Multidisciplinary approaches of Nuclear Medicines in diagnosis and treatment of Diseases

Aarti Anant Varne1\*

Kolhapur

Email Id- aarti.varne@gmail.com

Prianka Shashikant Lad2

 Neeta Sunil Gaonkar3

Vibha Shivajirao Patil4

**ABSTRACT**

Nuclear medicines mostly employ radiopharmaceuticals, which are useful for various diseases diagnosis as well as treatments. The nuclear medicine involved the use very small amount of radioactive material for diagnosis and to treat diseases. This article focused on different nuclear medicines techniques in diagnosis and treatment. The recent development of nuclear medicine involved PET (Positrona Emission Tomography), Single Photon Emission aComputerized Tomography (SPECT), Computed tomography-PET, Micro-acomputerized axial tomography (micro-CAT), Micro-PET (with ultra-high resolution). This study also involved the application of nuclear medicine in varios types of disorder including Cancer, Thyroid cancer, Neuroendocrine neoplasms, Bone metastases, Prostate cancer, Infection, Neurology, Cardiology.

**Keywords:** Nuclear medicine, Radiopharmaceuticals, Nuclear imaging, PET, SPECT.

**I. INTRODICTION**

Nuclear medicine is discipline that includes medical uses of radioactive materials in treatment ,diagnosis, and medical research. The. exception of the use of sealed sources of radiation in radiotherapy, according to the World Health Organization (WHO). Nuclear medicine is field of medicine which uses mostly radioactive substances for treatment as well as diagnosis in different types of health condition like heart diseases , neurological, cancer. There are increases the chronic diseases in world like heart diseases and cancer therefore there is need to discover new research call ‘molecular imaging’. The molecular imaging enables the characterization , visualization, quantification of biological processes involved in cellular level in human body[1]. In the field of medicine known as nuclear medicine, patients are given radioactive chemicals (to be ingested) in order to diagnose or treat illnesses. This is different from conventional radiology and radiotherapy methods, which typically apply radiation from external source.Radioactive isotopes are used in the medical speciality of nuclear medicine to diagnose and cure disease [2].

Nuclear medicine is the practice of performing medical treatments using radioactive material. The most typical way to do this is by injecting, eating, or breathing radioactive substances into the body. These radiotracers emit gamma rays, which are radioactive signals that can be followed by specialized cameras as they move through the body. The least amount of gamma radiation is administered to reduce the body’s exposure to radiation, despite the fact that it can be hazardous.

Nuclear medicine examines all cellular processes to ascertain how the body is operating. 1. Discover sickness in its earliest stages. 2. Concentrate treatment on particular cells 3. Keep track of treatment outcomes The most popular ways to give radionuclides are orally, intravenously, or, less frequently, intra-arterially, into the peritoneum, joint space, or CSF regions. In order to construct a radiopharmaceutical and enable preferential localization to organs of interest, these radionuclides are frequently chelated (labeled or tagged) with other molecules that give them their physiological features. In order to identify pathology and direct treatment, specialized cameras are employed to monitor the radiation emission from these unstable atoms. Managing interruptions may improve patient safety in nuclear medicine because it’s likely that they lead to poor administrations, especially while doing delicate work like making radiopharmaceuticals. On some general hospital wards, “quiet zones” and other interruption control techniques have been tested, although the proof of their effectiveness is scant. Additionally, there can be negative effects because certain signals or interruptions from equipment or other staff members may increase safety in specific situations .The main distinction between radiopharmaceuticals and conventional drugs is that the former has a therapeutic impact while the latter does not. Additionally, due to their quick disintegration, radiopharmaceuticals have a limited half-life. Because of this, radiopharmaceuticals must be prepared just before being administered. Therefore, it Is crucial for operator and patient protection that radiopharmaceuticals be prepared and used in a safe and knowledgeable manner [3].



