RECENT ADVANCES IN NUCLEAR MEDICINE

Ayush Rai

National Institute of Technology, Raipur

1 Abstract

Nuclear medicine has a long and illustrious history that has garnered enormous investment. New nuclear medicine methods have been developed as a result of these investments, which may detect diseases non-invasively and provide information that cannot be obtained with existing imaging technologies, as well as give tailored treatments. Overall, the use of nuclear medicine procedures is rapidly increasing, particularly as new imaging technologies such as positron emission tomography/computed tomography and single photon emission computed tomography/computed tomography improve the accuracy of disease detection, localization, and characterization, and as cyclotron automation and miniaturization, as well as advances in radiochemistry, make radiotracer production more practical. Recent advancements in the life sciences, such as molecular biology, genetics, and proteomics, have sparked the creation of better ways for identifying and treating disease based on a person's unique profile, a concept known as "personalized medicine." Research that provides a better understanding of normal and pathological processes, greater knowledge of the mechanisms by which individual diseases arise, superior identification of disease subtypes, and better prediction of an individual patient's treatment responses will help personalized medicine grow. The process of improving patient care, on the other hand, is complicated and time-consuming. Expanding the use of nuclear medical procedures has the potential to speed up, simplify, and lower the costs of developing and delivering better health care, as well as make customized medicine easier to execute. In this paper we are going to discuss recent advances in the field of nuclear medicine, it's advantage, it's design disadvantages and also walk through the future prospects in the field of nuclear medicine.

2 Introduction

Nuclear medicine's current clinical applications include the ability to diagnose diseases like cancer, neurological disorders, and cardiovascular disease in their

early stages, allowing for earlier treatment and lower morbidity and mortality. Non-invasively assess therapeutic response, reducing patients' exposure to the toxicity of ineffective treatments and allowing alternative treatments to be started sooner and provide molecularly based information.
Emerging opportunities in the field of nuclear medicine consists of its capability in understanding the relationship between brain chemistry and behaviour; assessing the atherosclerotic cardiovascular system; assessing the efficacy of new drugs and other forms of treatment, speeding their introduction into clinical practise; and using targeted radionuclide therapeutics to individualize treatment for cancer patients by tailoring the dose. Further, build new technological platforms to help researchers find and validate novel molecular imaging probes, biomarkers, and radio therapeutic drugs more quickly and at a reduced cost. Produce higher-resolution, more sensitive imaging devices for detecting and quantifying illness more quickly and correctly; improve radionuclide production, chemistry, and automation to lower the cost and increase the availability of radiopharmaceuticals by inventing a new miniaturized particle accelerator and associated technologies to produce short-lived radionuclides for local use in research and clinical programmes; and develop and exploit hybrid imaging instruments, such as positron emission tomography/magnetic resonance imaging (PET/MRI) to improve disease diagnosis and treatment.

3 Current Developments

Nuclear medicine's current clinical applications include the capacity to:
1. Diagnose diseases in their early stages, such as cancer, neurological disorders (e.g., Alzheimer's and Parkinson's diseases), and cardiovascular disease, allowing for faster treatment and lower morbidity and mortality.
2. Assess therapy response noninvasively, decreasing patients' exposure to the toxicity of unsuccessful medicines and allowing alternative treatments to be started sooner; and offer cancer and some endocrine diseases with molecularly focused treatment (e.g., thyroid disease and neuroendocrine tumors).

4 Emerging opportunities:

In nuclear medicine, new opportunities include the potential to:
1. Recognise the link between brain chemistry and behaviour (for example, addictive behaviour, eating disorders, and depression).
2. Determine the state of the atherosclerotic cardiovascular system.
3. Learn about new drug metabolism and pharmacology.
4. Evaluate the efficacy of novel medications and other therapies in order to expedite their entry into clinical practise; by modifying the properties of the targeting vehicle and the radionuclide.
5. Use targeted radionuclide therapies to individualise treatment for cancer patients;

6. Build new technology platforms (for example, integrated microfluidic chips and other automated screening technologies) to speed up and minimise the cost of discovering and testing new molecular imaging probes, biomarkers, and radiotherapeutic medicines.
7. Develop higher-resolution, more sensitive imaging instruments to detect and quantify disease more quickly and accurately; further develop and exploit hybrid imaging instruments, such as positron emission tomography/magnetic resonance imaging (PET/MRI), to improve disease diagnosis and treatment; and improve radionuclide production, chemistry, and automation to reduce the cost and increase the availability of radiopharmaceuticals by inventing a new miniaturised particle accretion system.

5 Applications:

A. Gastrointestinal system
The use of nuclear medicine in the gastrointestinal (GI) system is beneficial in the investigation of a variety of disorders. Patients are given minimal amounts of radiation during this noninvasive and painless examination. It is simple to do and is used to diagnose and track gastrointestinal illnesses. The sensitivity of detecting gastrointestinal problems is increased by the extended acquisition time for most exams. Scintigraphy is commonly used to evaluate organ function as well as the kinetics of gastrointestinal transit or excretion.

