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MLS 314 ASSIGNMENT

### A radioactive tracer, radiotracer, or radioactive label, is a chemical compound in which one or more atoms have been replaced by a radionuclide so by virtue of its radioactive decay it can be used to explore the mechanism of chemical reactions by tracing the path that the radioisotope follows from reactants to products. Tracer isotopes used in radiolabelling include: tritium which is produced by neutron irradiation of 6Li, 11C, 13N, 15O, 32P, 99mTc etc

The most common radioactive isotope used in radioactive tracers is technetium-99m. It is an isotope of an artificial element, technetium, with a half-life of six hours, which provides enough time to perform the necessary diagnostic procedures, but provides patient safety. It is versatile and can be targeted to a specific organ or body part and emits gamma rays that provide the necessary information. Other radioactive tracers include iodine-131 for thyroid conditions, iron-59 iron to study metabolism in the spleen and potassium-42 for potassium in the blood

**Radiolabeling** or **radiotracing** is thus the radioactive form of isotopic labelling.Radioactive tracers are substances that contain a radioactive atom to allow easier detection and measurement. (Radioactivity is the property possessed by some elements of spontaneously emitting energy in the form of particles or waves by disintegration of their atomic nuclei.) For example, it is possible to make a molecule of water in which one of the two hydrogen atoms is a radioactive tritium (hydrogen-3) atom.

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 (add radioactive atoms) 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.

Radioactive tracers utilize the positive qualities of radioactivity, the ability to emit a signal, while minimizing the negative effects. Isotopes use elements with a short half-life to reduce the dangers of radioactive exposure to the patient. A half-life represents the amount of time it takes for one-half of a substance's radioactivity to decay. For example, a material with a half-life of six hours will lose half of its radioactivity in six hours and then another one-half at the 12-hour mark, leaving one-fourth of its strength. The shorter the half-life the less radioactive exposure

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.

Approved tracers are called radiopharmaceuticals since they must meet FDA’s exacting standards for safety and appropriate performance for the approved clinical use. The nuclear medicine physician will select the tracer that will provide the most specific and reliable information for a patient’s particular problem. The tracer that is used determines whether the patient receives a SPECT or PET scan.

PRINCIPLE OF RADIOACTIVE TRACERS

The principle behind the use of radioactive tracers is that an atom in a chemical compound is replaced by another atom, of the same chemical element. The substituting atom, however, is a radioactive isotope. This process is often called radioactive labeling. The power of the technique is due to the fact that radioactive decay is much more energetic than chemical reactions.

The two main ways in which radioactive tracers are used are:

1. When a labeled chemical compound undergoes chemical reactions one or more of the products will contain the radioactive label. Analysis of what happens to the radioactive isotope provides detailed information on the mechanism of the chemical reaction.
2. A radioactive compound is introduced into a living organism and the radio-isotope provides a means to construct an image showing the way in which that compound and its reaction products are distributed around the organism.

APPLICATION OF RADIOACTIVE TRACERS

Radioactive isotopes have many useful applications in a wide variety of situations, for example, they can be used within a plant or animal to follow the movement of certain chemicals. In medicine, they have many uses, such as imaging, being used as tracers to identify abnormal bodily processes, testing of new drugs and conducting research into cures for disease.

## Phosphorus uptake by plants

Plants take up phosphorus-containing compounds from the soil through their roots. By adding a small amount of radioactive phosphorus-32 to fertiliser and then measuring the rate at which radioactivity appears in the leaves, it is possible to calculate the rate of uptake of phosphorus from the soil. The information gathered could help plant biologists to identify plant types that can absorb phosphorus quickly. These plants may give better yields resulting in more food or fibre at less expense.

## Pesticide levels

To measure pesticide levels, a pesticide can be tagged with a radioisotope such as chlorine-36, and this is applied to a field of test plants. Over a period of time, radioactivity measurements are made. Estimates can then be made about how much accumulates in the soil, how much is taken up by the plant and how much is carried off in run-off surface water.

## Medical tracers

Radioactive isotopes and radioactively labelled molecules are used as tracers to identify abnormal bodily processes. This is possible because some elements tend to concentrate (in compound form) in certain parts of the body – iodine in the thyroid, phosphorus in the bones and potassium in the muscles. When a patient is injected with a compound doped with a radioactive element, a special camera can take pictures of the internal workings of the organ. Analysis of these pictures by a specialist doctor allows a diagnosis to be made.

The thyroid gland, situated in the neck, produces a hormone called thyroxine, which regulates the rate of oxygen use by cells and the generation of body heat. Within each molecule of thyroxine, there are 4 iodine atoms. If a patient is made to drink a solution of sodium iodide that has been doped with radioactive iodine-131, most of it will end up in the thyroid gland. A special camera can capture the radiation emitted by the iodine-131, and an image of the gland can be constructed. An assessment can then be made about the shape, size and functioning of the gland.

