NUCLEAR MEDCINE

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1. OVERVIEW

Nuclear medicine is a medical specialty that utilizes small amounts of radioactive materials, known as radiopharmaceuticals, to diagnose and treat various diseases. It combines the fields of nuclear physics, chemistry, and medicine to provide valuable diagnostic information and therapeutic options.

In nuclear medicine, patient is administrated with radiopharmaceuticals either orally or intravenously. These radiopharmaceuticals are made up of radioactive isotopes which emits gamma rays or positrons, which can be detected by specialized imaging devices called Positron emission tomography (PET scan).

Nuclear medicine has wide range of application in medical field. It is commonly used for diagnosis and to identify stage of different types of cancer. It can also detect abnormalities in cardiovascular system such as blocked arteries or damaged heart muscles.

In addition to diagnosis purpose, nuclear medicine offers therapeutic options as well. With the help of a technique named targeted radionuclide therapy, treatment of certain types of cancer such as thyroid cancer and neuroendocrine tumour is possible. In this technique radioactive substance can be delivered to specific target cancerous tumours to shrink or destroy them.

One of the key advantages is its ability to offer both anatomical and functional information simultaneously, which aids physician in early detection and characterization of diseases which leads to better treatment planning.

2. PRINCIPLES OF NUCLEAR MEDICINE

It is branch of medical imaging which utilizes the principle of nuclear physics, radiochemistry and computer technology to study the structure and functions of the body. Nuclear medicine involves the use of radioactive substances known as radiopharmaceuticals to diagnose and treat various medical conditions. Diagnose are done by using Gamma cameras or positron emission tomography.

2.1 Radiopharmaceuticals

Radiopharmaceuticals plays an important role in nuclear medicine. These are group of pharmaceutical drugs containing radioactive isotopes, which can be used as diagnostic and therapeutic agents. These are substances are designed to be administrated to the patients either orally, intravenously, or by inhalation.

Radiopharmaceuticals consist of two main components: a biologically active compound and a radioactive isotope. The biologically compounds, also known as a pharmaceutical, is responsible for targeting specific organ or tissues within the body. It can be a naturally occurring molecule or a synthetic compound.

Different radiopharmaceuticals used for various diagnostic and treatment purposes. Some of the widely used radiopharmaceuticals are:

2.1.1 Technetium-99m (Tc-99m) compound:

Tc-99m is the most commonly used radioactive isotope in nuclear medicine. It is a radioactive isotope of the element technetium. It is often combined with pharmaceuticals to create radiopharmaceuticals for imaging various organs such as the heart, bones, kidneys, liver, and lungs.

Tc-99m can be combined with various pharmaceuticals due to its favourable nuclear properties and short half-life (approximately 6 hours). This bond between Tc-99m and pharmaceuticals compounds makes them biologically active and target specific organs or tissues. For example, Tc-99m is bound to a compound named methylene diphosphonate (MDP), to create Tc-99m MDP. This pharmaceutical is used for bone imaging, mainly in diagnosis and monitoring the bone metastases. In this case Tc-99m serves as radioactive tracer, while the MDP compound acts as a bone-seeking agent. After injecting into the patient, the Tc-99m MDP is taken up by bones and emits gamma radiation, these gamma rays are detected by gamma cameras.

Radiopharmaceuticals	**Target organ**
Technetium-99m pertechnetate	• Thyroid imaging • Parathyroid subtraction study • Intestinal and rectal functional studies
Technetium-99m sulfur colloid	• Splenic and hepatic imaging • Bone marrow and soft tissue infection scan • Lymphatic imaging
Technetium-99m methylene diphosphonate (MDP)	Bone scintigraphy
Technetium-99m macroaggregated albumin (MAA)	Lung perfusion imaging
Technetium-99m teboroxime	Cardiac imaging
Technetium-99m mebrofenin	Liver function analysis
Technetium-99m ethyl cysteinate dimer (ECD)	CNS imaging
Technetium-99m hexamethylpropyleneamine oxime (HMPAO)	Cerebral perfusion imaging
Technetium-99m mercaptoacetyl triglycine (MAG3)	Renal imaging

2.1.2 Fluorine-18 (F-18) compound:

Fluorine-18(F-18) is a radioactive isotope of fluorine that is widely used in nuclear medicine. It has a half-life of 110 minutes, which allows the imaging studies to be performed within a reasonable time period.

