Pharmaceutical Sciences & Analytical Research Journal
ISSN: 2640-6659

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*Mini Review* *Volume 7 Issue 1*

# PET- (Positron Emission Tomography) Scan & Chemistry

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**Received Date:** January 06, 2025; **Published Date:** February 03, 2025

## Abstract

PET-CT Scan is recommended for the diagnosis of tumour growth related to cancer cells. In addition this methodology is also applied for the detection of biochemical changes taking place in the body. In this article, the focus is to show how nuclear chemistry is associated in the process of scanning using positron emission tomography (PET Scan).

**Keywords:** PET-CT Scan; Tumour Cells; Cancer Diagnosis; Nuclear Chemistry

## Abbreviations

CT: Computed Tomography; MRI: Magnetic Resonance Imaging; FDG: Fluorodeoxyglucose; UCL: University College London; PET: Positron Emission Tomography.

## Introduction

The important applications of nuclear chemistry have been utilized successfully in the process of conducting "Positron emission tomography, popularly known as PET-CT scan. The various metabolic activity of the cells of body tissues in our body is examined using PET-CT which is a combination of nuclear medicine and biochemical analysis. Monitoring the growth of tumours associated with cancer cells is basically identified using PET-CT scan technique and mainly applied in findings the abnormal growths found in brain, heart conditions and status of cancer cells in patients.

Minute amount of a radioactive substance, known as "Radiopharmaceutical (radionuclide or radioactive tracer)" is employed during the procedure for the examination of the tissue under investigation in PET-CT scan nuclear medicine procedure. This evaluation procedure evaluates the metabolism of different organ or tissues and also detects the physiological functions and the details of anatomical structural pattern of the organs and tissues under scan. Simultaneously PET-CT evaluates biochemical functions and detects related abnormalities. PET-CT is a much more advanced technique in the detection of early biochemical changes in an organ or tissue which are highly beneficial for the doctors in the identification of critical diseases compared with other imaging processes such as "Computed tomography (CT)" and "Magnetic resonance imaging (MRI)". Oncologists (doctors having specialization in cancer treatment), neurologists, neurosurgeons (doctors having specialization in the surgery and treatment of brain as well as nervous system related diseases) and cardiologists (doctors having specialization related to the treatment of the heart) are always preferred PET-CT compared with other imaging systems. However, as advances in PET technologies continue, this procedure is beginning to be used more widely in other areas. The mechanism of PET-CT scanning machine (it is a devise which has a big hole at the center) is to detect

photons, the subatomic particles emitted by a radionuclide in the organ or tissues which are under examination. In this technology, the radionuclides are prepared by enclosing a radioactive atom with the chemical substances used. Usually, radioactive oxygen, carbon is used to attach with glucose to develop a chemical substance because majority of our organs utilize glucose for their metabolism. For instance, in the PET-CT scanning of brain, a radioactive atom is attached with glucose to develop a radioactive nuclei called "Fluorodeoxyglucose" (FDG). Usage of FDG for the scanning in other organs is very common because of cost efficiency and the natural development of glucose in our metabolic processes.

In addition to oxygen and carbon other radioactive atoms (nitrogen, gallium) in PET-CT scanning. In the case of determination of blood flow of an organ or tissue under investigation, either radioactive gallium or oxygen is used with glucose. In the beginning of the scanning procedure, radionuclide is administered into the vein through an intravenous line. After that the patient is taken to the scanning devise and the focus of the scanning machine is rolled over the part of the body which is under examination. When the process starts, the radionuclide is broken and start emitting positrons. The positrons collide with electrons and produces "Gamma rays" which is also known as "annihilation photons". At this stage, scanner detects the annihilation photons, which reaches at the detectors in coincidence at 180 degrees apart from one another. The attached computer of PET-CT scanner analyzes the developed gamma rays and converts the information to create an "Image map of the organ or tissue" which is under study. The radionuclide inserted inside the tissue or organ affects "how brightly the tissue or organ appears on the image and indicates the "stage/status of the organ or tissue" as well as their function. The most common use of PET-CT scanning is in the detection of cancer cells in the tumour and the evaluation of the cancer cells after treatment. In addition, PET scans are used to diagnose "Dementia" known as deterioration of mental health, "Alzheimer's disease" as well as other neurological conditions such as "Parkinson's disease".

"Huntington's disease", a hereditary disease of the nervous system can be detected using PET-CT scan and helps in identifying the causes of dementia. "Epilepsy" and related fits disorder of the autistic child's and abnormal movements and posture can be clearly identified in PET-CT scanning procedure (Figure 1).

