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APPLICATION OF RADIOISOTOPES ON THE BASIS OF ^{18}F (FDG) AND ^{99m}Tc

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At present, methods of nuclear physics researches are one of the informative and safe methods of examining the human body [1]. Various radioisotopes are actively used in nuclear medicine and therapy, both for diagnostic and therapeutic purposes to detect pathological changes in human organs and systems [2]. For such studies radiopharmaceuticals which include compounds labeled with radioisotopes are used. As a mark of biologically important ultrashort-living positron-emitting radionuclides ^{11}C, ^{13}N, ^{15}O, ^{18}F are used. These radioisotopes are used for the differential diagnosis of malignant and benign neoplasms, determining the prevalence of the tumor process, the early detection of relapses and evaluating the effectiveness of the treatment.

An increasing diagnostic role in oncology is played by positron emission tomography (PET). Radionuclide diagnostic methods can be used to diagnose and treat cardiological, oncological, and neurological diseases [3, 4].

The main tasks of radionuclide diagnostics in the study of cancer patients are the following:

• differential diagnosis of malignant tumors and benign neoplasms;

• determination of the prevalence of the tumor process (clarification of the stage of the process);

• detection of relapses and metastases after treatment;

• evaluation of the effectiveness of antitumor therapy.

In this paper, the results of the use of radionuclides based on ^{18}F and technetium ^{99m}Tc by PET and single photon emission computed tomography (SPECT) are presented.

As the main method of research, the PET method was used, the newest method based on the use of ultrashort-lived radioisotopes [5, 6].

The most important component of PET is the cyclotron, which makes it possible to obtain labeled positron-emitting radiopharmaceuticals [7].

These radioisotopes were produced on the medical cyclotron (IBA-18) of the ACC, as well as the radioactive technetium ^{99m}Tc, which is produced at the nuclear reactor in the Institute of Nuclear Physics of Almaty and supplied to the Republic Diagnostic Center.

Patients were examined by PET/CT and SPECT, using the above radionuclides in the department of radioisotope diagnostics of the University Medical Center of Astana.

The main physical conditions for obtaining radionuclides are ^{18}F radionuclide was obtained upon irradiation of ^{18}O isotope nuclei by a beam of accelerated protons with an energy of 15 MeV by the reaction:

$$^{18}O \ (p,n) \ ^{18}F \qquad (1)$$

Water, enriched in the isotope ^{18}O, was used as the target substance. The resulting radionuclide ^{18}F is stabilized in the chemical form of fluoride, ^{18}F ([^{18}F], F^-). Next, the formation of radionuclides of nitrogen-^{13}N and ^{17}F. At the indicated parameters of irradiation, ^{16}O and ^{17}O, contained as impurities in the irradiated material, undergo nuclear reactions with the formation of radionuclides ^{13}N($T_{1/2}$(^{13}N)=9.96min.), ^{17}F ($T_{1/2}$ (^{13}N)=70 s.) , respectively:

$$^{16}O\ (p,\alpha)^{13}N \quad (2)$$

$$^{17}O\ (p,n)^{17}F \quad (3)$$

The chemical forms of stabilization of ^{13}N are gaseous nitrogen $[^{13}N]N_2$. Radionuclide ^{17}F is stabilized in the chemical form of fluoride, fluorine-17 fluoride, ^{18}F ($[^{18}F]$, F^-).

The content of ^{13}N and ^{17}F in the preparation at the time of its manufacture can not theoretically exceed 0.01%, which makes it possible not to determine radionuclide impurities in the target product.

«^{18}F-FDG» is a non-specific tumorotropic radiopharmaceutical and accumulates in increased amounts in malignant tumor cells and metastases, which is associated with their inherent hyperglycolysis [8-12]. The degree of accumulation of fluorodeoxyglucose, ^{18}F in the cells of malignant tumors correlates with the degree of their malignancy. The drug also allows to evaluate the effect of the treatment, as in effective treatment the level of accumulation of the drug in tumors decreases, and when ineffective - does not change or increases.

Fluoro-deoxyglucose ^{18}F is actively transported to cells by transporter proteins, where it undergoes phosphorylation to produce fluorodeoxyglucose-6-phosphate, ^{18}F (FDG), a product that does not enter into further reactions, and is retained in malignant tumor cells. In unchanged cells of tissues and organs dephosphorylation is observed with the formation of fluorodeoxyglucose, which is excreted from normal cells and can be redistributed.