F-18 is typically used in the form of F-18 fluorodeoxyglucose (FDG). FDG is an analog of glucose which is labelled with F-18. Its is taken up by cells in a manner similar to glucose. However, once it enters the cells, it gets trapped and cannot me metabolized further. This leads to accumulation of FDG in areas with increased glucose metabolism, such as cancer cells. By detecting these areas with the help of PET scan, the diagnosis can be done.

Others F-18 radiopharmaceuticals used are;

Radiopharmaceuticals	**Part being imaged**
F-18 Sodium Fluoride (NaF)	Used in bone scans to detect and evaluate bone metastases
F-18 Fluorocholine (FCH)	Prostate cancer
F-18 Fluorothymidine (FLT)	FLT is used to assess cell proliferation and is often used in cancer imaging
F-18 Fluciclovine (Axumin)	Fluciclovine is used in PET imaging for the detection of recurrent prostate cancer

2.1.3 Iodine-131 (I-131) compound:

I-131 is a radioactive isotope used for diagnostic and therapeutic purposes, particularly in treatment of thyroid diseases. It emits beta particles, which selectively target and destroy thyroid tissue with conditions such as hyperthyroidism and thyroid cancer. I-131 has a half life of 8 days. During the process of decay, it emits gamma radiation, as well as beta particles which can be used for therapeutic purposes. I-131 is mainly useful for targeted treatment and diagnostic imaging of certain conditions.

Some common I-131 radiopharmaceuticals include:

1. **Iodine-131 sodium iodide (NaI):** This compound is primarily used for therapeutic purposes. It is often administered orally and selectively accumulates in the thyroid gland, where it emits beta particles that destroy the overactive thyroid tissue. This is commonly used for treatment of hyperthyroidism and certain types of thyroid cancer.
2. **Iodine-131 metaiodobenzylguanidine (MIBG):** MIBG is used for diagnostic imaging and treatment of neuroendocrine tumors, such as pheochromocytoma and neuroblastoma.
3. **Iodine-131 tositumomab (Bexxar):** This radiopharmaceutical is used for the treatment of non-Hodgkin's lymphoma. It consists of a monoclonal antibody that specifically targets CD20 antigens found on the surface of certain B-cell lymphomas. When labelled with I-131, it delivers localized radiation to the cancer cells, aiding in their destruction.

2.1.4 Gallium-67 (Ga-67) compounds:

Gallium-67 (Ga-67) is a radioactive isotope of gallium, which has a physical half-life of approximately 78 hours. These compounds are used in a procedure known as gallium scanning or gallium scintigraphy.

The most commonly used gallium-67 compound in clinical practice is gallium citrate. Ga-67 has a high affinity for areas of inflammation, infection, and certain types of cancer, allowing it to accumulate in these sites.

Gallium scanning is commonly used in the evaluation of various conditions, including:

1. **Infection:** It helps to identify the presence and location of infections, such as osteomyelitis, abscesses, and certain types of pneumonia.
2. **Inflammation:** Ga-67 scanning can detect areas of inflammation, such as in rheumatoid arthritis or vasculitis.

3. **Cancer:** It is useful in imaging certain types of cancer, such as lymphomas, melanomas, and lung cancer.
4. **Fever of unknown origin:** When the cause of a persistent fever is unclear, gallium scanning can be helpful in identifying potential sources of infection or inflammation.

2.2 Imaging Techniques:

In nuclear medicine, various imaging techniques are used to visualize the physiological processes and structures within the body. Here are some of the common imaging techniques used in nuclear medicine:

2.2.1 Single-Photon Emission Computed Tomography (SPECT):

Single-Photon Emission Computed Tomography (SPECT) is a medical imaging technique used to visualize the distribution of a radioactive tracer within the body.

When the patient is injected with radiotracer, it circulated through the bloodstream and reaches the targeted organ or tissue. When the radioactive isotope within the radiotracer undergoes radioactive decay, it emits gamma rays. A SPECT system consists of a gamma camera, which is equipped with a collimator, scintillation crystals, and photomultiplier tubes (PMTs). The collimator is a lead or tungsten device that helps to collimate the gamma rays, allowing only photons traveling in a specific direction to reach the scintillation crystals.