**Figure 1:** PET-CT scanning procedure.

Using this modern procedure, the radiologists and physicians are recording the images of the organs or cells under investigation of an individual's body. Analyzing scanning radiologists can easily identifies if a person is at risk of critical diseases like cancer, heart blockage, lung disease and other neurological disorders. "Positron", also known as positive beta particle developed in this scanning procedure by the nuclear reactions is a mass-less particle but it has a positive charge of one [1]. It is similar to an electron as both have the same mass, but it has a positive charge instead of a negative charge. Positrons developed in nuclear reactions are commonly represented by any one of the symbols "$_{+1}e^0$ or $_{+1}\beta$". Emission of a positron may be represented by:

$$_1p^1 \longrightarrow {}_0n^1 + {}_{+1}e^0$$

This represents how the positron ($_{+1}e^0$) comes out of the nucleus while the neutron remains inside the nucleus. In the identification of "Cancer cells" in PET-CT scanning, carbon-11 is used as the "tracer element" in the nuclear reaction.

$$_6C^{11} \longrightarrow {}_5B^{11} + {}_{+1}e^0$$

During this nuclear reaction, the nuclide changes into a different element and gives off a positron particle. The atomic number of the new element is lowered by one while

the mass of the new element remains due the decay of the tracer carbon atom.

### General Procedure of PET CT Scan

The procedure starts with the intervenous injection to inject the patient with a solution which is used by the body to produce energy, like glucose. The chemical used must be a positron-emitting substance [2]. It's because when the PET-CT scanner detect the collisions of the positrons with electrons, the two species disappear. During the process, the nuclear reaction create two gamma photons to move apart in opposite directions. The computer linked with scanner record these detected gamma rays and also creates an image of the portion where the active glucose is located. PET-CT helps the radiologist to locate the exact areas where metabolic changes are taking place. PET-CT scanning shows exactly where the injected glucose is being used either in brain, the heart muscle or in a growing tumour. In case of a cancer patient, the cancer cells develop a denser area image due to the cells' high metabolic rates in comparison with normal cells of the body.

### Applications of PET Scans

PET scanning is one of the most advanced methodology in the medical and research field for its wide applicability. Clinical diagnosis of many difficult diseases and disorders are correctly identified in this technique because it is very effective in targeting radionuclides to produce positron which ultimately helps in clear image development of the affected area. PET scanning is especially effective in the "Detection of Cancer" because the activity of the injected glucose is very active and is easily traced in developed images [3]. PET scanning is considered to be most accurate procedures in the detection of tumour growth associated with cancer cells. PET-CT scan is highly is very sensitive in the diagonosis of lymphoma, malignant melanoma, breast, lung, colon and cervical cancers and provides the future direction of treatment to the patient. This also includes metastatic diseases and helps both the radiologist and physician to more accurately decide how to proceed with chemotherapy or applying radiation therapy. He scan reports are compared on PET scans before and after a chemotherapy or radiation therapy course. Whether a successful course of chemotherapy/radiotherapy is done may be visible by a PET scan by comparing the before and after images of the treatment. As our brain is more active with the intake of more oxygen, therefore, PET imaging of the "Brain" is based upon the use of tracer nuclide "Oxygen-15". The activity of brain and its rapid use of glucose produces highly vivid colored images that indicate where the most activities in the brain are functioning. In case of brain stroke, tracer nuclides that are used in PET-CT scanning include krypton-79 and nitrogen-13. Certain brain diseases and cardiovascular functions for an individual can be diagnosed very clearly from the PET-CT scanning imaging. Cancer cells as well as abnormal growth in "Prostate gland and urinary bladders" can be clearly detected in PET-CT and the patients may be informed accordingly for the needful. Recently many such cases have been diagnosed using this technique and is highly beneficial for the patients to proceed for quick medical attention for recovery. Hence, use of this technique is highly recommended.

Carbon-11 and Fluorine-18 are two radionuclide tracers used in PET scan for psychiatric patients so that radionuclide selectively bind to receptors in the brain and helps in further research in psychiatry. The psychiatric conditions include schizophrenia and mood disorders [4].

The first concept of PET camera was identified in 1974 by Michael Phelps and it was delivered to Department of Medicine, UCL (University College London) in1976. The first PET-CT scanning devise was built and installed at the University of Pittsburgh in 1998. India's first PET-CT scan was installed at the Radiation Medicine Centre (BARC) in Mumbai in 2002. India's first dedicated PET-CT scanner was started functional from 2004 at "Tata Memorial Cancer Research Centre" followed by AIIMS, New Delhi and Apollo Hospital, Chennai in 2008. Nowadays, almost all the cities India are having well equipped PET-CT scanners in hospitals and diagnostic centres.

Though PET-CT is an advanced procedure for early detection of cancer cells and abnormal tumour growth but the procedure is costly. Therefore, this technique may not be affordable by all patients. Also, availability of PET-CT technique is not available in rural areas or village hospitals, therefore, patients are referred to city hospitals to avail this modern technique.

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