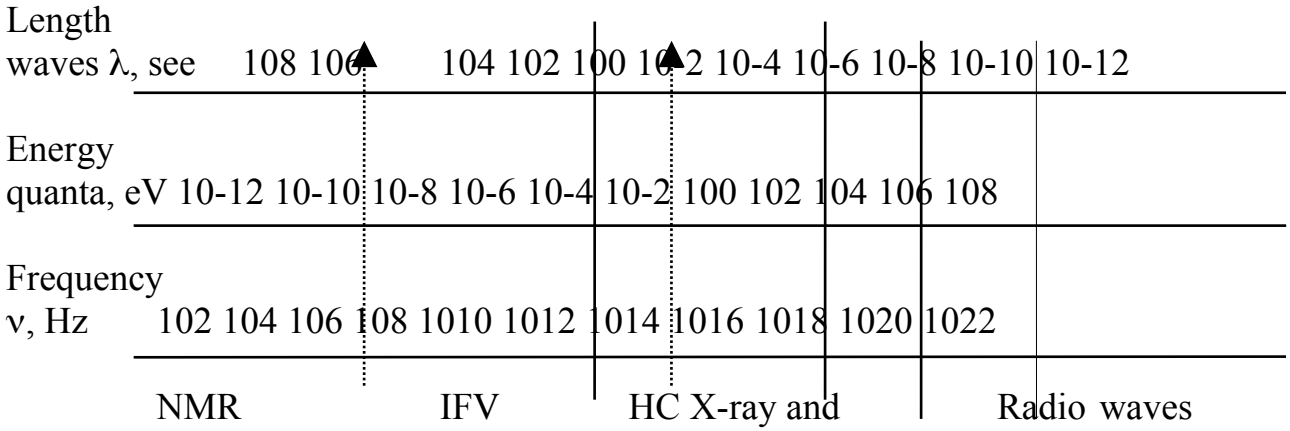
7) strongly expressed biological action.

Nature and properties of ionizing radiation.
All ionizing radiation is divided into corpuscular and photonic.
Corpuscular include alpha-emittedno (α) (nuclei of helium atoms), beta radiation β^- and positrons β^+*),*protons (p), neutrons (n °) and others (more than 200). Alpha particles have a very high energy (up to 10 MeV), with which for the first time in 1919, irradiating the nuclei of atoms, nitrogen received a new chemical element - oxygen and positron.
Photon radiation includes: γ- and X-rays. γ-radiation is high-frequency electromagnetic oscillations (quanta) that are formed during nuclear transformations (wavelength 10-10-10-13 m) and propagate in quantum portions at the speed of light. They were discovered in 1900 by the Frenchman P. Willard.

X-ray - also electromagnetic quantum radiation, but the method of its production is extranuclear (in vacuum X-ray tubeskah in the inhibition of electrons by the target - the anode).

Table 1.1. SPECTRUES OF ELECTROMAGNETIC AND SOUND RADIATION

ELECTROMAGNETIC



SOUND

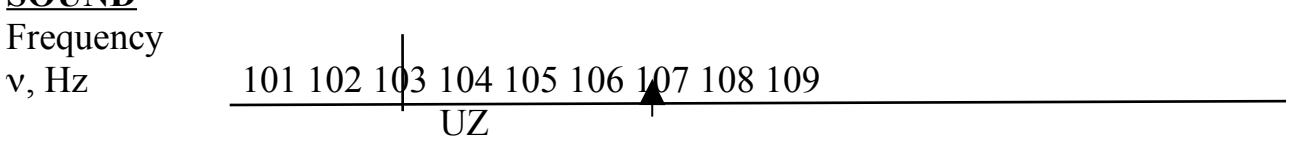


Table 1.2. Physical properties of ionizing radiation

Type of change level	**Radiation energy, MeV**	**Velocity of propagation in vacuum, km / s**	**Length of run in air**	**Length of run in body tissues.**	**Ionizing capacity (ionization density per unit path in air)**
Alpha particles	1-10	20000	Up to 20 cm.	Up to 50 microns	10000-20000 pairs / mm
Beta particles	0.1-2	270000	Up to 15 m	Up to 1 cm	5-10 pairs / mm
Gamma, X-ray rays	0.1-20	300000	Hundreds of meters	Tens of centimeters	1 pair / cm

Primary physicochemical changes that occur in the first fraction of a second lead to the formation of the following links of the reaction, which develop after the direct act of irradiation and bold deep changes in cells and tissues of organisms at considerable intervals. The long-running controversy over the years over whether the direct effect of particles and electrons on chemical bonds in molecules of biochemically important components or OH cells is caused indirectly and has lost its sharpness after numerous studies have shown that a significant role in the action of ionizing radiation is played by the aqueous phase of cells and tissues of the body.

Aqueous phases are directly adjacent to the surfaces of biomolecules with a large number of reaction groups. The water bridges separating these molecules do not exceed 3-4 molecular radii, not to mention that the aqueous phase contains newly formed chemically active organic compounds. Under these conditions, the formed radicals have the ability to react directly with biomolecules and recombination processes are minimized.

