

NUCLEAR MEDICINE

Abstract

Nuclear medicine is a branch of medicine that uses radioactive substances in extremely small quantities to diagnose and treat a variety of conditions, such as heart and blood vessel problems, some malignancies, and neurological disorders. Nuclear medicine (NM) has witnessed both evolutionary and revolutionary advances during the past several decades. 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, as well as the dynamic and responsive trends in the global development and use of radiopharmaceuticals (RPh), are major contributors to this.

Keywords: Nuclear Medicine, Radioactive Tracers, PET, SPECT, Applications.

Radioactive tracers, commonly referred to as radiopharmaceuticals, are used in nuclear medicine to diagnose and treat diseases by evaluating how the body is working. These radioactive tracers may be tracked by doctors using cameras that were designed specifically for this purpose. Single photon emission computed tomography, often known as SPECT, and positron emission tomography, sometimes known as PET scans, are the two imaging techniques used most frequently in nuclear medicine.

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I. RADIOACTIVE TRACERS

Radioactive tracers are composed of carrier molecules that are tightly linked to a radioactive atom. These carrier molecules can take on a variety of shapes, depending on the scan's objective. Some tracers even employ the patient's own cells, while others use compounds that interact with certain body proteins or carbohydrates. For instance, doctors may radiolabel (add radioactive atoms to) a sample of the patient's red blood cells in order to determine the particular source of intestinal bleeding. A SPECT scan is used to follow the blood's path inside the patient after it is reinjected. If there is any radioactive accumulation in the intestines, doctors can identify the problem. For the majority of nuclear medicine diagnostic procedures, the radioactive tracer is administered intravenously to the patient. A radioactive tracer can, however, also be administered orally, directly into an organ, or via inhalation. The method of tracer administration will depend on the disease process being studied. Authorised tracers are referred to as radiopharmaceuticals since they must abide by the FDA's high standards for safety and acceptable performance for the allowed clinical use.

II. SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)

SPECT imaging technology creates three-dimensional tomographic images of the distribution of radioactive tracer molecules that have been injected into the patient's body. The 3D pictures are created by combining a large number of projection photos of the body taken at various angles. The gamma camera detectors in SPECT imagers can detect the gamma ray emissions from the tracers that have been injected into the patient. A gamma ray is a kind of light that has a different wavelength than visible light.

III. POSITRON EMISSION TOMOGRAPHY (PET)

For three-dimensional images in PET scans, radiopharmaceuticals are also employed. The primary difference between SPECT and PET scans is the type of radiotracers used. SPECT scans measure gamma rays whereas PET scans create positrons as a result of radiotracer degradation. Positron particles are oppositely charged and have masses comparable to electrons. The electrons in the body interact with them, and when the two particles collide, they obliterate one another. This annihilation generates a little amount of energy in the form of two photons that face each other. The detectors in the PET scanner measure these photons, and the information they gather is subsequently used to create images of inside organs. One of the common organs for which nuclear medicine is utilised for diagnosis is the thyroid, along with scans of the heart, lung, kidneys, gallbladder, and other organs. In positron emission tomography (PET), a sort of nuclear medicine, the tracer is utilised to demonstrate the normal activity of cells, giving more in-depth knowledge of how organs are functioning and whether there is cell damage. Magnetic resonance imaging (MRI) or computed tomography (CT) scans, which create three-dimensional images of the organ, are routinely paired with PET scans.

1. Heart disease, Alzheimer's disease, and abnormalities of the brain are among the illnesses that are routinely diagnosed with PET scans.
2. Learning everything there is to know about malignant tumours in order to make the best decision possible.

IV. WHAT CAN NUCLEAR MEDICINE SCANS SERVE TO DIAGNOSE?

Heart disease, especially blocked coronary arteries, is typically detected via SPECT scans, which are also used to track the disease's progression. Additionally, there are radiotracers for the identification of gallbladder disease, bone issues, and intestinal bleeding. Parkinson's disease in the brain may now be detected using SPECT agents, and it can be separated from dementias and movement disorders that have similar anatomical associations. PET scans are primarily used to diagnose cancer, monitor its progression, assess the efficacy of treatment, and discover metastases. Given that glucose consumption is dependent on how active cells and tissues are, it is substantially greater in cancer cells that proliferate fast. Most cancers' rate of glucose consumption roughly related to how aggressive they are. The greatest tracer is now available for identifying cancer. Its metastatic spread in the body has been demonstrated over the past 15 years to be slightly modified radiolabeled glucose molecules.