When gamma rays pass through collimator, it interacts with the scintillation crystal, typically made of a material like sodium iodide doped with thallium [NaI(Tl)]. The gamma ray transfers its energy to the crystal, causing the atoms within the crystal to become excited. These excited atoms release their energy in the form of visible light photons. These photons are detected by the photomultiplier tubes (PMTs) mounted on the gamma camera. PMTs are sensitive to light and convert it into an electrical signal. The electrical signals from the PMTs are amplified, shaped, and converted into digital signals by the SPECT system. These signals contain information about the position and energy of the detected gamma ray.

The digital signals are processed and reconstructed to create a three-dimensional image of the radiotracer distribution within the patient's body. The reconstructed SPECT image can be displayed on a computer monitor and further analysed by medical professionals.

SPECT is particularly useful in nuclear medicine for assessing various conditions, including:

1. Cardiac imaging
2. Brain imaging
3. Bone scans
4. Lung imaging

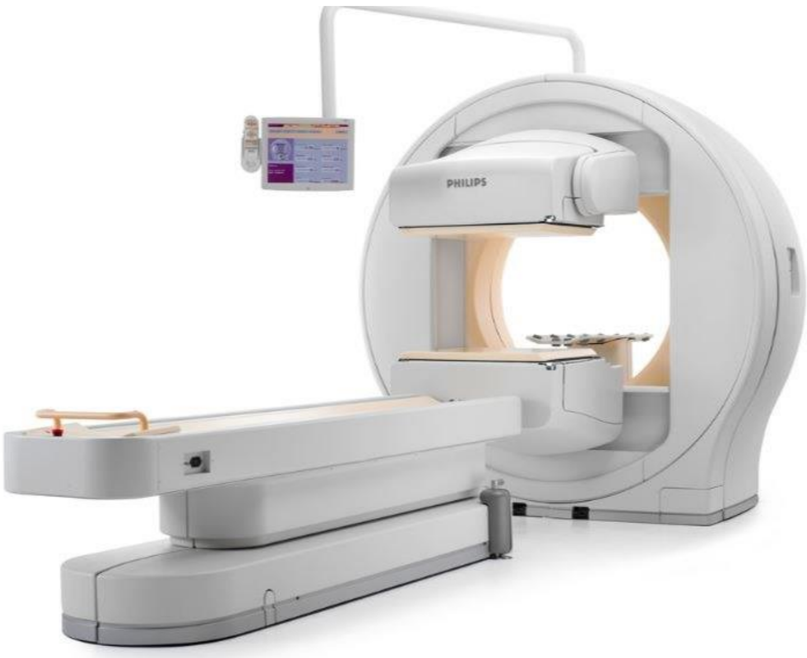

Figure: Single-Photon Emission Computed Tomography

2.2.2 Positron Emission Tomography (PET):

PET imaging uses radiopharmaceuticals that emit positrons, which are positively charged particles. A positron-emitting radionuclide, such as fluorine-18 (18F), is chemically attached to a biologically active molecule, creating a radiotracer. This radiotracer is injected into the patient's body.

Inside the body, the radiotracer undergoes positron decay. When a positron encounters an electron, they annihilate each other, resulting in the release of two gamma rays with a 180-degree angle of separation.

The gamma rays emitted during positron annihilation are detected by a ring of scintillation detectors surrounding the patient. Scintillation crystals (10,000-20,000) like Bismuth germanate (BGO), Lutetium oxyorthosilicate (LSO), and Gadolinium oxyorthosilicate (GSO) are used.

When two or more detectors detect the photons at the same time, it is called annihilation coincidence detection (ACD). This provides information about the location of the positron annihilation in the patient's body. The ACD data collected by the detectors are processed by a computer system to reconstruct a three-dimensional image of the radiotracer distribution in the body. This information can be used to diagnose and monitor various conditions such as cancer, heart disease, and neurological disorders.

The ACD method of detection is much powerful and need no collimator. Hence, the efficiency of PET scanner is about 10-20 times that of SPECT camera.

