Radionuclide

Currently, the standard 18-column periodic table contains 118 elements. Nuclides of elements that are capable of spontaneous radioactive transformation of nuclei are called **radionuclides**. During this radioactive transformation, radioactive radiation is released. There are many more radionuclides than stable nuclides, currently around 2000 are known. Each element is represented by several radioisotopes. Some radionuclides, especially those with a high nuclear number, can undergo **further transformation** after decay (decay series) and thereby increase the **radiation load** of the organism. Each radionuclide has its characteristic **half-life**, **type of transformation** and **activity**.

Radionuclides are used in medicine for **labeling** various substances, monitoring their amount and metabolism.

- quantitative methods monitor the amount of radiation from the sample,
- qualitative methods are used to determine the distribution of the radionuclide (in organs, cells).

A summary of individual radionuclides used in nuclear medicine and their characteristic properties is shown in the chart:

The Chart of Radionuclides Used in Nuclear Medicine

radionuklides	half-time	a kind of transformation	energy
^{11}C	20 minutes	beta$^+$, positrons	0.96 MeV
^{13}N	10 minutes	beta$^+$,positrons	1.19 MeV
^{15}O	2 minutes	beta$^+$,positrons	1.73 MeV
^{18}F	110 minutes	beta$^+$,positrons	0.635 MeV
^{68}Ga	68 minutes	beta$^+$,positrons	1.9 MeV
^{82}Rb	1.3 minutes	beta$^+$,positrons	3.15 MeV
^{57}Co	272 days	EZ, gamma	122 keV
^{51}Cr	27,7 days	EZ, gamma	320 keV
^{67}Ga	78 hours	EZ, gamma	91, 185, 300, 394 keV
^{123}I	13 hours	EZ, gamma	157 KeV
^{125}I	60 days	EZ, gamma	35 keV
^{131}I	8 days	beta$^-$,beta; gamma	606 keV; 80, 284 364 keV
^{111}In	2,8 days	EZ, gamma	171, 245 keV
^{81m}Kr	13,3 seconds	IP, gamma	190 keV
^{99}Mo	67 hours	beta$^-$,beta; gamma	1.214 MeV; 141,181,740 keV
^{32}P	14,3 days	beta$^-$,beta	1.709 MeV
^{153}Sm	47 hours	beta$^-$,beta; gamma	630, 700, 803 keV; 103 keV (34%)
^{89}Sr	50,5 days	beta$^-$,beta	1.488 MeV
^{99m}Tc	**6 hours**	**IP, gamma**	**140 keV**
^{201}Tl	73 hours	EZ, gamma	78, 167 keV
^{133}Xe	36,4 days	EZ, gamma	172, 203 keV
^{90}Y	64 hours	beta$^-$,beta	2,28 MeV
^{186}Re	90,6 hours	beta$^-$,beta; gamma	1.07 MeV; 137 keV
^{223}Ra	11,4 days	alpha	5.75 MeV
^{211}At	7,2 hours	alpha	5.87 MeV
^{212}Bi	1,01 hours	alpha + beta$^-$, alpha; beta	6.09 MeV; 2.25 MeV

Use of Radionuclides

Laboratory methods based on radiation detection (e.g. RIA) are giving way to new methods (ELISA) that do not use ionizing radiation, as work with radionuclides requires expensive security and means higher risk. Previously, however, they were the only way to monitor cellular events (DNA synthesis, metabolic pathways, etc.).

Radioisotopes play an absolutely key role in nuclear medicine, where they are used to produce radiopharmaceuticals. We distinguish between radionuclides for **diagnostic** and **therapeutic** use. Their distribution is then monitored by special devices (e.g. PET, Gamma-camera, ...).

Diagnostic Radionuclides

^{99m}Technetium

^{99m}Technetium (zkráceně ^{99m}Tc) is today the most commonly used radioisotope in scintillation examinations in nuclear medicine. The letter *m* denotes **the metastable** state of the nucleus, which is at a higher energy level and emits γ photons during deexcitation.

