Journal of Radiation Researches, vol.10, No.2, 2023, Baku
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pp. 21-29

PACS: 81.40.Wx

APPLICATION OF RADIOPHARMACEUTICALS IN THE DIAGNOSIS AND TREATMENT OF ONCOLOGICAL DISEASES

G.E. Ahmadova[1], M.Y. Abdullayeva[1], J.A. Nagiyev[2], A.J. Mikayilova[3]

[1]Azerbaijan State Oil and Industry University, MSE AR
[2]İnnovation and Digital Development Agency Nuclear Research Department, AR
[3]Institute of Radiation Problems, MSE AR
gunelhmdova856@gmail.com; mayaabdullayeva@hotmail.com; Jalal.Naghiyev@idda.az; mikayilova.a.c@gmail.com

Abstract: Radiopharmaceuticals have gained approval as pivotal components of contemporary medical technologies in the realm of diagnosis and treatment of oncological diseases. These medications are used to closely monitor, diagnose, and treat diseases within the medical field. In the treatment of oncological diseases, the diagnostic and treatment procedures facilitated by these pharmaceuticals offer essential insight for disease classification and the effective targeting of dangerous tumor centers. Radiopharmaceuticals widely used in modern medical-diagnostic imaging are biological precursors functioning as ligands that selectively bind radioactive isotopes to themselves. The production of radiopharmaceuticals (RP) since the 1970s has significantly propelled the evolution of nuclear medicine, notably imaging systems, and radioactivity detection devices, thereby fostering the emergence of a new medical specialty.

This article delves into the primary application facets and the medical significance of radiopharmaceutical drugs employed in our country for diagnosing and treating oncological diseases. Within the article, the purity level of the radioisotope composition of RPs, containing Ac-225 and F-18 radionuclides, utilized in our country was studied through high-resolution gamma-ray spectroscopy. The integration of radiopharmaceutical drugs and radioactivity detection devices enables a more accurate diagnosis of oncological diseases and the meticulous monitoring of treatment progression. These medications, with the rapid development and features in the medical field, develop more efficacious diagnosis and treatment methods for oncological diseases.

Keywords: radiopharmaceutical medicine, therapy, treatment, oncological diseases, scintillography.

1. Introduction

Radiopharmaceuticals constitute an advanced field of medical biotechnology that plays an important role in the diagnosis and treatment of oncological diseases. These medications are based on the principles of harnessing radiation and nuclear energy to enhance the precision of disease diagnosis, meticulously monitor the targeted treatment, and distinctly delineate the location of tumors and the function of the cell.

The paramount advantage of these technologies is their capacity to yield more accurate and descriptive information compared to the diagnostic methods applied after the treatment, which typically rely on the indicators of specific tumor cells. This affords medical professionals comprehensive insights into the volume, shape, and activity of tumors, facilitating meticulous monitoring of the treatment process.

This article provides comprehensive insight into the sources of application of radiopharmaceutical drugs in the diagnosis and treatment of oncological diseases. It delves into the operation principles of the technologies and explores their specific applications in medical and

clinical contexts. How these medications may potentially replace or enhance current diagnostic and treatment methods, contributing to the evolution of oncology medicine.

Radiopharmaceuticals assume a pivotal role in diagnosing and treating oncological (cancer) diseases. Radiopharmaceuticals constitute amalgamations of radioactive isotopes and drug molecules. These drugs are employed to target cancer cells and deliver radioactive substances to tumors. Some of the methods of utilizing radiopharmaceuticals in the diagnosis and treatment of oncological diseases include:

- Imaging and Diagnostics: Radiopharmaceuticals are used in imaging techniques (e.g., positron emission tomography - PET or single photon emission computed tomography - SPECT) to diagnose and assess cancer tumors. The utilization of radioactive isotopes enables the visualization of metabolic activity and the location of cancer tumors in the body.
- Radiotherapy Planning: Radiopharmaceuticals are used to more accurately determine the location and size of the tumor during radiotherapy treatment planning. This meticulous insight helps confine the treatment focus to cancer cells, minimizing the risk of damage to healthy tissues.
- Radiotherapy: In certain cases, radiopharmaceuticals may be included in radiotherapy treatment. They can be used to directly target the tumor site via injecting or implanting radioactive drugs into the cancer cells.
- Radiopharmaceutical Therapies: Radiopharmaceuticals can be used to treat some types of cancer. In particular, radionuclide therapies aim to target metastatic cancers and obliterate them by transporting radioactive substances into the cancer cells.

