Medical Imaging

Presented by

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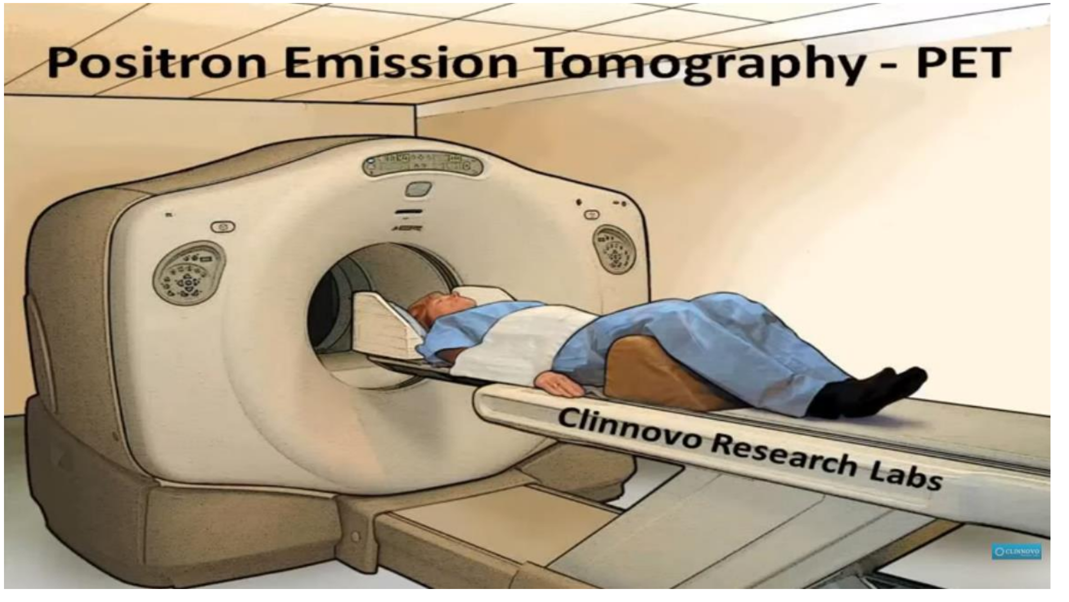
Second-year students

Questions

- **What is it?**
- **How does it work?**
- **What good is it?**



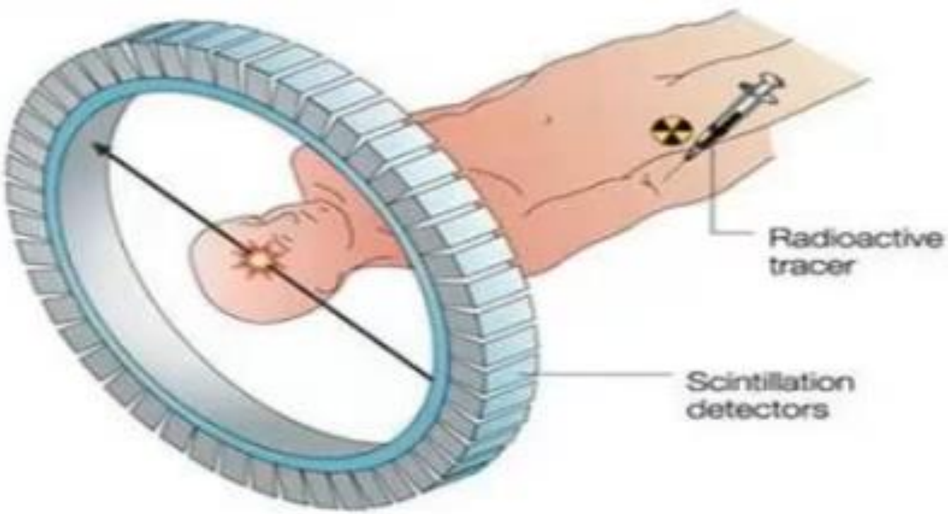
Positron Emission Tomography: What is it?

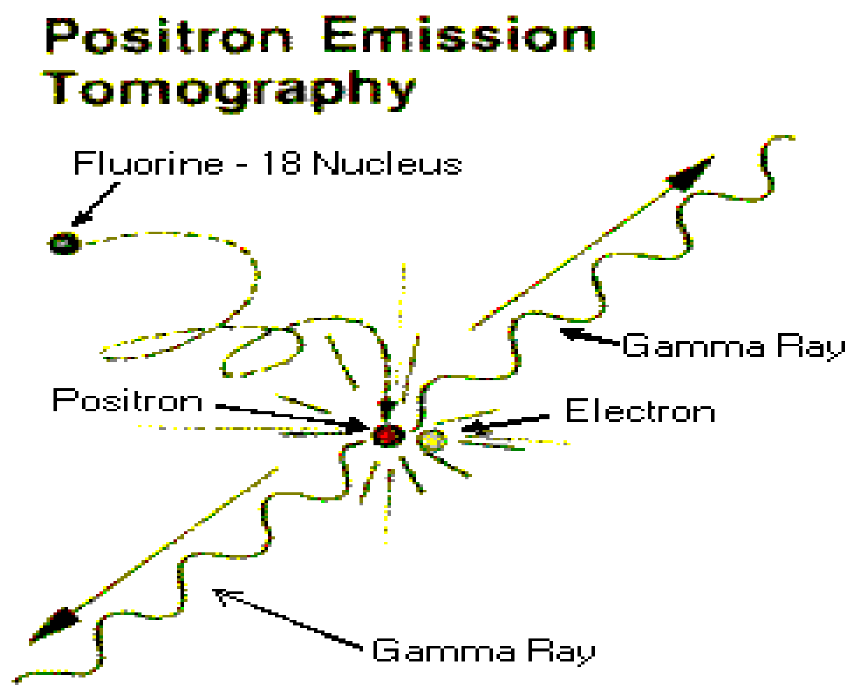
- PET stands for **"Positron Emission Tomography"**.
- It was developed in the mid 1970s and it was the first scanning method to give functional information about the brain.
- PET is a noninvasive, diagnostic imaging technique for measuring the metabolic activity of cells in the human body (Metabolic marker).
- Similar to CT in that the scanner detects radiation using a ring of detectors.
- Different than a CT scanner because the radiation is **emitted from inside the body**, rather than being **transmitted through the body (as in CT).**
- PET is a **functional imaging** modality. That means it is used to observe **where** in the body a particular function is occurring.
- Therefore PET is a **functional imaging** modality rather than being an anatomical image modality.