2.2.3 Planar Scintigraphy:

Planar scintigraphy is a two-dimensional imaging technique that involves the use of a gamma camera to capture the distribution of a radiopharmaceutical in the body.

The patient is positioned between the patient bed and a gamma camera, which consists of a large crystal scintillator coupled to a photomultiplier tube. When the radiopharmaceutical decays and emits gamma rays, these gamma rays penetrate the patient's body and interact with the scintillator crystal. The crystal absorbs the gamma rays and emits visible light photons in response.

The photomultiplier tube detects the light photons and converts them into electrical signals. The electrical signals from the photomultiplier tube are used to reconstruct an image of the distribution of the radiopharmaceutical in the patient's body.

2.2.4 Hybrid Imaging

Hybrid imaging in nuclear medicine refers to the combination of two or more imaging modalities to provide more comprehensive and accurate diagnostic information. The most commonly used hybrid imaging technique in nuclear medicine is the fusion of functional nuclear medicine images, typically single-photon emission computed tomography (SPECT) or positron emission tomography (PET), with anatomical images obtained from computed tomography (CT) or magnetic resonance imaging (MRI). This combination allows the simultaneous acquisition of functional and structural information.

The fusion of functional and anatomical imaging provides several advantages. By overlaying functional images onto anatomical images, it enables precise localization of functional abnormalities, improves lesion detection, and enhances the interpretation of nuclear medicine findings.

3.APPLICATION IN PHARMACY:

Pharmacists play a crucial role in nuclear medicine through their involvement in the preparation, dispensing, and management of radiopharmaceuticals.

3.1 Radiopharmaceutical Preparation:

Radiopharmaceutical prepared in a specialized area within pharmacy that involves the compounding and dispensing of radiopharmaceuticals. The Pharmacist should have advanced knowledge in radiation safety, radiopharmaceutical chemistry, and quality control procedures.

To prepare a radiopharmaceutical, appropriate radioactive isotope is chosen based on the specific diagnostic or therapeutic application.

Commonly used isotopes include technetium-99m, iodine-131, and fluorine-18.

By the process of radiolabeling, the radioisotope is attached with non-chemical substance (also known as a carrier or ligand). This can be achieved through various methods, such as chelation, covalent bonding, or physical adsorption. The choice of method depends on the properties of the radioisotope and the carrier. This process leads to formation radiopharmaceutical.

3.2 Quality Control and Assurance:

Quality control and assurance of radiopharmaceuticals by pharmacists is a crucial aspect of ensuring patient safety and effective medical imaging or therapy. Quality control is essential to maintain their potency, purity, and appropriate radiation levels.

Here are some key aspects of quality control and assurance in radiopharmaceuticals:

1. **Regulatory Compliance:** Pharmacists ensure that all radiopharmaceuticals meet the regulatory requirements set by local health authorities and international organizations such as the United States Pharmacopeia (USP) or the European Pharmacopoeia (Ph. Eur.).
2. **Facility Accreditation:** Radiopharmaceutical production facilities should have proper accreditation from Atomic Energy Regulatory Board (AERB) in India.
3. **Product Testing:** Radiopharmaceutical products undergo rigorous testing to verify their quality and efficacy. Pharmacists perform tests to assess product potency, radionuclide purity, radiochemical purity, and sterility. They use techniques such as high-performance liquid chromatography (HPLC), thin-layer chromatography (TLC), and gamma spectroscopy.
4. **Calibration and Quality Assurance:** Pharmacists ensure that all instruments used in the production and testing of radiopharmaceuticals are regularly calibrated and maintained.

5. **Documentation and Record Keeping:** Pharmacists maintain documentation and record-keeping systems to track the entire production process of radiopharmaceuticals

3.3 Radiopharmaceutical Dispensing:

Dispensing radiopharmaceuticals is a highly regulated process due to the potential risks associated with handling radioactive materials. Pharmacists dispensing radiopharmaceuticals must adhere to strict radiation safety protocols. This involves proper handling, storage, and disposal of radioactive materials, as well as the use of personal protective equipment (PPE) to minimize radiation exposure risks.

