FGBOU VO SOGMA

Educational and methodological developments
For SOGMA students.

Topic: Physical bases of radiation diagnostics and radiation therapy.

Introduction.

Radiation diagnostics and radiation therapy is a science that covers all aspects of the use of X-ray, radioactive, infrared, ultrasound radiation and nuclear magnetic resonance in the field of health care, i.e. in order to study the normal human body, as well as the prevention, diagnosis and treatment of diseases. At the same time, this science includes radiobiology, which studies the effect of ionizing radiation on a living organism, as well as certain special branches of physics and technology. Thus, radiation diagnostics and radiation therapy unite several independent branches that are inseparable from each other and, in their combination, constitute the essence of this integral modern medical discipline. However, each of them has its own specific features, organizational forms and tasks of use in medicine.

Practical lesson number 1.

Topic: **Physical foundations of radiation diagnostics.**

The general goal of the lesson: to have an idea about the subject and tasks of radiological diagnostics . Have an idea about the methods of radiation diagnostics, the physics of ionizing and neoinizing radiation used in medicine, their diagnostic capabilities.

specific objectives of the lesson.

Know:

1. Subject, structure and tasks of radiation diagnostics.
2. Physical foundations of thermography, ultrasound diagnostics, X-ray diagnostics, including computed tomography, magnetic resonance imaging.
3. The device of an x-ray tube, obtaining x-rays and their properties.
4. The device and sanitary and hygienic requirements for the X-ray diagnostic room.
5. Know the properties of ionizing radiation and how to protect against them.

Be able to:

1. Determine the method of radiation research.
2. To know the diagnostic capabilities of each method of radiation diagnostics and be able to prescribe the necessary radiation examination to the patient.
3. Determine the quality of the x-ray.

Base of holding and material equipment:

1. study room
2. Ultrasound room
3. X-ray diagnostic room
4. Tables, X-ray tube, sets of radiographs, fluorograms , thermograms, electroroentgenograms .

Literature:

1. L.D. Lindenbraten , I.P. Korolyuk . Medical radiology (basics of radiation diagnostics and radiation therapy). Moscow 2000
2. L.D. Lindenbraten , F.M. Lyass "Medical Radiology".
3. L.D. Lindenbraten , I.P. Korolyuk . Medical radiology and radiology. M. "Medicine ". 1993 г.
4. Radiation diagnostics. Textbook for high schools. Ed. prof. Trufanova G.E. M., "GEOTAR-Media", 2007

Information block:

X-rays opened a new era in the development of physics and all of natural science, helped to penetrate the secrets of the nature and structure of matter, and led to revolutionary changes in medicine . X-rays were discovered on November 8, 1895. Wilhelm Konrad Roentgen, Professor at the University of Vnerzburg , Germany. The first report "On a New Kind of Rays" was published in January 1896 in the form of 17 brief theses, from which it became known that open rays are capable of:

а) penetrate to one degree or another through all bodies;
б) cause the luminescence of fluorescent substances;
в) cause blackening of a photographic plate;
г) spread in a straight line;
д) do not change its direction under the influence of a magnet, etc.

In three subsequent communications, he formulated all the properties of x-rays and the technique for obtaining them.

X-rays are generated in a glass vacuum tube, on one side of which a spiral cathode filament is soldered, which has a separate electrical filament circuit, on the other side - an anode. A high voltage is connected to these two electrodes of the X-ray tube at the right time with the cathode connected to the negative and the anode to the positive poles. When a filament current is applied to the cathode coil, a cloud of free electrons is formed around it (thermionic emission). When a high voltage is applied, free electrons rush to the anode at high speed. When electrons slow down in the anode material, their kinetic energy is converted to a greater extent into thermal energy (up to 99%), and about 1% into X-ray energy.