Compared to other radionuclides, it has many advantages. **It is easily obtained** by the decay of artificially prepared ^{99}molybdenum, which is most often placed in a radionuclide generator. The energy of its photons is **140 keV** and the half-life is about **6 hours**, meaning a small radiation load for the organism. At the same time, its energy is sufficient for good radiation detection. A short half-life allows the administration of a radiopharmaceutical with higher activity, which gives us better examination results (more signals).

^{99m}Tc is obtained from generators in the form of **pertechnate** (technetate) TcO^{-4}. This can be directly used in the examination of the thyroid gland. The reduction of pertechnate with stannous chloride produces a substance that very willingly participates in other chemical reactions, which is used to **attach to a carrier** (identification of the substance).

^{67}Gallium

^{67}Ga is administered in the form of **67Ga-citrate** when examining tumors and inflammation. It is specifically taken up in the **hepatocellular ca., lymphomas, malignant melanoma and in soft tissue sarcomas**. It is also used to locate **inflammatory foci**. But it can also accumulate physiologically in the active tissue of the thymus and thyroid gland.

Iodine Radionuclides

Unbound **^{131}I** is the longest-used radionuclide. It is a **mixed β and γ emitter**. *The β component* causes tissue radiation and is not scintigraphically detectable, therefore 131 I is not recommended for diagnostic examinations. It is widely used in the therapy of differentiated carcinomas of the thyroid gland (not medullary!). Doses with less activity are given in hyperactive goiter. *The γ component* of radiation is suitable for monitoring the course of therapy (post-therapeutic scintigraphy), or for diagnostic purposes to **search for metastases**. In the diagnosis of thyroid cancers we administer a smaller dose than during therapy.

In the case of nuclear accidents, it is necessary to give the population non-radioactive iodine, which saturates the thyroid gland. Otherwise, radioactive iodine would be trapped and, when it decays, it could lead to malignancies and severe damage to the gland.

Unbound **^{123}I** and **^{125}I** can be used for purely diagnostic purposes, they are picked up similarly to 131 I. In bound form, they are used like other radionuclides, e.g. in the labeling of monoclonal antibodies (125 I-MoAb).

^{18}Fluorine

^{18}F is a **positron emitter**. In the form of **^{18}F-FDG** (fluorodeoxyglucose), it is the most widely used radiopharmaceutical in **PET examinations**, when glucose metabolismin the examined area is displayed. Its disadvantages are **a short half-life**, the supply of fluorine must therefore be very fast (accelerators must be close by), **high energy of annihilation radiation** (2x 511 keV) and high requirements for **radiation protection**.

^{201}Thallium

^{201}Tl is an artificial radionuclide which, with $T_{1/2}$=72 hours ransforms into the mercury isotope ^{201}Hg. ^{201}Tl is used in myocardial perfusion scintigraphy. One of the disadvantages of ^{201}Tl Tl is its long half-life, which creates a greater burden on the body. That is why today it is replaced by the isotope Technetium ^{99m}Tc, which has a similar use, but thanks to its $T_{1/2}$=6 hours it burdens the body less.

^{111}Indium

^{111}In is used in immunoscintigraphy to diagnose cancer.

^{81m}Kr - Krypton

Is used in scintigraphy of pulmonary ventilation.

Other Radionuclides

Other radionuclides used include:

- **^{11}C, ^{13}C** – short half-life, used in lung ventilation scintigraphy and in the breath test with labeled urea;
- **^{45}Ca** – examination of bone metabolism;
- **^{32}P** – monitoring of metabolic events in cells (e.g. DNA synthesis).

Therapeutic Radionuclides

As therapeutic radionuclides, we use those that have high activity and a short radiation range. Radionuclides, which are specifically absorbed in tissues and undergo **β transformation** , are used in the therapy of certain cancer diseases. **Open α emitters** are not yet used therapeutically. However, research is currently underway that could change this fact. α emitters have a very short range, with a specific application they would only destroy tumor tissues. But their radiation is so "hard" (high LET → tissue damage) that we would rather burden the patient.

