Research, Society and Development, v. 9, n. 7, e834974671, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i7.4671

Aspectos físico-químicos e aplicações dos radiofármacos na medicina nuclear

Physico-chemical aspects and applications of radiopharmaceuticals in nuclear medicine

Aspectos físico-químicos y aplicaciones de los radiofármacos en la medicina nuclear

Recebido: 18/05/2020 | Revisado: 28/05/2020 | Aceito: 30/05/2020 | Publicado: 17/06/2020

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Resumo

O presente estudo tem o objetivo de fazer uma análise diante das características físicas e químicas dos radiofármacos, bem como suas aplicações no método de medicina nuclear, através de uma revisão de literatura que selecionou 14 artigos completos, nos idiomas inglês e português, publicados de 2016 até 2020. Os radiofármacos são elementos radioativos, que possuem na sua composição interna um radionuclídeo e são utilizados na Medicina Nuclear para fins de diagnóstico e terapia de várias doenças. Possuem algumas características muito importantes para que sejam escolhidos para a utilização no que se diz respeito ao processo de diagnóstico por imagem, já que, essas substâncias precisam ter um tempo de meia-vida muito curtos para que sejam usados na clínica diagnóstica, outros aspectos físicos e químicos devem ser analisados como o modo de decaimento (alfa, beta ou gama), emissão de energia e condições de temperatura e umidade. Precisam ser preparados de acordo com normas rigorosas de controle e qualidade de processamento, para que assim, possa assegurar que as doses de radiação que o paciente recebe sejam mínimas e o resultado esperado seja eficaz. São diversos tipos de exames que se utilizam radioisótopos, como a PET-Scan, a cintilografia de perfusão miocárdica e pulmonar, cintilografia renal, cintilografia óssea, entre outros. Portanto, a correlação existente entre os radiofármacos e a medicina nuclear desencadeiam um importante passo para a área médica nos tempos atuais, por ser capaz de diagnosticar doenças complexas de forma precoce utilizando um nível de radiação baixo.

Palavras-chave: Radiofármacos; Radionuclídeo; Medicina Nuclear; Cintilografia.

Abstract

This study aims to make an analysis of the physical and chemical characteristics of radiopharmaceuticals, as well as their applications in the method of nuclear medicine, through a literature review that selected 14 full papers, in English and Portuguese, published from 2016

to 2020. Radiopharmaceuticals are radioactive elements, which have in their internal composition a radionuclide and are used in Nuclear Medicine for diagnosis and therapy of various diseases. They have some very important characteristics to be chosen for use in the diagnostic imaging process, since these substances need to have a very short half-life to be used in the diagnostic clinic, other physical and chemical aspects must be analyzed such as decay mode (alpha, beta or gamma), energy emission and temperature and humidity conditions. They need to be prepared in accordance with strict standards of control and processing quality, so that you can ensure that the radiation doses the patient receives are minimal and the expected result is effective. There are several types of tests that use radioisotopes, such as PET-Scan, myocardial and pulmonary perfusion scintigraphy, renal scintigraphy, bone scintigraphy, among others. Therefore, the correlation existing between radiopharmaceuticals and nuclear medicine triggers an important step for the medical area in the current times, as it is capable of diagnosing complex diseases early using a low radiation level.

Keywords: Radiopharmaceuticals; Radionuclide; Nuclear Medicine; Scintigraphy.

Resumen

Este estudio tiene por objeto hacer un análisis de las características físicas y químicas de los radiofármacos, así como de sus aplicaciones en el método de la medicina nuclear, mediante una revisión de la literatura que seleccionó 14 documentos completos, en inglés y portugués, publicados entre 2016 y 2020. Los radiofármacos son elementos radiactivos que tienen en su composición interna un radionúclido y se utilizan en la medicina nuclear para el diagnóstico y la terapia de diversas enfermedades. Como estas sustancias deben tener una vida media muy corta para ser utilizadas en la clínica de diagnóstico, deben analizarse otros aspectos físicos y químicos como el modo de descomposición (alfa, beta o gamma), la emisión de energía y las condiciones de temperatura y humedad. Deben prepararse de acuerdo con estrictas normas de control y calidad de procesamiento, de modo que se pueda asegurar que las dosis de radiación que recibe el paciente son mínimas y que el resultado esperado es efectivo. Existen varios tipos de pruebas que utilizan radioisótopos, como el PET-Scan, la gammagrafía de perfusión miocárdica y pulmonar, la gammagrafía renal, la gammagrafía ósea, entre otras. Por lo tanto, la correlación existente entre los radiofármacos y la medicina nuclear desencadena un paso importante para el área médica en los tiempos actuales, ya que es capaz de diagnosticar enfermedades complejas de forma temprana utilizando un nivel de radiación bajo.

Palabras clave: Radiofármacos; Radionúclido; Medicina nuclear; Escintigrafía.

