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(REVIEW ARTICLE)

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Review of nuclear medicine imaging used in medical diagnostics

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Abstract

In this review, we will provide an overview of the role of nuclear medicine in Medical Diagnostics. Nuclear medicine is defined as the diagnosis and treatment of disease using radiolabeled compounds known as radiopharmaceuticals. Nuclear imaging produces images by detecting radiation from different parts of the body after a radioactive tracer material is administered. The images are recorded on a computer and film. Different types of nuclear imaging tests have different preparation instructions. Nuclear imaging is used primarily to diagnose or treat illnesses. Conditions diagnosed by nuclear medicine imaging include: Blood disorders, Thyroid disease. including hypothyroidism, Heart disease, Gallbladder disease, Lung problems, Bone problems, and kidney disease. Nuclear medicine, in combination with radiological modalities, gives extra information for diagnosis, prognosis, staging, treatment management, and the evaluation of responses to therapy in a non-invasive manner.

Keyword: Nuclear medicine; Medical imaging; Radioactive tracer; Gamma emission and positron emission

1. Introduction

Nuclear medicine (NM) is a specialized branch of medical imaging practiced by residency-trained NM specialists and, in limited circumstances, radiologists [1]. Nuclear medicine techniques use unsealed radioactive substances in diagnosis and therapy. In diagnostic NM, radioactive substances are administered, usually intravenously, to patients, and the radiation emitted is measured. Nuclear medicine imaging primarily shows the physiological function of the system being investigated while also providing low-resolution anatomical data. Nuclear medicine imaging is a method of producing images by detecting radiation from different parts of the body after a radioactive tracer is given to the patient. The images are digitally generated on a computer and transferred to a nuclear medicine physician, who interprets the images to make a diagnosis. Radioactive tracers used in nuclear medicine are, in most cases, injected into a vein. For some studies, they may be given by mouth. These tracers aren't dyes or medicines, and they have no side effects [2]. The amount of radiation a patient receives in a typical nuclear medicine scan tends to be very low. Nuclear medicine tests use a small amount of radioactive material combined with a carrier molecule. This compound is called a radiotracer. These tests help diagnose and assess medical conditions. They are non-invasive and usually painless. When a radiotracer is injected into the body, it builds up in certain areas of the body. Radiotracers go to the area of the body that needs to be examined, such as a cancerous tumor or inflamed area. They can also bind to certain proteins in the body. The most common radiotracer is F-18 fluorodeoxyglucose (FDG). It is just one of many radiotracers in use or in development. FDG is a compound similar to glucose, or sugar. Highly active cancer cells need more energy than normal cells. As a result, they absorb more glucose [3]. An imaging device that detects energy given off by FDG creates pictures

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that show the location of the radiotracer in the body. Radiotracers are usually given via injection, but they may also be swallowed or inhaled [4].

2. Nuclear medicine techniques

Nuclear medicine techniques are frequently used medical imaging procedures for the diagnosis and staging of various diseases. Nuclear medicine imaging modalities detects radiation emitted from the administered radiopharmaceutical. There are several nuclear imaging techniques which are based on the different types of ionizing radiation: gamma emission and positron emission [5].

2.1. Gamma radiation, scintigraphy, and SPECT

When a radioactive substance decays, it can emit various types of radiation: alpha, beta, gamma, or neutrons. For medical imaging, gamma rays can be detected by gamma cameras. Gamma photons are detected by crystals present in gamma cameras. In the crystals, the gamma photons are converted into photons of light. In turn, these photons are converted into an electric signal by a photomultiplier. Subsequently, electric signals are processed into an image. As the gamma photons are emitted in all directions, gamma cameras are equipped with a collimator. A collimator is a Tungsten or lead device with channels that filters the gamma rays. Only the gamma rays perpendicular to the channels will go through and will be detected by the gamma. A gamma camera system usually consists of two detectors. By aiming the camera to the organ/region of interest, a two-dimensional image of this area is obtained. This method is called planar scintigraphy. Whole body imaging can be performed by acquiring several bed positions. Single photon emission computed tomography (SPECT) uses the same principle as the gamma camera. With SPECT, 3-dimensional images can be obtained by acquiring several 2-dimensional images of the same area at different angles. For this, the gamma cameras rotate around the patient. The 2-dimensional images are then used to compute a 3-dimensional image. Planar scintigraphy is one of the cornerstones of nuclear medicine and is still used in current clinical practice, although modern and more advanced imaging techniques are predominant nowadays. For example, planar scintigraphy with radiolabeled bisphosphonates is still used for the detection of bone metastasis of various types of cancer. Bisphosphonates accumulate in areas with high "bone turnover", such as bone metastases. Another example of is imaging of thyroid cancer and hyperthyroidism by radioactive iodine. Iodine is taken up by thyroid cells and in particular diseased thyroid cells. By using iodine-123, the diseases thyroid cells can be visualized. Consecutively, the diseased cells can be treated with the beta emitter iodine-131. As iodine-131 also has gamma emission, the treatment effect can also be visualized by imaging [6].

