# FUTURE OF NUCLEAR MEDICINE

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## INTRODUCTION

This area of radiography is frequently used to identify and treat anomalies that first appear extremely early in the course of a disease like thyroid carcinoma.[5]

Radiology and nuclear medicine both employ radiation. In nuclear medicine, the body is injected with radioactive substances known as radiopharmaceuticals or radioisotopes. X-rays are introduced into the body externally in radiology. Soft tissue, like the intestine, is difficult to see on a routine X-ray without the application of a contrast agent because X-rays pass through it.[1]

The use of radio-pharmaceuticals (RPh) for every treatment makes nuclear medicine a special specialty due to its complicated and crucial reliance on them. A carrier molecule that provides bio-specificity for the organ, lesion, or dysfunction being treated is combined with a radioisotope created in a research reactor or particle accelerator, such as a medical cyclotron, to deliver radiation for detection-based imaging or targeted therapy.[3]

For the care of patients, diagnostic radiological tests such as computed tomography (CT) and magnetic resonance imaging (MRI), as well as nuclear medicine imaging, are crucial, especially for making an accurate diagnosis and staging or restaging of a disease.[4]

## NUCLEAR MEDICINE IN TREATMENT[1]

Radioactive iodine (I-131) is one illustration. It has been used for more than 50 years to treat hyperthyroidism, or an overactive thyroid, and thyroid cancer. Additionally used to treat non-Hodgkin lymphoma and cancer-related bone discomfort. Radioactive iodine is injected into the body during iodine-131 targeted radionuclide treatment (TRT). This chemical destroys thyroid or cancer cells when they ingest it. I-131 can be administered orally or via a beverage.[1]

It could be feasible to include chemotherapy with drugs to create imaging agents that only bind to cancer cells. Only the targeted cells, not the adjacent healthy tissue, are killed by chemotherapy. Some of the negative effects of chemotherapy might be lessened.[1]

Nuclear medicine (radiation treatment) and immunotherapy are combined in radio immunotherapy (RIT). There are several radionuclides utilized. I-131, sometimes known as radioactive iodine treatment, is the most popular. Treatments for 90Y-ibritumomab-tiuxetan or zevalin-lymphoma are further alternatives. Treatment for lymphoma and multiple myeloma with tositumomab or bexxar.[1]

Researchers in the fields of molecular biology, sophisticated polymer chemistry, nanotechnology, and biomedical engineering are looking into ways to transport medications to the right spot without damaging nearby tissues. If they are breastfeeding, pregnant, or think they could be pregnant, health practitioners should be aware of this.[1]

## THERAPY[1]

There is no specific equipment required when a patient receives I-131 thyroid therapy. It is a one-time only procedure. On the day of therapy, the patient shouldn't eat or drink after midnight. If a thyroid condition is being treated, regular thyroid medication should be stopped three to seven days prior to therapy. The radioactive iodine will continue to exit the body during the following two to five days since the body won't be able to absorb it completely.[1]

Avoid interacting with others, especially children and expectant women. The body releases iodine through the urine. Additionally eliminated by feces, perspiration, vaginal discharge, saliva, and tears. Following therapy, women are recommended to postpone becoming pregnant for six to twelve months.[1]

## SAFETY IN NUCLEAR MEDICINE[1]

Radiation exposure that is too high may harm tissues or organs or raise the risk of cancer. Imaging techniques and nuclear medicine are regarded as non-invasive and generally safe. The advantages often outweigh the risks due to their efficiency in detecting illness. Nuclear medicine involves administering large doses of radioactive material. The advantages frequently outweigh the hazards since the therapy frequently targets deadly conditions. To protect patients, the USFDA and the nuclear regulatory commission (NRC) strictly control the use of radioactive materials in nuclear medicine.[1]

## RADIOACTIVE TRACERS[2]

Carrier molecules that are firmly bound to a radioactive atom make up radioactive tracers. Some tracers even use the patient's own cells and molecules that interact with a particular protein or sugar in the body. As an illustration, doctors may radio label a sample of the patient's RBCs if they need to identify the precise cause of intestinal bleeding. 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.[2]

Positron emission tomography (PET) and Single-photon emission computed tomography (SPECT) are two examples of imaging methods. Both of these methods offer thorough details regarding "how a body organ is functioning."[2]

Single-photon emission computed tomography (SPECT) is a diagnostic tool that generates three-dimensional (tomographic) pictures of the placement of radioactive tracer molecules inside a patient's body. The gamma rays that are emitted from the tracers that have been injected into the patient can be detected by the gamma camera detectors on SPECT imagers.[2]

