Molecular Imaging and Thyroid Cancer

SNMMI SOCIETY OF NUCLEAR MEDICINE AND MOLECULAR IMAGING

Thyroid cancer starts in the thyroid gland, a butterfly-shaped gland located under the Adam's apple in the front of the neck.

According to the American Cancer Society, approximately 37,000 new cases of thyroid cancer were diagnosed and more than 1,600 people died from the disease in 2009.

Treatment of thyroid cancer includes surgery to remove all or most of the thyroid and possibly the lymph nodes in the neck, I-131 radiotherapy, external beam radiation therapy, chemotherapy, and thyroid hormone therapy.

New developments in molecular imaging technologies are dramatically improving the ways in which thyroid cancer is diagnosed and treated. Research in molecular imaging is also contributing to our understanding of the disease and directing more effective care of patients with thyroid cancer.

What is molecular imaging and how does it help people with thyroid cancers?

Molecular imaging is a type of medical imaging that provides detailed pictures of what is happening inside the body at the molecular and cellular level. Where other diagnostic imaging procedures—such as x-rays, computed tomography (CT) and ultrasound—predominantly offer anatomical pictures, molecular imaging allows physicians to see how the body is functioning and to measure its chemical and biological processes.

Molecular imaging offers unique insights into the human body that enable physicians to personalize patient care. In terms of diagnosis, molecular imaging is able to:

- provide information that is unattainable with other imaging technologies or that would require more invasive procedures such as biopsy or surgery
- identify disease in its earliest stages and determine the exact location of a tumor, often before symptoms occur or abnormalities can be detected with other diagnostic tests

As a tool for evaluating and managing the care of patients, molecular imaging studies help physicians:

- determine the extent or severity of the disease, including whether it has spread elsewhere in the body
- select the most effective therapy based on the unique biologic characteristics of the patient and the molecular properties of a tumor or other disease
- determine a patient's response to specific drugs
- accurately assess the effectiveness of a treatment regimen
- adapt treatment plans quickly in response to changes in cellular activity
- assess disease progression
- identify recurrence of disease and help manage ongoing care

Molecular imaging procedures are noninvasive, safe and painless.

How does molecular imaging work?

When disease occurs, the biochemical activity of cells begins to change. For example, cancer cells multiply at a much faster rate and are more active than normal cells. Brain cells affected by dementia consume less energy than normal brain cells. Heart cells deprived of adequate blood flow begin to die.

As disease progresses, this abnormal cellular activity begins to affect body tissue and structures, causing anatomical changes that may be seen on CT or MRI scans. For example, cancer cells may form a mass or tumor. With the loss of brain cells, overall brain volume may decrease or affected parts of the brain may appear different in density than the normal areas. Similarly, the heart muscle cells that are affected stop contracting and the overall heart function deteriorates.

Molecular imaging excels at detecting the cellular changes that occur early in the course of disease, often well before structural changes can be seen on CT and MR images.

Most molecular imaging procedures involve an imaging device and an imaging agent, or probe. A variety of imaging agents are used to visualize cellular activity, such as the chemical processes involved in metabolism, oxygen use or blood flow. In nuclear medicine, which is a branch of molecular imaging, the imaging agent is a radiotracer, a compound that includes a radioactive atom, or isotope. Other molecular imaging modalities, such as optical imaging and molecular ultrasound, use a variety of different agents. Magnetic resonance (MR) spectroscopy is able to measure chemical levels in the body, without the use of an imaging agent.

Once the imaging agent is introduced into the body, it accumulates in a target organ or attaches to specific cells. The imaging device detects the imaging agent and creates pictures that show how it is distributed in the body. This distribution pattern helps physicians discern how well organs and tissues are functioning.

What molecular imaging technologies are used for thyroid cancer?

The most commonly used molecular imaging procedure for diagnosing and guiding the treatment of thyroid cancer are radioiodine scans and positron emission tomography (PET) scanning, which is often used in conjunction with computed tomography (CT) scanning. I-131 radiotherapy is also used to treat thyroid cancer after the thyroid is surgically removed.

What is a radioiodine scan and how is it performed?

Radioiodine scanning involves using a small amount of radioactive iodine and a gamma camera to detect cancer cells. The patient either swallows a capsule of I-123, which is absorbed by the thyroid gland and thyroid cells located elsewhere in the body. Using a gamma camera, the front of the patient’s neck (or the entire body for a whole-body scan) is imaged several hours later to determine how the radioactive iodine has accumulated. Areas of the thyroid that absorb more iodine than surrounding tissue are called hot nodules and are not cancerous. Areas that absorb less iodine are called cold nodules and may be cancerous. However, cold nodules may also be benign. As a result, the radioiodine scan alone cannot be used to diagnose thyroid cancer.

Radioiodine scans are often used in conjunction with a biopsy to determine whether a patient has thyroid cancer. In addition, whole-body, I-131 radioiodine scans are very useful to determine whether the cancer has spread throughout the body.

Radioiodine scans are also used in the care and management of patients with differentiated thyroid cancer, which includes papillary, follicular and Hurthle cell thyroid cancers.

What is PET?

PET involves the use of an imaging device (PET scanner) and a radiotracer that is injected into the patient's bloodstream. A frequently used PET radiotracer is 18F-fluorodeoxyglucose (FDG), a compound derived from a simple sugar and a small amount of radioactive fluorine.