The great merit of Roentgen in science is that he not only discovered unknown rays, but also described their properties with sufficient completeness, however, the nature of x-rays was studied later in 1912 by the German physicists Laue, Knieping and Friedrich, who studied the passage of x-rays through a crystal proved that they have the properties of interference and diffraction, characteristic of electromagnetic oscillations. Those. X-rays are electromagnetic waves. In the general wave spectrum, X-rays are between ultraviolet and gamma rays.

At present, more than ten physical properties of X-rays are known, four of the most important of them opened the way to their widest application in medicine.

I. X-rays have a penetrating ability, passing through different objects, they carry certain information about the structure of these substances.
II. X-rays, passing through some substances, cause them to fluoresce (glow). Thanks to this property, rays were discovered, and these substances, called luminophores, began to be widely used in medicine. Their glow under the influence of X-rays gave rise to one of the main methods of X-ray examination - fluoroscopy. In radiography, phosphors make it possible to increase the radiation exposure to the x-ray film in the cassette due to the use of intensifying screens, the surface layer of which is made of fluorescent substances. Improving the quality of phosphors, i.e. an increase in the brightness of their glow significantly reduces the dose of radiation to both patients and staff of X-ray rooms.
III. X-rays have a photographic effect. Like visible light, falling on a photographic emulsion, they act on silver halide, increasing its chemical activity and partially reducing silver. This property of X-rays is based on radiography - obtaining images on photosensitive materials.
IV. X-rays cause ionization of the media through which they pass. Hence their name - ionizing radiation. The ionization effect is the formation of positive and negative ions from neutral atoms and molecules. When X-rays pass through any substance, they collide with its molecules and give them some or all of their energy. As a result, the atoms and molecules of a substance are split into fragments - ions, different in mass and charge. Air ionization in the X-ray room increases the electrical conductivity of the air, increases static electric charges on the objects of the room, which adversely affect the body. In order to eliminate such an undesirable effect, supply and exhaust ventilation is installed in X-ray rooms.
V. X-rays have a biological effect that is generally regarded as damaging. Only small doses of radiation can lead to certain positive physiological changes in a living organism, which has also found application in the treatment of a number of diseases. In high doses, X-rays are used to treat malignant tumors.

The biological effect of radiation on the body is directly dependent on its absorption by body tissues. To measure the amount of absorbed energy, the concept of radiation dose is introduced. The <u>dose</u> is understood as the amount of absorbed energy per unit volume of the irradiated substance.

The energy absorbed per unit volume of the irradiated substance per unit time is called <u>dose rate</u> .

SI dose units.

<u>The absorbed dose unit</u> is Gray (Gy)=1 J /kg.

Off-system units:

<u>ray</u> is the amount of x-ray or gamma rays, under the influence of which ions are formed in 1 cm^{3} of air (at t^{0} -0^{0} and normal atmospheric pressure), carrying a charge of one electrostatic unit of each sign, i.e. 2.08×10^{9} pairs of ions. The derivative units of the roentgen are milliroentgen, a thousandth of a roentgen, and microroentgen, a millionth of a roentgen. The dose rate unit is taken as roentgen per second, milliroentgen per second, roentgen per hour, etc.

Classification of methods of X-ray examination.

I. Basic: fluoroscopy, radiography, fluorography, electroroentgenography .
II. Additional: tomography, computed tomography, X-ray kymography, mammography, X-ray cinematography .
III. Contrast, special methods of X-ray examination: bronchography, angiography, urography, etc.

Fluoroscopy - obtaining a positive summary image of internal organs and external structures on a fluorescent screen at the time X-rays pass through them. Advantages: accessibility, cost-effectiveness, the possibility of polypositional research. Disadvantages: high radiation exposure, subjectivity.

X- ray - obtaining a negative image of the studied objects on x-ray film, which can be preserved for decades. Advantages: better detection of small details, the possibility of observing the process in dynamics, reduction of radiation exposure. Disadvantages: an increase in material costs (for film, photoreagents, etc.), obtaining an image in only one projection.

Fluorography is an x-ray examination with obtaining an image of the studied organs on photographic film. Such an image is always reduced in size. Advantages: mass character, profitability. Disadvantages: some of the fine details are lost when photographing an image from a fluorescent screen.