Positron emission tomography (PET): Radiopharmaceuticals are also used in PET scans to provide 3D pictures. The kind of radio tracer utilized differs between SPECT and PET scans most significantly.[2]

The radio tracers used in PET scans decay to become positrons, which are tiny particles with nearly the same mass as electrons but the opposite charge. Generates a little quantity of energy in the form of two photons that go in opposing directions when it reacts with electrons. This reaction causes the two particles to annihilate one other. In PET, photons are detected by detectors, and images of interior organs are made using this data.[2]

## USE OF NUCLEAR MEDICINE SCANS[2]

The main purposes of SPECT scans are to identify and monitor the development of cardiac disease, including blocked coronary arteries. Intestinal hemorrhage, gall bladder disease, and other conditions can all be detected with radiotracers. Recent developments in SPECT technology have made it easier to diagnose Parkinson's disease in the brain.[2]

The primary goals of PET scans are to identify cancer and track its development, progression, response to treatment, and detection of metastasis. Utilization of glucose relies on the level of cellular and tissue activity, and it is significantly higher in cancer cells that divide quickly. Most tumors' level of aggressiveness and rate of glucose uptake are approximately correlated.[2]

F-18 labeled deoxyglucose, often known as FDG, has been demonstrated to be the greatest tracer for identifying cancer and its metastatic spread in the body during the past 15 years.[2]

The PET/CT scanner, a hybrid device that produces both PET and CT scans of the same body areas, has emerged as the primary imaging technique for the staging of most malignancies worldwide.[2]

The FDA has authorized a PET probe to help in the proper detection of Alzheimer's disease, which was previously only possible to identify accurately after a patient passed away. Without this PET imaging test, it may be challenging to distinguish between Alzheimer's disease and other types of dementia that affect older individuals.[2]

## PET/CT[6]

PET/CT is a procedure which combines the image from positron emission tomography (PET) and computed tomography (CT) it is done simultaneously with same machine due to which more detailed images with better information of areas inside the body then either scan gives by itself.[6]

## Historical background of PET/CT[6]

It was developed as a research device by investigators constructed by David Townsend (at the University of Geneva), first of all a prototype is developed funded by NCI installed at "University of Pittsburgh" and was used to study selected patients with cancer this new innovation not only helped to diagnose the cancer but also enhanced the information by PET/CT.[6]

Later it was commercialised by manufacturers CTI PET systems in Knoxville, TN (now Siemens molecular imagining) and new devices were made for clinical use.[6]

PET/CT is being used since November 2001.[6]

## Implications for the nuclear medicine community[6]

It looks like nuclear medicine and radiology community is divided over this issue into three blocks: supporters, critics/opponents and impartial observers with reference to presentation first results with clinical PET/CT during year 2002 scientific meetings (SNM, EANM and RSNA) , Some opponents questioned about clinical relevance of data presented "inline" PET/CT systems, mostly referring to their individual or institutional experience with simultaneous displays of PET/CT data to on adjacent monitors of for self made fusion software programs and calming that the similar if not identical result could have been obtained with software image fusion of separate CT and PET data as compared to all users of PET/CT which supported the clinical use of this technique.[6]

## Future and PET/CT technology[6]

It is a new technology which is here to stay while much work is remain to be done, It is clear with all the researches and data that had been collected with help of PET/CT that it decreases the imagining time per patient and significantly reduces the number of equivocal PET interpretations. It also improves accuracy of PET imagining an affect clinical dision making.[6]

The decision regarding whether PET/CT should be part of equipment in a given nuclear medicine or radiology practice largely depends upon population.[6]

As it have many advantages of combined PET/CT over either PET alone or conventional image fusion approaches: "one image says more than thousand words".[6]

## CLINICAL EXAMINATION BY NUCLEAR MEDICINE[7]

- Radiological imaging of heart, kidney, gall bladder and thyroid.
- Position emission tomography(PET), a type of nuclear medicine used to examine the proper functioning of the cell or any damage to the body cells.
- To provide the three dimensional (3-D) imaging, PET combindly used with computed tomography or magnetic resonance imaging (MRI)

## EXAMINATION BY PET IMAGING[7]

- In the examination of heart diseases, Alzheimer's disease and brain disorder.
- It makes diagnosis of the Myeloma cells more informative so the best treatment can be given to the patient.