The utilization of radiopharmaceuticals stands as a crucial facet in cancer diagnosis and treatment, offering a targeted approach to reach cancer cells and deliver radioactive substances directly to tumor sites. Nonetheless, the application of these drugs demands expertise and meticulous planning due to their radiation exposure. Consequently, the incorporation of radiopharmaceuticals is managed by a multidisciplinary healthcare team and carefully tailored to the unique circumstances of each patient.

Radiopharmaceuticals encompass exclusive chemical preparations employed in medicine and medical devices made from radioisotopes. These drugs, along with the radioisotopes assume a pivotal role in the diagnosis and treatment of oncological diseases. The photons and spectral emissions generated by the collaborated radioisotopes are harnessed for medical research and emergency diagnostics. Herein, I explain in more detail how radiopharmaceuticals are used in the diagnosis and treatment of oncology diseases:

1. ***Oncological diagnostics:***

- Positron Emission Tomography (PET): During this procedure, special radiopharmaceuticals are administered and used for its nuclear study. It is used to meticulously assess the patient's condition and identify metastatic occurrences.
- Single-Photon Emission Computed Tomography (SPECT): radiopharmaceuticals are also administered in the course of a SPECT scan. Employing this method enables the evolution of organ states and facilitates the detection of disease areas.
- Localization Using Label-Free Radiopharmaceuticals: Label-free radiopharmaceuticals are used to show pertinent conditions and localize disease regions within the oncological context.

2. ***Oncological treatment:***

- Radioimmunotherapy (RIT): Radiopharmaceuticals can be used to treat the disease. They are chosen based on the specific radioactive properties relevant to particular diseases, according to the condition, and affect the cells.

- Radioisotope Therapy: Special radioisotopes are administered and their radioactivity is used for therapy. In this way, the disease cells are destroyed and the volume of tumors is reduced.

In the realm of oncology diagnosis and treatment, radiopharmaceuticals assume a crucial role as indispensable medical tools. Nonetheless, the application of these procedures necessitates meticulous medical expertise and specialized studies to precisely prescribe the treatment.

Radiopharmaceuticals constitute a pivotal category of medications that play a key role in the diagnosis and treatment of oncological diseases, leveraging nuclear energy for this purpose. The fundamental principles of utilization of radiopharmaceuticals in the diagnosis and treatment of oncological diseases include:

1. Scintigraphy: Radiopharmaceuticals play a crucial role in acquiring information about oncological diseases through the images captured by the camera. This technique aids in determining the location and size of tumors, as well as monitoring the recovery progress of the disease. Scintigraphy is a research method used in the diagnosis and monitoring of disease in medicine. During this study, disease centers and cell functionality are described. This is achieved through the use of radiopharmaceuticals.

Scintigraphy studies primarily aim to determine if the applied radiopharmaceutical reaches a specific area of the disease and detect dangerous changes in that area. These studies ensure the precise determination of the composition and specific properties of the administered radiopharmaceutical and guarantee its controlled delivery to the disease center.

Scintigraphy studies are organized through images captured by cameras. These images provide intricate details about disease centers, cell functionality, and the presence of dangerous tumors. It is an important tool for diagnosing oncological diseases, determining the volume and location of tumors, monitoring the results of treatment, and improving the treatment process. Scintigraphy is employed to obtain more precise and scientifically grounded information, especially in cancer diagnosis and treatment.

2. Positron Emission Tomography (PET): Radiopharmaceuticals are used with PET scans to determine the extent of disease dissemination and its involvement at the organ level. This helps to assess and track the efficacy of administered treatment. Positron Emission Tomography (PET) stands as a diagnostic imaging technique within the domain of nuclear medicine, employed for the diagnosis and monitoring of diseases. The primary goal of this method is to meticulously describe the centers of disease dissemination and cell functions separately.