**Fig No.1: Radiopharmaceuticals in diagnosis and therapy**

**A. Nuclear Imaging**

Small amounts of radioactive material are used in nuclear medicine, a subspecialty of medical imaging, to diagnose or treat a wide range of illnesses, such as various cancers, heart conditions, and other abnormalities of the body. Nuclear imaging analyzes the function of the organ, tissue, or bone to identify the root cause of the medical issue. Radionuclide imaging techniques, often known as nuclear medicine procedures, are non-invasive and typically painless medical examinations that aid doctors in the diagnosis of medical disorders. Radiopharmaceuticals or radiotracers, which are radioactive substances, are used in these imaging scans.

**B. Nuclear medicine techniques**

Diagnostic techniques in nuclear medicine use radioactive tracers that emit gamma radiation from within the body.



**Fig No.2: Types of Nucleara Medicine techniques Radiopharmaceuticals in diagnosisa and therapy**

**C. The Role of Radiotracers in Molecular Imaging Techniques**

Radiopharmaceuticals and radiotracers are chemicals that mimic the behavior of certain biological processes. They are utilized for a flow visualization through various medical imaging, including CARPT- Computed Radioactive Particle Tracking, SPECT- Single Photon Emission Computed Tomography, and PET- Positron Emission Tomography.

**D. Radiotracers used in the investigation of metabolic pathways**

• To quantitatively assess the metabolic process, radioisotopes of the parent chemical, such as 11C-glucose and 11C-palmitate , follow the same metabolic fate.

• Because they are typically maintained by tissue and improve imaging, analogues of original molecule, such as FDG- [2-18F]-2-fluoro-2-deoxyglucose and (-methyl-iodophenyl-pentadecanoic acid), provide qualitative assessments of metabolism.

**Table No. 1: Common PET tracer in oncology [4,5]**

|  |  |  |
| --- | --- | --- |
| **Isotope** | **Radiotracers**  | **Targets** |
| ¹¹C | [¹¹C] Choline  | Phosphocholine |
| 2-[11C]thymidine | DNA synthesis. Tumour cell proliferation.Drug pharmacokinetics |
| l-Methyl-[11C]methionine | Amino acid transporter |
| ¹²⁴I | Na[¹²⁴I] | Gene expression  |
| ¹⁵O | [¹⁵O]H2O | Perfusion  |
| [¹⁵O]CO  | Blood volume  |

**E. Common SPECT tracer**

A radionuclide having a pure gamma emitter and a 6 h half-life is 99mTc. By means of an isomeric transition, it degrades into 99Tc (at energies between 140.5 and 142.6 keV). It can be extracted as [99mTc(VII)]-O4 solution from 99Mo/99mTc generators. These characteristics make 99mTc nearly ideal for SPECT and planar scintigraphy imaging. The most popular imaging agents in nuclear medicine are technetium-labeled radiopharmaceuticals, which have a wide range of uses: thyroid, bone, renal, myocardial perfusion, gastrointestinal, hepatic, cerebral, and other imaging.

**F. Single photon emissionn computed tomography (SPECT)**

Nuclear imaging techniques like single-photon emission computted tomography (SPECT) are frequently employed in diagnostic medicine. It enables the clinician to evaluate the functionality and perfusion of particular tissues. The fundamentals of single-photon emission computed tomography imaging are reviewed in this activity, along with the underlying imaging mechanism, indications, and contraindications, the technique used and the personnel needed, complications, and the clinical importance of this imaging modality in medicine.

Imaging societies create SPECT imaging indications, some of which are significant and are listed here. These signs consist of:

1. Assessing persons suspected of having dementia
2. Locating the epileptic foci before surgery
3. Detection of encephalitis
4. Following a subarachnoid hemorrhage, vascular spasm is being monitored and evaluated.
5. During surgical operations, brain perfusion maps are created.
6. Evaluation and detection of cerebrovascular illness
7. Predicting a patient’s prognosis after a traumatic brain injury
8. The clinical appearance of brain death being supported
9. This page lists a number of oncology-related indications.[6]



**Fig No 3- SPECT imaging**

**G. Uses of Nuclear Medicine and Molecular Imaging**.

In patient care, medical study, and drug discovery, nuclear medicine and molecular imaging becoming more and more significant. For almost all of the body’s major organ systems, nuclear as well as molecular diagnostic imaging tests are now readily available. Nuclear medicine based treatments for cancer and other diseases are becoming more and more common. Patients with cancer, cardiovascular disease, and brain diseases receive crucial care from molecular imaging and nuclear medicine:

* Nuclear and molecular imaging can significantly alter the course and results of patient care in a wide range of cancer types, including lymphoma, esophageal, colon, and lung cancer.
* Nuclear imaging offers imaging agents that successfully identify changes in the brain associated with Alzheimer’s disease in addition to helping doctors diagnose dementia.
* Myocardial perfusion imaging, a form of nuclear medicine also offers a very accurate test for diagnosing coronary artery disease .

Scientists from a range of fields are improving their understanding of molecular mechanisms and pathways of disease in the laboratory with the use of nuclear medicine technology. Nuclear medicine as well as molecular imaging also contribute to the expedited creation of new and more effective pharmaceuticals by assisting researchers in promptly evaluating potential therapies.

**H. Applications of nuclear medicines**

**a. Thyroid cancer**

In resent studies SPECT used for management of differentiated thyroid cancer (DTC). RAI – that is radioiodine ablatio is used in patients for post -surgical based clinical and histopathalogic risk.. RAI whole-body scintigraphy (WBS) at the completion of ablation can change the risk stratification. In this 124I-iodide PET/CTPretreatand posttherapy SPECT/CT.

**b. Neuroendocrine neoplasms**

Neuroendocrine neoplasms (NENs) are one of the a heterogeneous group of tumours originate mostly in GI tract and lungs which having neuroendocrine cells, pituitary, thyroid and parathyroid glands, adrenal medulla. somatostatin receptor (SSR) expression or catecholamine uptake is main target for the assessment of SSR – positive NENs. Radiolabelled octreotide is used with the addition, of PET/CT with 68Ga-labelled somatostatin analogues. Catecholamine metabolism is assessed with [11C]5-hydroxytryptophan (5-HTP),

123I-metaiodobenzylguanidine (mIBG), 18FDOPA.

**c. Bone metastases**

Bone metastases are associated bone cancer which have more prognosis and decreased survival. Bone scintigraphy (BS) used for detection of metastases in the presence of a reactive increase in bone formation process. It is can also be detected using FDG PET/CT. The imaging modality plays an important role in assessing skeletal involvement in cancer, mostly in the case of lesions with a osteolytic than osteoblastic pattern.

**d. Prostate cancer**

Recently PET radioligands development used against prostate-specific membrane antigen (PSMA). This has role in diagnostic workup of prostate cancer . SPECT/CT with 99mTc-MIP 1404 (PSMA-ligand subtype) used for the detection of small LNs.

**e. Infection**

Infection seeking tracers labelled with single-photona-emitting radionuclides include autologous leukocytes (WBCs) labelled with 111In-oxine or 99mTc-hexamethylpropyleneamine oxime and 99mTcubiquicidin 29-41 were used. 67Ga-citrate is used in a few scenarios such as osteomyelitis (OM) of the spine. SPECT/CT used for both early stage diagnosis of infection and precise localization [6].

**f. Neurology**

99mTc-HMPAO / 99mTc-ethyl cysteinate dimer is used for SPECT imaging of the brain perfusion which is performed in brain related diseases like dementia and epilepsy. Parathyroid diseases - 99mTc-sestamibi (MIBI) SPECT/CT is used in workup of patients with hyperparathyroidism (HPT). Variable acquisition protocols are used, including single-tracer dual-phase studies and subtraction imaging following99mTcpertechnetate or 123I-iodide administration.

**g. Cardiology**

Cardiology places a high value on myocardial perfusion imaging with SPECT, particularly in the diagnosis and risk assessment of coronary artery disease (CAD). Currently, three SPECT imaging substances are being used in therapeutic settings: 201Tl-Cl, 99mTc(I)-sestamibi, and 99mTc(V)-tetrofosmin. Due to restrictions on the [201Tl]-Cl’s extended half-life, attenuation artifacts brought on by the low characteristic X-ray emission in the region of 69 to 81 keV, and administered dose restrictions brought on by radiation load, it is employed less frequently than Tc counterparts[ 7].

