Introductory Lecture

RADIOLOGY & MEDICAL IMAGING

DR VIKRANT GUPTA
LECTURER RADIOLOGY
DATED: 01/07/2020

WHAT IS RADIOLOGY?

- Radiology represents a branch of medicine that deals with radiant energy in the diagnosis and treatment of diseases by using imaging technologies (Modalities), This field can be divided into two broad areas

- Diagnostic radiology
- Interventional radiology.

DIAGNOSTIC RADIOLOGY

- Diagnostic radiologists use medical images such as X-rays, ultrasound, CT scans and MRI scans to diagnose diseases anywhere in the body.

DIAGNOSTIC RADIOLOGY

- Neuroradiology
- Paediatric radiology
- Breast imaging
- Cardiovascular radiology
- Chest radiology
- Gastrointestinal radiology
- Genitourinary radiology
- Musculoskeletal radiology
- Emergency radiology
- Nuclear radiology

INTERVENTIONAL RADIOLOGY

A subspecialty of radiology that focuses on the diagnosis and treatment of patients utilizing minimally invasive interventional techniques (non-surgical procedures)

- These include
  - Imaging & treatment of blood vessels (angiography)
  - Biopsy procedures,
  - Cardiac Catheterization,
  - Angioplasty (balloon dilation of blood vessels)
  - Stents
  - laser treatment of varicose veins
  - fluid abscess drainage

WHAT IS MEDICAL IMAGING?

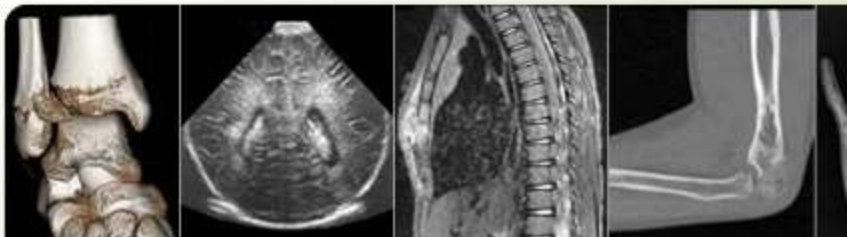
- Medical imaging is the visualization of body parts, tissues, or organs, for use in clinical diagnosis, treatment and disease monitoring. Imaging techniques encompass the fields of radiology, nuclear medicine and optical imaging and image-guided intervention

NUCLEAR MEDICINE

- Branch of medical imaging that uses small amounts of radioactive material (radioisotopes), to diagnos and determine the severity of or treat a variety of diseases
- Including many types of cancers, heart disease, gastrointestinal, endocrine, neurological disorders & o abnormalities within the body
- Most common nuclear medicine modalities used in clinical practice
  - Single-photon emission computed tomography (SPECT)
  - Positron emission tomography (PET).

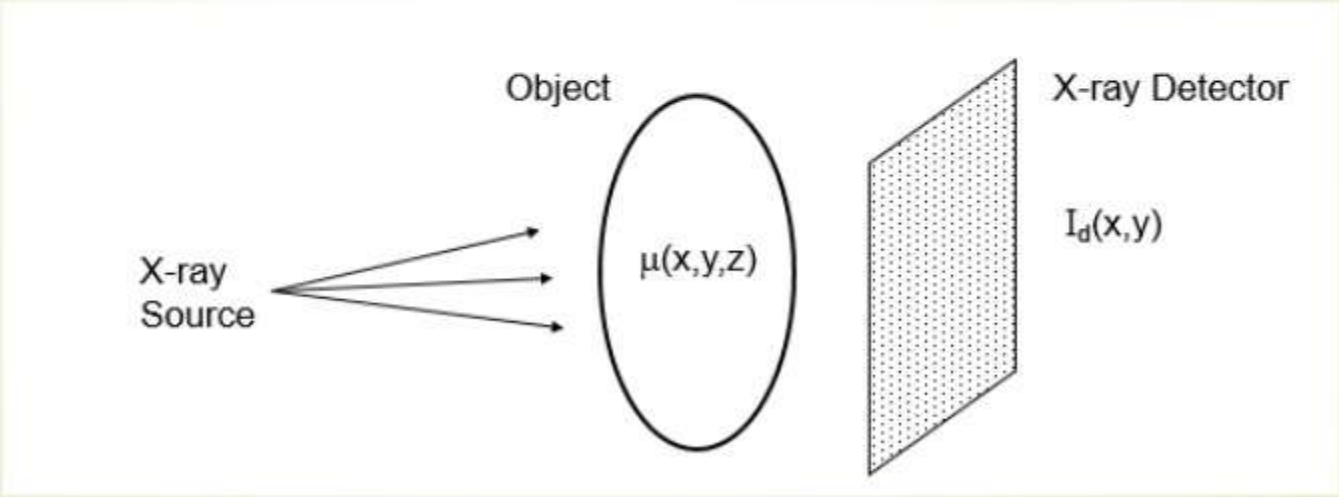
RADIOLOGY TECHNIQUES (MODALITIES)