Radicals formed during water radiolysis: H, OH, NO2 oxidize and reduce various organic compounds. However, it can be assumed that in the initial stage of radiation damage the decisive role belongs to oxidation reactions and biological action is associated with radicals that oxidize OH and NO2.

5. Materials of methodical providing of employment.

5.1. Tasks for self-examination of the ascending level of knowledge and skills.

1. Know the basics of nuclear physics (types of ionizing radiation, units of measurement, dosimetry).
2. Choose the right materials to protect against the main types of ionizing radiation.
3. Know the structure of the cell, apply knowledge of the mechanism of cell division to explain the effects of ionizing radiation on cells, tissues, organs, etc., classify organisms by types and species.
4. Know the structure of different types of cells and tissues, determine the types of tissues, apply knowledge to explain the effects of ionizing radiation, classify tissues.
5. Know the basic metabolic processes in the human body, determine the mechanisms of action of ionizing radiation and assess their harmful effects, compare the effects of various harmful factors on physiological processes in the body.

5.2. The information necessary for the formation of knowledge and skills can be found in textbooks:

Basic:

1. Radiology (radiation diagnostics and radiation therapy). Kyiv, Book Plus, 2018. -721 p.
3. Radiology (radiation diagnostics and radiation therapy). Test tasks. Part 1. Kyiv, Book Plus. 2015. -104 p.
4. Radiology (radiation diagnostics and radiation therapy). Test tasks. Part 2. Kyiv, Book Plus. 2015. -168 p.
5. Radiology (radiation diagnostics and radiation therapy). Test tasks. Part 3. Kyiv, Book Plus. 2015. -248 p.

Auxiliary:

6. Diagnostic, therapeutic and prophylactic algorithms in internal medicine: teaching method. Method. / [B. I. Denesyuk and others]; for ed. Prof. VI Denesyuk; Vinnytsia. Nat. Med.un-t them. MI Pirogov, Dept. Inside. Medicine № 3. - Kyiv: DZK Center, 2015. - 151 p. : fig., tab.

7. Clinical Radiology: The Essentials Fourth Edition by Daffner MDFACR, Dr. Richard H., Hartman MD, Ph.D. Ma (2014) - 4th edition. 2014. 546 p.
8. Radiology for the wards / a student - to - student guide. Latha G. Stead, Matthew S. Kaufman, S. Matthew Stead, Anjali Bhagra, Nora E. Dajani.2009. 265 p.

5.3.Orienting map for independent work with literature on the topic "The main properties of ionizing radiation. Biological effect of ionizing radiation on healthy and pathologically altered cells "

№	**Task**	**Instructions for the task**	**Independent records of students**
1.	To study the structure of the atom. Law of radioactivity.	Radioactivity, types of radioactive transformations of the atom, units of activity.	
2.	To study the interaction of ionizing radiation with substances.	α-particles, β-particles, γ-radiation; photoelectric effect, Compote effect. Physico-chemical processes and biological processes under the action of ionizing radiation.	

6. Materials for self-control over the quality of training.

Questions for self-control.

1. Define the concept of biological action of ionizing radiation.
2. What are the distinctive properties of ionizing radiation?
3. Basic physical mechanisms of ionizing radiation action.
4. What is the relative biological effect of different types of ionizing radiation?
5. What factors affect the biological action of ionizing radiation?
6. Species, individual, tissue differences of biological action of ionizing radiation.
7. Dose, dose rate, vol´irradiated tissue.
8. What is the need for knowledge of the biological action of ionizing radiation?
9. List the mechanism of mutations under the influence of radiation.
10. What is the direct and indirect effect of ionizing radiation?
11. What determines the effect of ionizing rays on the body?
12. What are the stages of biological action of ionizing radiation?

7. Practical work (tasks) performed in class:

1. Draw in a workbook a diagram of the division of the cell and the cell

itself. Give an explanation.

2. Draw a diagram of water radiolysis in a workbook. Give an explanation.

3. Draw tables in the workbook with the basic units of radioactivity. Give an explanation.

4. Draw schematic principles of operation of basic devices for radiometry. Give an explanation ..

5. Draw schematic principles of the main devices for dosimetry. Give an explanation ..

6. Draw schematic principles of anti-inflammatory action of ionizing radiation. Give an explanation.

7. Draw schematic principles of antitumor action of ionizing radiation. Give an explanation

8. **Topic of the next lesson:**"Physical and technical foundations of radiation diagnostics in dentistry. Physical and technical bases of X-ray research ".

9. Tasks for UDRS and NDRS on the topic of the next lesson:

Types of modern methods of diagnostic tests of teeth and maxillofacial area (ionizing and non-ionizing). Indications and contraindications to MRI and ultrasound; advantages and disadvantages. X-ray methods of examination of teeth and maxillofacial area. Rule of orthoradiality. Contact and remote methods. Intraoral radiographs of teeth. Interproximal radiography. Orthopanoramic radiography. Image formation method. Analog and matrix X-ray image receivers.

Methodical recommendations were _____ as. Katerina DOIKOVA