SINGLE PHOTON EMISSION COMPUTER TOMOGRAPHY (SPECT)

Single-photon emission computed tomography (**SPECT**, or less commonly, **SPET**) is a nuclear medicinetomographic imaging technique using gamma rays.[1] It is very similar to conventional nuclear medicine planar imaging using a gamma camera.[2] However, it is able to provide true 3D information. This information is typically presented as cross-sectional slices through the patient, but can be freely reformatted or manipulated as required.

The technique requires delivery of a gamma-emitting radioisotope (a radionuclide) into the patient, normally through injection into the bloodstream. On occasion, the radioisotope is a simple soluble dissolved ion, such as an isotope of gallium(III). Most of the time, though, a marker radioisotope is attached to a specific ligand to create a radioligand, whose properties bind it to certain types of tissues. This marriage allows the combination of ligand andradiopharmaceutical to be carried and bound to a place of interest in the body, where the ligand concentration is seen by a gamma camera.

- SPECT is a nuclear medicine technique used to create a 30 image of the distribution of the adminsted radio pharmaceutical.
- SPECT cameras detect only radion that produce a cascaded emission of single photons.
- Rgs of SPECT radionuctides are TC-99m, Ti-201, I-123, 7n-111, and Xe-133.
- Main component is a single gamma camera movement on a specialized mechanical gentry that automatically rotates the camera 360^0 around the patient.
- SPECT acquire data is a series of multiple projection at cncrincents of 2 or more degrees. Camera is moved a limited no of times (Usually 6)n in limited angle systems.
- Image is reconstructed by filtered back projection algorithm.
- Once non target data are filtered off, the reconstructed 3D image is derived from back projection which will have multi angled; 2D views and projects them onto a computer monitor.
- Transverse slias (axial or trans axial) are obtained by combining the projected data.
- SPECT can one multiple camera heads.
    - Dual Head system→ 2, 180^O opposed camera heads.

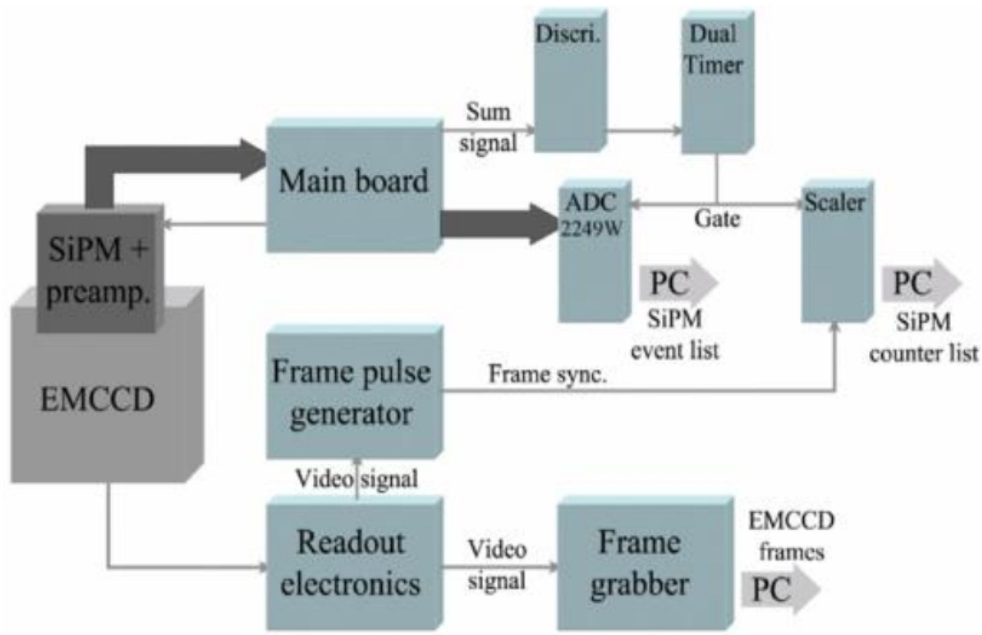
Accusation time reduced by half

Triple Head System→ Improves Sensitivity

- Sensitivity of SPECT is determined by the total area of detector surface that is viewing the organ of interest.

- Detector to improve sensitivity.
    - Bank of dis detectors, stationary ring of detectors and a unique ten beam collimator that rotates in front of the stationary detectors. (highly sensitive)
    - Another method uses a set of 12 and ventilation detectors coupled with a complex scanning motion to produce tomographic images.