- X-ray radiography
- Fluoroscopy
- CT - computer tomography
- MRI - magnetic resonance imaging
- PET - positron emission tomography
- SPECT - single photon emission computed tomography
- Ultrasound



PROJECTION (PLAIN) RADIOGRAPHY / X-RAY RADIOGRAPHY

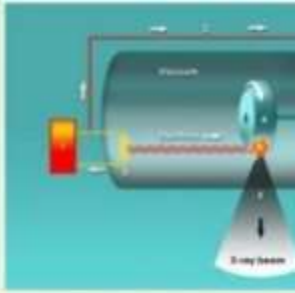
Radiographs are produced by the transmission of X-Rays (without added contrast materials such as barium or iodine) through a patient to a capture device then converted into an image for diagnosis.



X-RAYS

- X-rays are basically electromagnetic radiations which are used to create images of inside your body.
- The images show the parts of your body in different shades of black and white due to different level of absorption of x-rays by different tissues
- Calcium in bones absorbs x-rays the most, so bones look white. Fat and other soft tissues absorb less, and look gray.
- Air absorbs the least, so lungs look black.

X-RAY PRODUCTION



- X-rays are generated via interactions of the accelerated electrons with electrons of tungsten nuclei within the tube anode.
- There are two types of X-ray generated:
  - Characteristic radiation
  - Bremsstrahlung radiation.
- Advantages - relative inexpensiveness and the possibility to obtain them by using mobile or portable machines
- Disadvantages are the limited range of densities it can demonstrate and the use of ionizing radiation.

FLUOROSCOPY

- Fluoroscopy is a type of medical imaging that shows a continuous X-ray image on a monitor, much like an X-ray movie.

- During a fluoroscopy procedure, an X-ray beam is passed through the body. The image is transmitted to a monitor so the movement of a body part or of an instrument or contrast agent ("X-ray dye") through the body can be seen in detail.

Ultrasound

- High-frequency sound waves are used to visualize soft tissue structures in the body in real time.
- Ionizing radiation is not utilized in the technique, but the quality of the images obtained using ultrasound is highly dependent on the skill of the person performing the exam.
- Ultrasound probes utilize acoustic energy above the audible frequency of humans in order to produce images.
- As there is no ionizing radiation with this modality, it is particularly useful in imaging of children and pregnant women.

Ultrasound

DRAWBACKS:

gas filled and bony structures cannot be image (they absorb ultrasound beam)

ADVANTAGES:

- good for cysts/ cystic structures and fetus in its amniotic fluids

CT (COMPUTED TOMOGRAPHY) SCANNING

- Refers to a computerized x-ray imaging procedure in which a narrow beam of x-rays is aimed at a patient and quickly rotated around the body, producing signals that are processed by the machine's computer to generate cross-sectional images—or "slices"—of the body.
- These slices are called tomographic images and contain more detailed information than conventional x-rays.