3.4 Radiation Safety:

Radiation safety is an essential aspect of working with radiopharmaceuticals, and pharmacists play a crucial role in ensuring the safe handling and administration of these radioactive substances. Proper shielding is essential to minimize radiation exposure. This includes wearing appropriate personal protective equipment (PPE) such as gloves, lab coats, and lead aprons. Storage areas for radiopharmaceuticals must have appropriate shielding, such as lead-lined containers or cabinets, to reduce radiation exposure to personnel and the environment. Radiation monitoring devices, such as personal dosimeters are used, to track their occupational radiation exposure.

3.4 Dose Calculation:

Pharmacists are responsible for determining the appropriate dose of radiopharmaceuticals for individual patients. They consider factors such as the patient's weight, body surface area, organ function, and the specific diagnostic or therapeutic procedure being performed. Pharmacists use established guidelines, protocols, and mathematical formulas to calculate the optimal dose based on these factors.

3.5 Contamination Control:

Pharmacists should take precautions to prevent contamination of surfaces, equipment, and personnel during the handling of radiopharmaceuticals. Specialized instruments, such as radiation detectors and wipe tests are used, to detect and measure the presence of radioactive materials. If contamination is detected, appropriate measures should be taken to decontaminate the affected areas.

3.6 Waste Management:

Proper management of radioactive waste is a crucial aspect of contamination control. Pharmacists ensure that radioactive waste is segregated, labelled, stored, and disposed of according to regulatory guidelines.

4.APPLICATION IN NURSING:

Nursing professionals play a crucial role in supporting and caring for patients undergoing nuclear medicine tests and treatments.

4.1 Patient Education:

Nurses are responsible for providing information to patients about nuclear medicine procedures, including explaining the purpose, potential risks, and benefits. They help relieve any fears or concerns patients may have and ensure they understand the instructions and preparations required.

4.2 Patient Preparation:

Nurses assist in preparing patients for nuclear medicine examinations, which includes:

1. **Clothing**: Patients should be said to change into a hospital gown or remove any clothing that contains metal, as metal objects can interfere with the imaging process.
2. **Fasting requirements:** In certain nuclear medicine scans, fasting may be necessary before the procedure. Provide clear instructions on when the patient should start fasting and what they can or cannot consume during that time.
3. **Medication review:** Review the patient's medication list, including over-the-counter drugs and supplements. Some

medications may interfere with nuclear medicine procedures or require temporary discontinuation.

4. **Allergies and previous reactions:** Inquire about the patient's known allergies, especially to medications or contrast agents used in nuclear medicine. Ensure the patient's allergy information is documented and readily accessible to the nuclear medicine team.
5. **Pregnancy and breastfeeding:** Confirm if the patient is pregnant or breastfeeding, as some nuclear medicine procedures may pose risks to the fetus or require temporary termination of breastfeeding.
6. **Consent and paperwork:** Ensure the patient has signed the necessary consent forms for the nuclear medicine procedure. Verify that all required paperwork, such as medical history forms or questionnaires, are completed accurately.

4.3 Patient Monitoring:

Nurses monitor patients during nuclear medicine procedures to assess their vital signs and observe for any adverse reactions. Patient's vital signs, including heart rate, blood pressure, and oxygen saturation should be monitored carefully. They remain alert for any signs of complications and report them to the appropriate medical personnel.

4.4 Post-Procedure Care:

After nuclear medicine tests or treatments, nurses continue to monitor patients and provide appropriate post-procedure care. This involves ensuring that patients are hydrated, managing any side effects, and addressing any immediate concerns related to the procedure.

4.5 Documentation and Record-Keeping:

Nurses maintain accurate and detailed records of patient assessments, procedures, and treatments. They document the administration of radiopharmaceuticals, monitor patient responses, patient vitals and report any adverse reactions or complications.

5. CONCLUSION:

Nuclear medicine plays a significant role in both pharmacy and nursing practice. Pharmacists contribute to the appropriate selection, preparation, and dispensing of radiopharmaceuticals, ensuring patient safety and compliance. Nurses, on the other hand, play a crucial role in patient preparation, patient monitoring , and post-procedure care. By working together, pharmacists and nurses optimize the use of nuclear medicine techniques, providing valuable diagnostic and therapeutic options to patients.