Nuclear Medicine Technique

Abstract:

Molecular imaging is emerging as an exciting new discipline that deals with imaging of disease on a cellular or genetic level. Nuclear medicine has traditionally focused on non-invasive imaging of in vivo physiology using radiolabeled tracers. As such, molecular imaging has its roots in nuclear medicine and in many ways is a direct extension of this field. The myriad of biological processes that may be targeted for molecular nuclear imaging can be grouped into direct and indirect strategies, depending on the type of imaging probe. The direct strategy uses de novo synthesis of molecular probes targeted to a specific molecular marker such as a receptor, transporter, or enzyme. For each novel target, new radiolabeled compounds are required as well as characterization of their detection sensitivity, interaction specificity, pharmacokinetics of delivery, and signal-to-noise ratio. The indirect strategy entails the use of a pre targeting molecule that is subsequently activated upon occurrence of a specific molecular event, which in turn is targeted by a specific molecular radio probe. Reporter gene imaging falls into this category and provides a rapid and convenient tool to monitor gene expression by yielding a phenotype that is readily imaged upon expression. The remarkable efforts currently focused on the molecu-

lar nuclear technology signify its importance and wide range of application. With continued improvements in instrumentation, identification of novel targets, and design of better radio probes, molecular nuclear imaging promises to play an increasingly important role in disease diagnosis and therapy.

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Introduction:

Nuclear medicine is a medical specialty involving the application of radioactive substances in the diagnosis and treatment of disease. Nuclear medicine imaging, in a sense, is "radiology done inside out" or "endoradiology" because it records radiation emitting from within the body rather than radiation that is generated by external sources like X-rays. In addition, nuclear medicine scans differ from radiology, as the emphasis is not on imaging anatomy, but on the function. For such reason, it is called a physiological imaging modality. Single photon emission computed tomography (SPECT) and positron emission tomography (PET) scans are the two most common imaging modalities in nuclear medicine.Nuclear medicine uses small amounts of radioactive material called radiotracers. Doctors use nuclear medicine to diagnose, evaluate, and treat various diseases. These include cancer, heart disease, gastrointestinal, endocrine, or neurological disorders, and other conditions. Nuclear medicine exams pinpoint molecular activity. This gives them the potential to find disease in its earliest stages. They can also show whether you are responding to treatment.

Nuclear medicine Technique:

Nuclear medicine uses a special gamma camera and single-photon emission-computed tomography (SPECT) imaging techniques. The gamma camera records the energy emissions from the radiotracer in your body and converts it into an image. The gamma camera itself does not emit any radiation.

Diagnosis:

Nuclear medicine is noninvasive. Except for intravenous injections, it is usually painless. These tests use radioactive materials called radiopharmaceuticals or radiotracers to help diagnose and assess medical conditions.

Radiotracers are molecules linked to, or ”labeled” with, a small amount of radioactive material. They accumulate in tumors or regions of inflammation. They can also bind to specific proteins in the body. The most common radiotracer is F-18 fluorodeoxyglucose (FDG), a molecule similar to glucose. Cancer cells are more metabolically active and may absorb glucose at a higher rate. This higher rate can be seen on PET scans. This

allows your doctor to detect disease before it may be seen on other imaging tests. FDG is just one of many radiotracers in use or in development.
You will usually receive the radiotracer in an injection. Or you may swallow it or inhale it as a gas, depending on the exam. It accumulates in the area under examination. A special camera detects gamma ray emissions from the radiotracer. The camera and a computer produce pictures and supply molecular information.
Many imaging centers combine nuclear medicine images with computed tomography (CT) or magnetic resonance imaging (MRI) to produce special views. Doctors call this image fusion or co-registration. Image fusion allows the doctor to connect and interpret information from two different exams on one image. This leads to more precise information and a more exact diagnosis. Single photon emission CT/CT (SPECT/CT) and positron emission tomography/CT (PET/CT) units can perform both exams at the same time. PET/MRI is an emerging imaging technology. It is not currently available everywhere.

Therapy :
Nuclear medicine also offers therapeutic procedures, such as radioactive iodine (I-131) therapy that use small amounts of radioactive material to treat cancer and other medical conditions affecting the thyroid gland, as well as treatments for other cancers and medical conditions.
Non-Hodgkin's lymphoma patients who do not respond to chemotherapy may undergo radioimmunotherapy (RIT).
Radioimmunotherapy (RIT) is a personalized cancer treatment that combines radiation therapy with the targeting ability of im-

munotherapy, a treatment that mimics cellular activity in the body's immune system. See the Radioimmunotherapy (RIT) page for more information.

What is nuclear medicine :

Nuclear medicine is a specialized area of radiology that uses very small amounts of radioactive materials, or radiopharmaceuticals, to examine organ function and structure. Nuclear medicine imaging is a combination of many different disciplines. These include chemistry, physics, mathematics, computer technology, and medicine. This branch of radiology is often used to help diagnose and treat abnormalities very early in the progression of a disease, such as thyroid cancer.
Because X-rays pass through soft tissue, such as intestines, muscles, and blood vessels, these tissues are difficult to visualize on a standard X-ray, unless a contrast agent is used. This allows the tissue to be seen more clearly. Nuclear imaging enables visualization of organ and tissue structure as well as function. The extent to which a radiopharmaceutical is absorbed, or "taken up," by a particular organ or tissue may indicate the level of function of the organ or tissue being studied. Thus, diagnostic X-rays are used primarily to study anatomy. Nuclear imaging is used to study organ and tissue function.
A tiny amount of a radioactive substance is used during the procedure to assist in the exam. The radioactive substance, called a radionuclide (radiopharmaceutical or radioactive tracer), is absorbed by body tissue. Several different types of radionuclides are available. These include forms of the elements technetium, thallium, gallium, iodine, and xenon. The type of radionuclide

used will depend on the type of study and the body part being studied.