## 2. Positron emission tomography (PET)

Positron emission tomography (PET) is a technique that measures physiological function by looking at blood flow, metabolism, neurotransmitters, and radiolabelled drugs. PET offers quantitative analyses, allowing relative changes over time to be monitored as a disease process evolves or in response to a specific stimulus.[​](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1126321/figure/fig1/)A positron emission tomography (PET) scan measures important body functions, such as blood flow, oxygen use and glucose use. The information gathered helps doctors find out how well organs and tissues are functioning.

<https://www.ncbi.nlm.nih.gov/core/lw/2.0/html/tileshop_pmc/tileshop_pmc_inline.html?title=Click%20on%20image%20to%20zoom&p=PMC3&id=1126321_1449_f2.jpg>

Radionuclides used in PET scanning are isotopes with short half–lives, such as carbon-11 (~20 min), nitrogen-13 (~10 min), oxygen-15 (~2 min) and fluorine-18 (~110 min). These radionuclides are added into compounds normally used by the body such as glucose (or variations of glucose), water or ammonia. Such labelled compounds are known as radiotracers. In some situations, the patient is required to breath oxygen gas labelled with oxygen-15.

The technique is based on the detection of radioactivity emitted after a small amount of a radioactive tracer is injected into a peripheral vein. The tracer is administered as an intravenous injection usually labelled with oxygen-15, fluorine-18, carbon-11, or nitrogen-13. The total radioactive dose is similar to the dose used in computed tomography.

The radionuclides used in PET decay by a process called positron emission. A positron is the antimatter version of the electron. When a positron meets an electron, an annihilation event occurs, resulting in the production of two gamma rays. The two emitted gamma rays travel in opposite directions.

PET SCANNER

Positron emission tomography (PET) is different to other medical imaging techniques because it requires patients to be injected with a radioactive substance. The images a PET scanner produces shows where in the body the radioactive substance has been transported. This means a PET image is a picture of what is happening metabolically in the body compared to other medical imaging techniques that show the structure or parts of the body.

The scanning instrument picks up the location of these gamma rays and, with the aid of a powerful computer, generates a map of where these events are occurring. By combining the PET scan with a CT scan, a more complete picture of how well an organ is functioning can be made.

Due to the short half-lives of most radioisotopes, the radiotracers must be produced using a cyclotron (a type of particle accelerator) and radiochemistry laboratory that are close to the PET imaging facility. The half-life of fluorine-18 is long enough such that fluorine-18 labelled radiotracers can be manufactured commercially at an off-site location.

USES OF PET SCAN

### Oncology

PET scanning with the tracer fluorine-18S (18F) fluorodeoxyglucose (FDG), called FDG-PET, is widely used in clinical oncology. FDG is a glucose analog that is taken up by glucose-using cells and phosphorylated by hexokinase (whose mitochondrial form is significantly elevated in rapidly growing malignant tumours)

### Neuroimaging

PET scan of the human brain

* Neurology: PET neuroimaging is based on an assumption that areas of high radioactivity are associated with brain activity. What is actually measured indirectly is the flow of blood to different parts of the brain, which is, in general, believed to be correlated, and has been measured using the tracer oxygen -15.
* Neuropsychology / Cognitive neuroscience: To examine links between specific psychological processes or disorders and brain activity.
* Psychiatry: Numerous compounds that bind selectively to neuroreceptors of interest in biological psychiatry have been radiolabeled with C-11 or F-18
* Stereotactic surgery and radiosurgery: PET-image guided surgery facilitates treatment of intracranial tumors, arteriovenous malformations and other surgically treatable conditions

1. Cardiology, atherosclerosis and vascular disease study: FDG-PET can help in identifying hibernating myocardium.

### Infectious diseases

Imaging infections with molecular imaging technologies can improve diagnosis and treatment follow-up. Clinically, PET has been widely used to image bacterial infections using fluorodeoxyglucose (FDG) to identify the infection-associated inflammatory response

### Musculo-skeletal imaging

PET imaging has been used for imaging muscles and bones. [18F]FDG is the most commonly used tracer for imaging muscles, and [18F]NaF is the most widely used tracer for imaging bones

#### Study of Muscles

PET is a feasible technique for studying skeletal muscles during exercises like walking.Also, PET can provide muscle activation data about deep-lying muscles (such as the vastus intermedialis and the gluteus minimus) compared to techniques like electromyography, which can be used only on superficial muscles directly under the skin. However, a disadvantage is that PET provides no timing information about muscle activation because it has to be measured after the exercise is completed. This is due to the time it takes for FDG to accumulate in the activated muscles

#### Bones

Together with NaF, PET for Bone Imaging has been in use for 60 years for measuring regional bone metabolism and blood flow.