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CHAPTER 14

Nuclear Medicine

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Introduction

Nuclear Medicine utilizes radioactive material within the body to perceive how organs and tissue are working (for analysis) or for target oriented drug design and annihilate harmed or infected organs or tissue (for treating diseases). Nuclear medication is a clinical specialty that utilizes radioactive tracers (radio-pharmaceuticals) to survey physical processes and to analyze and treat infection. Exceptionally planned cameras permit specialists to follow the way of this type of radioactive tracers. SPECT (Single Photon Emission Computed Tomography) and PET (Positron Emission Tomography) sweeps these are two common and normal imaging in atomic medication. The implication of Nuclear medicine in Medical Imaging, Organ scan, Radio-logical techniques in diagnosis and treatment are elaborated in this chapter.

Figure 1: Diagrammatic representation of Nuclear medicine used for diagnosis
(Source: Center for Medical Imaging - Nuclear Medicine-Hometown Health, www.independentimaging.com)

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Imaging using radioisotopes

For diagnosis, therapy, and diagnosis, radioisotopes are widely used (in vivo and in vitro).

***In-vivo* Imaging using radioisotopes**

The morphology of radiopharmaceuticals in organs (the morphology) and their course over time (the function) can be determined through nuclear medicine (NM) studies in vivo, which result from the physical interactions between tracers and specific physiological processes within the body. Lately new systems for application of radioactive tracers to finding, observing and treatment of a wide range of illnesses have been carried out, building up the steadily developing interest within this application. Around 10 thousand imaging centers for CNM are introduced around the world and around 200 for PET. NM concentrates in vivo are many times delegated two primary sorts: those for morphological and those for utilitarian examinations. Rigorously this implies that we can distinguish the limitation of radio-drugs in organs (for example the morphology of the tracer circulation) and its course over the long haul, coming about because of physico-substance communications of the tracers with the living cells, in the grouping of explicit physiological cycles.

Organs Scan using radionuclide

A radionuclide is a substance that emits gamma rays, a form of radioactivity. It is sometimes referred to as a radioisotope or isotope. Radionuclides are usually introduced into the body by injection into a vein. Depending on the test, it may be administered as eye drops, ingested, or inhaled. Different kinds of radionuclides exist. Certain ones have a propensity to gather or concentrate in particular tissues or organs. Thus, the type of radionuclide to be used for a given body part scan depends on it. For instance, radioactive iodine that is injected into a vein is rapidly absorbed by the thyroid gland's tissues. It is therefore employed to scan the thyroid gland.

A gamma camera is used to detect gamma type of rays emitted from matter or organ. The gamma camera picks up on the gamma rays coming from inside the body, transforms them into an electrical signal, and sends it to a computer. The computer creates an image by transforming the varying levels of radioactivity released into various hues or tones of gray. An image of a lung perfusion scan shows this below.

- **A bone scan:** One typical kind is a bone scan. When there is high bone activity, a radionuclide that accumulates in certain regions is employed (where bone cells are breaking down or rebuilding sections of the bone). In order to identify bone regions affected by cancer, infection, or other damage, a bone scan is performed. 'Hot spots' on the scan image are these areas of activity.
- **A kidney scan:** Given that the selected radionuclide is absorbed by kidney cells and excreted in urine, a kidney scan can evaluate the function of a kidney. As a result, the scan can identify kidney scars as well as the efficiency of the kidney's urine flow to the bladder.
- **Lung perfusion sca**n (also called a 'VQ scan') can detect blood clot in lungs.
- **A heart scan:** It can survey blood stream to the heart muscle. Areas of unfortunate blood stream to the heart muscle don't 'take up' the radionuclide well overall and this will be displayed in the image.
- **A thyroid scan:** There are instances when a thyroid scan can be performed in order to determine if a patient has hyperthyroidism, or an overactive thyroid. For instance, some tiny bumps, called nodules, can occasionally be the site of excessive activity and appear as "hot spots" in the images.
- **Lacrimal scintigraphy** is done to test the capability of tear channels (lacrimal conduits) here radionuclide is provided as eye drops.
- In people suffering from lymphoedema, which is a type of swelling of the legs, lymphoscintigraphy is performed to check if the lymph nodes are being drained properly.

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In-vitro imaging using radioisotopes

As a result of radioisotope applications in vitro, they have become a vital tool for the analysis of biochemical reactions as well as in drug therapy. Radioisotopes are used in numerous applications ranging from external gamma-ray sources in radiotherapy to direct cell irradiation for the treatment of metabolic disorders. The specialty of nuclear medicine *in vivo* is now firmly devoted to the functional imaging of human organs. One of NM's primary areas of study is functional imaging, which offers information beyond the basic morphologic representation of structures. NM transmits information that is fundamentally metabolic in nature, as opposed to the structural information provided by other imaging modalities like CAT (computerized axial tomography) and NMI (nuclear magnetic resonance imaging). This property is significant in early identification and diagnosis, since metabolic perturbations precede structural modifications in the genesis of pathogenic processes and the size of the functional lesions are typically different from those of the corresponding anatomical lesions. It's important to keep in mind that the term "functional imaging" refers to a wide range of activities that fall into three categories: imaging of metabolic processes, excluding excretory function (ligand–receptor interaction); imaging of organ motions (heart, blood); and imaging of excretory functions (kidneys, liver).