V. 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).

VI. 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.

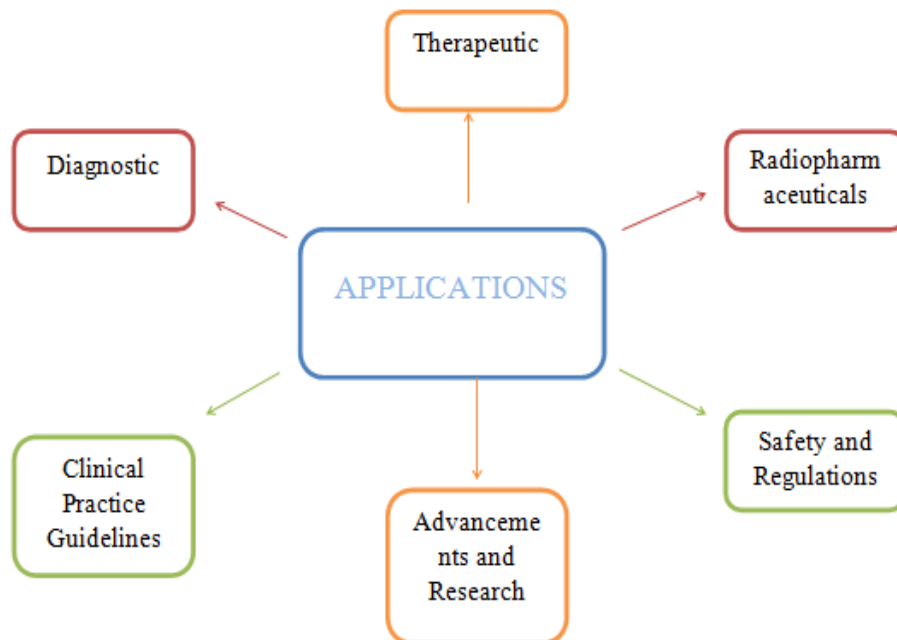
VII. NUCLEAR MEDICINE DIRECTIONS

1. Regulatory Issues for NM

- Because new uses come along more quickly than rules can adjust, commercial entities—both financial and political—are making decisions rather than scientific bodies.
- Among these elements are:
 - A general sense of overregulation;
 - Costs of regulation (for hospital staff);
 - Official training and experience criteria that is murky and inconsistent across the nation;
 - Training and experience criteria that is wildly inconsistent from one hospital/clinic to another.

2. Concerns about the Direction of Nuclear Medicine Include

- Payers do not fund the substantial costs associated with developing medications, such as Zevalin.
- NM lab running costs (drugs, supplies, and tech salaries) are increasing even as overall revenue is decreasing.
- Lack of qualified personnel (technologists, medical professionals, and scientists – professionalisation of the industry)
- Specialty groups fighting each other on a level playing field (inadequate representation of unequal training and experience in the market and certifying organisations)
- NM laboratory' operating expenses (drugs, supplies, and technicians' wages) are increasing even if overall income is down.



VIII. APPLICATIONS

1. **Diagnostic Uses:** Nuclear medicine may be used to watch and study metabolic processes, blood flow, and organ function. Two frequently used diagnostic methods are positron emission tomography (PET) and single-photon emission computed tomography (SPECT) examinations.
2. **Therapeutic Applications:** Nuclear medicine may also be used therapeutically to treat diseases including painful bone metastases, thyroid issues, and some malignancies like lymphoma and thyroid cancer.
3. **Radiopharmaceuticals:** Essential to nuclear medicine are radiopharmaceuticals. They consist of a radionuclide (radioactive isotope) and a pharmaceutical component. The appropriate radiopharmaceutical should be selected based on the medical issue being investigated or treated.

- 4. Safety and Regulations:** Strict safety regulations must be followed while using radioactive materials in nuclear medicine to protect patients and medical staff. Radioactive materials must be utilised safely, and regulatory agencies like the International Atomic Energy Agency (IAEA) and the U.S. Nuclear Regulatory Commission (NRC) are crucial for guaranteeing this.
- 5. Technological Advances and Research:** Nuclear medicine is a field that is always evolving as a result of ongoing research. New radiopharmaceuticals, imaging techniques, and treatment approaches are being developed to improve patient care and results.
- 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.

IX. CONCLUSION

Modern medicine requires ionising radiation. Most of the time, physicians use the data to swiftly determine the patient's ailment. Finding functional problems with the thyroid, bones, heart, liver, and many other organs is straightforward. In addition to clinical nuclear medicine and radiology practise and research, radioisotopes are used in a wide range of scientific fields, including pharmacology, drug development, genetics, molecular biology, nutrition, nuclear physics, environmental chemistry, geology, and industrial manufacturing. X-ray imaging, computed tomography scans, diagnostic and therapeutic nuclear medicine, brachytherapy, the gamma knife, and linear accelerators are just a few of the technological advancements that have completely changed how doctors diagnose and treat patients. . The tens of thousands of lives saved each year and the vast majority of individuals whose quality of life these technologies have improved allow us to quantify the benefits of radiation to human health. Although ionising radiation offers numerous benefits and is utilised in medicine, there are also potential risks for patients, medical professionals, and the general public. The diagnostic and therapeutic methods used to address them can aggravate acute injuries and chronic disorders like cancer.

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