1. Introduction

Nuclear medicine can be characterized as the medical and radiological specialty that uses radioactive compounds for evaluation purposes, in order to present diagnosis for physiological conditions and also for therapeutic purposes, besides being able to contribute to more complex procedures, such as surgeries. One of its characteristics is the very high sensitivity, which helps a lot in the detection of pathophysiology of specific organs, this is only possible because of the use of substrates with radioactive atoms that integrate their interior composition and metabolizing substances that already exist in the human body, such as oxygen and glucose (Miguel, 2017, Dartora, 2018)

These radioactive elements act more in the therapy and early diagnosis of pathologies that range from common pathologies such as inflammatory problems in the organs to more delicate pathologies such as cancer. It is important to point out that each specific type of radiopharmaceutical has a certain affinity with the organ to be studied and, at the same time, emits radiation during its use. Thus, for there to be really the affinity mentioned above, there must be a certain compatibility between the metabolic processes of the organ to be analyzed through the procedure and the radioisotopes that have been defined to perform it (Costa el al., 2018).

There are a wide range of radiopharmaceuticals that are used in Brazil for diagnostic tests within nuclear medicine, from PET-Scan to scintigraphy. However, the modality of examination is who will determine which radionuclide will be used for the completion of the imaging examination, so that the detection and identification of a possible pathology can be performed. For example, technetium-99, which is one of the most used in the country and in the diagnostic mode, is more effective for scintigraphy and thyroid examinations. Technetium (99m-tc) is obtained together with the result of molybdenum decay, which potentiates it even more, making it very effective in its metabolic and diagnostic process. In addition, other characteristics of radionuclides must be taken into consideration so that they are chosen for the procedure in nuclear medicine, such as the half-life (half-integration period), which is the period necessary for the radioactive isotope to decay by half, where it is necessary for the radiopharmaceutical to have a low half-life to be applied in nuclear medicine examinations and its decay mode, which can be in alpha, beta or gamma, where elements that have a decay mode in beta, have purposes for diagnosis and therapy (Monteiro 2017, Gaonkar et al., 2019).

2. Methodology

This research is an integrative bibliographical review study, for this purpose, a cunsult and selection of scientific data in the virtual platforms Scielo (Scientific Electronic Library Online), Google Academic and PubMed through the following keywords : Radiopharmaceuticals, Radionuclides, Nuclear Medicine and Scintigraphy. The period of analysis of these data was from January to April 2020. The following guiding question was also used: what are the physico-chemical aspects of these elements and what are their applications in nuclear medicine?

These articles were then selected through inclusion criteria, they were complete articles, indexed in the appropriate platforms from 2016 to 2020 (last five years), published in Portuguese and English in national and international specialized scientific journals. They were also selected through criteria, articles of experimental design (clinical trials, randomized or not) on metrology, application and efficacy of radioisotopes in nuclear medicine, case reports and literature reviews, in order to provide a relevant explanation on the subject. In addition, studies were used that had a qualitative and quantitative approach, with clear methodologies and scientific bases among the results obtained.

Scientific articles indexed to the platforms mentioned before 2016 and which did not contain a relevant theoretical basis in relation to the subject were excluded from this research.

3. Results and Discussion

Taking into account the supervision of radiological protection, this is the responsibility of the National Nuclear Energy Commission (CNEN), which carefully establishes the dose limits of individuals exposed to occupational radiation in order to protect them from the effects of ionizing radiation. In addition, CNEN is also responsible for the regulations governing the control and quality of these elements, from their production in the nuclear reactor to the radiopharmacies (Bergamo 2019, Ruzzarin et al., 2017).

A study on the characteristics of radiopharmaceuticals, such as emission (decay mode) and half-life was published with data from radioactive elements commonly used in nuclear medicine. These characteristics are taken into consideration when defining the radioisotope to be used in the procedure, in order to obtain a good performance of the examination and acceptance of the element by the body of the patient submitted (Table 1) (Ferreira, 2018).

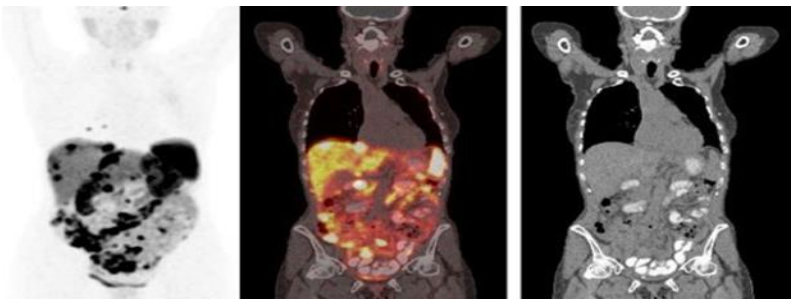
Table 1: Main radiopharmaceuticals and their characteristics.

Isotope	Issue/Half-life
Tc-99m	Range/6h
I-131	Beta and gamma/8 days
Ga-67	Range/3.26 days
Tl-201	Range/3.04
I-123	Range/13.2h
Sm-153	Beta and gamma/1.95 days
F-18	Positron (range) /109 minutes

Source: Adapted by the Author.