During Positron Tomography, radiopharmaceutical treatments, which are special preparations, are employed for diagnosing and monitoring diseases. These preparations amalgamate radioactive isotopes and disintegrate within the human body over a specific timeframe. Upon arrival, images are captured, revealing the function and characteristics of specific organs and cells as a part of foundational medicine.

During a PET treatment, radioactivity is introduced into the biological organism, and then the radioactivity levels in human organs and tissues are measured using a PET scanner. The resulting images, obtained after the examination, provide detailed information about the presence of the disease, the dissemination centers, and the cell functionality. This examination is a pivotal tool for diagnosing oncological diseases, conducting evaluations of the disease, and assessing treatment results. PET treatment finds application in diverse medical domains, including cancer, neurological diseases, vascular issues, and various other medical fields. In our country, the preeminent radiopharmaceutical drug used in nuclear medicine and PET-CT imaging for diagnosing oncological diseases is ^{18}FDG 2-deoxy-2-[18F]fluoro-D-glucose, referred to as a radiosugar labeled with the F-18 radioisotope. Due to its short half-life and positron emission, F-18 is extensively utilized in molecular imaging of biological and biochemical processes,

facilitating the early detection of various diseases and the assessment of treatment response through positron emission tomography (PET) [7].

The production of ^{18}FDG is a multi-step process, and this process begins with the acceleration of protons to an energy level of 14.6 MeV and the production of F-18 fluoride nucleotide in a cyclotron by focusing on a cone-shaped water target enriched with the O-18 isotope as a target. Then, tetraacetyl-FDG is obtained as a result of a chemical combination reaction with acetonitrile in the presence of mannose triflate cryptofix catalysts, a precursor form of glucose. The obtained compound is hydrolyzed in the presence of sodium hydroxide solution to obtain 18-FDG.

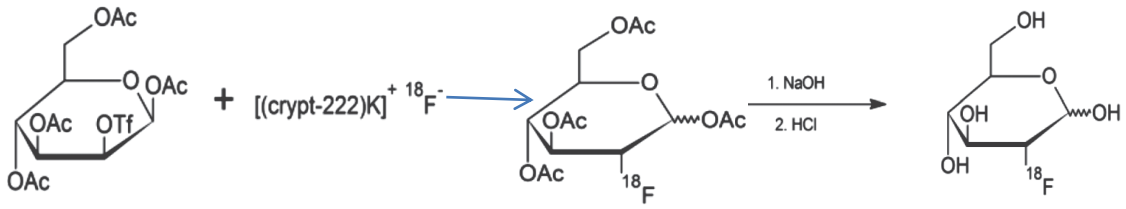

Fig. 1. Synthesis mechanism of ^{18}FDG 2-deoxy-2-[18F]fluoro-D-glucose

After laboratory analysis, such as quality control, radioisotope content purity, and sterility testing, the produced RP can only be used for medical diagnostic purposes. Taking this into account, we have studied the purity of the radioisotope composition of 18-FDG RP by high-resolution gamma spectrometry.