## STEPS FOR THE CLINICAL USE NUCLEAR MEDICINE[7]

Follow the specified guidelines when using nuclear medicine on Pregnant women and Children.

- Decide the route of administration (I.V. , Oral or Inhalation)
- Now wait for the distribution of the nuclear medicine throughout the body So that the treatment and diagnosis of a disease can be performed.
- Now the patient will lie down or to walk or to sit into or on the pathway of the imaging machine.
- Now the camera situated in machine will examine the body organ or tissue.
- Imaging report will be provided to the patient so the healthcare professionals can diagnose the disease and proper functioning of the body organ or tissue.
- Nuclear medicine will be excreted from the body within some hour and also depend on the type of nuclear medicine used.

## IMPACT OF NUCLEAR MEDICINE AND RPh ON HEALTHCARE DELIVERY[3]

Currently, it's estimated that approximately 40 million nuclear medicine diagnostic investigations are performed worldwide each year, with 10 to 15 million of those studies being for therapeutic purposes.[3]

Nuclear medicine has made advancements and reached important turning points.

Nuclear medicine saw a significant upsurge in the 1980s and 1990s with the introduction of $^{99m}$Tc-based imaging agents (planar at first, then SPECT later), and more recently with PET tracers, particularly F-18 (since 2000), after the widespread use of I – 13l for both diagnosis and therapy. The RPh evolution has progressed along a more reliable pathway of interdisciplinary efforts, which has been further enhanced by the adoption of better targeting tactics by meticulously identifying relevant moieties of biochemical origin, connected with a particular lesion or malfunction of clinical concern.[3]

Several RPh, particularly in 3 key areas, were developed and released as a result of the R&D focus on clinical needs:

(i) For the skeletal system, as the bone is a common site for cancer metastasis.

(ii) for myocardial imaging, as a management tool for the large-volume cardiac patient; utility demonstrated initially with 201 TICI and subsequently more widely with $^{99m}$Tc-based RPh (sestamibi, tetrofosmin).

(iii) for tumor targeting in cancer patients, for both imaging and therapy.[3]

**One can cite the following major milestones of high clinical significance[3]**

the introduction of $^{99m}$Tc generators and its RPh, as well as "kits" for user-friendly compounding.

(a) $^{201}$TICI is used for myocardial perfusion imaging (MPI), while $^{99m}$Tc products (sestamibi, tetrofosmin) are later introduced for a purpose comparable to this.

Improvements in the strategic targeting of tumors for imaging and therapy (I and T, theranostics) and success stories of using small molecule vectors with the RI pair, 68Ga and 177Lu for PET imaging and therapy, respectively. A technique that combines highly-specific biological tracers like 18F, 11C, and other positron emitters like 68Ga, 64Cu, etc. with high-resolution PET/CT imaging, particularly for uses in cancer and neurology.

Since then, terminology like MC-produced 18 F (110min) and 18F-fluorodeoxyglucose (FDG), which were formerly unfamiliar terms in nuclear medicine, have become standard phrases. Radionuclide treatment (RNT) based on RPh has made another significant advancement. In the past ten years, the use of 177 Lu (6.7d) as an alluring therapeutic RI for targeted tumor therapy has grown significantly, with Indian contributions being well recognized on a global scale. Two alpha emitters, 223 Ra for the relief of bone pain and 225 Ac to replace 177 Lu for more effective tumor treatment, are being tested.

Theranostic techniques are gaining popularity since they employ the same vector molecule for imaging with diagnostic RI (18F, 68Ga) and treatment with therapeutic RI (177Lu, 98Y).[3]

## NUCLEAR MEDICINE IMAGING

After a patient receives a radioactive tracer, nuclear medicine imaging is a technique for creating pictures by detecting radiation from various bodily areas.

Digital pictures created on a computer that are sent to a nuclear medicine doctor who uses them to diagnose patients. The majority of the time, radioactive tracers used in nuclear medicine are injected into a vein. They could be administered orally for some research. These tracers have no negative effects because they are neither dyes or medications.

The structure and function of organs and tissues may be seen by nuclear imaging. To investigate how organs and tissues operate, nuclear imaging is performed. Body tissue absorbs the radioactive chemicals, also known as radionuclides. Technetium, thallium, gallium, iodine, and xenon are some examples of radionuclides. Depending on the sort of investigation and the body part being investigated, a particular radionuclide will be employed. A radiation detector picks up radiation. The gamma camera is the most popular kind of detector. Tumors, infections, hematomas, organ enlargement, or cysts are just a few of the disorders that radionuclide measurement may evaluate and identify.