How Does It Work?

1. A small amount of positron-emitting radioisotope is injected into the subject.
2. This radioisotope is bound to a metabolite that is used in the function we wish to observe.
3. As the radioisotope decays, it gives off positrons.
4. Each positron collides with an electron, and they annihilate each other. But the event releases two gamma rays in opposite directions. These rays are each 511 keV.
5. The scanner listens for 2 gamma rays being acquired at the same time…these 2 rays likely originated from the same annihilation event. Hence, we know that the radioisotope was somewhere along the line connecting the two detectors.
6. The PET scanner are detected the 2 gamma rays and translated them into an image through computer processing.

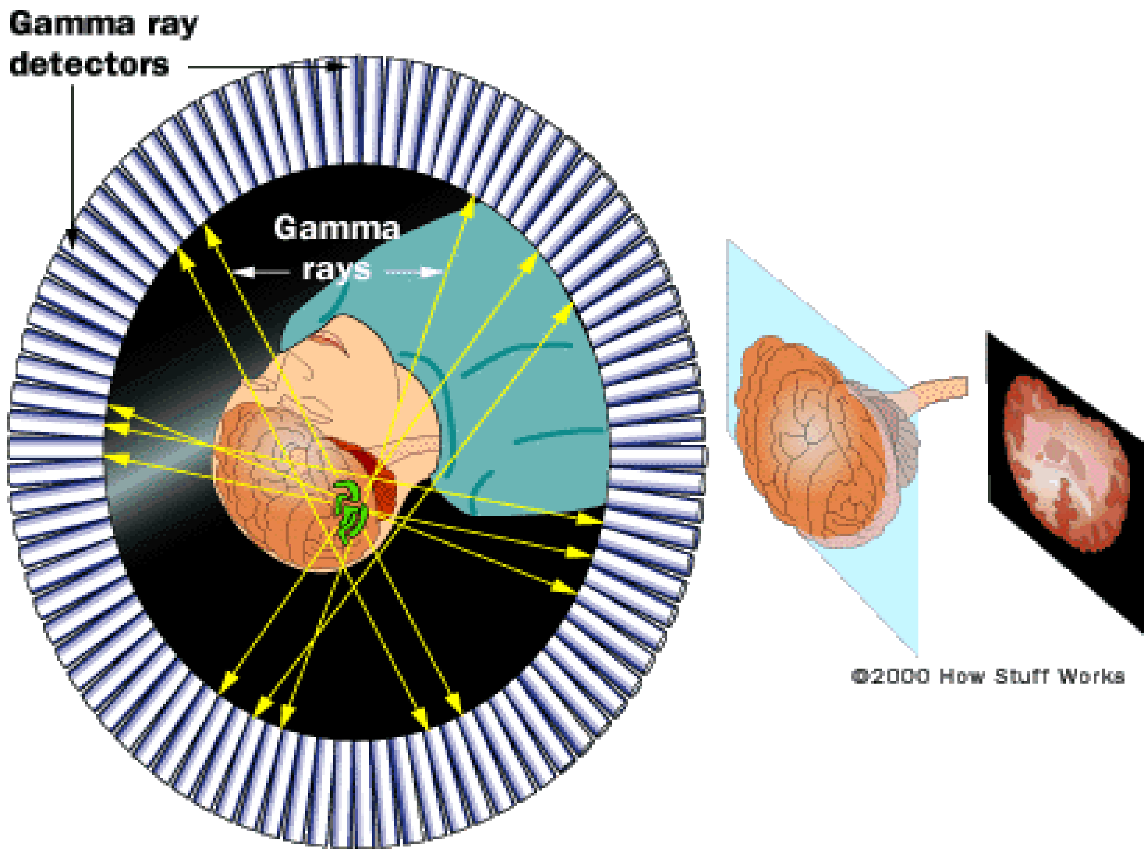
How Does It Work?





How do we detect photons (gamma rays)?

PET detects these photons with a PET camera which allows to determine where they came from, where the nucleus was when it decayed, and also knowing where the nucleus goes in the body.



How is it performed?

- A nurse or technologist will take you into a special injection room, where the radioactive substance is administered as an intravenous injection (although in some cases, it will be given through an existing intravenous line or inhaled as a gas). It will then take approximately 30 to 90 minutes for the substance to travel through your body and accumulate in the tissue under study. During this time, you will be asked to rest quietly and avoid significant movement or talking, which may alter the localization of the administered substance. After that time, scanning begins. This may take 30 to 45 minutes.
- Some patients, specifically those with heart disease, may undergo a stress test in which PET scans are obtained while they are at rest and again after undergoing the administration of a pharmaceutical to alter the blood flow to the heart.
- Usually, there are no restrictions on daily routine after the test, although you should drink plenty of fluids to flush the radioactive substance from your body.

http://www.radiologyinfo.org/content/petomography.htm

Example:

For example, glucose can be tagged to produce Fluoro-2-Deoxy-Glucose (FDG)

- The FDG will migrate to the sites where glucose is being consumed rapidly.
- Malignant tumors require a lot of glucose to grow, and tend to cause a locally high concentration of FDG.
- PET imaging can estimate the concentration of the radioisotope in tomographic sections (slices).
- PET scans take a long time (30 mins. To 3 hrs.), so patient motion is a problem. After that time, the radioisotope has decayed to a very low level; the half-life of FDG is 108 minutes.