After the radionuclide has been given and has collected in the body tissue under study, radiation will be given off. This radiation is detected by a radiation detector. The most common type of detector is the gamma camera. Digital signals are produced and stored by a computer when the gamma camera detects the radiation.

By measuring the behavior of the radionuclide in the body during a nuclear scan, the healthcare provider can assess and diagnose various conditions, such as tumors, infections, hematomas, organ enlargement, or cysts. A nuclear scan may also be used to assess organ function and blood circulation.

The areas where the radionuclide collects in greater amounts are called "hot spots." The areas that do not absorb the radionuclide and appear less bright on the scan image are referred to as "cold spots."

In planar imaging, the gamma camera remains stationary. The resulting images are two-dimensional (2D). Single photon emission computed tomography, or SPECT, produces axial "slices" of the organ in question because the gamma camera rotates around the patient. These slices are similar to those performed by a CT scan. In certain instances, such as PET scans, three-dimensional (3D) images can be performed using the SPECT data.

Nuclear medicine scans :

Scans are used to diagnose many medical conditions and diseases. Some of the more common tests include the following:

Renal scans. These are used to examine the kidneys and to find any abnormalities. These include abnormal function or obstruction of the renal blood flow.

Thyroid scans. These are used to evaluate thyroid function or to better evaluate a thyroid nodule or mass.

Bone scans. These are used to evaluate any degenerative and/or arthritic changes in the joints, to find bone diseases and tumors, and/or to determine the cause of bone pain or inflammation.

Gallium scans. These are used to diagnose active infectious and/or inflammatory diseases, tumors, and abscesses.

Heart scans. These are used to identify abnormal blood flow to the heart, to determine the extent of the damage of the heart muscle after a heart attack, and/or to measure heart function.

Brain scans. These are used to investigate problems within the brain and/or in the blood circulation to the brain.

Breast scans. These are often used in conjunction with mammograms to locate cancerous tissue in the breast.

Diagnostic medical imaging

Diagnostic

In nuclear medicine imaging, radiopharmaceuticals are taken internally, for example, through inhalation, intravenously or orally. Then, external detectors (gamma cameras) capture and form images from the radiation emitted by the radiopharmaceuticals. This process is unlike a diagnostic X-ray, where external radiation is passed through the body to form an image.

3D:

SPECT is a 3D tomographic technique that uses gamma camera data from many projections and can be reconstructed in different planes. Positron emission tomography (PET) uses coincidence detection to image functional processes.Nuclear medicine tests differ from most other imaging modalities in that diagnostic tests primarily show the physiological function of the system being investigated as opposed to traditional anatomical imaging such as CT or MRI. Nuclear medicine imaging studies are generally more organ-, tissue- or disease-specific (e.g.: lungs scan, heart scan, bone scan, brain scan, tumor, infection, Parkinson etc.) than those in conventional radiology imaging, which focus on a particular section of the body (e.g.: chest X-ray, abdomen/pelvis CT scan, head CT scan, etc.). In addition, there are nuclear medicine studies that allow imaging of the whole body based on certain cellular receptors or functions. Examples are whole body PET scans or PET/CT scans, gallium scans, indium white blood cell scans, MIBG and octreotide scans.

Hybrid scanning techniques:

In some centers, the nuclear medicine scans can be superimposed, using software or hybrid cameras, on images from modalities such as CT or MRI to highlight the part of the body in which the radiopharmaceutical is concentrated. This practice is often referred to as image fusion or co-registration, for example SPECT/CT and PET/CT. The fusion imaging technique in nuclear medicine provides information about the anatomy and function, which would otherwise be unavailable or would require a more invasive procedure or surgery.

Radioactive tracers :

Radioactive tracers are made up of carrier molecules that are bonded tightly to a radioactive atom. These carrier molecules vary greatly depending on the purpose of the scan. Some tracers employ molecules that interact with a specific protein or sugar in the body and can even employ the patient's own cells. For example, in cases where doctors need to know the exact source of intestinal bleeding, they may radiolabel (add radioactive atoms) to a sample of red blood cells taken from the patient. They then reinject the blood and use a SPECT scan to follow the path of the blood in the patient. Any accumulation of radioactivity in the intestines informs doctors of where the problem lies.For most diagnostic studies in nuclear medicine, the radioactive tracer is administered to a patient by intravenous injection. However a radioactive tracer may also be administered by inhalation, by oral ingestion, or by direct injection into an organ. The mode of tracer administration will depend on the disease process that is to be studied.

Benifits:

Provides information on how organs, tissues, and cells are working. (Other common imaging procedures only show the structures.)

Can be used also in targeted treatments to kill or damage harmful or cancerous cells, reduce the size of tumors, or reduce pain.

Risk:

Radiation doses are usually higher than in common imaging like x-rays. This means these procedures are slightly more likely to increase the possibility you may get cancer later in life. Some nuclear medicine procedures are longer and use more radiation than others. These could cause skin reddening and hair loss. You may give off small amounts of radiation right after your procedure and need to take steps to protect others from exposure.

Conclusion:

The end result of the nuclear medicine imaging process is a dataset comprising one or more images. In multi-image datasets the array of images may represent a time sequence (i.e. cine or movie) often called a ”dynamic” dataset, a cardiac gated time sequence, or a spatial sequence where the gamma-camera is moved relative to the patient. SPECT (single photon emission computed tomography) is the process by which images acquired from a rotating gamma-camera are reconstructed to produce an image of a ”slice” through the patient at a particular position. A collection of parallel slices form a slice-stack, a three-dimensional representation of the distribution of radionuclide in the patient.

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