



General Nuclear Medicine

Nuclear medicine imaging uses small amounts of radioactive materials called radiotracers that are typically injected into the bloodstream, inhaled or swallowed. The radiotracer travels through the area being examined and gives off energy in the form of gamma rays which are detected by a special camera and a computer to create images of the inside of your body. Nuclear medicine imaging provides unique information that often cannot be obtained using other imaging procedures and offers the potential to identify disease in its earliest stages.



Tell your doctor if there's a possibility you are pregnant or if you are breastfeeding and discuss any recent illnesses, medical conditions, allergies and medications you're taking. Depending on the type of exam, your doctor will instruct you on what you may eat or drink beforehand, especially if sedation (anesthesia) is to be used. Leave jewelry at home and wear loose, comfortable clothing. You may be asked to wear a gown.

What is General Nuclear Medicine?

Nuclear medicine is a branch of medical imaging that uses small amounts of radioactive material to diagnose and determine the severity of or treat a variety of diseases, including many types of cancers, heart disease, gastrointestinal, endocrine, neurological disorders and other abnormalities within the body. Because nuclear medicine procedures are able to pinpoint molecular activity within the body, they offer the potential to identify disease in its earliest stages as well as a patient's immediate response to therapeutic interventions.

Diagnosis

Nuclear medicine imaging procedures are noninvasive and, with the exception of intravenous injections, are usually painless medical tests that help physicians diagnose and evaluate medical conditions. These imaging scans use radioactive materials called radiopharmaceuticals or radiotracers.

Radiotracers are molecules linked to, or "labeled" with, a small amount of radioactive material that can be

detected on the PET scan. They are designed to accumulate in cancerous tumors or regions of inflammation. They can also be made to bind to specific proteins in the body. The most commonly used radiotracer is F-18 fluorodeoxyglucose, or FDG, a molecule similar to glucose. Cancer cells may absorb glucose at a higher rate, being more metabolically active. This higher rate can be seen on PET scans, and that allows your doctor to identify disease before it may be seen on other imaging tests. FDG is just one of many radiotracers in use or in development for a variety of conditions throughout the body.

Depending on the type of nuclear medicine exam, the radiotracer is either injected into the body, swallowed or inhaled as a gas and eventually accumulates in the organ or area of the body being examined. Radioactive emissions from the radiotracer are detected by a special camera or imaging device that produces pictures and provides molecular information.

In many centers, nuclear medicine images can be superimposed with computed tomography (CT) or magnetic resonance imaging (MRI) to produce special views, a practice known as image fusion or co-registration. These views allow the information from two different exams to be correlated and interpreted on one image, leading to more precise information and accurate diagnoses. In addition, manufacturers are now making single photon emission computed tomography/computed tomography (SPECT/CT) and positron emission tomography/computed tomography (PET/CT) units that are able to perform both imaging exams at the same time. An emerging imaging technology, but not readily available at this time is PET/MRI.

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

What are some common uses of the procedure?

Physicians use nuclear medicine imaging procedures to visualize the structure and function of an organ, tissue, bone or system within the body.

In adults, nuclear medicine is used to:

Heart

- visualize heart blood flow and function (such as a myocardial perfusion scan)
- detect coronary artery disease and the extent of coronary stenosis
- assess damage to the heart following a heart attack
- evaluate treatment options such as bypass heart surgery and angioplasty
- evaluate the results of revascularization (blood flow restoration) procedures

- detect heart transplant rejection
- evaluate heart function before and after chemotherapy (MUGA)

Lungs

- scan lungs for respiratory and blood flow problems
- assess differential lung function for lung reduction or transplant surgery
- detect lung transplant rejection

Bones

- evaluate bones for fractures, infection and arthritis
- evaluate for metastatic bone disease
- evaluate painful prosthetic joints
- evaluate bone tumors
- identify sites for biopsy

Brain

- investigate abnormalities in the brain in patients with certain symptoms or disorders, such as seizures, memory loss and suspected abnormalities in blood flow
- detect the early onset of neurological disorders such as Alzheimer's disease
- assist in surgical planning and identify the areas of the brain that may be causing seizures
- evaluate for abnormalities in a chemical in the brain involved in controlling movement in patients with suspected Parkinson's disease or related movement disorders
- evaluation for suspected brain tumor recurrence, surgical or radiation planning or localization for biopsy