Tomography is an X-ray examination technique that allows obtaining a layer-by-layer image of the organ under study. The effect, as it were, of dismembering the summation picture of the object under study is achieved by the fact that the X-ray tube and the film cassette, connected to each other by a special lever in different planes, move towards each other and the plane in which their axes of motion coincide is clearly displayed on the film. Tomography should be purposeful, from the many layers of the object under study, according to X-rays in two mutually perpendicular projections, those whose images carry the maximum information about it are selected.

Computed tomography is a technique for obtaining an image of a thin transverse layer of an organ under study by mathematical processing in a computer of data on the absorbing capacity of tissues when X-rays pass through them. The formation of a computed tomographic image is provided by three successive stages of the study:

1. transillumination of the object under study by a narrow beam of x-rays with a circular motion of the x-ray source.
2. registration of the transmitted radiation through the object with digital processing of the degree of its attenuation.
3. converting the resulting digital image into an analog one, i.e. visualizing it.

X- ray kymography is an X-ray examination technique that objectively reflects the frequency and amplitude of movements of the contours of the organs under study.

With its help, a number of functional features of the heart, large vessels, ribs, diaphragm, etc. are studied. Graphic recording of the movements of these organs is carried out on x-ray film using x-rays that have passed through the organ and a special moving lead grating with many parallel slots.

Special methods of X-ray examination are methods using contrast agents. The name of special research methods often come from the root of the word denoting the organ under study (anatomical region), which formed a pathological structure in the organ (wound, fistula, abscess) or the prefix used for the x-ray machine with the addition of the term "graphy". When gas contrast is used, the prefix " pneumo " is added.

Thermography is a method of recording infrared radiation from the surface of the human body for the diagnosis of various diseases and pathological conditions. The physiological basis of thermography is an increase in the intensity of infrared radiation over pathological foci due to an increase in blood supply and metabolic processes in them or a decrease in its intensity in areas with reduced blood flow and concomitant changes in tissues and organs.
The presence of a pathological process is manifested by the following signs:

а) the appearance of abnormal zones of hyperthermia or hypothermia;
б) violation of the normal thermotopography of the vascular pattern;
в) change in temperature gradient.

So inflammatory processes give a temperature gradient in the range of 0.7 - 1 ^{0}, with acute inflammation 1 -1.5 ^{0}, with purulent-destructive - 1.5-2.0 ^{0}.

Currently, ultrasound diagnostics is being promoted among the leading methods of radiation diagnostics . The physiological basis of the method is echolocation , i.e. reception of ultrasonic signals reflected from the interfaces of tissue media with different acoustic properties. The possibility of conducting multiple studies, harmlessness, lack of contraindications (except for the severe general condition of the patient and the presence of a pacemaker), allows it to be used in almost all areas of medicine. There are several main types of ultrasound diagnostics. One-dimensional - A-method (echography), two-dimensional - B-method (echotomography or sonography) and dopplerography.

The youngest method of radiation diagnostics is magnetic resonance imagingbased on nuclear magnetic resonance. NMR is the process of absorption by nuclei in a constant magnetic field of the energy of electromagnetic radiation with a transition to a higher energy level, and then returning to its original state with the loss of excess energy in the form of radiation of the same frequency. The effect of magnetic resonance is observed in atomic nuclei containing an odd number of protons.
Different tissues of the body differ from each other in the content of protons, i.e. by proton density. Absorption of radiation energy by tissues will accordingly be different. Registration of the amount of energy emitted back and displaying it on the monitor screen in the form of signals of various intensities makes it possible to distinguish

tissues by this indicator. The adipose tissue has the highest proton density, which is always brightly displayed on the monitor screen, the smallest is the compact bone tissue, which always looks dark. The proton density of water is taken as 1.0.

Test questions.