CT SCAN - USES

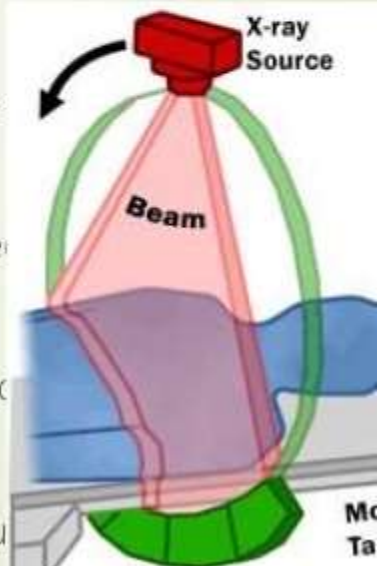
- Diagnose muscle and bone disorders - such as bone tumors and fractures
- Pinpoint the location of a tumor, infection or blood clot
- Guide procedures such as surgery, biopsy and radiation therapy
- Detect and monitor diseases and conditions - such as cancer, heart disease, lung nodules and liver masses
- Monitor the effectiveness of certain treatments, such as cancer treatment
- Detect internal injuries and internal bleeding

TYPES OF CT SCANS

- Head or brain CT
- Neck CT
- CT of the chest
- Abdominal and pelvic CT (CT Scanning of the Abdomen)
- Sinus CT
- Spine CT
- CT Angiography (*computed tomography technique used to visualize arterial and venous vessels throughout the body)*

HOW DOES CT WORK?

- Unlike a conventional x-ray—which uses a fixed x-ray tube— a CT scanner uses a motorized x-ray source that rotates around the circular opening called a **gantry.**
- During a CT scan, the patient lies on a bed that slowly moves through the gantry while the x-ray tube rotates around the patient, shooting narrow beams of x-rays (*Collimated)* through the body.
- CT scanners use special digital x-ray detectors, which are located directly opposite x-ray source.
- As the x-rays leave the patient, they are picked up by the detectors and transmitte a computer.
- Each time the x-ray source completes one full rotation, the CT computer generate 2D image slice of the patient.
- Image slices can either be displayed individually or stacked together by the compu



MRI (Magnetic Resonance Imaging)

WHAT IS AN MRI SCAN?

- A magnetic resonance imaging (MRI) uses a strong magnetic field and radio waves to create detailed images of the organs and tissues within the body.
- An MRI scan uses a large magnet, radio waves, and a computer to create a detailed cross-sectional image of the patient's internal organs and structures.
- The scanner itself typically look like a large tube with a table in the middle, allowing the patient to slide into the tunnel.
- An MRI scan differs from CT scans and X-rays because it does not use ionizing radiation that can be potentially harmful to a patient.

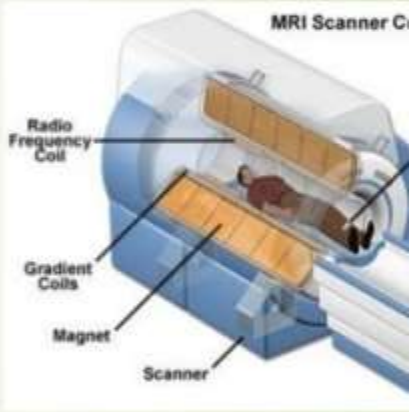
WHAT ARE MRI SCANS USED FOR?

- Abnormalities of the brain and spinal cord
- Tumors, cysts, and other abnormalities in various parts of the body
- Injuries or abnormalities of the joints, such as back pain
- Certain types of heart problems
- Diseases of the liver and other abdominal organs
- Causes of pelvic pain in women (e.g. fibroids, endometriosis)
- Suspected uterine abnormalities in women undergoing evaluation for infertility

- Sometimes, patients will be injected with intravenous (IV) contrast liquid to improve the appearance of a certain body tissue.