Other Systems

- identify inflammation or abnormal function of the gallbladder
- identify bleeding into the bowel
- assess post-operative complications of gallbladder surgery
- evaluate lymphedema
- evaluate fever of unknown origin
- locate the presence of infection
- measure thyroid function to detect an overactive or underactive thyroid
- help diagnose hyperthyroidism and blood cell disorders
- evaluate for hyperparathyroidism (overactive parathyroid gland)
- evaluate stomach emptying
- evaluate spinal fluid flow and potential spinal fluid leaks

In adults and children, nuclear medicine is also used to:

Cancer

- stage cancer by determining the presence or spread of cancer in various parts of the body
- localize sentinel lymph nodes before surgery in patients with breast cancer or skin and soft tissue tumors

- plan treatment
- evaluate response to therapy
- detect the recurrence of cancer
- detect rare tumors of the pancreas and adrenal glands

Renal

- analyze native and transplant kidney blood flow and function
- detect urinary tract obstruction
- evaluate for hypertension (high blood pressure) related to the kidney arteries
- evaluate kidneys for infection versus scar
- detect and follow-up urinary reflux

In children, nuclear medicine is also used to:

- investigate abnormalities in the esophagus, such as esophageal reflux or motility disorders
- evaluate the openness of tear ducts
- evaluate the openness of ventricular shunts in the brain
- assess congenital heart disease for shunts and pulmonary blood flow

Nuclear medicine therapies include:

- Radioactive iodine (I-131) therapy used to treat some causes of hyperthyroidism (overactive thyroid gland, for example, Graves' disease) and thyroid cancer
- Radioactive antibodies used to treat certain forms of lymphoma (cancer of the lymphatic system)
- Radioactive phosphorus (P-32) used to treat certain blood disorders
- Radioactive materials used to treat painful tumor metastases to the bones
- I-131 MIBG (radioactive iodine labeled with metaiodobenzylguanidine) used to treat adrenal gland tumors in adults and adrenal gland/nerve tissue tumors in children

How should I prepare?

You may be asked to wear a gown during the exam or you may be allowed to wear your own clothing.

Women should always inform their physician or technologist if there is any possibility that they are pregnant or if they are breastfeeding. See the Safety page for more information about pregnancy and breastfeeding related to nuclear medicine imaging.

You should inform your physician and the technologist performing your exam of any medications you are taking, including vitamins and herbal supplements. You should also inform them if you have any allergies and about recent illnesses or other medical conditions.

Jewelry and other metallic accessories should be left at home if possible, or removed prior to the exam because they may interfere with the procedure.

You will receive specific instructions based on the type of scan you are undergoing.

In some instances, certain medications or procedures may interfere with the examination ordered. See the Radioactive Iodine (I-131) Therapy page for instructions on how to prepare for the procedure.

What does the equipment look like?

The special camera and imaging techniques used in nuclear medicine include the gamma camera and single-photon emission-computed tomography (SPECT).

The gamma camera, also called a scintillation camera, detects radioactive energy that is emitted from the patient's body and converts it into an image. The gamma camera itself does not emit any radiation. The gamma camera is composed of radiation detectors, called gamma camera heads, which are encased in metal and plastic and most often shaped like a box, attached to a round circular donut shaped gantry. The patient lies on the examination table which slides in between two parallel gamma camera heads that are positioned above the patient and beneath the examination table. Sometimes, the gamma camera heads are oriented at a 90 degree angle and placed over the patient's body.

SPECT involves the rotation of the gamma camera heads around the patient's body to produce more detailed, three-dimensional images.

A PET scanner is a large machine with a round, donut shaped hole in the middle, similar to a CT or MRI unit. Within this machine are multiple rings of detectors that record the emission of energy from the radiotracer in your body.

A computer aids in creating the images from the data obtained by the gamma camera.

A probe is a small hand-held device resembling a microphone that can detect and measure the amount of the radiotracer in a small area of your body.

There is no specialized equipment used during radioactive iodine therapy, but the technologist or other personnel administering the treatment may cover your clothing and use lead containers to shield the radioactive material you will be receiving.