PET-Scan, is an English acronym, which being translated into Portuguese is understood as Positron Emission Tomography, which is one of the methods of application of radiopharmaceuticals for the diagnostic process, where the readionuclide is introduced into the patient and goes directly to meet some substance that is metabolized by the human body, In this case, which can be oxygen or glucose, when the encounter occurs, the two substances mix, giving rise to a kind of radioactive tracer, which is attached to the organ or tissue in which the patient is being submitted for diagnosis. In this method (Figure 1) the most used radiopharmaceutical is Fluoride-18, also called FDG (Lapa et al., 2016).

Figure 1: PET-Scan exam images.



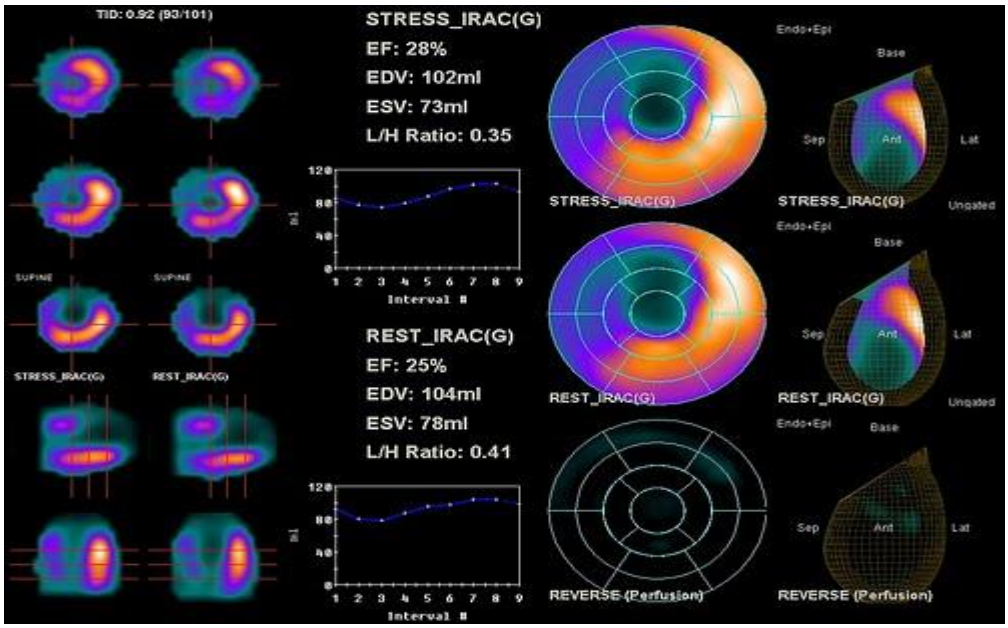
Source: Portal of Radiology.

Another method of applying radiopharmaceuticals in nuclear medicine is scintigraphy, which is a method where a low dose of radiation is used, it is introduced into the patient via oral or venous route and allows the functionality of the patient's organs to be analysed, unlike other types of radiodiagnostic examinations, which analyse the anatomy (Mello et al, 2018).

In Scintigraphy, the most analyzed organ is the heart and its adjacent structures, such as coronary arteries and myocardial muscle, as well as possible problems that may affect these areas, such as coronary obstructions, through cardiac perfusion. The exam procedure (if

necessary) occurs in two phases: rest and stress; in which a radiopharmaceutical is introduced into the patient. At rest, a 20 mm dose of Ci 99mTc-sestamibi is introduced and, after an interval of 30-40 minutes, the image is taken. In the stress phase, the same element and dose is introduced with the help of a drug that stimulates stress, but the image acquisition time decreases to between 15-30 minutes (Dondi, 2018, Reis et al., 2017).

Figure 2: Myocardial scintigraphy images.



Source: Cardio.

Static or dynamic renal scintigraphy is a method indicated for the analysis of the functionality of the renal system, being possible to detect some inflammation or some type of renal scar, in more serious cases, these damages can cause loss of renal function. Through the use of technetium-99 (99m-tc), which is the radiopharmaceutical used in this test, which allows the specific dimensional study, morphology, renal location, evaluation of the renal cortex and detection of infectious lesions (Júnior, 2018).

There are also other types of scintigraphy, such as pulmonary perfusion, which is indicated when a possible pulmonary embolism is suspected. Bone scintigraphy, performed to analyze the patient's skeletal system and thus detect metastases or other bone and metabolic diseases. Bile duct scintigraphy, which is indicated for the diagnosis of some hepatic dysfunction. It is important to note that there are other types of scintigraphy, such as those of the tear ducts and genital regions, however they are less common in relation to those cited above (Irion, 2017).

4. Final Considerations

Even though there is still little research on this subject and the production of radiopharmaceuticals in Brazil is still very scarce, it triggers an interest from the scientific community that develops studies on these elements, because radiopharmaceuticals can be major contributors to diagnosis and therapy of many diseases, because they have several favorable factors around their dynamics.

It is known that every day they develop new techniques to obtain even more effective radioisotopes, capable of being responsible for pathologies at the molecular level and thus make their activity within the medical area bring even safer and more effective results.

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