What are some of the uses for PET

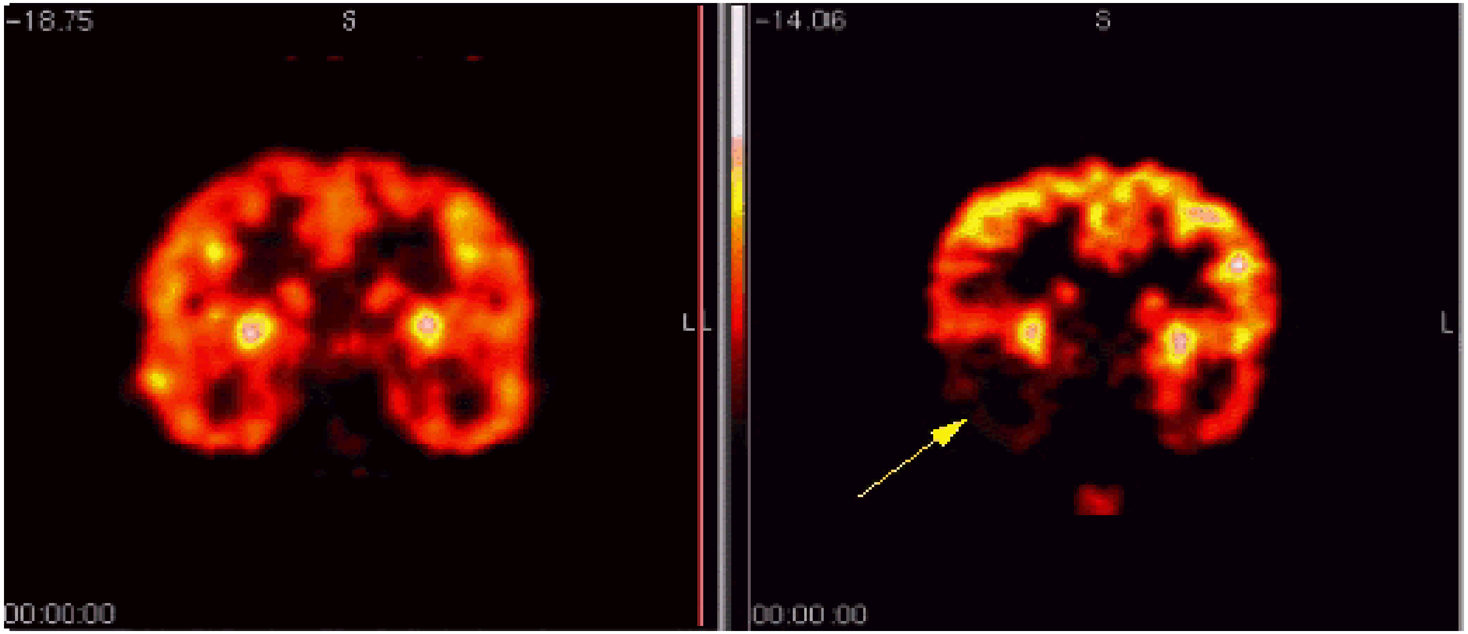
- Patients with conditions affecting the brain
- Heart
- Certain types of Cancer
- Alzheimer's disease
- Some neurological disorders

Htt://www.nucmed.buffalo.edu/petdef.htm

Patients with brain disorders

- PET scans of the brain are used to evaluate patients who have memory disorders of an undetermined cause, suspected or proven brain tumors or seizure disorders that are not responsive to medical therapy and are therefore candidates for surgery.

http://www.radiologyinfo.org/content/petomography.htm



Normal brain

Image of the brain of a 9 year old female with a history of seizures poorly controlled by medication. PET imaging identifies the area (indicated by the arrow) of the brain responsible for the seizures. Through surgical removal of this area of the brain, the patient is rendered "seizure-free".

Htt://www.nucmed.buffalo.edu/petdef.htm

Heart Conditions

PET scans of the heart are used to determine blood flow to the heart muscle and help evaluate signs of coronary artery disease. PET scans of the heart can also be used to determine if areas of the heart that show decreased function are alive rather than scarred as a result of a prior heart attack, called a myocardial infarction. Combined with a myocardial perfusion study, PET scans allow differentiation of nonfunctioning heart muscle from heart muscle that would benefit from a procedure, such as coronary bypass for instance.

http://www.radiologyinfo.org/content/petomography.htm

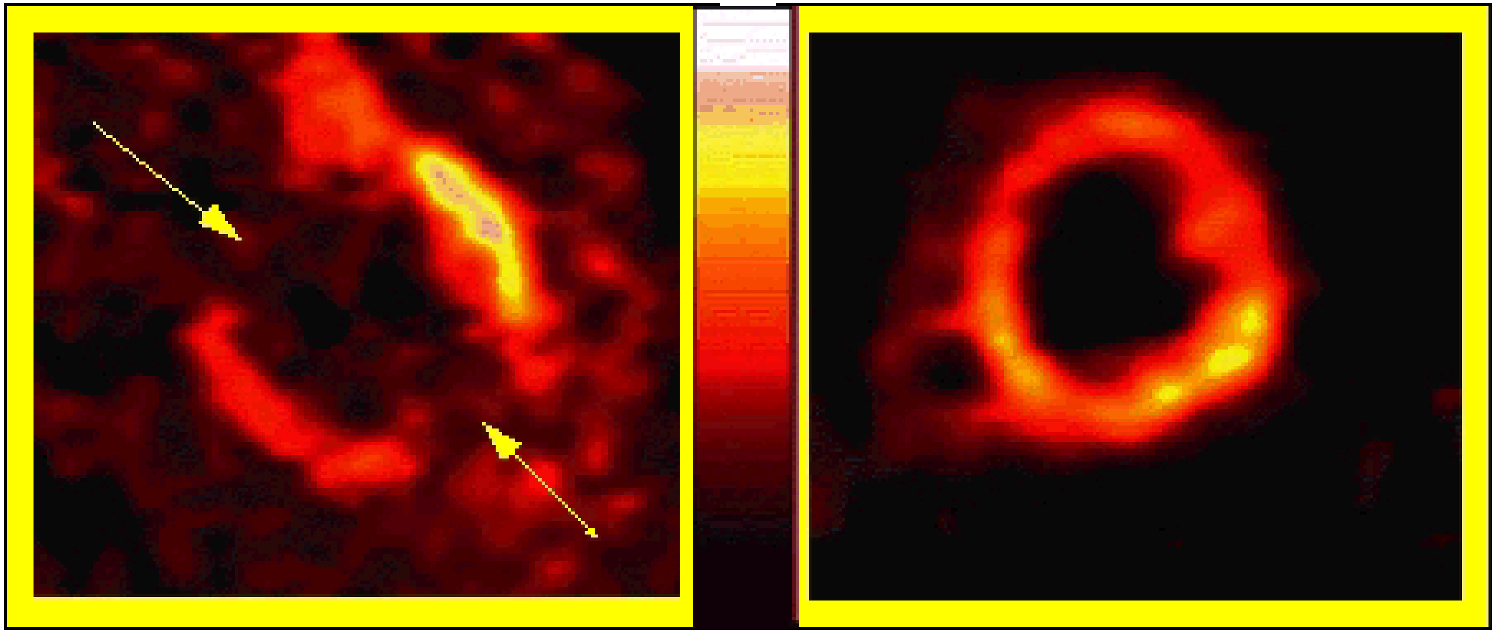


Image of heart which has had a mycardial infarction (heart attack). The arrow points to areas that have been damaged by the attack, indicating "dead" myocardial tissue. Therefore, the patient will not benefit from heart surgery, but may have other forms of treatment prescribed.