How does the procedure work?

With ordinary x-ray examinations, an image is made by passing x-rays through the patient's body. In contrast, nuclear medicine procedures use a radioactive material, called a radiopharmaceutical or radiotracer, which is injected into the bloodstream, swallowed or inhaled as a gas. This radioactive material accumulates in the organ or area of your body being examined, where it gives off a small amount of energy in the form of gamma rays. Special cameras detect this energy, and with the help of a computer, create pictures offering details on both the structure and function of organs and tissues in your body.

Unlike other imaging techniques, nuclear medicine imaging exams focus on depicting physiologic processes within the body, such as rates of metabolism or levels of various other chemical activity, instead of showing anatomy and structure. Areas of greater intensity, called "hot spots," indicate where large amounts of the radiotracer have accumulated and where there is a high level of chemical or

metabolic activity. Less intense areas, or "cold spots," indicate a smaller concentration of radiotracer and less chemical activity.

In radioactive iodine (I-131) therapy for thyroid disease, radioactive iodine (I-131) is swallowed, absorbed into the bloodstream in the gastrointestinal (GI) tract and absorbed from the blood by the thyroid gland where it destroys cells within that organ.

Radioimmunotherapy (RIT) is a combination of radiation therapy and immunotherapy. In immunotherapy, a laboratory-produced molecule called a monoclonal antibody is engineered to recognize and bind to the surface of cancer cells. Monoclonal antibodies mimic the antibodies naturally produced by the body's immune system that attack invading foreign substances, such as bacteria and viruses.

In RIT, a monoclonal antibody is paired with a radioactive material. When injected into the patient's bloodstream, the antibody travels to and binds to the cancer cells, allowing a high dose of radiation to be delivered directly to the tumor.

In I-131MIBG therapy for neuroblastoma, the radiotracer is administered by injection into the blood stream. The radiotracer binds to the cancer cells allowing a high dose of radiation to be delivered to the tumor.

How is the procedure performed?

Nuclear medicine imaging is usually performed on an outpatient basis, but is often performed on hospitalized patients as well.

You will be positioned on an examination table. If necessary, a nurse or technologist will insert an intravenous (IV) catheter into a vein in your hand or arm.

Depending on the type of nuclear medicine exam you are undergoing, the dose of radiotracer is then injected intravenously, swallowed or inhaled as a gas.

It can take anywhere from several seconds to several days for the radiotracer to travel through your body and accumulate in the organ or area being studied. As a result, imaging may be done immediately, a few hours later, or even several days after you have received the radioactive material.

When it is time for the imaging to begin, the camera or scanner will take a series of images. The camera may rotate around you or it may stay in one position and you may be asked to change positions in between images. While the camera is taking pictures, you will need to remain still for brief periods of time. In some cases, the camera may move very close to your body. This is necessary to obtain the best quality images. If you are claustrophobic, you should inform the technologist before your exam begins.

If a probe is used, this small hand-held device will be passed over the area of the body being studied to measure levels of radioactivity. Other nuclear medicine tests measure radioactivity levels in blood, urine or breath.

The length of time for nuclear medicine procedures varies greatly, depending on the type of exam. Actual scanning time for nuclear imaging exams can take from 20 minutes to several hours and may be conducted over several days.

Young children may require gentle wrapping or sedation to help them hold still. If your doctor feels sedation is needed for your child, you will receive specific instructions regarding when and if you can feed your child on the day of the exam. A physician or nurse who specializes in pediatric anesthesia will be available during the exam to ensure your child's safety while under the effects of sedation. When scheduling the exam for a young child, ask if a child life specialist is available. A child life specialist is trained to make your child comfortable and less anxious without sedation and will help your child to remain still during the examination.

When the examination is completed, you may be asked to wait until the technologist checks the images in case additional images are needed. Occasionally, more images are obtained for clarification or better visualization of certain areas or structures. The need for additional images does not necessarily mean there was a problem with the exam or that something abnormal was found, and should not be a cause of concern for you.

If you had an intravenous line inserted for the procedure, it will usually be removed unless you are scheduled for an additional procedure that same day that requires an intravenous line.