Camera based SPECT



- A pallet (to reduce gamma ray alteration) supports the patient B/W 2 Scintillation cameras (radeally adjustable form 22-66cm detector surface to surface)
- Adjustable range allows the collimators to be in close proximity to patient.
- Data collected using contneus gantry during 360^{O} rotation.
- Acquisition time is 2-26 mins.
- 2 Na (71) crystals c FOV 40.6cm, are 9.5 mm thick.
- Detectors coupled to an array of 37 PMT's.
- Electronic circuitry includes circuit for positioning non-levearties and regional rensitivity variations.
- During acquisition, each X-Y pair of Gamma ray event coordinate digitized into a 128x 64 storage array in fuffer memory, together with detector identifying bit energy window identifying bit.
- A secondary window is used to reached events that have undergoes Compton scattering within the patient.
- The fast and common evaluation method for reconstruction of images is SPECT is by filtered back projection.

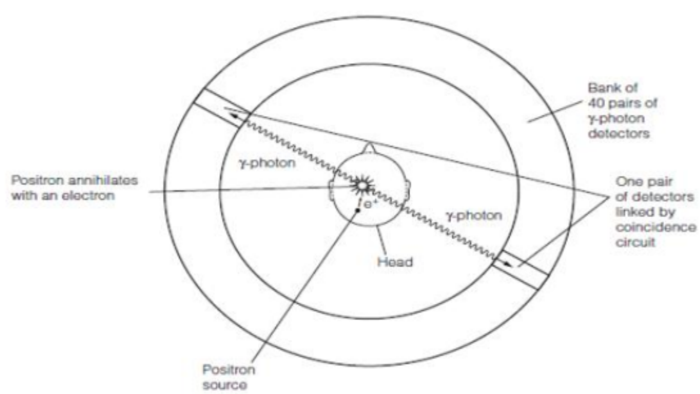
- Nowadays iterative algorithms or reconstruction method are used to prevent disturbances of artefacts.
- Parallel hole collimators is used for imaging organs like livers, lungs, and heart, for brain , fan beam collimators are used to increase sensitivity.
- Image display is dove on a system interfaced to a computer. 256x256 image format with 256 slides of gray with windowing and background subjection is available.
- Colors monitors are also provided and display station is also interfaced to a film recorder to obtain prints.
- An ECG gate can also be interfaced, to obtain end diastolic and end system SPECT images of the heart.
- Many were dyed image processing tools are used in the software. Some general also applications are image smoothing, interpolation, image addition or subtraction, background subtraction, contrast enhancements.

POSITRON EMISSION TOMOGRAPHY (PET)

An imaging technique for obtaining invivo cross sectional images of positions emitting isotopes that demonstrate biological function, physiology or pathology

Principle:-

- A chemical compound with the desired biological activity is labelled with a radioactive isotope that decays by emitting a positron.
- This emitted positron immediately combines with an electron and the two are naturally annitralated with the emission of 2 gamma rays.
- These 2 gamma rays travel in the opposite directions penetrate the surrounding tissue and are recorded outside the subjects by a circular array of detectors.



- A mathematical algorithm apptred by the computer rapidly reconstructs the apatial distribution of the radioactivity within the subject for a selected plane and displays resulting image on the monitor.
- The position (β^+) emitted from the proton such nucleus has a variable amount of KE.
- The β^+ combines with a free electron β^- and the masses are transmitted to two 511KeV gamma Rays which are emitted at $180^0 \pm 25^0$ to one another to satisfy conservation of momentum.