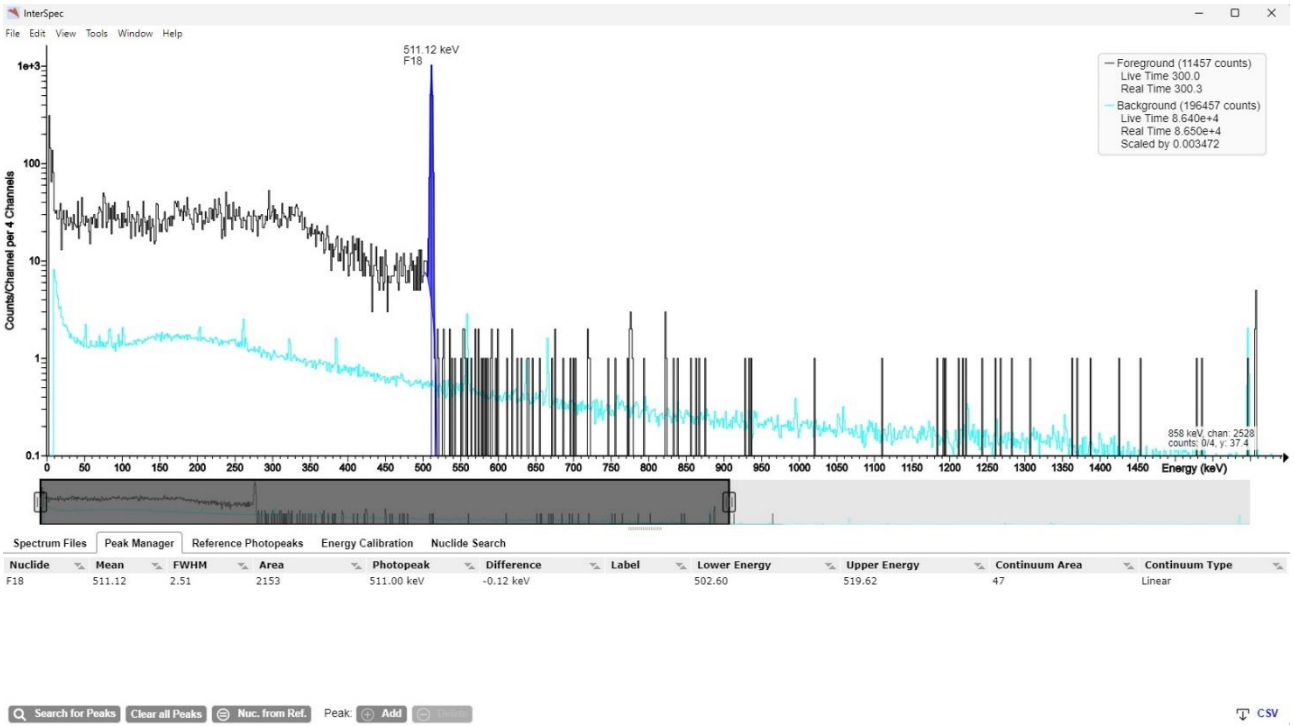

Fig. 2. Gamma spectrum of ^{18}FDG solution with 1000Bk activity

The purpose of the study was to monitor the formation of other isotopes of fluorine during synthesis. It is known that fluorine has several isotopes, including 19F, 18F, 17F, 20F and 21F. Except for 19F, these isotopes are radioactive and have a very short half-life, especially, 17F, 20F, and 21F. The scientific community utilizes 19F and 18F. F-18, which has a half-life of 109.8 minutes, emits a positron that collides with an electron, which is called an "annihilation reaction" and produces two photons that have 511 keV gamma radiation at an angle of 180° in opposite directions from each other. As can be seen from the figure, the captured gamma spectrum reveals one photopeak at 511 keV, with no other peaks observed. This photopeak exactly corresponds to the gamma spectrum of the active F-18 radionuclide and indicates the absence of other contaminating radioisotopes in RP. A 511 keV annihilation gamma photopeak and Compton scattering of gamma rays are observed from F-18, a positron-emitting nuclide.

3. Radiotherapy: Radiopharmaceuticals play a primary role in treatments, such as radioiodine therapy, a form of radiotherapy. This procedure is used in the treatment of oncological diseases, and special radioactive substances are meticulously administered to the tumor center via the application of radiopharmaceutical drugs.

Radiotherapy is a medical treatment employed in the treatment of diseases, such as cancer. Radiation therapy aims to destroy or control cancer cells using radiation. Radiotherapy is performed with high-energy X-rays or other types of radiation. This process meticulously directs radiation sources to a specific area, targeting cancer cells. Radiotherapy is carefully planned to target cancer tumors or cancer cells. The treatment plan is created depending on the location and size of the tumor, the general health of the patient, and the goals of the treatment.

Radiotherapy treatment consists of a series of sessions. These sessions occur regularly over a period of time. In each session, the patient receives radiation therapy. During radiation therapy, accurate dose calculations are performed to avoid damaging healthy tissues while targeting cancer cells. In addition to targeting cancer cells, radiotherapy treatment can also damage normal cells. Therefore, side effects may occur during and after treatment. These side effects may vary depending on the area of treatment and the individual characteristics of the patient. Side effects may include fatigue, skin irritation, nausea, vomiting, and other radiation effects. Radiotherapy treatment can be used alone or in combination with other methods of cancer treatment, such as surgery or chemotherapy.