Additionally, evaluate blood circulation and organ function.[6]

“Hot spots” refer to areas where radionuclide collection is higher, and “Cold spots” refer to areas where it is lower. Nuclear imaging tests are required since they are primarily used to identify and treat illnesses.[6]

Nuclear medicine imaging is used to diagnose a variety of conditions, including:

Kidney disease including infections, scars, or blockages, Cancer, Heart disease, Gall bladder disease, Lungs trouble, Bone difficulties, including infections and fractures, thyroid disease including Hypothyroidism.

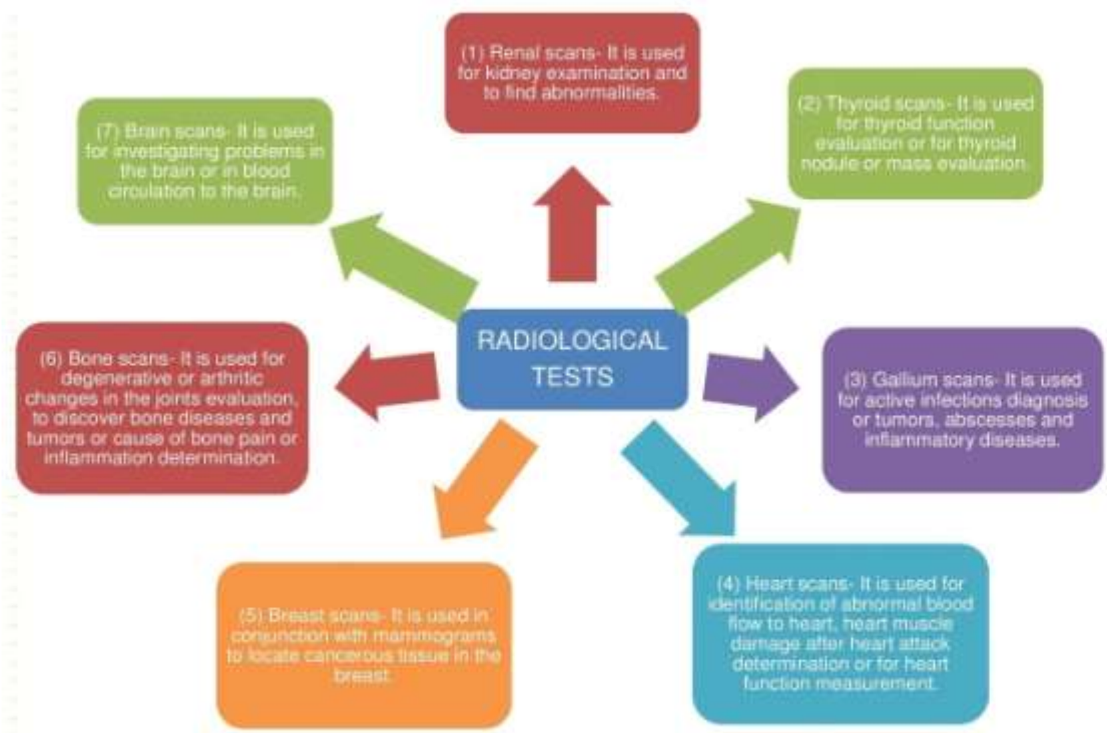
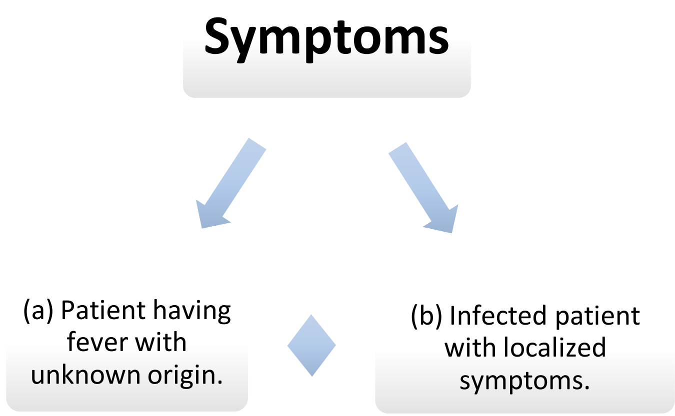



