

Positron emission tomography

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Positron Emission Tomography

Introduction

Positron Emission Tomography or PET is an imaging technique in nuclear medicine that gives a high-resolution 3D image of the body or organ under investigation, and gives functional as well as structural information about the body. The basic principle is that a radioactive substance that is introduced into the body emits positrons, which in turn emits pairs of gamma rays that are detected by the PET scan. By locating the position of gamma ray emission with reference to time of detection, a 3D picture of the body can be constructed.

How does Positron Emission Tomography work?

The imaging process starts with the injection of radionuclide tracer (also known as Radiopharmaceuticals) into the bloodstream. This is a radioactive isotope such as Oxygen-15 or more commonly Fluorodeoxyglucose-18 (FDG). These tracers are fused with a natural chemical that is relevant to the organ under study^[1]. After the radionuclide tracer is injected, it processed through the bloodstream to the organs to which the fused natural chemical corresponds. This allows for detailed examination and diagnosis of specific areas. Any positron emitting biologically active molecule can be used, but since FDG is an analogue of glucose, it can that can cross the blood brain barrier. The molecule is therefore widely used in neuroimaging. The great availability of soluble radioactive isotopes over gamma emitting isotopes is one of the advantages of PET scanning over other nuclear imaging techniques.

Positron emissions also know as B+ decay. PET utilizes Isotopes with a short half-life to undergo B+ decay to expose the patient only to an abbreviated time to radiation. The unstable radionuclide converts a proton into a Neutron, releasing a neutrino and a positron, as beta radiation. Positron annihilation then occurs when the emitted beta particle (β^+) collides with an electron (e^-). This happens almost instantly due to the abundance of electrons. Annihilation converts all energy into two gamma rays, which are emitted in opposite directions. The gamma rays are detected by the scanner, and an image can then be built up based on where in the body the reaction took place.

Pairs of gamma rays that are detected at the same time can be used to draw a line at 180° from the point of the reaction. This gives an image with high spatial resolution. Additionally, information about the functionality of the tissue can be gleaned from PET scanning. For example, specific biochemical changes such as metabolism can be quantified. The resultant image will have specific areas highlighted as areas of activity. This is another advantage of PET over other types of nuclear imaging.^[2]

What is it used for?

One of the most common applications of PET is neuroimaging. This can be structural (anatomical) or functional (physiological). In structural neuroimaging, a 3D image can reveal anatomical abnormalities, either congenital or trauma induced. In functional neuroimaging, the glucose analogue FDG-18 can show which areas of the brain are undergoing relatively more or less glucose metabolism. This kind of identification of brain activity is useful for thought identification (for example, if the subject is given a specific task) or metabolic activity (for example, to identify tumor growth).

In order to investigate a specific brain function, isotopes have been developed that can act as a ligand for certain neuroreceptor. For example, probes for Serotonin receptors labeled with Carbon-11 ^[3] or innovative radioligands such as nifene ^[4], a nicotinic acetylcholine receptor agonist which gives information about the activity of neuroreceptors via radioactive fluorine.

Other uses in neuroimaging include identification of surgical sites, the progression of Alzheimer's by labeling amyloid plaques, and evaluation of blood flow to different sites of the brain. This can reveal the need for emergency surgery by identifying any hematomas after trauma, for instance. The oncological uses for PET imaging are not just neurological, but can also show if the disease has spread to any other part of the body, analyze the effectiveness of cancer therapy, and to detect earlier a potentially malignant growth.

PET scans can also be used to diagnose certain bacterial infectious disease during early stages. It can also help distinguish different types of infectious disease when the symptoms are enough to determine what time of infection it is. Another practicality is that drugs administered for infection treatment can be monitored over time to determine effectiveness, allow for doctors to modify treatment plans accordingly. Tuberculosis one of the world most deadly diseases can be diagnosed as well as treatment can be monitored with the help of FDG radiopharmaceuticals and Positron Emission Tomography scans. ^[5]

What is the Procedure?

The patient usually is not allowed to eat six hours before the scan, and will either be wearing loose fitting clothes or a hospital gown. Certain items of clothing and jewelry will be removed as they may interfere with the scan. The radiotracer is then injected in the arm or hand via an IV (intravenous) line. The examination then starts about 60 minutes after the radiotracer has been injected into the bloodstream. This gives it time to be absorbed by the cells and distributed readily across the entire body. After the absorption time, the scanner table moves slowly around the part of the body under investigation. The patient will be asked to keep as still as possible as the scanner takes pictures of the body. The scan can last up to 30 minutes.

How is the image constructed?

The scanner itself detects gamma rays by means of a scintillator, which detects pairs of photons that are emitted during the positron-annihilation event. The exact location of the event can be discovered because gamma rays are emitted in pairs and travel in opposite locations. This means there will be a straight line of co-incidence between every pair of photons detected simultaneously by the scintillator. This is called the line of response (LOR). Each LOR therefore has a number of co-incidence events. Co-incidence events can be grouped spatially to form a 3D image. PET images can also be constructed with CT or MRI images overlaid to give clear information about how the functional areas identified with PET relate spatially to the rest of the brain or body.^[6] By the summation of these different scans, a high resolution and detailed picture can be created, illustrating a clear diagnostic for doctors.

References

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