1. What are X-rays and how are they produced?
2. X-ray tube device.
3. What are the properties of X-rays? What is the basis for their use in medicine?
4. Classification of methods of radiation diagnostics.
5. Principles and diagnostic possibilities of thermography.
6. Principles and diagnostic capabilities of ultrasound diagnostics.
7. Basic methods of X-ray examination.
8. Additional and special methods of X-ray examination.
9. Principles and methods of computed tomography.
10. What is the physical essence of magnetic resonance imaging.
11. Fundamentals of clinical dosimetry.
12. What properties of ionizing radiation are used to register them.

Test tasks.

1. The development of radiology is associated with the name of V. Roentgen, who discovered radiation, later named after him

A. in 1890
B. in 1895
V. in 1900
G. in 1905

2. The first radiographs in Russia were made by

A. M. I. Nemenov
B. I. P. Pavlov
V. A. S. Popov
G. D. I. Mendeleev

3. The attenuation of the radiation beam when passing through various objects depends

A. from absorption by the substance of the object
B. from the convergence of rays
V. from the interference of rays
G. from scattering
D. A and D are correct

4. Conventional x-ray image

A. Larger subject
B. smaller than the object being filmed
B. is equal to the object being filmed
D. all answers are correct

5. The diagnosis of the patient according to S.P. Botkin is established on the basis of

A. careful study of the diseased organ
B. application of additional techniques
B. use of functional tests
G. studying the state of the whole organism

6. The first institute of X-ray radiology profile in our country was organized

A. in Moscow
B. in Kyiv
V. in Leningrad
G. in Kharkov

7. The first X-ray machine in Russia designed

A. M. I. Nemenov
B. A. S. Popov
V. A. F. Ioffe
G. M. S. Ovoshchnikov

8. The historic meeting of the Medical-Physical Society, at which V.K. Roentgen reported on his discovery, took place

A. November 8, 1895
B. November 25, 1895
V. December 28, 1895
G. January 23, 1896

9. The discovery of X-rays was carried out

A. in Berlin
B. in Vienna
V. in Würzburg
G. in Magdeburg

10. The methods of radiation diagnostics do not include

A. radiography
B. thermography
B. radioscintigraphy
G. electrocardiography
D. sonography

11. Unit of measurement of X-ray dose rate

A. Roentgen

B. Rad
V. X-ray/min
G. Gray

12. Are not electromagnetic

A. infrared rays
B. sound waves
V. radio waves
D. x-rays

13. The readings of an individual X-ray dosimeter depend on

A. from the radiation power
B. from the hardness of radiation
V. from the duration of exposure
D. all answers are correct

14. The unit "roentgen" defines a dose

A. g-equivalent
B. absorbed dose
B. exposure dose
G. activity
D. equivalent dose

15. The intensity of radiation with increasing distance to the source of radiation changes by

A. Increases proportional to distance
B. decrease in inverse proportion to distance
B. magnification proportional to the square of the distance
D. decrease in inverse proportion to the square of the distance
D. does not change

Answers

1 - B
2 - B
3 - D
4 - A
5 - G
6 - B
7 - B
8 - B
9 - B
10 - G
11 - B
12 - B
13 - G
14 - B
15 - G

Practice #2

Topic: **Physical foundations of radiology. Radioactivity, radioactive radiation, their characteristics. Radinuclide diagnostics.**

General purpose of the lesson : To have an idea about radioactivity and radioactive emissions, their properties. The structure of the atom. Methods for recording radiation, the device of radio diagnostic equipment. Radionuclide diagnostics, its principles and diagnostic capabilities.

Specific objectives of the lesson:

Know:
1. The structure of the atom.
2. What is radioactivity, its qualitative and quantitative characteristics.
3. What is radiometry, radiography, gamma topography , what are radioactive isotopes and how to obtain them.
4. Know the physiological basis of radionuclide diagnostics.
5. Requirements for radiopharmaceuticals used for diagnostic purposes.