In our country, nuclear medicine methods are used in the radiotherapy of oncological diseases. Prostate-specific membrane antigen (PSMA) is meticulously administered in combination with the unique targeting radioisotopes Lu-177 and Ac-225 in patients with metastatic castration-resistant prostate carcinoma (mCRPC) [8].

PSMA has demonstrated profound therapeutic efficacy in heavily pre-treated mCRPC patients. We have performed gamma spectrometric measurements on several patients given the beta emitter 177Lu radioisotope conjugated to PSMA ligand. The fundamental aim of the study was to monitor the radioisotope purity of drugs in mCRPC patients through gamma spectrometry and clinical experiments to monitor the process of radioisotope elimination in the patient.

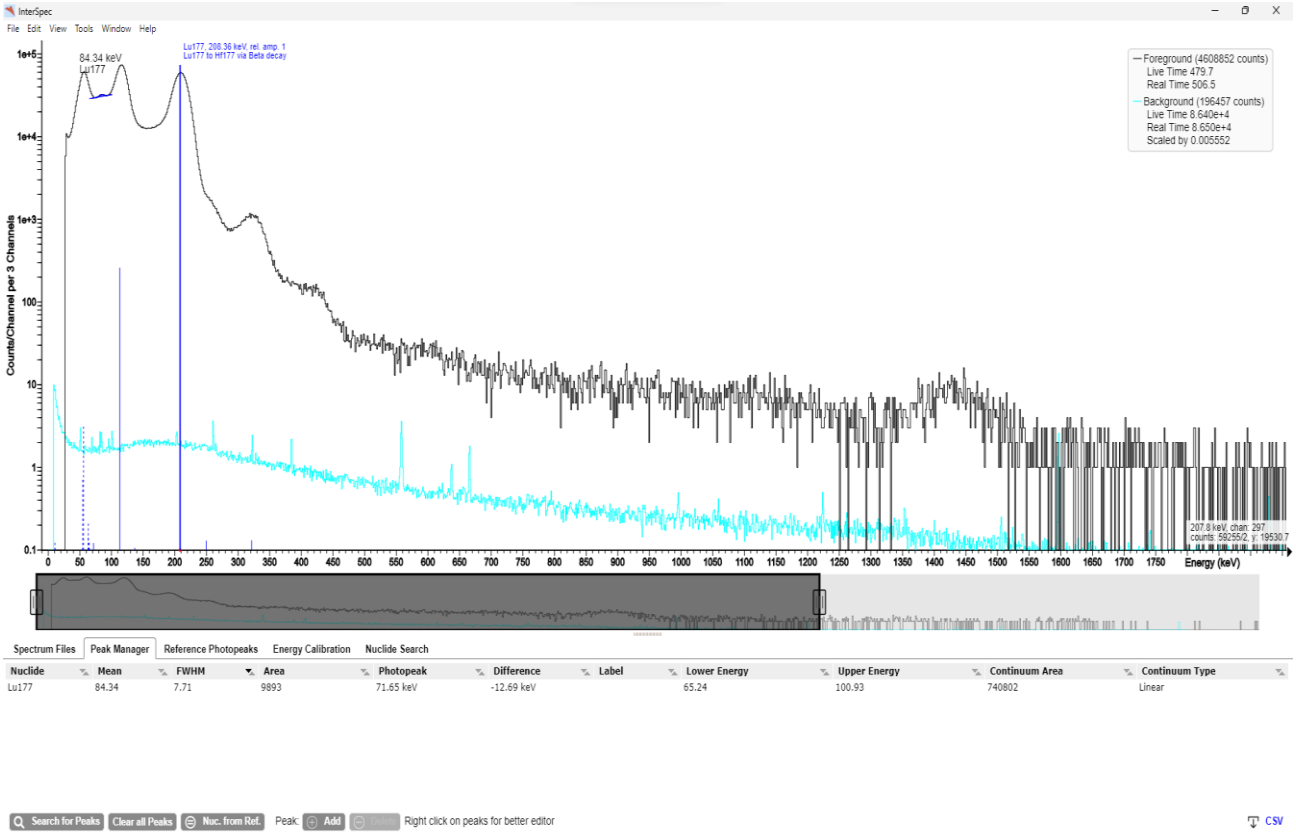

Fig. 3. Gamma spectrum of Lu-177-PSMA solution with 0.1 mCi activity

The treatment plan is determined depending on the type of cancer, stage, and general health of the patient. The expert specialists, tasked with designing and executing the treatment, diligently strive to ensure that the patient achieves the best results. Since radiotherapy aims to destroy or shrink cancer cells, it can enhance the prospects of effectively managing the cancer or achieving complete recovery. However, every patient is different and treatment results may vary from person to person. Therefore, the treatment plan and expectations are individualized for each patient.

