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 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.

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 immunotherapy, a treatment that mimics cellular activity in the body's immune system. See the Radioimmunotherapy (RIT) page (https://www.radiologyinfo.org/en/info/radio-immuno) 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 (https://www.radiologyinfo.org/en/info/alzheimers)
• 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 wear a gown during the exam or be allowed to wear your own clothing.

Women should always tell their doctor and technologist if they are pregnant or breastfeeding. See the Safety in X-ray, Interventional Radiology and Nuclear Medicine Procedures (https://www.radiologyinfo.org/en/info/safety-radiation) page for more information about pregnancy and breastfeeding related to nuclear medicine imaging.

Tell the doctor and your exam technologist about any medications you are taking, including vitamins and herbal supplements. List any allergies, recent illnesses, and other medical conditions.

Leave jewelry and accessories at home or remove them prior to the exam. These objects may interfere with the procedure.

Your doctor will tell you how to prepare for your specific exam.

In some instances, certain medications or procedures may interfere with the examination ordered. See the Radioactive Iodine (I-131) Therapy (https://www.radiologyinfo.org/en/info/radioiodine) page for instructions on how to prepare for the procedure.

What does the equipment look like?

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. It has radiation detectors called gamma camera heads. These are encased in metal and plastic, often shaped like a box, and attached to a round, donut-shaped gantry. The patient lies on an exam table that slides in between two parallel gamma camera heads, above and beneath the patient. Sometimes, the doctor will orient the gamma camera heads at a 90-degree angle over the patient's body.

In SPECT, the gamma camera heads rotate around the patient's body to produce detailed, three-dimensional images.

A PET scanner is a large machine with a round, donut-shaped hole in the middle. It looks like a CT or MRI unit. Multiple rings of detectors inside the machine record the energy emissions from the radiotracer in your body.

A computer creates the images using the data from the gamma camera.

A probe is a small hand-held device resembling a microphone. It measures the amount of radiotracer in an 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?
Ordinary x-ray exams pass x-rays through the body to create an image. Nuclear medicine uses radioactive materials called radiopharmaceuticals or radiotracers. Your doctor typically injects this material into your bloodstream. Or you may swallow it or inhale it as a gas. The material accumulates in the area under examination, where it gives off gamma rays. Special cameras detect this energy and, with the help of a computer, create pictures that detail how your organs and tissues look and function.

Unlike other imaging techniques, nuclear medicine focuses on processes within the body. These include rates of metabolism or levels of various other chemical activities. Areas of greater intensity are called “hot spots.” These may show large concentrations of the radiotracer 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 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 bloodstream. The radiotracer binds to the cancer cells allowing a high dose of radiation to be delivered to the tumor.

**How is the procedure performed?**

Doctors perform nuclear medicine exams on outpatients and hospitalized patients.

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

For most exams, you will receive an injection of the radiotracer. Or, you may swallow it or inhale it as a gas.

The radiotracer can take several seconds to several days to travel through your body and accumulate in the area under study. Imaging may take place immediately, in a few hours, or several days later.

When imaging begins, the camera or scanner will take a series of images. The camera may rotate around you or stay in one position. You may need to change positions in between images. While the camera is taking pictures, you will need to remain still for brief periods. In some cases, the camera may move very close to your body. This is necessary to obtain the best quality images. Tell the technologist if you have a fear of closed spaces before your exam begins.

The technologist may pass a small hand-held probe over the body to measure radioactivity levels. Other 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.
After the exam, you may need to wait until the technologist determines if more images are needed. Sometimes, the technologist takes more images to clarify or better visualize certain areas or structures. The need for more images does not necessarily mean there was a problem with the exam or that something is abnormal. It should not cause you concern.

If you have an intravenous (IV) line for the procedure, your technologist will usually remove it. The technologist will leave it in place if you are to have another procedure that same day that requires an IV 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. Reports of significant discomfort or side effects are rare.

You will feel a slight pin prick when the technologist inserts the needle into your vein for the intravenous line. You may feel a cold sensation moving up your arm during the radiotracer injection. Generally, there are no other side effects.

Radiotracers have little or no taste. Inhaling a radiotracer feels no different than breathing the air around you or holding your breath.

With some procedures, the technologist may place a catheter into your bladder. This may cause temporary discomfort.

It is important to remain still during the exam. Nuclear imaging causes no pain. However, having to remain still or in one position for long periods may cause discomfort.

Unless your doctor tells you otherwise, you may resume your normal activities after your exam. A technologist, nurse, or doctor will provide you with any necessary special instructions before you leave.

The small amount of radiotracer in your body will lose its radioactivity over time through the natural process of radioactive decay. It may also pass out of your body through your urine or stool during the first few hours or days after the test. Drink plenty of water to help flush the material out of your body.


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 doctor specially trained in nuclear medicine will interpret the images and send a report to your referring physician.

**What are the benefits vs. risks?**

**Benefits**

- Nuclear medicine exams provide unique information that is often unattainable using other imaging procedures. This
information may include details on the function and anatomy of body structures.

- Nuclear medicine supplies the most useful diagnostic or treatment information for many diseases.
- 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 nuclear medicine exams use only a small dose of radiotracer, they have a relatively low radiation exposure. This is acceptable for diagnostic exams. Thus, the potential benefits of an exam outweigh the very low radiation risk.
- Doctors have been using nuclear medicine diagnostic procedures for more than six decades. There are no known long-term adverse effects from such low-dose exposure.
- Your doctor always weighs the benefits of nuclear medicine treatment against any risks. Your doctor will discuss the significant risks prior to treatment and give you an opportunity to ask questions.
- Allergic reactions to radiotracers are extremely rare and usually mild. Always tell the nuclear medicine personnel about any allergies you may have. Describe any problems you may have had during previous nuclear medicine exams.
- The radiotracer injection may cause slight pain and redness. This should rapidly resolve.
- Women should always tell their doctor and radiology technologist if there is any possibility that they are pregnant, or they are breastfeeding.


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 area of interest. Plus, imaging may take up to several hours to perform. In some cases, newer equipment can substantially shorten the procedure time.

The image resolution of nuclear medicine images may not be as high as that of CT or MRI. However, nuclear medicine scans are more sensitive for a variety of indications. The functional information they yield is often unobtainable using other imaging techniques.

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