Be able to:
1. Determine the activity of a radioactive substance according to the isotope passport.
2. Determine the indications for radionuclide research.
3. Assess the clinical significance of the conducted radionuclide study.

Base of holding and material equipment:

1. Study room.
2. Tables.
3. Detectors for registration of radiation .

Literature:

1. L.D. Lindenbraten , I.P. Korolyuk “Medical radiology and radiology. M. Medicine "1993
2. L.D. Lindenbraten , I.P. Korolyuk . Medical radiology. Moscow 2000
3. L.D. Lindenbraten , F.M. Lyass . Medical radiology.
4. Radiation diagnostics. Textbook for high schools. Ed. prof. Trufanova G.E. M., "GEOTAR-Media", 2007

Information block:

Radioactivity is the ability of the nuclei of some chemical elements to spontaneously decay with the release of radiant energy in the form of alpha, beta and gamma rays. Natural radioactivity was discovered by the French physicist A. Becquerel in 1896, who discovered the emission of invisible rays from uranium salts, causing the photographic emulsion to blacken like X-rays. The studies of Marie and Pierre Curie, Rutherford found that the beam of radioactive rays is inhomogeneous and in a magnetic field broke up into its constituent parts: alpha rays deviated to the negative pole and were positively charged particles, beta rays deviated to the positive pole, and gamma rays did not deviate at all and were electromagnetic waves, like x-rays. Later it was found that alpha rays are complex particles consisting of two protons and two neutrons, beta rays are a stream of electrons, or positrons, if the beta radiation is positive.
Radioactive rays have properties:

1. Penetrate through various media.
2. Ionize the environment through which they pass.
3. Cause the glow of certain substances - phosphors.
4. Cause blackening of the photographic emulsion.
5. They have a biological effect.

A deep study of the properties of radioactive elements led the English physicist Rutherford in 1911. to the creation of a planetary model of the structure of the atom. This model, improved by the Danish scientist Niels Bohr and the Russian scientist Ivanenko, is still in use today, because it helps to understand the phenomenon of radioactivity. All atoms are neutral and consist of a positively charged nucleus and negatively charged particles, electrons, revolving around it. According to the periodic table, you can represent the structure of the atom of any chemical element. The nucleus of an atom is made up of protons and neutrons. The number of protons is the charge of the nucleus - in the periodic table the serial number. The sum of protons and neutrons is the mass number, i.e. atomic weight. The number of protons in the nucleus corresponds to the number of electrons in the electronic levels, the number of the latter is determined by the period. The number of electrons in the outer electronic level is determined by the group, and chemically it is the valency. Protons and neutrons are held within the nucleus by forces called nuclear forces. Stable stable nuclei contain certain numbers of protons and neutrons. If the nucleus contains an excess of protons or neutrons, then it is unstable, radioactive. Spontaneously changing its composition, the nucleus eventually falls into a stable region.
1934 was marked by the discovery of the French scientists Frederic and Irene Joliot - Curie phenomena of artificial radioactivity. This is how the well-known term “radioactive isotope” appeared. At present, by bombarding stable chemical elements with neutrons, it is possible to obtain a radioactive isotope of any chemical element, currently called radionuclides. That. the possibility of introducing radionuclides into the patient's body, to monitor their location with the help of radiodiagnostic equipment. The method is called radionuclide diagnostics, and the radionuclides introduced into the body are called radiopharmaceuticals (RP).

Characterization of radioactivity.

Half-life is the time it takes for half of the atoms of a radioactive substance to decay. The fraction of atoms decaying per unit time is decay constant.
The activity of a radioactive substance is the number of atoms decaying per unit time.
Specific activity - the number of decaying atoms per unit time per unit mass of a substance.

Activity units.

According to the SI system
Becquerel is one disintegration per second.

Derivatives:

Kilobecquerel - 1000 becquerels.
Megabecquerel - 1,000,000 becquerels.

Off-system units.

Curie - $3.7x10^{10}$ disintegrations per second.

