MULTIDISCIPLINARY APPROACHES OF NUCLEAR MEDICINES IN DIAGNOSIS AND TREATMENT OF DISEASES

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 in nuclear medicine involved PET (Positrona Emission Tomography), Single Photon Emission Computerized Tomography (SPECT), Computed tomography-PET (PET-CT), Micro-computerized 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.

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I. INTRODUCTION

Nuclear medicine is discipline that includes all medical uses of radioactive materials in 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 a 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].

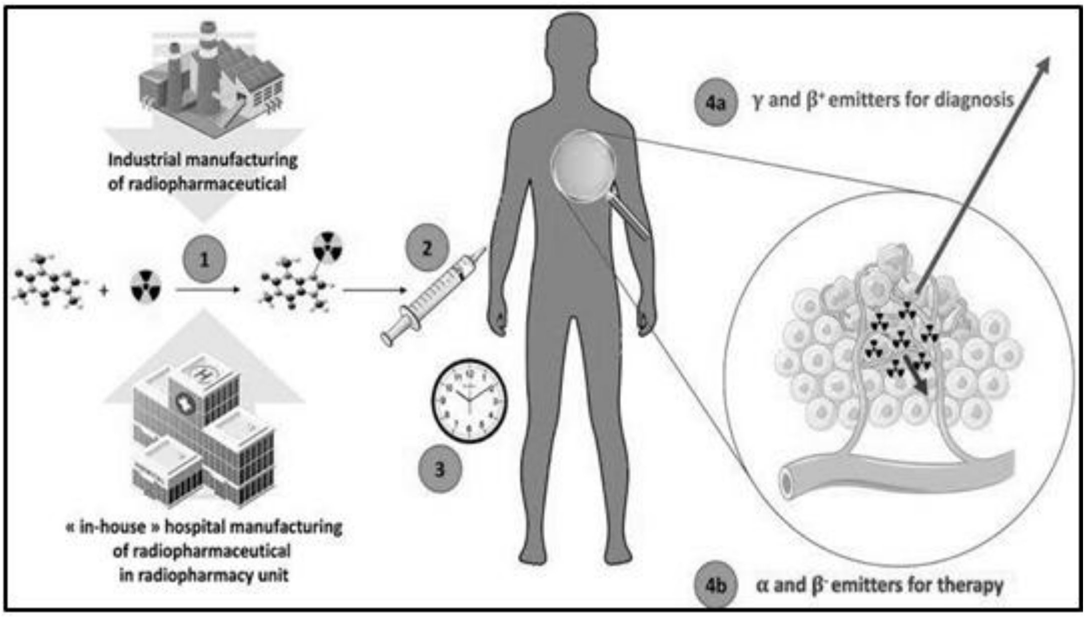

Figure 1: Radiopharmaceuticals in diagnosis and therapy

II. 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.

III. NUCLEAR MEDICINE TECHNIQUES

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

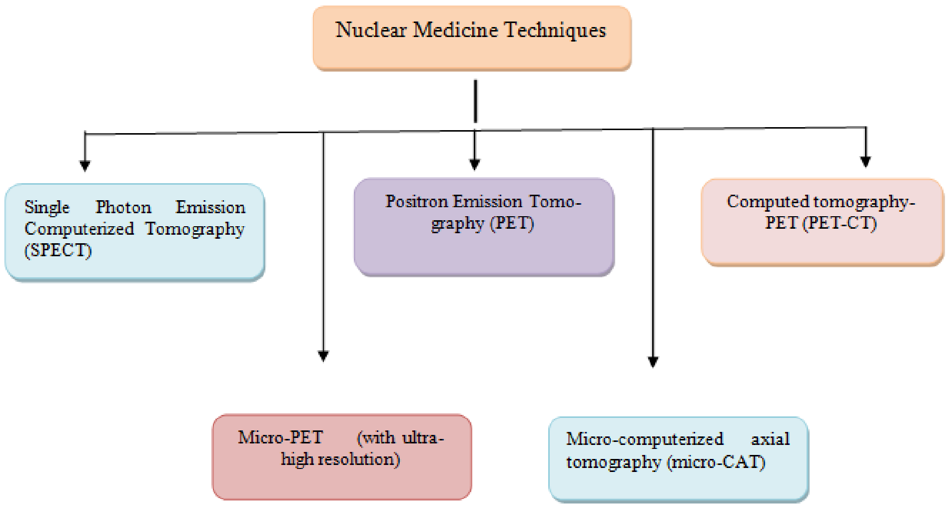

Figure 2: Types of Nuclear Medicine techniques Radiopharmaceuticals in diagnosis and therapy

IV. THE ROLE OF RADIOTRACERS IN MOLECULAR IMAGING TECHNIQUES

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

V. RADIOTRACERS USED IN THE INVESTIGATION OF METABOLIC PATHWAYS FALL INTO TWO CATEGORIES

1. To quantitatively assess the metabolic process, radioisotopes of the parent chemical, such as ^{11}C-palmitate and ^{11}C-glucose, follow the same metabolic fate.
2. Because they are typically maintained by tissue and improve imaging, analogues of the original molecule, such as [2-18F]-2-fluoro-2-deoxyglucose [FDG] and (-methyl-iodophenyl-pentadecanoic acid), provide qualitative assessments of metabolism.