Normal heart

Htt://www.nucmed.buffalo.edu/petdef.htm

Cancer Patients

- Used to determine if there are new or advancing cancers by analysis of biochemical changes.
- It is used to examine the effects of cancer therapy by characterizing biochemical changes in the cancer. PET scans can be performed on the whole body.

http://www.radiologyinfo.org/content/petomography.htm

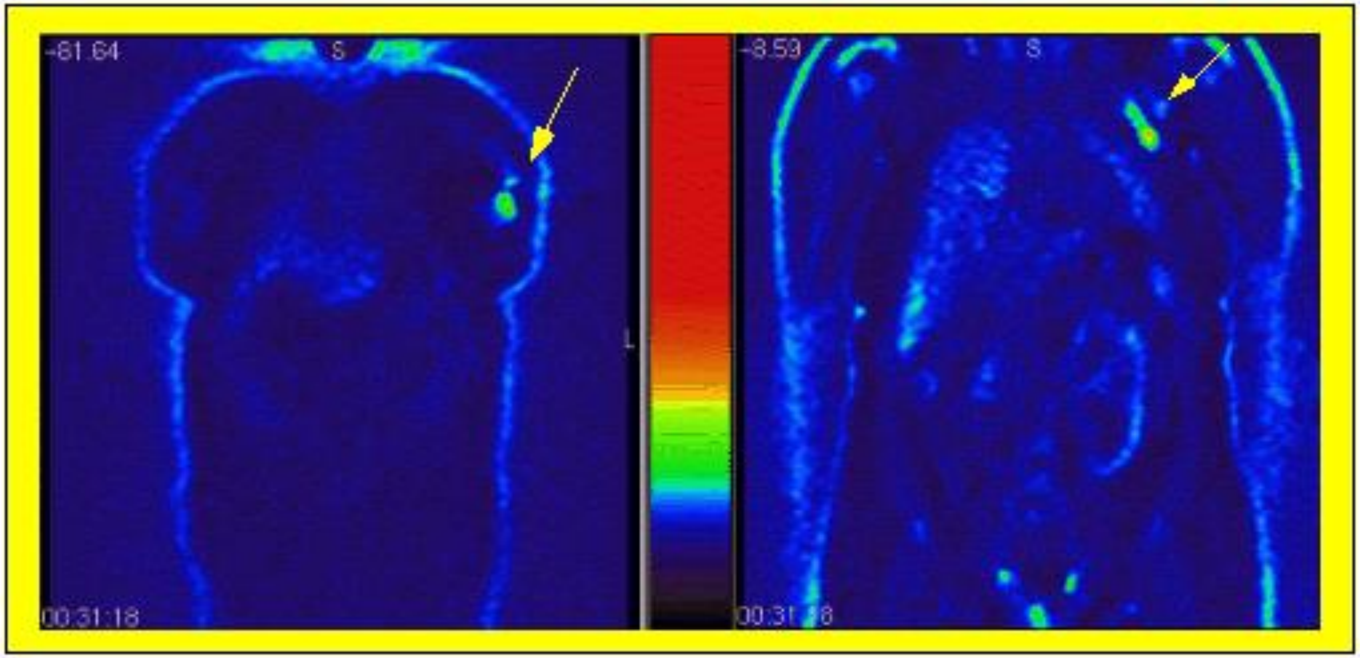


Image showing malignant breast mass that was not revealed by conventional imaging techniques such as CT, MRI, and mammogram.

Image of same patient with enlarged left axillary lymph nodes (indicated by arrows), which through biopsy were found to be metastatic (spread from another location). The whole body scan reveals a mass in the left breast (indicated by arrow), that was malignant and subsequently removed.