^{131}I - Iodine

It is used for the treatment of hyperfunction of the thyroid gland **(for more than 50 years)** and for the treatment of differentiated carcinomas of the thyroid gland.

^{90}Y - Yttrium

It is administered in the form of a colloid and is used for radionuclide synovectomy.

^{89}Sr - Strontium

It is used for the treatment of painful bone metastases, binds to the hem of osteoblastic activity around the metastases and palliative treatment of bone malignancies.

Production of Radionuclides

Nowadays, only artificially prepared radionuclides that achieve high purity are used for the needs of nuclear medicine. They are obtained from:

- **cyclotrons**
- **radionuclide generators**
- **nuclear reactors.**

Production in a Cyclotron

Positively charged particles (deuterons, protons, helium nuclei) are accelerated and hit a target made of "mother" elements. Through nuclear interactions, they are built into the structure of the target atoms and change their nuclear and proton numbers → change of elements. After irradiation, a radionuclide is released from the target by chemical reactions, the remaining "parent" element does not react and is not released.

Radionuclides Produced in Cyclotrons

- **^{111}In**,
- **^{123}I**,
- **^{201}Tl**,
- other radionuclides can also be produced (e.g. ^{67}Ga), but generators are more suitable for obtaining them (see below).

Nuclear Reactors

Radioisotopes can be obtained from nuclear reactors that most often fission ^{235}U by isolating them from the fission products, and the resulting neutrons can be used.

Neutrons , produced by the fission of uranium, are too fast, have high energy, and when they interact with the nucleus, it would split. Therefore, it is necessary to slow down (moderate) neutrons. Slow, so-called thermal, neutrons then easily combine with the nucleus, often with the emission of a γ photon.

Similar radionuclides are obtained from **fission products as from neutron interactions.** Different chemical methods are used for purification (distillation, chromatography, precipitation). However, only radionuclides with a longer half-life can be obtained.

Radionuclides obtained from reactors or by neutron irradiation

- **^{99}Mo**,
- **^{59}Fe**.

Radionuclide generators

Due to their price, size, simplicity and ease of use, they are the most widely used source of radionuclides.

1. Generator ^{99}Mo → ^{99m}Tc
2. Generator ^{81}Rb → ^{81m}Kr
3. Generator ^{68}Ge → ^{68}Ga
4. Generator ^{90}Sr → ^{90}Y

Generator ^{99}Mo -> ^{99m}Tc

^{99}Mo (T ½ 66 h.) → ^{99m}Tc (T ½ 6 h.) → ^{99}Tc (2.1x105 years) The basis is a lead-shielded column containing aluminum oxide with adsorbed ^{99}Mo (T ½ 66 hodin). ^{99}Mo is converted by beta-decay to^{99m}Tc, which is very weakly bound to aluminum oxide and is washed out by elution with sterile physiological solution into a sterile lead-shielded vacuum vial. The generator is usable for two weeks.

Generator ^{81}Rb -> ^{81m}Kr

^{81}Rb (T ½ 4.6 h.) → ^{81m}Kr (T ½ 13 s., 191 keV) he generator is placed in a lead cover directly next to the patient and gaseous ^{81m}Kr is washed out by the air stream. The distribution of radioactivity in the lungs after inhalation is visualized by a gamma camera.

Generator ^{68}Ge -> ^{68}Ga

^{68}Ge (T ½ 287 dní) → ^{68}Ga (T ½ 68 minut) ^{68}Ga – positron emitter for PET, used to image neuroendocrine tumors.

Generator ^{90}Sr -> ^{90}Y

^{90}Sr (T ½ 28 let) → ^{90}Y (T ½ 64.2 hodin) ^{90}Y – used for radiation synovectomy.

Links

Related Articles

- Radiopharmaceuticals
- PET
- Scintigraphy
- Radionuclide generator

Source

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