1. Investigation of gastroesophageal reflux
Scintigraphy, especially in youngsters, is the most sensitive noninvasive approach for identifying gastroesophageal reflux. Colloids with low esophageal and gastric mucosa absorption rates are utilised, reflecting the kinetics of the tracer inside the digestive system. Episodes of gastroesophageal reflux are identified after oral administration of 99mTc colloid, with a field of view including the stomach and oesophagus, and information on the quantity and length of the reflux, as well as the point at which it arrives, is collected. It has the advantage of continuous and longer acquisition, which improves the method's sensitivity. In the case that the ingested substance refluxes into the pulmonary tree, other important information collected includes an assessment of pulmonary aspiration.

2. Salivary gland imaging
This test evaluates the salivary glands' function and excretion in both the initial diagnosis and the post-treatment follow-up. Tumors, cysts, inflammatory or infectious illnesses, calculosis, and Sjögren's syndrome are the most common indications.
The radioisotope utilised is pertechnetate, an anion that, like the anions that make up saliva, is concentrated and released by the epithelial cells of the salivary glands. As a result, this material represents saliva synthesis and physiological secretion.

3. Scintigraphy on esophageal transit and emptying
Scintigraphy of the esophageal transit is a noninvasive procedure that involves the administration of a radiotracer through the mouth and provides information on esophageal motility, as well as the duration of esophageal transit and segmental motor abnormalities like adynamia and lack of coordination. It is used to diagnose and monitor patients with suspected primary or secondary motor disorders, including achalasia, scleroderma, diffuse esophageal spasm, nutcracker oesophagus, diabetic enteropathy, nonspecific motor disorders, Chagas' disease, neoplasm, systemic lupus erythematosus etc

B. Cardiovascular system
In the noninvasive evaluation of heart physiology, nuclear medicine examinations play a significant role.

1. Myocardial perfusion imaging
MPI provides a high sensitivity for evaluating left ventricular wall perfusion and hence indirectly assessing coronary flow. The ischemic cascade is the foundation and greatest argument for using nuclear medicine to assess coronary artery disease.
Thallium-201 chloride and 99mTc-labeled pharmaceuticals can be used to do myocardial perfusion imaging (sestamibi, tetrofosmim and teboroxime). Fasting for at least 4 hours before using thallium-201 chloride is required. When compared to thallium-201 chloride, radiopharmaceuticals labelled with 99mTc have the best rate of counts and the least sensitivity to determine viability.

2. Myocardial viability imaging
The primary goal of cardiac viability testing is to determine which patients are candidates for coronary artery bypass grafting (CABG). Improvement in regional left ventricular function, global left ventricular function (ejection fraction), symptoms, functional capacity, cardiac remodelling, and long-term prognosis were all used to determine the clinical impact of CABG.
The presence of live myocardium can be determined using thallium-201 chloride imaging and a home-redistribution procedure. The existence of ischemia can be determined using the stress-rest-reinjection protocol, as well as other related information.

C. Genitourinary tract imaging The genitourinary system is classified into superior and inferior genitourinary tracts in nuclear medicine. The kidneys are included in studies examining the superior genitourinary tract, allowing for the assessment of multiple characteristics such as blood flow, function, anatomy, and integrity of the collection system, which aids in the identification of various illnesses. Radionuclide cystography and testicular scintigraphy are used to study the lower genitourinary tract.

1. Hypertension of renovascular origin

The renal dynamic research is conducted in two phases for this condition: one using an angiotensin converting enzyme inhibitor as a stimulus one hour before to the administration of the radiopharmaceutical, and the other simply examining renal dynamic without stimulus as the study baseline.

The conventional pattern of diagnosis for renovascular illness is an abnormal study with activation of the angiotensin converting enzyme inhibitor and a normal baseline study, according to the pathophysiology of the disease.

2. Renal transplant

Renal dynamic studies are primarily utilised in renal transplantation to assess the most prevalent problems, such as acute tubular necrosis and rejection. Acute tubular necrosis and acute rejection have extremely similar scintigraphic patterns, with maintained or slightly decreased flow and a lower glomerular filtration rate. The key to diagnosing is the timing and symptoms. Renal graft dysfunction due to acute tubular necrosis should improve or remain stable in serial renal tests, while rejection shows gradual worsening. For kidney transplant dysfunction, ultrasonography is now the technique of choice.

D. Dacryoscintigraphy

This test is recommended in cases with epiphora. It's a straightforward and painless test that involves injecting microdrops of pertechnetate into the epicanthus of the eyes. The radiotracer should travel through the palpebral fissure, lacrimal canaliculi, lacrimal sac, nasolacrimal ducts, and nasal cavity in a normal examination. The radiotracer does not progress in the retention or blockage patterns.