After intravenous injection of fluorodeoxyglycoside ^{18}F rapidly leaves the bloodstream and gradually accumulates in organs and tissues. From the body, fluorodeoxyglucose ^{18}F is excreted through the kidneys into the bladder, so the kidneys, ureters and bladder are also visualized normally. More than 50% of the administered amount of RFP is excreted from the body with urine in the first 2 hours after the injection. In the brain, increased accumulation of RFP is observed in the cortex and deep structures, and the content of RFP in gray matter is 2 times higher than in white matter. Accumulation of the drug in the human myocardium is (3 ÷ 4) % of the injected. the optimal body / background ratio in the study of the myocardium and the brain is reached after (35-40) minutes after intravenous administration of the drug and persists for another (25-30) minutes, which is sufficient for PET. The optimal tumor / normal tissue ratio is observed after (45-120) min after administration of the drug, and remains after (240-360) minutes after administration.

In the present work, we present the results obtained by the PET method using the radionuclide ^{18}F intended for studying the functional activity of tissues and organs, as well as for studying the anatomo-morphological features.

As an example, Figure 1 shows the results obtained by the PET/CT method on the basis of the Republican Diagnostic Center of the Branch of the Corporate Foundation "University Medical Center" Nazarbayev University. Figure 1 shows the accumulation of fluorodeoxyglucose in the patient's body, which indicates the presence of neoplasm in the bones of the patient's jaw, and also in the area of the breast. The patient was diagnosed with PET/CT and 18-fluorodeoxyglucose was used to detect the affected area. Since cancer cells absorb 18 times more glucose than a normal cell, metabolic disturbances in the mammary gland and accumulation of the drug in the lower part of the jaw of the patient have been revealed.

Figure 1 clearly shows the patient's area of involvement, metastases spread to the lower jaw, which indicates by a green arrow.

With any diagnosis, it becomes necessary to localize the tumor and determine the focus of the disease. This patient suffers from osteoblastoclastoma, which is a single tumor, characterized by a richly vascularized tissue consisting of fusiform or ovoid cells and numerous giant cells like osteoclasts that are evenly distributed over the tumor tissue.

A number of authors [13, 14] refer it to the group of osteodystrophies, other researchers consider it to be a true tumor. In the osteoblastoklastoma spine, from 2% to 10% of all tumor diseases of the skeleton occurs, accounting for 11-13% of all tumors of the spine. Somewhat more

often observed in males. The tumor often affects both the posterior bone structures and the vertebral bodies. A tumor can affect one or more vertebrae, a sacral site in the spine is a favorite site of localization. The slow grow of the tumor is mainly observed. There are cellular and lytic forms of osteoblastoclast. By the majority of authors both forms are considered as phases of one process passing in each other.

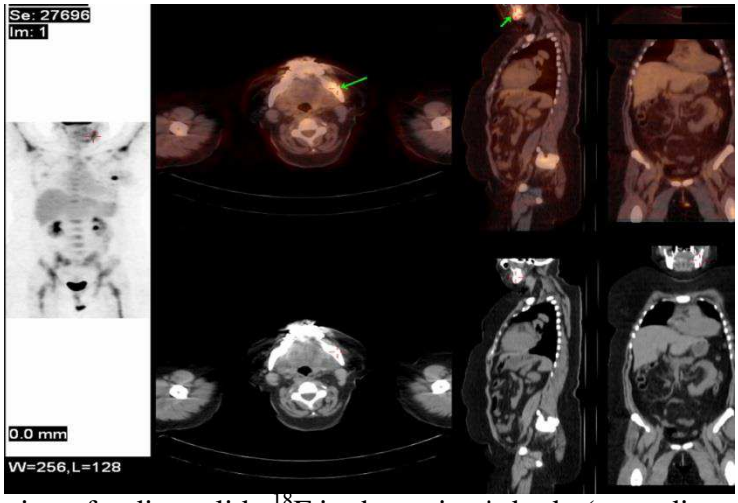

Figure 1 - Distribution of radionuclide ^{18}F in the patient's body (according to PET-CT data, it can be seen that the radionuclide has spread along the lower jaw)