Table 1 : Common PET tracer in oncology [4,5]

Isotope	Radiotracers	Targets
^{11}C	[^{11}C] Choline	Phosphocholine
	2-[11C]thymidine	DNA synthesis. Tumour cell proliferation. Drug pharmacokinetics
	l-Methyl-[11C]methionine	Amino acid transporter
^{124} I	Na[^{124} I]	Gene expression
^{15} O	[^{15} O]H_2O	Perfusion
	[^{15} O]CO	Blood volume

VI. COMMON SPECT TRACER

A radionuclide having a pure gamma emitter and a 6 h half-life is ^{99m}Tc. By means of an isomeric transition, it degrades into ^{99}Tc (at energies between 140.5 and 142.6 keV). It can be easily extracted as a [^{99m}Tc(VII)]-O4 solution from ^{99}Mo/99mTc generators. These characteristics make ^{99m}Tc 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.

VII. SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)

Nuclear imaging techniques like single-photon emission computed 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]

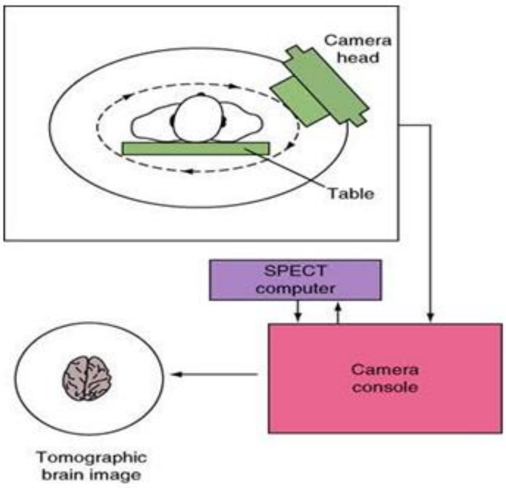

Figure 3: SPECT Imaging

VIII. USES OF NUCLEAR MEDICINE AND MOLECULAR IMAGING

In patient care, medical study, and drug discovery, nuclear medicine and molecular imaging are becoming more and more significant. For almost all of the body's major organ systems, nuclear and 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 nuclear medicine and molecular imaging:

1. 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.
2. Nuclear imaging now offers imaging agents that successfully identify early changes in the brain associated with Alzheimer's disease in addition to helping doctors diagnose dementia.
3. Myocardial perfusion imaging, a form of nuclear medicine, offers a very accurate test for diagnosing coronary artery disease.

