17/MHS06/013

Medical physics

MLS 314

1. What are radioactive tracers?

A radioactive tracer is a chemical compound in which one or more atoms have been replaced by a radioisotope. Monitoring its radioactive decay, a radiotracer can be used to explore the mechanism of chemical reactions. 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 (iodine-123, technetium-99m, xenon-133 ) 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. They are also used for flow visualization through different technologies, such as Single Photon Emission Computed Tomography (SPECT), Position Emission Tomography (PET) and Computed Radioactive Particle Tracking (CARPT).

1. Discuss explicitly one application of tracer in medicine

**Single Photon Emission Computed Tomography (SPECT)**

A single photon emission computed tomography (SPECT) scan is an imaging test that shows how blood flows to tissues and organs. It may be used to help diagnose seizures, stroke, stress fractures, infections, and tumors in the spine.

**How does a SPECT scan work?**

SPECT is a nuclear imaging scan that integrates computed tomography (CT) and a radioactive tracer. The tracer is what allows doctors to see how blood flows to tissues and organs. Before the SPECT scan, a tracer is injected into your bloodstream. The tracer is radiolabeled, meaning it emits gamma rays that can be detected by the CT scanner. The computer collects the information emitted by the gamma rays and displays it on the CT cross-sections. These cross-sections can be added back together to form a 3D image of your brain. Instead of just "taking a picture of anatomical structures", a SPECT scan monitors level of biological activity at each place in the 3-D region analyzed. Emissions from the radionuclide indicate amounts of blood flow in the capillaries of the imaged regions. In the same way that a plain X-ray is a 2-dimensional (2-D) view of a 3-dimensional structure, the image obtained by a gamma camera is a 2-D view of 3-D distribution of a radionuclide.

SPECT imaging is performed by using a gamma camera to acquire multiple 2-D images (also called projections), from multiple angles. A computer is then used to apply a tomographic reconstruction algorithm to the multiple projections, yielding a 3-D data set. This data set may then be manipulated to show thin slices along any chosen axis of the body, similar to those obtained from other tomographic techniques, such as magnetic resonance imaging (MRI), X-ray computed tomography (X-ray CT), and positron emission tomography (PET).

The radioisotopes typically used in SPECT to label tracers are iodine-123, technetium-99m, xenon-133, thallium-201, and fluorine-18. These radioactive forms of natural elements will pass through your body and be detected by the scanner. Various drugs and other chemicals can be labeled with these isotopes. The type of tracer used depends on what your doctor wants to measure. For example, if your doctor is looking at a tumor, he or she might use radiolabeled glucose (FDG) and watch how it is metabolized by the tumor.

The test differs from a PET scan(a nuclear medicine test in which tissue function can be imaged.) in that the tracer stays in your blood stream rather than being absorbed by surrounding tissues, thereby limiting the images to areas where blood flows. SPECT scans are cheaper and more readily available than higher resolution PET scans.

**Application**

SPECT can be used to complement any gamma imaging study, where a true 3D representation can be helpful, such as tumor imaging, infection (leukocyte) imaging, thyroid imaging or bone scintigraphy. Because SPECT permits accurate localization in 3D space, it can be used to provide information about localized function in internal organs, such as functional cardiac or brain imaging.

In the nuclear power sector, the SPECT technique can be applied to image radioisotope distributions in irradiated nuclear fuels. Due to the irradiation of nuclear fuel (e.g. uranium) with neutrons in a nuclear reactor, a wide array of gamma-emitting radionuclides are naturally produced in the fuel, such as fission products (cesium-137, barium-140 and europium-154) and activation products (chromium-51 and cobalt-58). These may be imaged using SPECT in order to verify the presence of fuel rods in a stored fuel assembly for IAEA safeguards purposes, to validate predictions of core simulation codes, or to study the behavior of the nuclear fuel in normal operation, or in accident scenarios.

**What does a SPECT scan show?**

A SPECT scan is primarily used to view how blood flows through arteries and veins in the brain. Tests have shown that it might be more sensitive to brain injury than either MRI or CT scanning because it can detect reduced blood flow to injured sites. SPECT scanning is also useful for presurgical evaluation of medically uncontrolled seizures. The test can be performed between seizures (interictal) or during a seizure (ictal) to determine blood flow to areas where the seizures originate.

**Who performs the test?**

A specially trained nuclear medicine technologist will perform the test in the Nuclear Medicine department of the hospital, or at an outpatient imaging center. Wear comfortable clothing and be prepared to stay for 1 to 2 hours.

**What happens during the test?**

First, you will receive an injection of a small amount of radioactive tracer. You'll be asked to rest for about 10-20 minutes until the tracer reaches your brain. Next, you'll lie comfortably on a scanner table while a special camera rotates around your head. Be sure to remain as still as possible so that the machine can take accurate pictures. To acquire SPECT images, the gamma camera is rotated around the patient. Projections are acquired at defined points during the rotation, typically every 3–6 degrees. In most cases, a full 360-degree rotation is used to obtain an optimal reconstruction. The time taken to obtain each projection is also variable, but 15–20 seconds is typical. This gives a total scan time of 15–20 minutes.

Multi-headed gamma cameras can accelerate acquisition. For example, a dual-headed camera can be used with heads spaced 180 degrees apart, allowing two projections to be acquired simultaneously, with each head requiring 180 degrees of rotation. Triple-head cameras with 120-degree spacing are also used.

Once the scan is complete, you can leave. Be sure to drink plenty of fluids to flush the tracer from your body.

**What are the risks?**

The tracer is radioactive, which means your body is exposed to radiation. This exposure is limited, however, because the radioactive chemicals have short half-lives. They breakdown quickly and are removed from the body through the kidneys.

The long-term risk of radiation exposure is usually worth the benefits of diagnosing serious medical conditions. Your exposure risk could vary, however, depending on how many CT or other scans you have had. Women who are pregnant or nursing should not undergo a SPECT scan. Some people may have an allergic reaction to the tracer or the contrast agent.