For patients with thyroid disease who undergo radioactive iodine (I-131) therapy, which is most often an outpatient procedure, the radioactive iodine is swallowed, either in capsule or liquid form.

Radioimmunotherapy (RIT), also typically an outpatient procedure, is delivered through injection.

I-131MIBG therapy for neuroblastoma is administered by injection into the blood stream. Children are admitted to the hospital for treatment as an inpatient and will stay overnight in a specially prepared room. Special arrangements are made for parents to allow participation in the care of their child while undergoing this therapy.

What will I experience during and after the procedure?

Except for intravenous injections, most nuclear medicine procedures are painless and are rarely associated with significant discomfort or side effects.

When the radiotracer is given intravenously, you will feel a slight pin prick when the needle is inserted into your vein for the intravenous line. When the radioactive material is injected into your arm, you may feel a cold sensation moving up your arm, but there are generally no other side effects.

When swallowed, the radiotracer has little or no taste. When inhaled, you should feel no differently than when breathing room air or holding your breath.

With some procedures, a catheter may be placed into your bladder, which may cause temporary discomfort.

It is important that you remain still while the images are being recorded. Though nuclear imaging itself causes no pain, there may be some discomfort from having to remain still or to stay in one particular position during imaging.

Unless your physician tells you otherwise, you may resume your normal activities after your nuclear medicine scan. If any special instructions are necessary, you will be informed by a technologist, nurse or

physician before you leave the nuclear medicine department.

Through the natural process of radioactive decay, the small amount of radiotracer in your body will lose its radioactivity over time. It may also pass out of your body through your urine or stool during the first few hours or days following the test. You should also drink plenty of water to help flush the radioactive material out of your body as instructed by the nuclear medicine personnel.

See Safety in Nuclear Medicine Procedures for more information.

You will be informed as to how often and when you will need to return to the nuclear medicine department for further procedures.

Who interprets the results and how do I get them?

A radiologist or other physician who has specialized training in nuclear medicine will interpret the images and send a report to your referring physician.

What are the benefits vs. risks?

Benefits

- Nuclear medicine examinations provide unique information—including details on both function and anatomic structure of the body that is often unattainable using other imaging procedures.
- For many diseases, nuclear medicine scans yield the most useful information needed to make a diagnosis or to determine appropriate treatment, if any.
- A nuclear medicine scan is less expensive and may yield more precise information than exploratory surgery.
- Nuclear medicine offers the potential to identify disease in its earliest stage, often before symptoms occur or abnormalities can be detected with other diagnostic tests.
- By detecting whether lesions are likely benign or malignant, PET scans may eliminate the need for surgical biopsy or identify the best biopsy location.
- PET scans may provide additional information that is used for radiation therapy planning.

Risks

- Because the doses of radiotracer administered are small, diagnostic nuclear medicine procedures result in relatively low radiation exposure to the patient, acceptable for diagnostic exams. Thus, the radiation risk is very low compared with the potential benefits.
- Nuclear medicine diagnostic procedures have been used for more than five decades, and there are no known long-term adverse effects from such low-dose exposure.
- The risks of the treatment are always weighed against the potential benefits for nuclear medicine therapeutic procedures. You will be informed of all significant risks prior to the treatment and have an opportunity to ask questions.
- Allergic reactions to radiopharmaceuticals may occur but are extremely rare and are usually mild.

Nevertheless, you should inform the nuclear medicine personnel of any allergies you may have or other problems that may have occurred during a previous nuclear medicine exam.

- Injection of the radiotracer may cause slight pain and redness which should rapidly resolve.
- Women should always inform their physician or radiology technologist if there is any possibility that they are pregnant or if they are breastfeeding. See the Safety page for more information about pregnancy, breastfeeding and nuclear medicine exams.

What are the limitations of General Nuclear Medicine?

Nuclear medicine procedures can be time consuming. It can take several hours to days for the radiotracer to accumulate in the body part of interest and imaging may take up to several hours to perform, though in some cases, newer equipment is available that can substantially shorten the procedure time.

The resolution of structures of the body with nuclear medicine may not be as high as with other imaging techniques, such as CT or MRI. However, nuclear medicine scans are more sensitive than other techniques for a variety of indications, and the functional information gained from nuclear medicine exams is often unobtainable by other imaging techniques.

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