**Title: Nuclear Medicine**

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**Abstract**

In the specialty of medicine known as nuclear medicine, radioactive materials are used in very small doses to diagnose and treat a wide range of illnesses, including certain cancers, neurological disorders, and heart and blood vessel issues. Over the course of several decades, the field of nuclear medicine (NM) has undergone both evolutionary and revolutionary changes. This is largely due to the dynamic and responsive trends in the global development and use of radiopharmaceuticals (RPh), as well as the introduction of advanced imaging systems with quantification capabilities, such as single-photon emission computed tomography/computed tomography [PET]/CT, positron emission tomography [PET]/CT, and PET/magnetic resonance. Naturally, the NM-RPh progress made along the road has taught us many important lessons. To ensure effective communication with the referral medical community and healthcare policymakers, it is felt essential for the NM-RPh community to have list(s) of indications for NM, classified on the value-level basis, at NM gross-level and specific medical specialty-wise, and the corresponding RPh needed.

**KEYWORDS:** Nuclear Medicine, Radioactive Tracers, PET, SPECT, Applications

**NUCLEAR MEDICINE**

Nuclear medicine is a branch of medicine that evaluates body functioning and utilises radioactive tracers (also known as radiopharmaceuticals) to identify and cure disease. Doctors are able to follow the passage of these radioactive tracers thanks to specially created cameras. The two most popular imaging modalities in nuclear medicine are single photon emission computed tomography, or SPECT, and positron emission tomography, or PET scans.

**Radioactive tracers**

Carrier molecules that are firmly bound to a radioactive atom make up radioactive tracers. Depending on the goal of the scan, these carrier molecules can have many different forms. others tracers use chemicals that interact with certain body proteins or sugars, and others even use the patient's own cells. For instance, if doctors need to pinpoint the precise cause of intestinal bleeding, they may radiolabel (add radioactive atoms to) a sample of the patient's red blood cells. The blood is then reinjected, and a SPECT scan is used to trace the blood's course inside the patient. Doctors can pinpoint the issue if there is any radioactive buildup in the intestines.

A patient receives an intravenous injection of the radioactive tracer for the majority of nuclear medicine diagnostic procedures. However, a radioactive tracer can also be given through oral intake, direct injection into an organ, or by inhalation. The disease process that will be investigated will determine the manner of tracer delivery.

Since authorised tracers must adhere to the FDA's strict requirements for safety and adequate performance for the permitted clinical application, they are known as radiopharmaceuticals.

**Many medical conditions and diseases are diagnosed using scans. Some of the more popular tests include the following**:

1. **Renal scans**, which are used to examine the kidneys and detect any abnormalities, such as abnormal renal function or obstruction of the renal blood flow;
2. **Thyroid scans**, which are used to assess thyroid function or to more accurately diagnose a thyroid nodule or mass;
3. **Bone scans**, which are used to assess any arthritic and/or degenerative changes in the joint.
4. **Heart scans** are used to spot abnormal blood flow to the heart, to calculate the extent of heart muscle damage after a heart attack, and/or to measure heart function.
5. **Gallium scans** are used to diagnose active infectious and/or inflammatory diseases, tumours, and abscesses.
6. **Brain scans** are used to look into issues with the brain or with the blood circulation to the brain.
7. **Breast scans** are frequently combined with heart scans.

**Single Photon Emission Computed Tomography (SPECT)**

Tomographic pictures in three dimensions of the distribution of radioactive tracer molecules that have been injected into the patient's body are produced by SPECT imaging equipment. A vast number of projection photographs of the body taken at various angles are combined to create the 3D images. The gamma ray emissions from the tracers that have been injected into the patient can be picked up by the gamma camera detectors in SPECT imagers. A kind of light that travels at a different wavelength than visible light is known as a gamma ray. The detectors can be moved in a precise circle around a patient who is laying still on a pallet thanks to the cameras' mounting on a revolving gantry.

**Positron Emission Tomography (PET)**

Radiopharmaceuticals are also used in PET scans to provide three-dimensional pictures. The kind of radiotracers utilised is the primary distinction between SPECT and PET scans. While positrons are produced during the radiotracer decay during PET scans, gamma rays are measured by SPECT scans. A positron is an oppositely charged particle having a mass that is similar to an electron. These interact with the body's electrons, and when the two particles come together, they destroy one another. Two photons that go in opposing directions are produced as a modest quantity of energy as a result of this annihilation. These photons are measured by the PET scanner's detectors, which then use the data to produce pictures of inside organs. Scans of the heart, lung, kidneys, gallbladder, and thyroid are among the common organs for which nuclear medicine is used for diagnosis. In positron emission tomography (PET), a type of nuclear medicine, the tracer is used to show the natural activity of cells, providing more detailed information on how organs are working and if there is damage to the cells. PET scans are frequently combined with magnetic resonance imaging (MRI) or computed tomography (CT) scans, which produce three-dimensional pictures of the organ.