$180^0 \pm 25^0$

511 KeV ⟵ ⟶ 511KeV

± r ± re

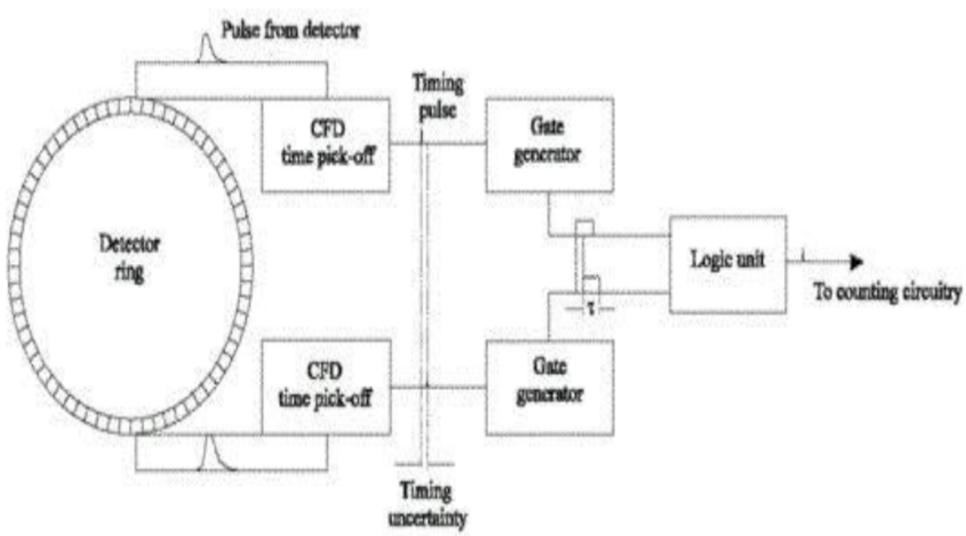
The isotopes used are ^{11}C, ^{13}N, ^{15}O and ^{18}F

Two design types of PET's are

1) Large area detectors which require rotation around the patient to provide necessary degree of angular sampling
2) Multiple individual crystal detector surrounding the patient in a circular or hexagonal array.

Collimators are not usually required and pulse processing needs to be faster.

Hoffmann PET System



- Gantry has large opening and can image brain and torso
- Detector system can be filtered to obtain oblique section.
- Scintillation crystals used are bismuth germinate (BGO) and they detect the 511KeV annilirilation eadration.

- Detectors arranged in circular ring geometry with 512 detectors per ring. Has 2 rings and produces 2 scanning plaves. Detectors are agganged in buckets C 16 detector packages. Each package contains 2 crystals and 2 PMT's. The bucket also contains amplifiers/dis cricimotors and few front end processing electronics.

Original PET Scanners

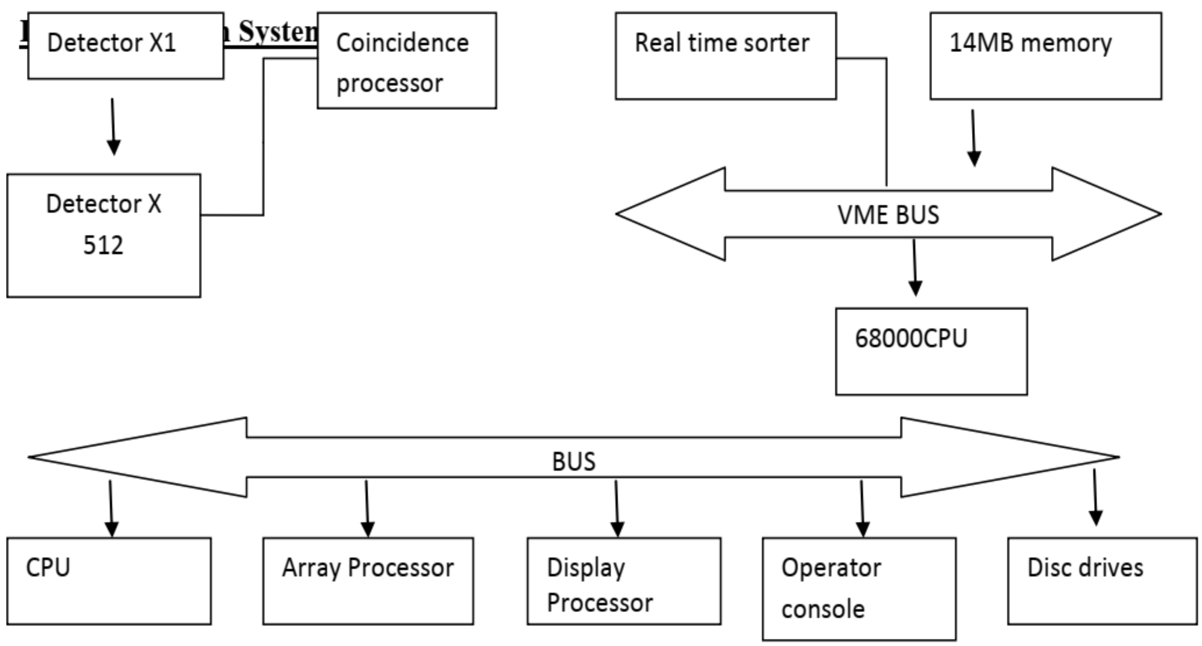
Thallium dropped scdium iodide detectors.