FIG. - SOME COMMON RADIOLOGICAL TESTS

## MICROBIAL INFECTION CAUSED BY NUCLEAR MEDICINE[8]

Radiological imaging may causes infection while using nuclear medicine with two major symptoms.[8]




Now a days to minimize or cure the infection some radioactive medicaments are used these are- technetium-99m nanocolloids, gallium-67 citrate, indium-111- and $^{99m}$Tc-labelled white blood cells, $^{99m}$Tc-antigranulocyte antibodies, and 99mTc-or $^{111}$In-labelled unspecified human immunoglobin.[8]

The information on changes in pathophysiological and pathobiochemical is provided by nuclear medicine imaging.[8]

## PATHOPHYSIOLOGY OF INFECTION CAUSED BY RADIOLOGICAL IMAGING USING NUCLEAR MEDICINE[8]

The infection caused by nuclear medicine act as the host defence mechanism of the body.[8]

This defence mechanism may be specific or non-specific. Non-specific mechanism of defence mechanism act against many microbial infections, while specific mechanism act against a particular or specific microbe.[8]


Specific microbe causes specific infection while radiological imaging using nuclear medicine explained as monoclonal antibody against pneumocystis carinii that reported 85.7% sensitivity and 86.7% specificity.

Non-specific defence mechanism have physical barriers to onslaught, secretion at primary sites or entry, integrant and phagocytic cells(monocytes and granulocytes)[8]

## RADIOACTIVE MEDICAMENTS USED IN THE INFECTION CAUSED BY NUCLEAR MEDICINE[8]

The main mechanism of uptake of radioactive medicaments will increase capillary permeability that instantly precedes leucocytic dwelling and it's also an indication of infection but also inflammation.[8]

| Radiopharmaceuticals | Half-life | Energy | Uptake mechanism |
|---|---|---|---|
| **$^{67}$Ga citrate** | **78hr** | **93, 185, 300 and 394 keV** | **Transferrin/lactoferrin Receptor binding** |
| **$^{99m}$Tc-nanocolloids** | **6hr** | **140 keV** | **Non-specific via capillary permeability/active uptake in activated endothelial cells** |
| **$^{99m}$Tc/$^{111}$In-labelled human Immunoglobulin(HIG)** | **6hr/67hr** | **173 and 247 keV** | **Non-specific via increased capillary permeability** |
| **$^{111}$In oxine/$^{99m}$Tc-HMPAO-labelled leucocytes** | **67hr/6hr** | **173 and 247keV/140 keV** | **Specific Chemotactic activation** |
| **$^{99m}$Tc-labelled granulocyte Anti-bodies** | **6hr** | **140 keV** | **Increased capillary permeability and specific binding or uptake as antibody labelled granulocytes** |

## PREVENTION FOR HARMFUL EFFECTS OF NUCLEAR MEDICINE[7]

- Wash your hands and foot frequently so that the radiation from the body will be reduce.
- Take large amount of water intake.
- Aware you radiologist before examination if you are pregnant or breastfeeding women.
- Consult with your physician if you are facing any problem.

## BENEFITS AND RISKS OF NUCLEAR MEDICINE[7]

**BENEFITS[7]**

- Reports the image examination about the proper functioning of all the body organ or tissue.
- Used in the treatment of Cancer, thyroid, etc. disease.

**RISK[7]**

- High use of nuclear medicine may increases the chances of cancer to the patient.
- Nuclear medicine can causes skin reddening and hair loss.

## USES OF NUCLEAR MEDICINE IN HEALTHCARE SYSTEM[7]

- Nuclear medicine are being administered to the body to check the proper functioning of all the body organs or tissue and to act on specified organ or tissue in treatment of a particular disease.[7]

- Working comparison between Nuclear Medicine and X-rays
  A. Nuclear Medicine[7]
     i. Nuclear medicines are administered via I.V. , Oral or inhalation.
     ii. Absorption of nuclear medicine can be seen in the imaging of the body tissues.
     iii. Nuclear medicine shows functioning of the body parts or organs.
     iv. Nuclear Medicine are used in the treatment as well as in the diagnosis of a disease.

  B. X-rays[7]
     i. High-energy electromagnetic radiation passes through the body.
     ii. To examine the structure of the body with imaging by X-rays.
     iii. X-rays shows the structural frame of the body (i.e. bones and joints)
     iv. X-rays are used in the diagnosis of a disease.

Either high degree of radiation from the environment or nuclear medicine effect the human body and increases the chances to causes carcinogenicity to the human body.[7]

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