Derivatives:

Microcurie - $3.7x10^{7}$ disintegrations per second.
Millicurie - $3.7x10^{4}$ disintegrations per second.

Ionizing radiation is invisible, odorless, therefore, it is possible to measure them with the help of instruments that record the effect of radiation on physical, chemical and biological media. From here, physical, chemical, and other methods of recording radiation are distinguished. Physical methods are more often used: ionization and luminescent (scintillation) methods of registration of radiation. To perform radionuclide studies, various diagnostic devices have been developed that include a detector that converts ionizing radiation into electrical impulses, an electronic processing unit, and a data presentation unit. According to the type of the latter, they are distinguished: radionuclide imaging method , radiography, clinical and laboratory radiometry.
Radionuclide imaging is the acquisition of an image of the studied organ, part of the body or the entire body of the patient when radiopharmaceuticals are introduced into the body, using gamma scintigraphy. Options for gamma scintigraphy are single photon or two photon emission tomography. Sometimes a scanner is used for visualization, the study is called a scan.
To study the dynamics of the body's radioactivity, to study various physiological and biochemical processes in a number of installations, the results of the study can be recorded in the form of numbers and such a study can be carried out at repeated intervals and, based on the data obtained, judge the accumulation and excretion of radioactive material - this is radiometry. It is suitable for recording slow processes.
To study processes accompanied by a rapid change in the radiation intensity, continuous recording of pulses is required. In such cases, counting installations are used, in which the counting rate meter is connected to a recorder that draws a curve - a radiogram, and the registration method is called radiography. An example is the study of lung ventilation, hemodynamics, accumulation and excretion of radioactive substances by the liver, kidneys, etc.

To implement these methods, radionuclides (radioactive isotopes) or indicators labeled with them are used, which are called radiopharmaceuticals (RPMs).

A radiopharmaceutical is a chemical compound approved by the Pharmacopoeia Committee for administration to a person for diagnostic purposes, the molecule of which contains a radionuclide.

RFP must meet a number of requirements:

1. Be harmless.
2. The half-life must be sufficiently short, but must allow the necessary investigation to be carried out in time.
3. It is quickly excreted from the body.
4. Possess tropism for the studied organ or the studied metabolism.
5. Must have a certain emission spectrum.
6. Use in small (indicator) doses. An important minimum radiation exposure, for which the concepts are used.

The physical half-life is the decay time of half of the atoms of a radionuclide. The time during which the activity of a drug introduced into the body is reduced by half due to its excretion is called the biological half-life . The time during which the activity of the radiopharmaceutical introduced into the body is halved due to physical decay and excretion is called the effective half-life .

In some cases, a radionuclide study can be carried out without the introduction of radiopharmaceuticals into the body - in vitro , i.e. All studies are carried out in test tubes. It makes it possible to detect in biological fluids (blood, urine) hormones, enzymes, medicinal and other substances in negligible concentrations. The principle of this method, called radioimmunoassay , consists in the competitive binding of the desired stable and similar labeled substances with a specific receiving system.

Radionuclide analysis in vitro has come to be called radioimmunoassay because it is based on the use of immunological antigen-antibody reactions. However, in the future, other types of research were created, similar in goals and methodology, but differing in details . vitro . So if an antibody is used as a labeled substance, and not an antigen, the analysis is called immunoradiometric , but if tissue receptors are taken as a binding system, they talk about radioreceptor analysis .

Test questions.

1. What is radioactivity? Radioactive radiation and their characteristics.
2. The structure of the atom and the relationship of the structure of the atom with the table of chemical elements of Mendeleev.
3. What is artificial radioactivity? Obtaining radioactive isotopes.
4. What are radiopharmaceuticals and what are the requirements for them.

5. What is the difference between the distribution of radioactive isotopes in the body and the distribution of stable ones.
6. Methods for registration of radiation.
7. The device of radiodiagnostic equipment.
8. Principles and possibilities of radionuclide research.
9. What are the requirements for radiopharmaceuticals used for diagnostic purposes.