1. PET scans are frequently used to diagnose conditions including heart disease, Alzheimer's disease, and brain abnormalities.
2. Obtaining comprehensive information about malignant tumours to choose the most appropriate course of action

**What are the purposes of nuclear medicine scans?**

SPECT scans are generally used to identify cardiac disease and monitor its development, including blocked coronary arteries. Additionally, there are radiotracers for the detection of intestinal haemorrhage, gall bladder illness, and bone problems. With the use of SPECT agents, Parkinson's disease in the brain may now be diagnosed and distinguished from dementias and movement disorders with similar anatomical relationships.

The main goals of PET scans are to identify cancer, track its development, evaluate the effectiveness of treatment, and find metastases. Because glucose utilisation relies on how active **cells** and tissues are, it is significantly higher in cancer cells that divide quickly. The pace at which most tumours use glucose really approximately correlates with how aggressive they are.The greatest tracer now available for identifying cancer and its metastatic spread in the body has been demonstrated over the past 15 years to be slightly modified radiolabeled glucose molecules.

**Nuclear medicine imaging benefits**

1. Functional
2. Quantitative and sensitive.
3. Very secure.
4. Little radiation.
5. Monitoring and Follow-up
6. Examination of the entire body without increasing the patient's radiation exposure.
7. Very high specificity (no body-produced natural radioactivity).

**Nuclear medicine imaging drawbacks**

1. Not generally accessible.
2. Low SNR.
3. Need radiopharmaceuticals and NM equipment.
4. Relative price premium over X-ray or US.
5. The patient being exposed to radiation.
6. Low (5–10 mm) spatial resolution.
7. Slow picture capture.

**Nuclear Medicine Directions**

**Regulatory Issues for NM: -**

1. Decisions are being made by commercial entities rather than scientific groups (financial and political) as new applications occur faster than regulations can adapt.
2. These factors include:
3. A general feeling of overregulation;
4. Costs (in hospital personnel) of regulation that are not commensurate with the risks;
5. Official training and experience criteria that are unclear and variable across the country;
6. Training and experience criteria that are extremely variable from one hospital/clinic to another.

**Concerns about the direction of nuclear medicine include: -**

1. Payers do not cover the high expenses of medication development, such as with Zevalin.
2. -NM labs' operating expenses (drugs, supplies, and techs' wages) are rising while overall income is falling.
3. Lack of skilled workers (technologists, doctors, and scientists-professionalization of the field)
4. -Turf warfare between speciality groups (inadequate representation of uneven training and experience in the market and credentialing bodies)
5. -While overall income is falling, the costs of running NM laboratories (drugs, supplies, and technologists' salaries) are rising.

Therapeutic

Radiopharmaceuticals

Diagnostic

APPLICATIONS

Safety and Regulations

Clinical Practice Guidelines

Advancements and Research

**APPLICATIONS OF NUCLEAR MEDICINE**

1. **Diagnostic Uses:** • Organ function, blood flow, and metabolic processes may all be observed and studied using nuclear medicine. Positron emission tomography (PET) and single-photon emission computed tomography (SPECT) scans are two common diagnostic techniques.
2. **Therapeutic Applications:** Nuclear medicine may also be used therapeutically to treat conditions including thyroid problems, some cancers (such thyroid cancer and lymphoma), and bone metastases that are painful.
3. **Radiopharmaceuticals:** Radiopharmaceuticals are a fundamental component of nuclear medicine. They are compounds made up of a radionuclide (radioactive isotope) and a medicinal ingredient. Depending on the medical problem being researched or treated, the proper radiopharmaceutical should be chosen.
4. **Safety and Regulations: •** The use of radioactive materials in nuclear medicine necessitates compliance with stringent safety measures to safeguard patients and medical personnel. Regulatory organisations like the International Atomic Energy Agency (IAEA) and the U.S. Nuclear Regulatory Commission (NRC) are essential in ensuring that radioactive materials are used safely.
5. **Technological Developments and study**: Nuclear medicine is a profession that is always developing due to continuing study. To enhance patient care and outcomes, brand-new radiopharmaceuticals, imaging methods, and therapeutic strategies are always being created.
6. **Clinical Practise Guidelines**: Various medical associations and organisations provide recommendations for how nuclear medicine techniques should be used in particular clinical contexts. For healthcare practitioners, these suggestions are supported by evidence.

**Conclusion**

Ionising radiation is essential to modern medicine.Radiation is used in nuclear medicine to diagnose illnesses or to offer information about how a person's individual organs are working. The majority of the time, doctors utilise the data to quickly diagnose the patient's disease. It is simple to scan the thyroid, bones, heart, liver, and many other organs to identify functional issues. Radioisotopes have found use in a wide range of scientific fields, including nutrition, genetics, molecular biology, pharmacology, drug development, nuclear physics, environmental chemistry, geology, and industrial manufacturing, in addition to clinical nuclear medicine and radiology practise and research.Among the technologies that have revolutionised medical diagnosis and treatment include X-ray imaging, computed tomography scans, diagnostic and therapeutic nuclear medicine, brachytherapy, the gamma knife, and linear accelerators.  The advantages of radiation for human health may be quantified by the thousands of lives saved and the far greater numbers of people whose quality of life these technologies have enhanced every year. Ionising radiation is used in medicine because it has many advantages, but there are also possible hazards for patients, medical staff, and the general public. Acute injuries and chronic illnesses like cancer can be exacerbated by the diagnostic and therapeutic techniques used to treat them.

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