Once the FDG radiotracer accumulates in the body's tissues and organs, its natural decay includes emission of tiny particles called positrons that react with electrons in the body. This reaction, known as annihilation, produces energy in the form of a pair of photons. The PET scanner, which is able to detect these photons, creates three-dimensional images that show how the FDG is distributed in the area of the body being studied.

Areas where a large amount of FDG accumulates, called 'hot spots' because they appear more intense than surrounding tissue, indicate that a high level of chemical activity or metabolism is occurring there. Areas of low metabolic activity appear less intense and are sometimes referred to as 'cold spots.' Using these images and the information they provide, physicians are able to evaluate how well organs and tissues are working and to detect abnormalities.

PET-CT is a combination of PET and computed tomography (CT) that produces highly detailed views of the body. The combination of two imaging techniques—called co-registration, fusion imaging or hybrid imaging—allows information from two different types of scans to be viewed in a single set of images. CT imaging uses advanced x-ray equipment and in some cases a contrast-enhancing material to produce three dimensional images.

A combined PET-CT study is able to provide detail on both the anatomy and function of organs and tissues. This is accomplished by superimposing the precise location of abnormal metabolic activity (from PET) against the detailed anatomic image (from CT).

How is PET performed?

The procedure begins with an intravenous (IV) injection of a radiotracer, such as FDG, which usually takes between 30 and 60 minutes to distribute throughout the body. The patient is then placed in the PET scanner where special detectors are used to create a three dimensional image of the FDG distribution.

Scans are reviewed and interpreted by a qualified imaging professional such as a nuclear medicine physician or radiologist who shares the results with the patient's physician.

How is PET used for thyroid cancer?

Physicians use PET and PET-CT studies to:

- **diagnose and stage**: by determining the exact location of a tumor, the extent or stage of the disease and whether the cancer has spread in the body
- **plan treatment:** by selecting the most effective therapy based on the unique molecular properties of the disease and of the patient's genetic makeup
- **evaluate the effectiveness of treatment**: by determining the patient's response to specific drugs and ongoing therapy. Based on changes in cellular activity observed on PET-CT images, treatment plans can be quickly altered
- **manage ongoing care**: by detecting the recurrence of cancer

What are the advantages of PET for people with thyroid cancer?

PET scanning is very useful as an alternative to radioiodine scans for patients whose thyroid cancer does not take up or absorb radioactive iodine.

What is I-131 radiotherapy (RIT) and how is it performed?

I-131 radiotherapy is a treatment for thyroid cancer that typically follows surgery to remove the thyroid. The treatment is used to destroy any remaining cancerous or healthy thyroid tissue after surgery.

In I-131 radiotherapy, the radioactive material used is radioactive iodine I-131. The patient swallows the radioactive iodine in either liquid or pill form, which accumulates in and destroys both healthy and diseased thyroid cells.

What are the advantages of I-131 high-dose radiotherapy for people with thyroid cancer?

Physicians are using molecular imaging to determine the aggressiveness of breast disease, to select a course of therapy and to assess its effectiveness—sometimes after just one cycle of treatment—and to eliminate unnecessary surgeries after treatment by distinguishing active tumors from residual masses. Molecular imaging is also used to minimize the removal of axillary lymph nodes by determining which nodes are most likely to contain cancer cells. There are many new and emerging molecular imaging technologies that may benefit breast cancer patients, including:

- combined imaging systems, known as hybrid imaging, that may improve accuracy and allow physicians to see how cancer is affecting other systems in the body
- the use of PET imaging biomarkers, such as such as fluorothymidine (FLT) to show tumor proliferation and fluoroestrogen (FES) to detect estrogen receptors
- positron emission mammography (PEM)
- radioimmunotherapy (RIT).

Are molecular imaging procedures covered by insurance?

Medicare and private insurance companies cover the cost of most PET-CT scans. Check with your insurance company for specific information on your plan.

What is the future of molecular imaging and thyroid cancer?

In addition to increasing our understanding of the underlying causes of disease, molecular imaging is improving the way disease is detected and treated. Molecular imaging technologies are also playing an important role in the development of:

- screening tools, by providing a non-invasive and highly accurate way to assess at-risk populations
- new and more effective drugs, by helping researchers quickly understand and assess new drug therapies
- personalized medicine, in which medical treatment is based on a patient’s unique genetic profile

In the future, molecular imaging will include an increased use of:

- fusion or hybrid imaging, in which two imaging technologies are combined to produce one image
- investigational PET imaging biomarkers

- optical imaging
- new probes for imaging critical cancer processes
- reporter-probe pairs that will facilitate molecular-genetic imaging
- PET-CT to help administer more targeted radiation treatments

Clinical trials are underway to evaluate the use of the radiopharmaceuticals yttrium-90 labeled octreotide and indium-111-octreotide to treat patients whose thyroid cancer has spread to other parts of the body and is not responsive to treatment with I-131 radiotherapy.

About SNMMI

The Society of Nuclear Medicine (SNMMI) is an international scientific and medical organization dedicated to raising public awareness about nuclear and molecular imaging and therapy and how they can help provide patients with the best health care possible. With more than 18,000 members, SNMMI has been a leader in unifying, advancing and optimizing nuclear medicine and molecular imaging since 1954.

The material presented in this pamphlet is for informational purposes only and is not intended as a substitute for discussions between you and your physician. Be sure to consult with your physician or the nuclear medicine department where the treatment will be performed if you want more information about this or other nuclear medicine procedures.

Society of Nuclear Medicine and Molecular Imaging
1850 Samuel Morse Drive
Reston, VA 20190
www.snmmi.org
www.discovermi.org