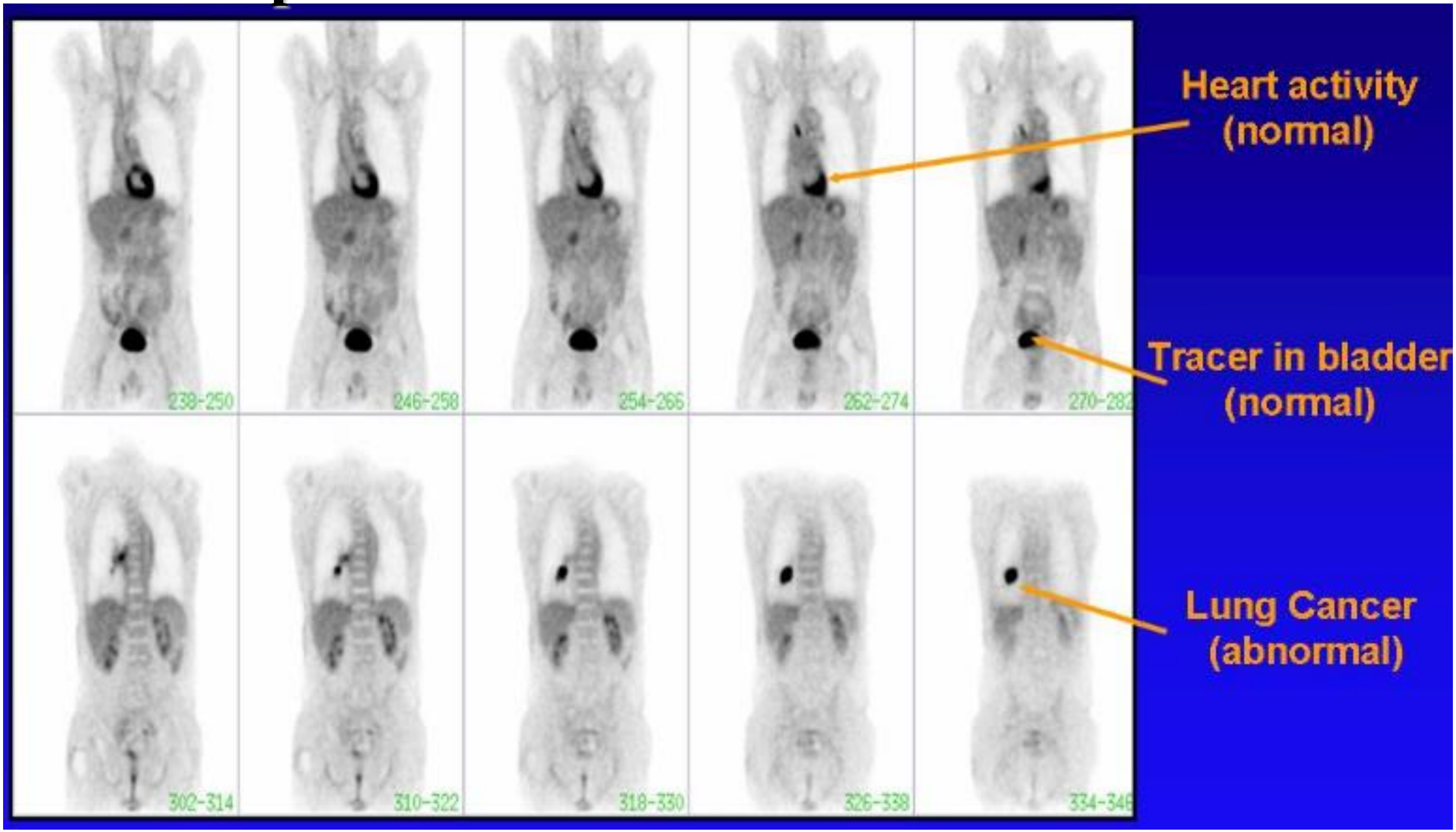
Alzheimer’s disease

- With Alzheimer’s disease there is no gross structural abnormality, but PET is able to show a biochemical change.

Limitations

- PET can give false results if a patient's chemical balances are not normal. Specifically, test results of diabetic patients or patients who have eaten within a few hours prior to the examination can be adversely affected because of blood sugar or blood insulin levels.
- Also, because the radioactive substance decays quickly and is effective for a short period of time, it must be produced in a laboratory near the PET scanner. It is important to be on time for the appointment and to receive the radioactive substance at the scheduled time. PET must be done by a radiologist who has specialized in nuclear medicine and has substantial experience with PET. Most large medical centers now have PET services available to their patients. Medicare and insurance companies cover many of the applications of PET, and coverage continues to increase.
- Finally, the value of a PET scan is enhanced when it is part of a larger diagnostic work-up. This often entails comparison of the PET scan with other imaging studies, such as CT or MRI.

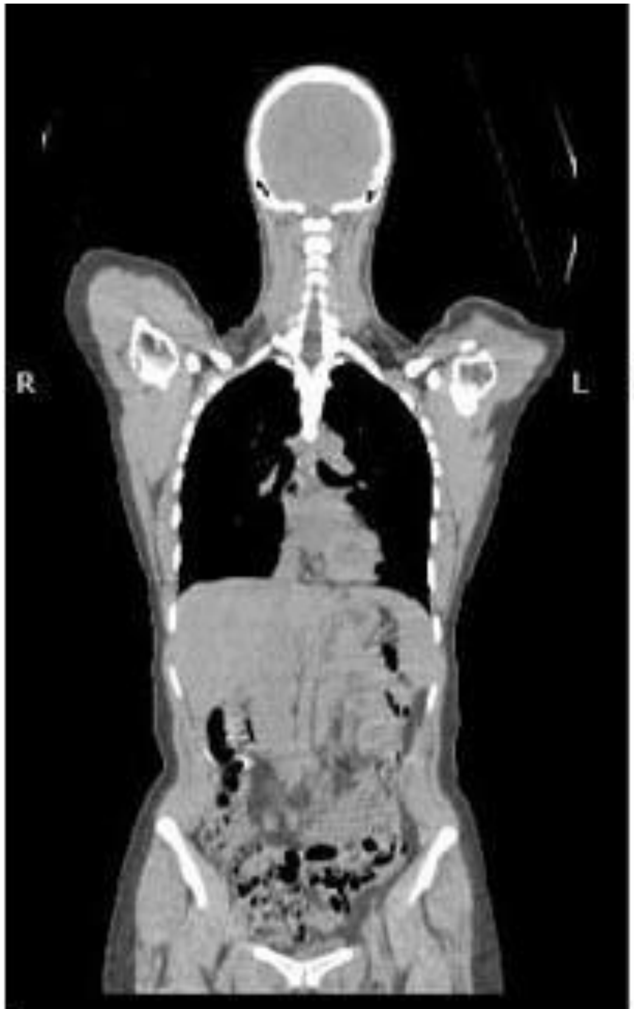
Example:



Heart activity
(normal)
Tracer in bladder
(normal)
Lung Cancer
(abnormal)
238-250
246-258
254-266
262-274
302-314
310-322
318-330
326-338