4. Tumor therapy: Radiopharmaceutical drugs are used to disrupt and alter the composition of malignant tumor cells using special radioactive isotopes. Tumor therapy encompasses various treatment approaches aimed at treating cancer tumors. Cancer tumors are caused by uncontrolled cell proliferation and harm to normal tissues. Tumor therapy aims to target and destroy cancer cells. Tumor treatment may involve a variety of methods, and the treatment plan is determined based on the patient's cancer type, tumor stage, general health, and other factors. Chemotherapy uses drugs to target cancer cells, arresting their growth and multiplication. Chemotherapy is often used as a systemic treatment and exhibits the capability to target cancer cells throughout the body. However, it can also pose a risk, potentially causing damage to normal cells.

Synthesis and incorporation: Radiopharmaceuticals are prepared for use through special emergency procedures and rigorous quality control is performed to verify the safety of radiopharmaceuticals. Synthesis, within this context, refers to the process of making a compound or substance in the realm of chemistry and other sciences. This process can be carried out in various ways, such as various chemical reactions, combining molecular components, or creating genetic material within organisms. Chemistry, in particular, places significant emphasis on the synthesis of both organic and inorganic compounds. The term incorporation has a broader meaning, denoting

the assimilation of something into a system, organization, or structure. The term is often used to refer to the integration of information, processes, data, or other elements across organizations, institutions, or systems. In biochemistry, "incorporation" extends to the process of uptake of foreign molecules or components within a cell.

Radiopharmaceutical drugs help to elevate the accuracy, specificity, and efficiency of the diagnosis and treatment of oncological diseases. These medications provide detailed information about the location and size of tumors, cell functionality, and the efficacy of the intended treatment of the disease. This is an advanced stage in the diagnosis and treatment of oncological diseases.

2. Conclusion

The utilization of radiopharmaceuticals for the diagnosis and treatment of oncological diseases can help to achieve significant results. We note some important points regarding the results of the use of radiopharmaceuticals in the diagnosis and treatment of oncological diseases:

Early detection: The integration of radiopharmaceuticals with nuclear medicine imaging techniques can help to detect cancer tumors at an early stage. This can enhance the chances of initiating treatment earlier and can be used to monitor the size and activity of tumors throughout the treatment process.

Treatment Planning: Radiopharmaceuticals are used during the planning of radiotherapy treatment, enabling precise targeting of tumors. This allows more radiation to be delivered to cancer cells during treatment and minimizes damage to healthy tissue.

Personalized treatment: Radiopharmaceuticals can help to personalize treatment plans based on an individual patient's cancer type and tumor characteristics. This allows for the development of more effective treatment options with reduced side effects.

Targeted Therapy: Radiopharmaceuticals are targeted directly at cancer cells, to minimize damage to healthy tissues while targeting cancer cells. This can help to mitigate potential side effects.

As a result, radiopharmaceuticals are used as an indispensable tool for diagnosis and treatment of oncological diseases. The utilization of these drugs ensures more accurate diagnoses, individualized treatment plans, and more effective treatment options.

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ПРИМЕНЕНИЕ РАДИОФАРМПРЕПАРАТОВ В ДИАГНОСТИКЕ И ЛЕЧЕНИИ ОНКОЛОГИЧЕСКИХ ЗАБОЛЕВАНИЙ

Г.Э. Ахмадова, М.Я. Абдуллаева, Дж.А. Нагиев, А.Дж. Микаилова

Резюме: Радиофармацевтические препараты получили признание как ключевые компоненты современных медицинских технологий в области диагностики и лечения онкологических заболеваний. Эти препараты используются для тщательного мониторинга, диагностики и лечения заболеваний в медицинской сфере. При лечении онкологических заболеваний диагностические и лечебные процедуры, проводимые с помощью этих препаратов, дают возможность классифицировать заболевания и эффективно воздействовать на опасные опухолевые очаги. Радиофармацевтические препараты, широко используемые в современной медико-диагностической визуализации, представляют собой биологические предшественники, функционирующие как лиганды, избирательно связывающие с собой радиоактивные изотопы. Производство радиофармацевтических препаратов (РФП) с 1970-х годов значительно ускорило развитие ядерной медицины, в частности систем визуализации, приборов для определения радиоактивности, тем самым способствуя появлению новой медицинской специальности.