Radioimmunoassay: Principle, Method and Application

Using radioisotopes, Radioimmunoassay is a delicate immunoassay procedure that guides in the distinguishing proof of antigens or antibodies in a sample. This sort of antigen-neutralizer cooperation happens in vitro. Radioimmunoassay (RIA) is the strategy of recognizing the antigen-antibody complex when radioisotopes, as opposed to compounds, are used as names to be combined with antigens or antibodies. A very delicate in vitro test for recognizing the presence of an antigen is called radioimmunoassay (RIA). The estimation of endogenous plasma insulin was the underlying utilization of RIA, which was at first revealed in 1960 by Solomon Berson and Rosalyn Yalow.

The idea of competitive binding is the foundation of traditional RIA techniques. Using this technique, radio-labeled and unlabeled antigens compete with one another to bind to the right kind of antibody. As a result, the amount of free (i.e., not bound to antibody) radio-labeled antigen in mixes containing both radio-labeled and unlabeled antigen is directly proportional to the amount of unlabeled antigen in the mixture when the appropriate antibody is added.

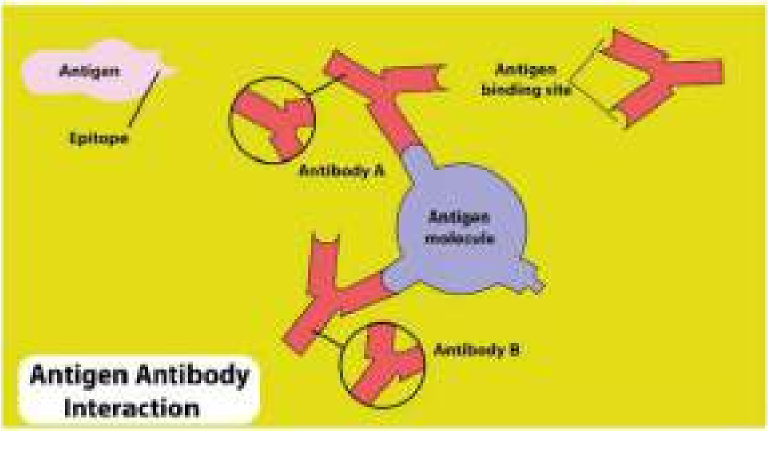

Figure2: Antigen-Antibody Interaction (Source: https://microbenotes.com)

Principle: Radioimmunoassay (RIA)

Formation of Ag-Ab complex by the specific binding of antibodies and antigens. The antigen can be tagged or coupled with radioisotopes. When it comes to binding on particular antibody paratopes, the sample's unlabeled antigens compete with radio-labeled antigens. The labeled antigens that have previously been

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connected to the antibodies are replaced by the unlabeled antigens. Antibodies bind with unlabeled antigens, thereby increasing the number of radiolabeled antigens in a solution. As a result, the amount of bound unlabeled antigens is closely correlated with the concentration of free labeled antigens.

Three principles are combined in this process.

1. In response to an antigen, an antibody binds, a competition binding reaction takes place, or a displacement reaction takes place. (It gives specificity).

2. Measurement of ray's emission from solution. (It gives sensitivity).

Method of Radioimmunoassay (RIA)

- Microtitre wells contain specific antibodies of known concentrations layered with hot antigens to make sure they are completely bound. If any unbound antigens remain in the wells, the radioactivity of the well will reach its maximum at this point.

- As soon as the unlabeled antigens are added to a well, they will bind to the antibodies and leave free labeled antigens. A gamma counter is then used to measure the radioactivity of the wells after washing carefully to remove these free labeled antigens.