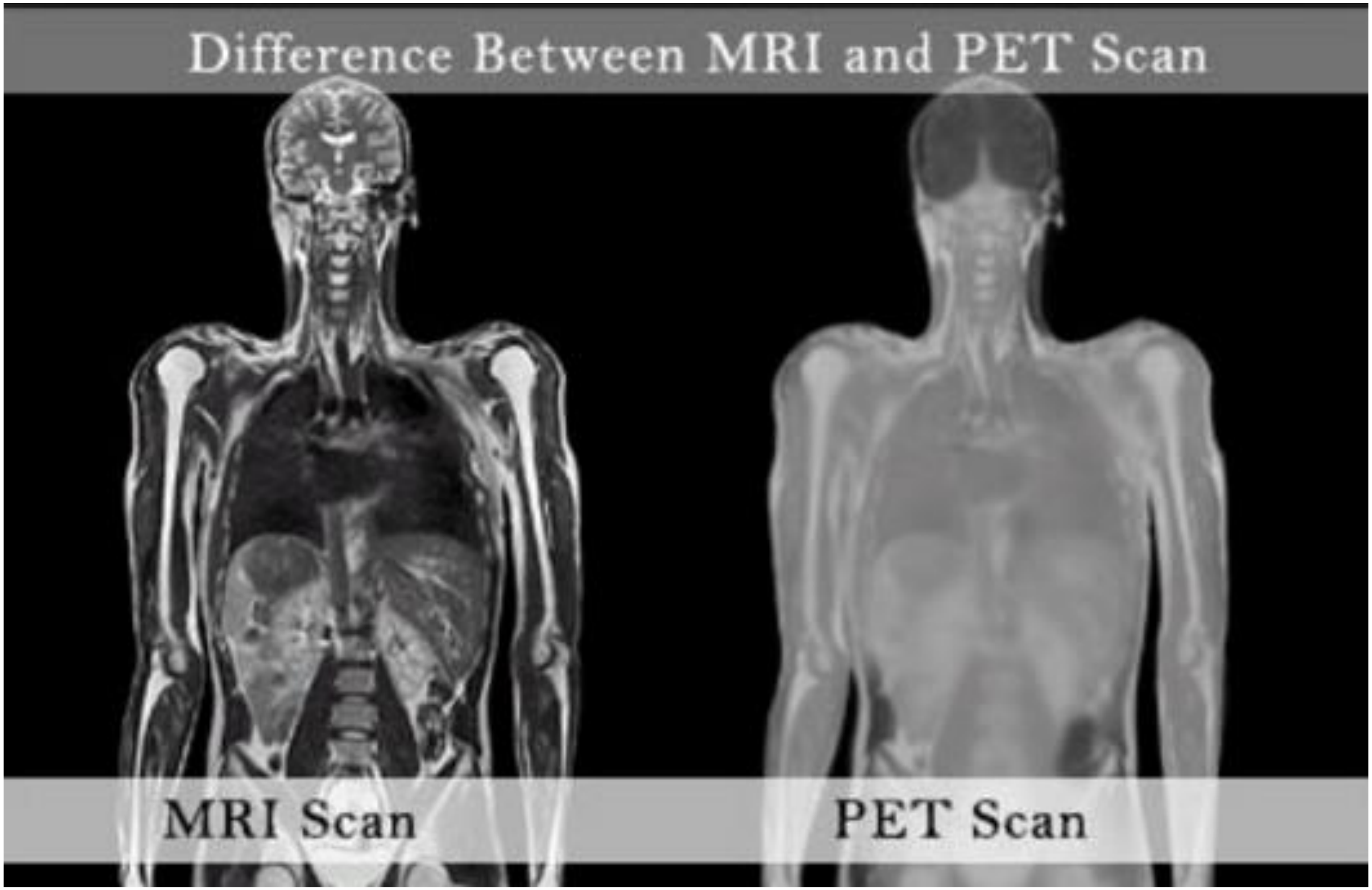
Example:

CT

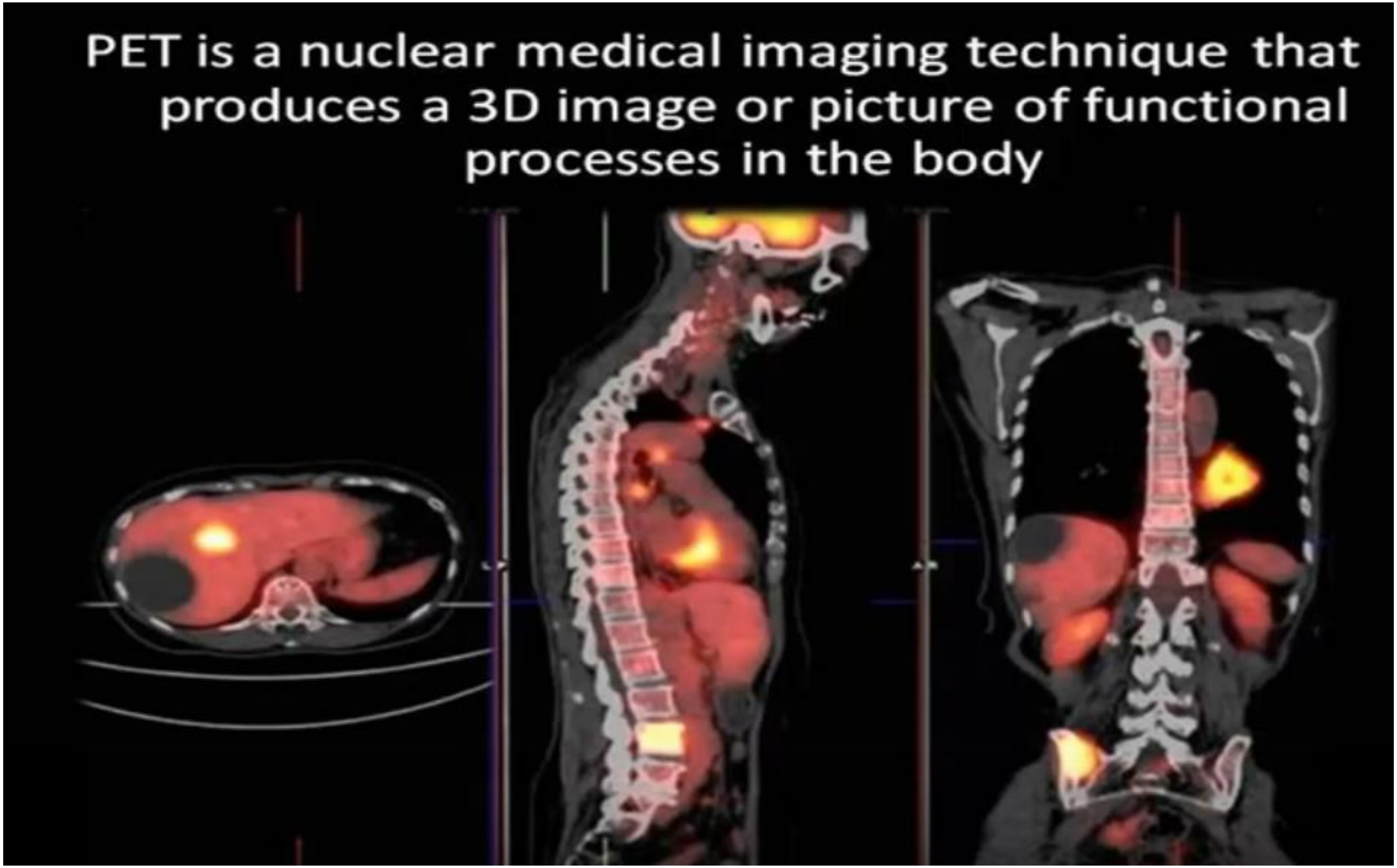


PET

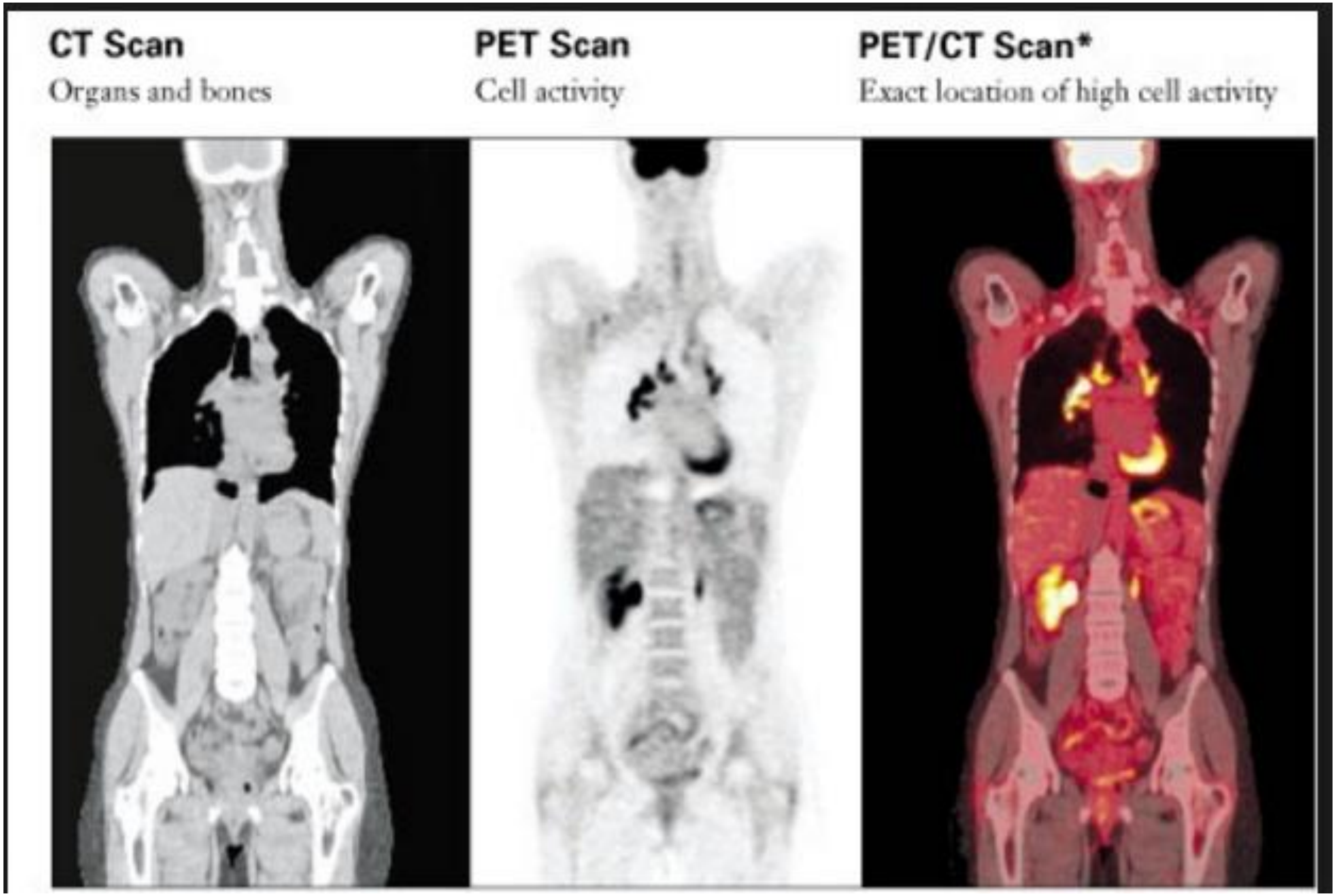
Example:



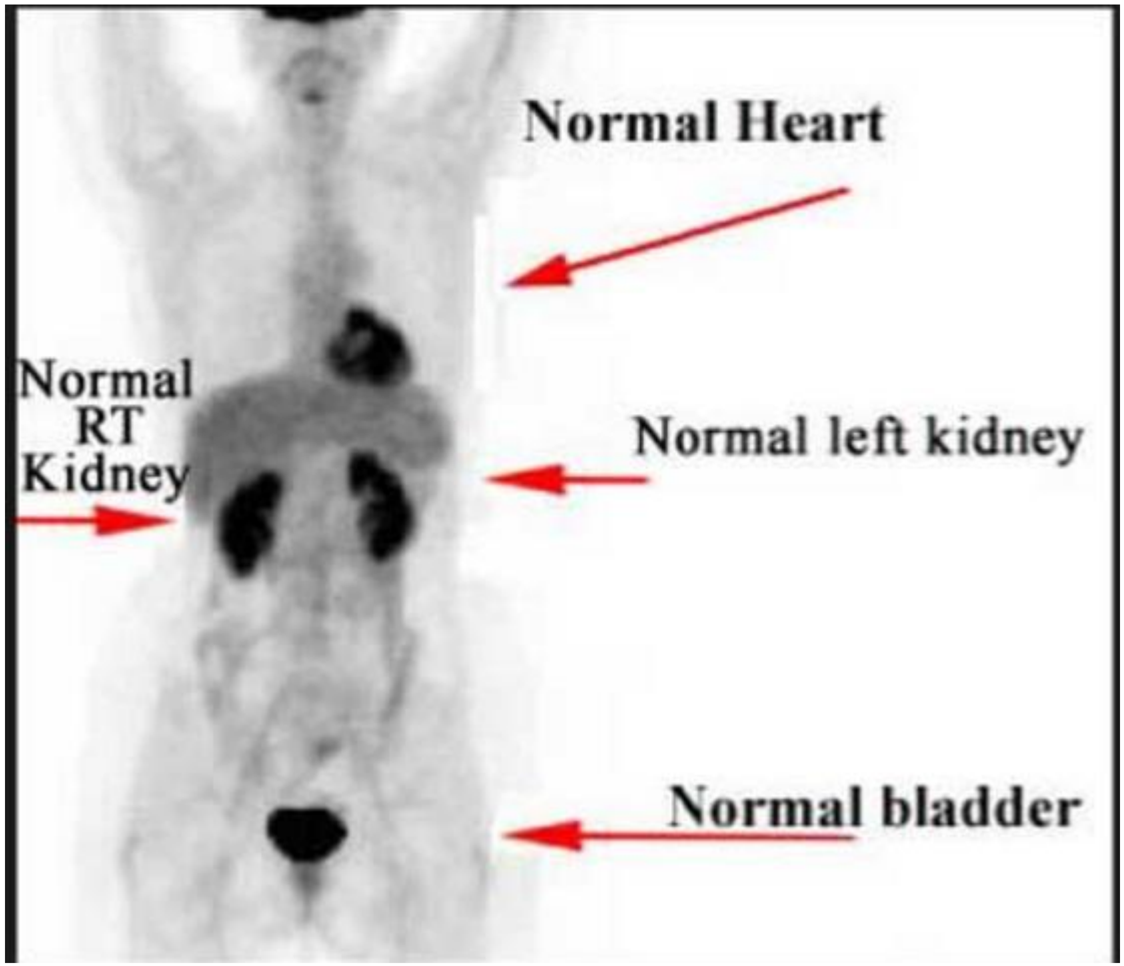
Example:


PET is a nuclear medical imaging technique that produces a 3D image or picture of functional processes in the body

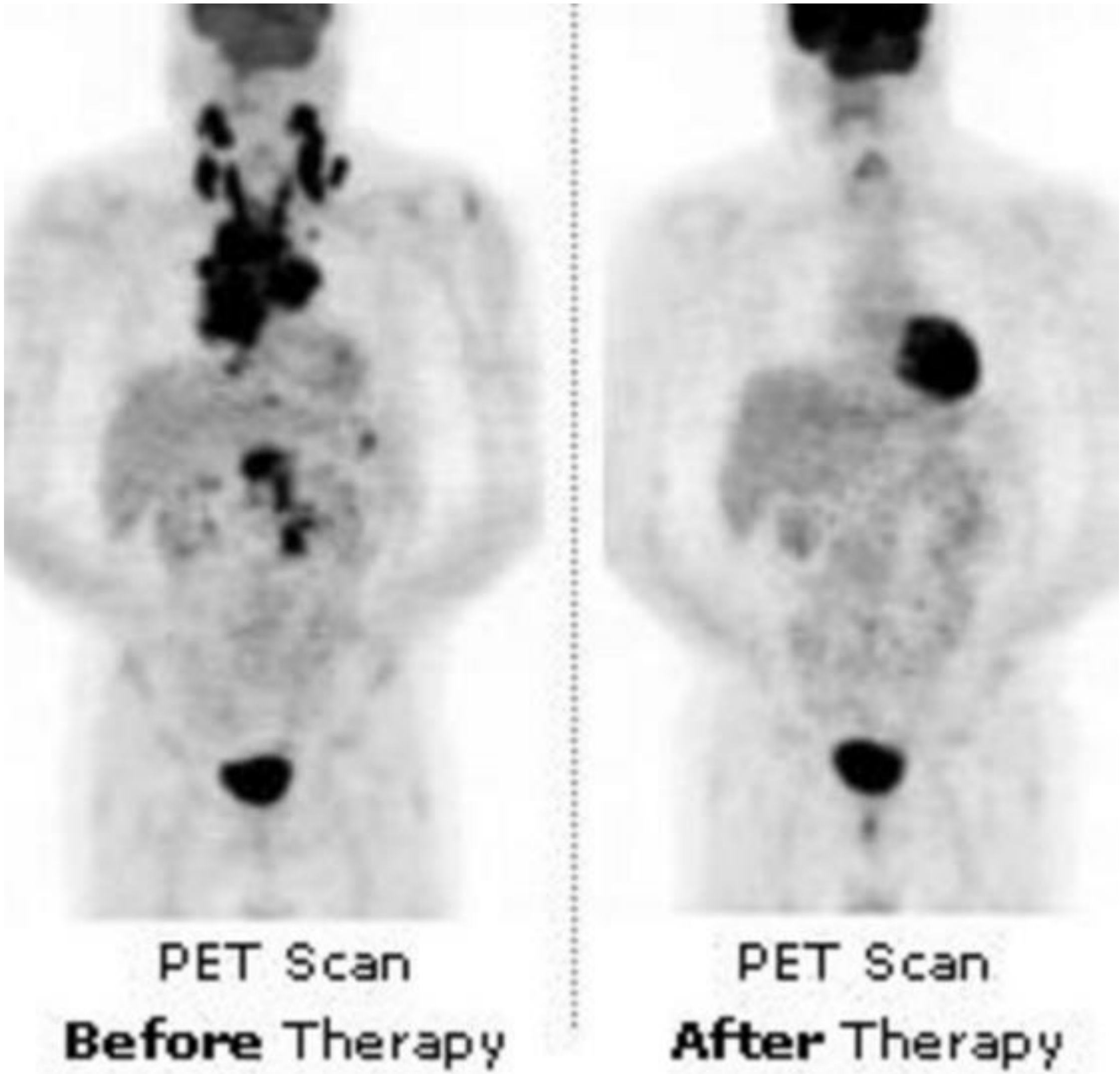
Example:


CT Scan
Organs and bones
PET Scan
Cell activity
PET/CT Scan*
Exact location of high cell activity

Example:


Normal Heart
Normal RT Kidney
Normal left kidney
Normal bladder

Example:



What are the differences between SPECT and PET?

- SPECT is similar to PET in its use of radioactive tracer material and detection of gamma rays. In contrast with PET, however, the tracers used in SPECT emit gamma radiation that is measured directly, whereas PET tracers emit positrons that annihilate with electrons up to a few millimeters away, causing two gamma photons to be emitted in opposite directions.
- A PET scanner detects these emissions "coincident" in time, which provides more radiation event localization information and, thus, higher spatial resolution images than SPECT.
- SPECT scans, however, are significantly less expensive than PET scans, in part because they are able to use longer-lived more easily obtained radioisotopes than PET.

Nuclear Medicine

- Year discovered: 1953 (PET), 1963 (SPECT)
- Form of radiation: Gamma rays
- Energy / wavelength of radiation: > 100 keV / < 0.01 nm (ionizing)
- Imaging principle: Accumulation or "washout" of radioactive isotopes in the body are imaged with x-ray cameras.
- Imaging volume: Whole body
- Resolution: Medium – Low (mm - cm)
- Applications: Functional imaging (cancer detection, metabolic processes, myocardial infarction)