**i. FDG-PET Radiotracers: A Widely Used Tool for Cancer Diagnosis and Staging**

Because it cannot be biochemically confused with glucose, the PET radiotracer [1-11C] glucose can track the precise course of glucose during the metabolism. This process causes the radiotracer to be taken up, retained, and excreted from the heart as well as release cardiomyocytes as 11CO2. In the alternative scenario, because the carbohydrate structure has changed from glucose to deoxyglucose, FDG is taken up and then phosphorylated by hexokinase without going through any additional metabolic processes in the cardiomyocyte. FDG is consequently imprisoned in the cell. On the basis of a kinetic study of the time-activity curves for FDG, glucose absorption and phosphorylation can be predicted initially. Regarding the oxidative destiny of glucose, this mechanism offers little information, and kinetic analysis shows irreversible trapping in contrast to the buildup and removal of other radiotracers. The irreversible radiotracers that are “trapped” in the cardiac substrate result in:

• Details on a certain metabolic process’s component;

• The relationship between the tracer and detection can change under various metabolic settings;

 • Differences in the structure of the parent compound and the radiotracer will affect how accurately the tracer detects the utilisation of the parent molecule. [8]

****

**Fig no. 4 : Mechanism of Glucose trapping in FDG-PET**

**Conclusion**

Nuclear medicine is the practice of performing medical treatments using radioactive material. There are different radioactive materials are used in very small quantity for diagnosis and treatment of diseases. In this review the a special mention rescent developments in Nuclear medicines loke PET, SPECT, Micro PET, etc. It also include multidisciplinary approach of nulear medicine in diseases diagnosis and treatment mostly including different types of cancer- Thyroid cancer, Bone metastases, Neuroendocrine neoplasms, Prostate cancer, cardiac disorders, infections. This is beneficial for the development of new research in nuclear medicines.

**References**

[1] Rafaela Monteiro, Pedro Costa“Survey on the knowledge of Portuguese society about Nuclear Medicine: A snapshot of the reality in the beginning of the decade” Journal of Medical Imaging and Radiation Sciences Volume 53, Issue 4, , Pages 571-579, December 2022

[2] Badawi, Ramsey “Nuclear medicine” Physics Education. 36. 452. (2001).

[3] Christopher Muscato “Nuclear medicine is a growing field of research and treatment. History of Nuclear Medicine.

[4] Leung K. [11C]Choline. 2004 Oct 1 [Updated 2011 Feb 7] “In: Molecular Imaging and Contrast Agent Database (MICAD)” Bethesda (MD): National Center for Biotechnology Information (US); 2004-2013.

[5] Mankoff D .A., Shields A..F, Link J.M., Graham M.M., Muzi M., Peterson L.M., Eary J.F., Krohn K.A. “Kinetic analysis of 2-[11C]thymidine PET imaging studies: validation studies” J Nucl Med.40(4):6, 14-24,1999

[6] Israel O, Pellet O, Biassoni L, De Palma D, Estrada-Lobato E, Gnanasegaran G, Kuwert T, la Fougère C, Mariani G, Massalha S, Paez D, Giammarile F. “Two decades of SPECT/CT – the coming of age of a technology: An updated review of literature evidence.” Eur J Nucl Med Mol Imaging, 46(10):1990-2012

.

[7] Crisan G., Moldovean- Cioroianu N.S, TimaruD.-G.; AndriesG., Cainap C., ChisV. “Radiopharmaceuticals for PET andSPECT Imaging: A Literature ReviewOver the Last Decade” Int. J. Mol. Sci. 23, 5023, 2022.

[8] Miele E., Spinelli G., Tomao F., Zullo A., De MarinisF., Pasciuti G.,Tomao, S. “Positron Emission Tomography (PET) radiotracers in oncology – utility of 18F-Fluoro-deoxy-glucose (FDG)-PET in the management of patients with non-small-cell lung cancer (NSCLC)” Journal of Experimental & Clinical Cancer Research, 27(1), 52., 2008.