Advantages are high efficiency

- Ease of fabrication
- Low cost

Disadvantage

Decreasing detection efficiency(smaller crystal for higher resolution)



- Many processors are used throughout the system to maximize speed for simultaneous data collection.
- Individual and average detector signals are amplified.
- Constant fraction discriminator-deternunes thine of interaction.
- Time encoder- converts events into 14 bit word with detector no and event time within 8Hrs.
- Coincidence processor-14 bit word sent here every 22 Hrs.
- Energy window controlled by MP in every bucket.
- Threshold of 220 KeV is used to detect scattered gamma rays.

- Fan beam geometry used.
- Main processor- motors + Controls the various processing jobs.
- Array processor- used to perform primary reconstruction
- Peripheral devices- display processor, controls, desk divices.
- GE 4096 PET System
- High resolution scanning system
- 4096 individual crystals are arrange in 8 rings of 512 crystals each. 2 PMT's attached to each set of 16 crystals (to increase position sampling). Crystal used in Bismuth generate.
- 30 slices obtained in a single acquisition interval.
- Patient port is 57cm that allows for large patient scanning
- Positioning accomplished by triple laser positioning system.
- Horizontal or acial table positioning controlled manually.
- 2 pin shaped Ge sources are used for transmission requirements, adjustment of gain and normalization of detector efficiencies.

- DAP (Data acquisition processor) uses a 68030 processor and dual lutel i960 RISC processor. This controls the real time acquisition of data for the system

ANGIOGRAPHY

Angiography or **arteriography** is a medical imaging technique used to visualize the inside, or lumen, of blood vessels and organs of the body, with particular interest in the arteries, veins, and the heart chambers. The word itself comes from the Greek words ἀγγεῖον *angeion*, "vessel", and γράφειν *graphein*, "to write" or "record". The film or image of the blood vessels is called an *angiograph*, or more commonly, an *angiogram*. This is traditionally done by injecting a radio-opaque contrast agent into the blood vessel and imaging using X-ray based techniques such as fluoroscopy.

Technique:

Depending on the type of angiogram, access to the blood vessels is gained most commonly through the femoral artery, to look at the left side of the heart and at the arterial system; or the jugular or femoral vein, to look at the right side of the heart and at the venous system. During an angiogram, a thin tube called a catheter is placed into a blood vessel in the groin (femoral artery or vein) or just above the elbow (brachial artery or vein). The catheter is guided to the area to be studied. Then an iodine dye (contrast material) is injected into the vessel to make the area show clearly on the X-ray pictures. This "dye, " properly called contrast, makes the blood flowing inside the blood vessels visible on an x-ray. The contrast is later eliminated from your body through your kidneys and your urine. This method is known as conventional or catheter angiogram. The angiogram pictures can be made into regular X-ray films or stored as digital pictures in a computer.

Reasons:

An angiogram to diagnose a variety of vascular conditions, including:

- Blockages of the arteries outside of your heart, called peripheral artery disease (PAD)
- Enlargements of the arteries, called aneurysms
- Kidney artery conditions, called renovascular conditions
- Problems in the arteries that branch off the aorta, called aortic arch conditions
- Malformed arteries, called vascular malformations
- Problems with your veins, such as deep venous thrombosis (DVT) or blood clots in the lungs called pulmonary emboli

Applications:

One of the most common angiograms performed is to visualize the blood in the coronary arteries. A long, thin, flexible tube called a catheter is used to administer the X-ray contrast agent at the desired area to be visualized. The catheter is threaded into an artery in the forearm, and the tip is advanced through the arterial system into the major coronary artery. X-ray images of the transient radio contrast distribution within the blood flowing inside the coronary arteries allows visualization of the size of the artery openings. Presence or absence of atherosclerosis or atheroma within the walls of the arteries cannot be clearly determined.

Neuro-vascular angiography]

Another increasingly common angiographic procedure is neuro-vascular digital subtraction angiography in order to visualise the arterial and venous supply to the brain. Intervention work such as coil-embolisation of aneurysms and AVM gluing can also be performed.

Peripheral angiography

Angiography is also commonly performed to identify vessel narrowing in patients with leg claudication or cramps, caused by reduced blood flow down the legs and to the feet; in patients with renal stenosis (which commonly causes high blood pressure) and can be used in the head to find and repair stroke. These are all done routinely through the femoral artery, but can also be performed through the brachial or axillary (arm) artery. Any stenoses found may be treated by the use of atherectomy.

