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Application of Radioactivity in Medicine

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Annotation: This article covers the areas of application of the phenomenon of radioactivity in medicine. It provides detailed information about the physicochemical properties of radioactive isotopes, their importance in diagnostics and treatment, as well as modern methods of nuclear medicine (PET, SPECT). The possibilities of effective treatment of cancer diseases through methods such as radiotherapy and radioactive iodine treatment are considered. The article also analyzes safety measures when working with radioactive substances and their role in scientific research. The article may be useful for representatives of the medical field, students, and researchers.

Keywords: Radioactivity, radioactive isotopes, nuclear medicine, radiotherapy, PET tomography, SPECT tomography, Technetium-99m, Iodine-131, Cobalt-60, radiopharmaceuticals, thyroid gland, cancer, ionizing radiation, diagnostics, brachytherapy, medical physicist, radiation safety, medical technologies, Nuclear medicine, biological research.

Introduction. Radioactivity is the spontaneous disintegration of some atomic nuclei, emitting ionizing radiation. This phenomenon was discovered by Henri Becquerel in 1896 and later studied in depth by Marie and Pierre Curie. The use of radioactivity in medicine has developed rapidly since the middle of the 20th century, and today it plays an important role in diagnosis, treatment, and scientific research.

Radioactive isotopes and their properties. Radioactive isotopes are atoms with unstable nuclei that contain an excess of neutrons. When they decay, they emit alpha, beta, or gamma radiation. The most commonly used isotopes in medicine are:

- ✓ Iodine-131 (I-131) – used in the treatment of thyroid diseases.
- ✓ Cobalt-60 (Co-60) – for irradiation of tumors in radiotherapy.
- ✓ Gallium-67, Thallium-201 – for the detection of heart and inflammatory diseases.

When these isotopes are injected into the body, they accumulate in certain tissues,and the radiation they emit is detected using special equipment.

2. Diagnostic applications. Radioactivity plays an important role in diagnostic medicine in diagnosing diseases, assessing organ function, and visualizing pathological processes. This field mainly includes the areas of nuclear medicine and radiology.

2.1. Nuclear medicine. Nuclear medicine is a diagnostic method aimed at studying the internal structures and functions of the body using radioactive isotopes.

Radionuclide scanning: A radioactive isotope (such as technetium-99m) is injected into the patient's body, and then the state of the organs is assessed by recording the radiation using a gamma camera. It is widely used to assess the function of the heart, kidneys, thyroid, bones, and liver.

SPECT (Single Photon Emission Computed Tomography): This method uses single-photon radiation to produce three-dimensional images. It is used in cardiac ischemia, cerebral circulation disorders, and oncological diseases.

PET (Positron Emission Tomography): The metabolic activity of tissues is determined using positron-emitting isotopes (such as fluorine-18). PET is important in detecting tumors in oncology, evaluating Alzheimer's disease in neurology, and studying myocardial activity in cardiology.

2.2. Radiology and X-rays. Radiology includes methods of studying the body through X-rays, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound.

Radiography: Plain X-rays are used to evaluate the condition of bones, lungs, heart, and other organs. This method is quick, inexpensive, and widely available.

Computed tomography (CT): A scan that uses X-rays to produce cross-sectional images of the body. CT scans provide in-depth views of the brain, chest, abdomen, and skeletal system.

Contrast agents: In some cases, radioactive contrast agents (such as barium sulfate) are used to make internal tissues more visible. These agents enhance the radiation and make it easier to detect pathological changes.

Radiopharmaceuticals. Radiopharmaceuticals are drugs labeled with radioactive isotopes that, when administered to the body, accumulate in target tissues. They are used to: Assess thyroid function (I-123, I-131), Examine blood supply to the heart muscle (Tl-201), Detect bone metastases (Tc-99m).

Uses in medical treatment. Radiotherapy is a method of destroying tumors using ionizing radiation. It is divided into two main types:

External beam radiotherapy – is performed using Cobalt-60 or linear accelerators.

Internal radiation (brachytherapy) – radioactive sources are placed directly into or near the tumor.

Radiotherapy is often used in combination with surgery and chemotherapy. It is particularly effective for cervical, prostate, brain, and breast cancers.

Radioactive iodine therapy. The isotope I-131 is used in hyperthyroidism and thyroid cancer. This isotope accumulates in the gland tissue, selectively irradiating and destroying it. This method is painless, non-invasive, and highly effective.

Scientific research and experimental applications. Radioactive isotopes are also widely used in the study of biological processes. For example: Isotope tracing methods - in the study of metabolism, blood circulation, and cell proliferation.

Radio biochemical synthesis - to determine the distribution of drugs in the body.

These methods are used to develop new drugs and study the molecular basis of diseases.

Radioactivity safety precautions. The following safety precautions must be observed when working with radioactive materials:

Dose control - the amount of radiation received by patients and medical personnel must be constantly monitored.

The half-life of the isotopes used is preferably short, as they are not retained in the body for long. Special protective equipment - gloves, mittens, lead shields.

Basic principles and the ALARA approach. Principle — harm reduction: The aim of radiation protection is to protect people from the harmful effects of ionizing radiation; exposure can come from external sources or from internal contamination. Harm can be deterministic (high doses cause specific tissue damage and acute radiation syndrome) or stochastic (low doses cause cancer).

ALARA: “As Low As Reasonably Achievable” — keeping all doses as low as technically and economically feasible. This is achieved in medical practice through protocols, device adjustments, and workflow optimization. Triple Protection: Time, Distance, Shield

Vaqt: Ekspozitsiya vaqtini minimallashtirish — qisqa skanlar, tezkor sozlamalar, tayyorgarlikni bemor xonasidan tashqarida yakunlash.

Time: Minimize exposure time—short scans, quick setup, complete preparation outside the patient room.

Distance: According to the inverse square law, moving away from the source leads to a sharp decrease in dose; maintaining maximum distance is a key criterion in workplace planning.

Shielding: Protection is enhanced by lead screens, walls, windows; personal shields (lead apron, shielded neckband, goggles) and room shielding (bunker design).

Patient safety and clinical protocols. Indication and optimization: Each screening/diagnostic/therapeutic procedure must be justified by clinical benefit; parameters (kV, mAs, DAP, CTDIvol) are selected at a minimum sufficient level.

Adaptation: Dose limitations and appropriate protocols in pediatric patients, limitation of repeat imaging, transparent consent, and risk/benefit explanation.

During the intervention: Real-time dose monitoring, reduction of fluoroscopy time, pulsing, collimation, distance maintenance, use of lead shields.

Radiotherapy: Limiting dose to healthy tissue through planning (TPS) and verification (IGRT), portal dosimeter, compliance check (QA); preventing unnecessary radiation exposure with safety interlocks.

Waste, emergency preparedness and management. Radioactive waste: Sorting (short vs. long half-life), decay-in-storage, sealed containers, marking, accounting and documentation; release with contamination control.

Emergency situations: Spill/contamination plans, evacuation routes, decontamination equipment, chain of communication, incident reports, and root cause analysis; drills are conducted regularly.

Conclusion. Radioactivity has revolutionized medicine. It provides high accuracy and efficiency in diagnosis and treatment. At the same time, caution and strict adherence to safety measures are required when working with it. In the future, it is expected that more effective and individualized medical technologies will be created based on radioactive isotopes.

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