2.2. Positron emission and PET

Another type of nuclear medicine imaging is based on the detection of isotopes that decay via positron emission. In this type of emission, a radioactive substance emits positrons. When a positron in its turn collides with an electron, annihilation takes place. During annihilation two photons are emitted in an angle of 180 degrees. With the imaging technique positron emission tomography, these emitted photons are detected and converted in an image. The photons are detected by a ring of detectors that surround the patient. When two photons are detected simultaneously by two detectors opposite each, it is likely to originate from an annihilation. The detection of these photo pairs will allow the determination of the location in the detector ring. All these events are the reconstructed into a 3-dimensional image. The most often used radiopharmaceutical for PET is [^{18}F] FDG (fluorodeoxyglucose). This radioactive analog of glucose is taken up by cells with a high metabolism. Since most tumor cells have an inefficient energy metabolism, they have a high glucose mechanism. As a result, tumor cells have a high accumulation of FDG. Recently, a novel radiopharmaceutical is increasingly used for the detection of prostate cancer. The radiopharmaceutical targets the prostate specific membrane antigen (PSMA). PSMA is expressed at high density and incidence on prostate cancer cells. PSMA-ligands, labeled with gallium-68 or fluorine-18 are used to detect primary prostate tumors and their metastases. Moreover, PSMA-ligands labeled with alpha- or beta-emitters are used for prostate cancer radionuclide therapy. The therapy can be monitored by PSMA PET scans [7].

3. Uses Nuclear Medicine Imaging

Nuclear medicine uses small amounts of radioactive material combined with a carrier molecule. This compound is called a radiotracer or radiopharmaceutical. Doctors use nuclear medicine imaging procedures to see what's happening at a cellular level and to better understand how the body is functioning. In adults, doctors use nuclear medicine to [8-10]:

3.1. Heart

- Look at blood flow and function (such as a myocardial perfusion scan)

- Detect coronary artery disease and the extent of coronary stenosis
- Assess damage to the heart following a heart attack
- Evaluate treatment options such as bypass heart surgery and angioplasty
- Evaluate the results of revascularization procedures
- Check for heart transplant rejection
- Check heart function before and after chemotherapy (muga)

3.2. Lungs

- Check for breathing and blood flow problems
- Assess lung function for surgery
- Check for lung transplant rejection

3.3. Bones

- Check bones for fractures, infection, and arthritis
- Evaluate metastatic bone disease, prosthetic joints, and bone tumors
- Look for biopsy sites

3.4. Brain

- Investigate abnormalities in patients with seizures, memory loss and blood flow problems
- Detect the early onset of neurological disorders such as alzheimer's disease
- Assist in surgical planning and radiation planning
- Identify areas of the brain that may be causing seizures
- Evaluate abnormalities in patients with suspected parkinson's disease or other movement disorders
- Check for a recurring brain tumor
- Look for biopsy sites

3.5. Other Body Systems

- Look for inflammation or abnormal function of the gallbladder
- Look for bleeding into the bowel
- Assess complications following gallbladder surgery
- Evaluate swelling caused by the backup of lymph fluid (lymphedema)
- Find the cause of unexplained fever
- Find infection
- Measure thyroid function
- Help diagnose blood cell disorders
- Evaluate how the stomach empties
- Evaluate the flow of spinal fluid and look for leaks.

4. Conclusion

Diagnostic nuclear medicine involves the use of radioactive tracers to image and/or measure the global or regional function of an organ. The radioactive tracer (radiopharmaceutical) is given to the patient by intravenous injection, orally or by other routes depending on the organ and the function to be studied. Doctors use nuclear medicine tests to diagnose, evaluate, and treat various diseases. These include cancer, heart disease, gastrointestinal, endocrine, or neurological disorders. Nuclear medicine determines how the body is functioning at a cellular level. It is able to: find disease in its earliest stages, target treatment to specific cells, and monitor response to treatment.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest exists among the Authors.

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