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

IX. APPLICATIONS OF NUCLEAR MEDICINES

1. **Thyroid Cancer:** In recent studies SPECT used for management of differentiated thyroid cancer (DTC) . RAI- that is radioiodine ablation is used in patients for post – surgical based clinical and histopathalogical risk. RAI whole-body scintigraphy (WBS) at the completion of ablation can change the risk stratification. In this ^{124}I-iodide PET/CTPretreatand posttherapy SPECT/CT.

2. **Neuroendocrine Neoplasms:** Neuroendocrine neoplasms (NENs) are one of the 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 ^{68}Ga-labelled somatostatin analogues. Catecholamine metabolism is assessed with ^{123}I-metaiodobenzylguanidine (mIBG), [^{11}C]5-hydroxytryptophan (5-HTP), ^{18}FDOPA.

3. **Bone Metastases:** Bone metastases are associated with bone cancer. Which have more prognosis and decreased survival. Bone scintigraphy (BS) used to detects 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 that plays an important role in assessing skeletal involvement in cancer, mostly in the case of lesions with a osteolytic than osteoblastic pattern.

4. **Prostate Cancer:** Recently PET radioligands development used against prostate-specific membrane antigen (PSMA) has diagnostic workup of prostate cancer . SPECT/CT with ^{99m}Tc-MIP 1404 (PSMA-ligand subtype) used for the detection of small LNs.

5. **Infection:** Infection seeking tracers labelled with single-photon-emitting radionuclides include autologous leukocytes (WBCs) labelled with ^{111}In-oxine or ^{99m}Tc-hexamethylpropyleneamine oxime and ^{99m}Tcubiquicidin 29-41 were used. ^{67}Ga-citrate is still used in a few scenarios such as osteomyelitis (OM) of the spine. SPECT/CT used for both early diagnosis of infection and precise localization [6].

6. **Neurology:** ^{99m}Tc-HMPAO or ^{99m}Tc-ethyl cysteinate dimer (ECD) is used for SPECT imaging of the brain perfusion which is performed in brain related diseases like dementia and epilepsy. Parathyroid diseases - ^{99m}Tc-sestamibi (MIBI) SPECT/CT is used in the workup of patients with hyperparathyroidism (HPT). Variable acquisition protocols are used, including single-tracer dual-phase studies and subtraction imaging following^{99m}Tcpertechnetate or ^{123}I-iodide administration.

7. **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: ^{201}Tl-Cl, 99mTc(I)-sestamibi, and ^{99m}Tc(V)-tetrofosmin. Due to restrictions on the [^{201}Tl]-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].

8. **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 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 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]

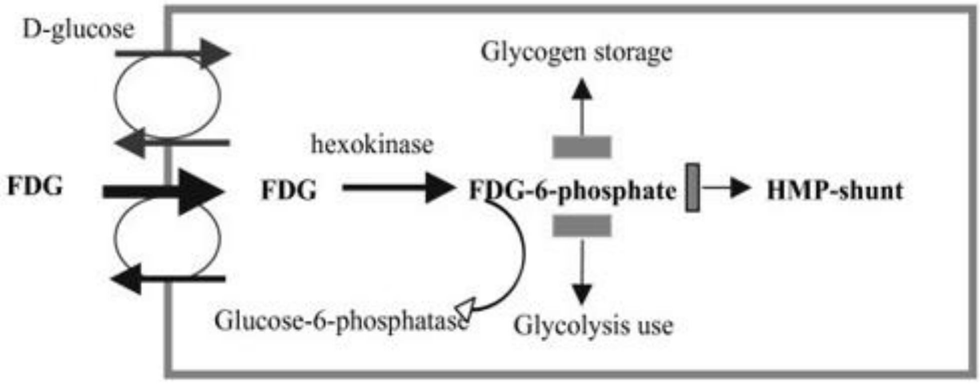

Figure 4: Mechanism of Glucose Trapping in FDG-PET

X. 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.

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