Risks:

Coronary angiography is a common medical test. It rarely causes serious problems. However, complications can include:

- Bleeding, infection, and pain at the catheter insertion site.
- Damage to blood vessels. Rarely, the catheter may scrape or poke a hole in a blood vessel as it's threaded to the heart.
- An allergic reaction to the dye that's used during the test.

Other, less common complications include:

- Arrhythmias (irregular heartbeats). These irregular heartbeats often go away on their own. However, your doctor may recommend treatment if they persist.
- Kidney damage caused by the dye that's used during the test.
- Blood clots that can trigger a stroke, heart attack, or other serious problems.
- Low blood pressure.
- A buildup of blood or fluid in the sac that surrounds the heart. This fluid can prevent the heart from beating properly.

As with any procedure involving the heart, complications can sometimes be fatal. However, this is rare with coronary angiography.

The risk of complications is higher in people who are older and in those who have certain diseases or conditions (such as chronic kidney disease and diabetes).

Collimator:

A collimator is a device that narrows a beam of particles or waves. The necessary shaping of the x ray beams are done by these. Collimators are used in neutron, X-ray, and gamma-ray optics because it is not yet possible to focus radiation with such short wavelengths into an image through the use of lenses as is routine with electromagnetic radiation at optical or near-optical wavelengths. Collimators are also used with radiation detectors in nuclear power stations for monitoring sources of radioactivity. To narrow can mean either to cause the directions of motion to become more aligned in a specific direction (i.e., make collimated light or parallel rays), or to cause the spatial cross section of the beam to become smaller (beam limiting device).

Collimators consists of a shutter made from a heavy metal like lead with a rectangular hole or

Collimators (beam limiting devices) are used in linear accelerators used for radiotherapy treatments. They help to shape the beam of radiation emerging from the machine and can limit the maximum field size of a beam.

Grids / Bucky Grids:

Grids are placed between the patient and the X-ray film to reduce the scattered radiation (produced mainly by compton effect) and thus improve image contrast.

They are made of parallel strips of lead with an interspace having an aluminum or organic spacer. The strips can be oriented either linear or crossed in their longitudinal axis. As the scatter radiation is increased in "thicker" patients and at larger field sizes, grids are useful in such scenarios to improve image contrast.

The working ability of a grid is described by the **grid ratio**, which is the ratio of height of the lead strips to the distance between two strips (the interspace). The higher the grid ratio, the better the image contrast but at a cost of increased patient dose. Grid ratio of 8:1 is generally used for 70-90 kVp technique and 12:1 is used for >90 kVp technique.

Radiographic Grid
• Used to reduce scatter radiation from reaching the image receptor (IR) through absorption
• Cleans up scatter radiation
• Inherent part of bucky, placed between the patient and IR
• Table or upright bucky usage – >60 kVp, 10 cm tissue
• When primary x-rays interact with the patient, x-rays are scattered from the patient in all directions.

Types

- focussed grids (most grids): strips are slightly angled so that they focus in space
- parallel grid: used for short fields or long distances
- moving grids (also known as Potter-Bucky grids): eliminates the fine grid lines that may appear on the image when focussed or parallel grids are used

Uses

Grids are commonly used in radiography, with grid ratio available in even numbers, such as 4:1, 6:1, 8:1, 10:1 or 12:1.

Generally used where the anatomy is >10 cm:

- abdomen
- skull

- spine (except lateral cervical)
- contrast studies
  - IVU
  - RGU
  - MCU
  - barium studies (including lateral cervical)
- breast (mammography): uses 4:1 grid ratio

- A bucky is typically used for table or wall mounted x-ray systems and holds the x-ray cassette and grid. A bucky, is a device found underneath the exam table, a drawer like device that the cassette and grid is slid into before shooting x-ray.

- The most common bucky size grids are 17 1/4 x 18 7/8, 17 1/4 x 17 3/4, and 18 x 18. Buckys are found in both medical and verterinarian offices.

- There is nothing special about a bucky grid other than its size.

- A reciprocating bucky is a device that moves the grid while the x ray is being taken. The motion keeps the lead strips from being seen on the image. The finer the lead strips, the less movement is needed.

Grid Frequency

• Number of strips or grid lines per inch or cm – 25 – 45 lines/cm, 60 – 110 lines/in – 25 – 80 lines/cm, 60 – 200 lines/in

• Higher grid frequency requires higher technique – Less grid lines appear in image – Often used in mammography

• 80 lines/cm, 200 lines/in

• Typically higher frequency grids have thinner lead strips