В данной статье рассматриваются основные аспекты применения и медицинское значение радиофармацевтических препаратов, используемых в нашей стране для диагностики и лечения онкологических заболеваний. В статье с помощью гамма-спектроскопии высокого разрешения исследована степень чистоты радиоизотопного состава РФП, содержащих радионуклиды Ac-225 и F-18, используемых в нашей стране. Интеграция радиофармацевтических препаратов и устройств для определения радиоактивности позволяет более точно диагностировать онкологические заболевания и тщательно следить за ходом лечения. Эти препараты, с учетом стремительного развития и особенностей медицинской сферы, разрабатывают более эффективные методы диагностики и лечения онкологических заболеваний.

Ключевые слова: радиофармацевтическая медицина, терапия, лечение, онкологические заболевания, сцинтиграфия.

RADİOFARMASEVTİK DƏRMAN VASİTƏLƏRİNİN ONKOLOJİ XƏSTƏLİKLƏRİN DİAQNOSTİKASI VƏ MÜALİCƏSİNDƏ TƏTBİQİ

G.E. Əhmədova, M.Y. Abdullayeva, C.Ə. Nağıyev, Ə.C. Mikayılova

Xülasə: Radiofarmasevtik dərman vasitələri, onkoloji xəstəliklərin diaqnostikası və müalicəsində modern tibbi texnologiyaların ən əsas hissələrindən biri olaraq təsdiq olunmuşdur. Bu dərmanlar, tibbin bir hissəsi kimi xəstəliyi yaxından izləmək, diaqnoz və müalicə etmək üçün istifadə olunur. Onkoloji xəstəliklərin müalicəsində, bu vasitələr tərəfindən tətbiq edilən diaqnostik və müalicə prosedurları, xəstəliyin təsnif edilməsi və təhlükəli şişlərin mərkəzi ilə effektiv müalicə üçün əsaslı məlumatlar təmin edir. Müasir tibbi-diaqnostik görüntüləmə metodunda geniş istifadə edilən radiofarmasevtik dərman vasitələri radioaktiv izotopları özünə selektiv birləşdirən liqand rolunu oynayan bioloji prekursorlardır. 1970-ci illərdən başlayaraq radiofarmasevtik dərman vasitələrinin (RFDV) istehsalı yeni bir tibbi ixtisasın inkişafına təkan verməklə, nüvə təbabəti xüsusilə görüntüləmə sistemləri, radioaktivliyi aşkar edən cihazların tətbiqi sahələrinin inkişafına gətirdi.

Bu məqalədə, ölkəmizdə tətbiq olunan radiofarmasevtik dərman vasitələrinin onkoloji xəstəliklərin diaqnostikası və müalicəsindəki əsas tətbiqi aspektləri və tibbi önəmi müzakirə olunacaq. Məqalədə ölkəmizdə tətbiq olunan Ac-225 və F-18 radionuklid tərkibli RFDV-nin radioizotop tərkibinin təmizlik dərəcəsi yüksəkayırdetmə qabiliyyətli qamma spektrometrik metodu ilə tədqiq edilmişdir. Radiofarmasevtik dərmanlar və radioaktivliyi aşkar edən cihazların tətbiqi ilə onkoloji xəstəliyin daha dəqiq diaqnoz edilməsi və müalicənin düzgün məcrada aparılmasını izləmək mümkün olur. Bu vasitələr, tibbi sahədəki sürətli inkişaf və xüsusiyyətlər ilə onkoloji xəstəliklərinin daha effektiv diaqnostikası və müalicə üsullarını inkişaf etdirir.

Açar sözlər: radiofarmasevtik dərman, terapiya, müalicə, onkoloji xəstəliklər, sintiqrafiya.