

# Molecular Imaging and Cancer

Cancer causes one in every four deaths in the United States, second only to heart disease. According to the National Cancer Institute, it is estimated that 606,520 people will die from the disease in 2020.

However, cancer death rates in the US are dropping (by at least one percent annually since 1991) and the five-year relative survival rate is 67.4 percent, from 2010-2016. Both statistics reflect improvements in early detection and treatment.

Molecular imaging has become part of standard care for many types of cancer. By allowing scientists and physicians to see what is happening in the body at a cellular level, molecular imaging provides unique information to assist in the detection, diagnosis, evaluation, treatment and management of cancer.

## What is molecular imaging and how does it help people with cancer?

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 cancer?

Positron emission tomography (PET) scans and combination PET and computed tomography (PET/CT) scans are routinely used to diagnose and treat a variety of 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 radiotracer 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 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 molecular imaging for cancer patients?

- PET is a powerful tool for diagnosing and determining the stage of many types of cancer, including lung, head and neck, colorectal, esophageal, lymphoma, melanoma, breast, thyroid, cervical, pancreatic and brain cancers. The value of PET for many other cancers is currently being investigated through the National Oncologic PET Registry.
- By detecting whether lesions are benign or malignant, PET scans may eliminate the need for surgical biopsy or identify the optimal biopsy location
- PET scans help physicians choose the most appropriate treatment plan and assess whether chemotherapy or other treatments are working as intended
- PET scans are currently the most effective means of detecting a recurrence of cancer.

## What are the advantages of molecular imaging for prostate cancer patients?

When detected early, prostate cancer has more than a 90 percent cure rate. Because treatment is highly individualized, molecular imaging technologies are dramatically improving the ways in which prostate cancer is diagnosed and treated. With the help of molecular imaging technologies, physicians are able to select the most effective therapy, taking into account a tumor's unique molecular properties. Molecular imaging also allows physicians to more accurately assess



how the disease is progressing.

Scientists also are working on new molecular imaging techniques that will:

- predict the aggressiveness of a tumor
- predict the outcome of treatment
- detect genetic markers of the disease
- assist physicians in developing even more tailored treatment plans

### **What are the advantages of molecular imaging for ovarian cancer patients?**

Ovarian cancer is highly curable when treated at an early stage. However, because there is no effective screening test for the disease, the majority of women are diagnosed at a late stage when survival rates are very low. Early detection and accurate diagnosis are key to increasing ovarian cancer survival rates.

Researchers believe molecular imaging holds promise for detecting ovarian cancer before it spreads into other areas of the body. Studies also show that hybrid imaging, such as a combined PET-CT scan, is highly accurate for detecting recurrent ovarian cancer and for determining the best possible treatment plan.

### **What are the advantages of molecular imaging for lung cancer patients?**

Molecular imaging is commonly used to improve the diagnosis and treatment of lung cancer. The detailed images provided by PET are able to accurately distinguish between benign and malignant tumors as small as one centimeter and to differentiate between extensive and limited disease. Information provided by PET imaging often eliminates the need for exploratory surgery or other invasive medical procedures.

In the future, scientists anticipate that molecular imaging procedures will be increasingly used to evaluate disease progression, assess treatment strategies and monitor treatment effects.

### **What are the advantages of molecular imaging for breast cancer patients?**

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 fluorothymidine (FLT) to show tumor proliferation and fluoroestrogen (FES) to detect estrogen receptors
- positron emission mammography (PEM)
- radioimmunotherapy (RIT).

## What are the advantages of molecular imaging for gastrointestinal cancer patients?

For many GI cancers, PET-CT is able to identify where cancer has spread in the body and to assess patient response to chemotherapy. PET-CT is helpful in nearly all aspects of colorectal cancer diagnosis and treatment, providing valuable information that directly affects treatment options including: identifying incidental cancers in the colon, staging, detecting cancer recurrence, distinguishing between cancer recurrence and post-therapy scarring in the colon, identifying secondary cancers in the liver or lung, and detecting cancer recurrence in patients who have an increased blood protein called carcinoembryonic antigen (CEA) Hodgkin's and non-Hodgkin's lymphoma; and detect cancer recurrence.

## What are the advantages of molecular imaging in drug development?

In addition to its role in the diagnosis and treatment of cancer, molecular imaging also serves as a valuable tool in pharmaceutical research and clinical trials.

Molecular imaging is helping scientists gain a better understanding of the basic mechanisms underlying the biology of cancer. Information provided by molecular imaging technologies has the potential to help the drug development and approval process become faster, more effective and less expensive. Researchers are also using molecular imaging to identify the most promising strategies for developing new drugs and to design clinical trials to test their effectiveness.

## What is the future of molecular imaging and cancer?

Prostate, ovarian and lung cancer are just a few of the many types of cancer in which molecular imaging can truly change the direction and outcome of patient care. The ability of molecular imaging to detect abnormalities very early in the progression of disease has the potential to change medicine from reactive to proactive, detecting and curing disease in its most treatable phase and saving countless lives.

### 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.

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Society of Nuclear Medicine and Molecular Imaging  
1850 Samuel Morse Drive  
Reston, VA 20190  
[www.snmmi.org](http://www.snmmi.org)  
[www.discovermi.org](http://www.discovermi.org)