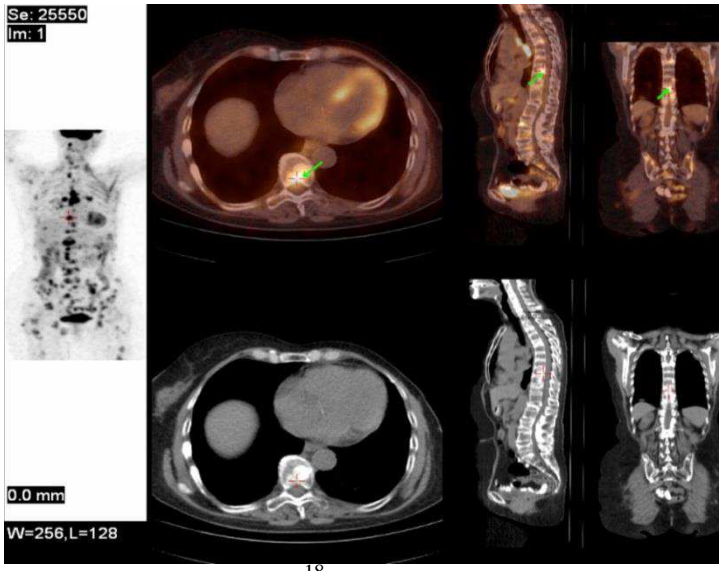

Figure 2 - Radionuclide distribution of ^{18}F (FDG) in the patient's body showed multiple metastatic center, including in vertebral bodies (indicated by an arrow)

At conducting of researches on a combined PET scanner, shown in Figure 2, it was found that the patient suffers from cervical cancer. For a full understanding of the diagnostic process and diagnosis based on the PET/CT image, Figure 3 is obtained. This is an enlarged PET/CT image of the affected area of the patient. On this figure there is a bright yellow spot, which indicates the presence of the disease and an extremely severe degree of the disease. Figure 3 also indicates lesions and metastases in the right lateral mass of the sacrum.

Figure 2 presents multiple metastatic center (the green arrow indicates center of neoplasm).

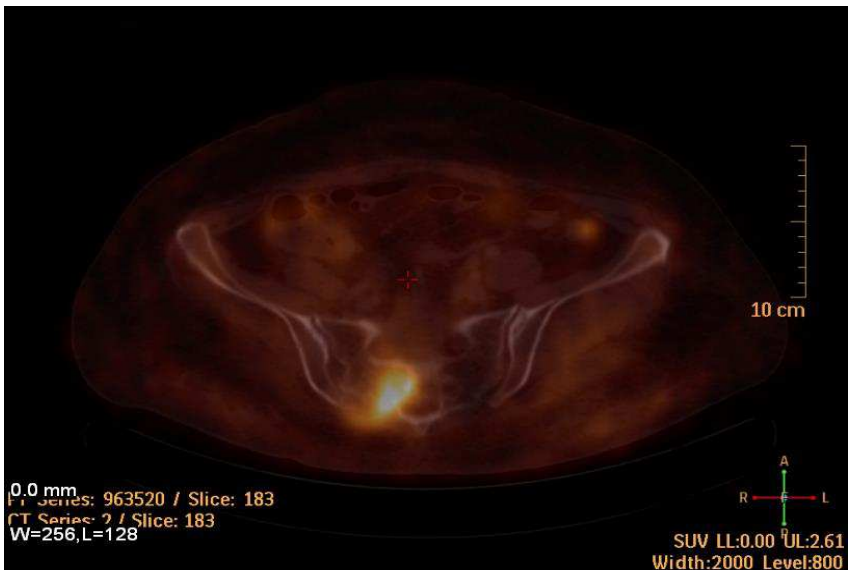

Figure 3 - An enlarged PET/CT image is a metastasis in the right lateral mass of the sacrum

In work also the researches received by a SPECT method with use of a radionuclide ^{99}Tc are carried out.

During the study of fluorodeoxyglucose distribution in the diagnosis of cancer, it was shown that clinical trials of ^{18}F confirmed its diagnostic importance. ^{18}F is an important radionuclide and can be used to visualize the biological state of a person and determine the area of the cancer.

As a result of the PET/CT data, effective doses (internal and external) were calculated, and the results of which calculated the total effective dose of patients depending on the body weight in the interval from 2.16 to 12.01 mSv and the background radiation of patients after passage of SPECT and PET studies. This allows to determine the number and frequency of PET/CT and SPECT diagnostic. The results of these calculations will be taken into account in subsequent possible examinations on PET/CT and SPECT tomography.

On the basis of the analysis it follows that patients with PET diagnostics receive a greater total irradiation than on SPECT diagnostics, since in SPECT tomography. This is explained that in SPECT X-ray tube is absent.

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