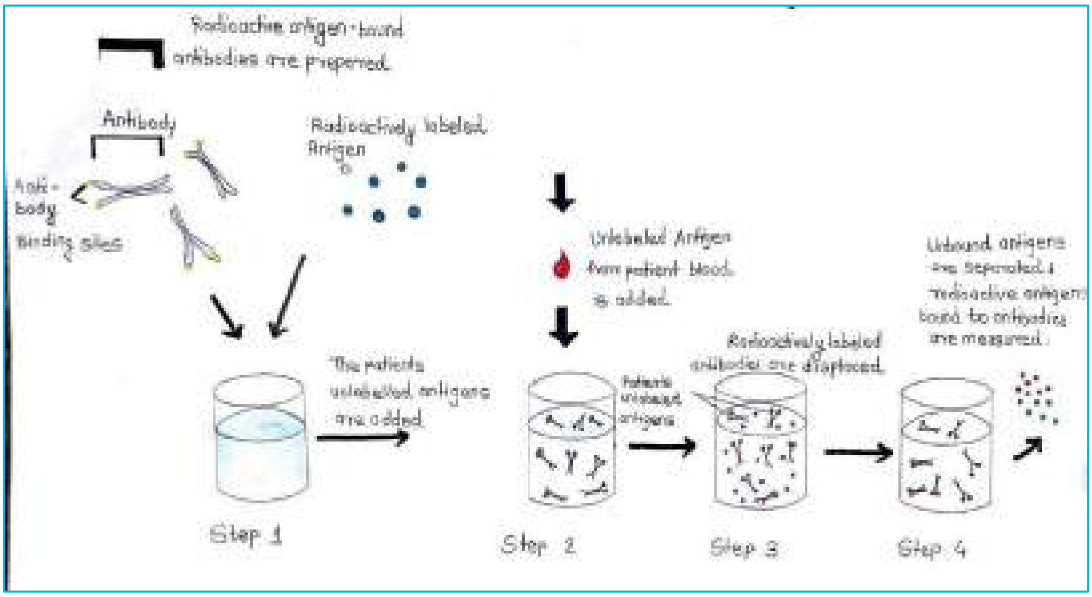

Figure: 3: Radioimmunoassay (RIA) technique Procedure. Image Source: Madeleine and Howell-Moroney, 2022.

Result Analysis for RIA

- Radioactivity will peak when the tagged antigens first attach to the antibodies.
- As the sample binds to antibodies and releases tagged antigens, the sample's radioactivity will drop.
- Therefore, it may be verified if the targeted antigen ligand is present in the sample by observing for signs of declining radioactivity. Additionally, it can be deemed a negative result if the radioactivity occurs unchanged.
- The radioactivity drops as the concentration of unlabeled antigens rises. A standard curve is created by charting the relationship between the concentration of unlabeled antigens and radioactivity (in percentage).
- To ascertain the antigen concentration, the sample to be tested is run in parallel using a similar protocol, and the radioactivity detected is calibrated using the standard curve.

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Radioimmunoassay (RIA) Applications

- Initially, it was employed for peptide hormone detection.
- Screening of several viral antigens
- Identification of several hormones and medications
- The identification of mycotoxins
- Detection of surface antigens
- Early detection of malignancy

Radioimmunoassay (RIA) Advantages

- Significant specificity and sensitivity of RIA method
- Detection of low amount antigen or antibodies.

Radioimmunoassay (RIA) Limitations

- Working with radioactive substances will be risky.
- Disposal of radioactive substances can be added up in ecosystem.
- Apparatus and reagents are costly.
- Radio-labeled substances have a less half-life.

Nuclear Medicine in Radio-pharmaceuticals

Radio-drugs are drugs containing radioactive isotopes. Both indicative and restorative services can be provided by them. Radio-drugs produce radiation themselves, unlike different media that retain or adjust outside electromagnetism or ultrasound after interaction with ligands or medication atoms. Radio-pharmacology is the division of pharmacology that exceptionally manages isotopes. The initial gathering of these mixtures is the radio-tracers used to analyze brokenness in body tissues. However radio-drugs are the most seasoned and stay the most well-known of such medications. Now a days there are potential and promising changes occur in these drugs for pharmacological solutions.

Examples of some of nuclear medicine radio-pharmaceuticals follow. ^{47}Ca gamma and beta emitter, ^{11}C is a positron emitter, ^{14}C is a beta emitter, ^{51}Cr is a gamma emitter,^{58}Co is a gamma emitter.

Summary

The spatial and temporal variations in the chemical composition of the human body are depicted in nuclear medicine. Since dynamics are the fundamental component of physiology and biochemistry, it is now evident that a static image of a biological system at one particular moment may be wholly insufficient. NM diagnostic approaches are often the best options for patients or experimental research due to their ability to identify functional dynamics as a result of their distinct functional content. As was already noted, nuclear medicine plays a major role in many fields where metabolic data is pertinent, including neurology, cardiology, oncology, orthopaedics, and others. Despite significant advancements in radiochemistry and radiopharmacology, the most commonly utilized radioisotope in diagnostic CNM (^{99m}Tc) from four decades ago, and is being reliably used at low cost, low radiation dose and convenient chemical properties.

The development of ligands tagged with ^{99m}Tc and ^{123}I for SPECT and ^{18}F or ^{11}C for PET, which interacts with receptors in neuron system, cancer, and cardiology, is the subject of current study in numerous laboratories throughout the world. New CZT gamma camera's improved performance and true mobility. Additionally, nuclear medicine may be able to establish functional diagnostics thanks to newly developed radio-pharmaceuticals. The mathematical methods for physiological translation and system are viewed as together in a similar segment. General parts of information handling techniques, including picture handling and computerized reasoning, are

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momentarily broke down. The numerical apparatuses that are most frequently used to help the understanding of organic peculiarities in atomic medication are thought of; these incorporate convolution and deconvolution strategies, Fourier examination, factorial investigation and brain organizing

Despite its potential, radionuclide treatment actually possesses an optional situation in contrast with elective treatment modalities for various reasons. Then again, contrasted with chemotherapy, immunotherapy, and outside pillar radiation, radionuclide treatment is less meddling and perilous. The administration of disease patients can be extraordinarily improved by progressing radionuclide treatment in treatment regimens, as this will boost the strategy's viability from an ontological stance.

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