HOW DOES AND MRI SCANNER WORK?

- An MRI scanner contains two powerful magnets
- The human body is largely made of water molecules, comprised of hydrogen & oxygen atoms are randomly arranged
- Magnetic resonance imaging (MRI) makes use of the potential energy stored in the body's hydrogen atoms. At the center of each atom lies protons, which serves as a magnet and is sensitive to any magnetic field.
- Those atoms are manipulated by very strong magnetic fields and radiofrequency pulses upon entering an MRI scanner, the first magnet causes the body's water molecules to align in one direction,(Radio waves 10,000 to 30,000 times stronger than the magnetic field of the earth)

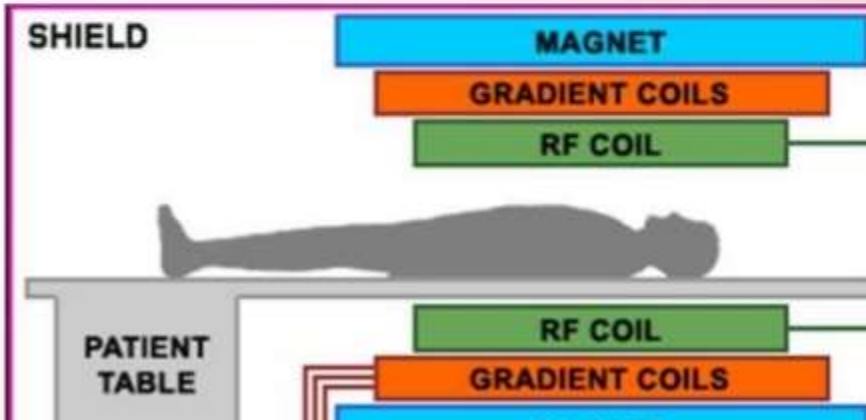


MRI SCANNER WORK?

- The second magnetic field is then turned on and off in a series of quick pulses, causing each hydrogen atom to alter its alignment and then quickly switch back to its original relaxed state when switched off.
- The magnetic field is created by passing electricity through gradient coils, which also cause the coils to vibrate, resulting in a knocking sound inside the scanner.
- Although the patient cannot feel these changes, the scanner can detect with a computer, can create a detailed cross-sectional image for the radiologist to interpret.
- Different protons send out different signals, depending on which tissue the proton can be found in. For example, a proton found in bone will emit a very different radio wave signal when compared to a proton found in blood.

MRI COMPONENTS

- Primary magnet
- Gradient magnet
- Radio Frequency (RF) coils
- Computer System



Functional Magnetic Resonance Imaging (fMRI)

- fMRI uses MRI technology to measure brain activity by monitoring blood flow in the brain by activation of brain areas by different types of physical sensation
- This gives an insight into the activity of neurons in the brain as blood flow increases in areas where neurons are active.
- This technique has revolutionized brain mapping by allowing researchers to assess the brain and spinal cord without the need for invasive procedures or injections of drugs.
- fMRI helps researchers learn about the function of a normal, diseased, or injured brain.

WHAT DOES AN MRI SCAN SHOW?

- Using an MRI scanner, it is possible to make pictures of almost all the tissue in the body.
- The tissue that has the least hydrogen atoms (such as bones) turns out dark, while the tissue that has many hydrogen atoms (such as fatty tissue) looks much brighter.
- By changing the timing of the radio-wave pulses it is possible to gain information about the different types of tissues that are present.

CT SCAN vs MRI SCAN

- A **CT Scan** is best suited for viewing bone injuries, diagnosing lung and chest problems, and detecting cancers.
- An **MRI** is suited for examining soft tissue in ligament and tendon injuries, spinal cord injuries, brain tumors, etc.
- CT scans are widely used in emergency rooms because the scan takes fewer than 5 minutes. An MRI, on the other hand, can take up to 30 minutes.
- An MRI typically costs more than a CT scan. One advantage of an MRI is that it does not use radiation while CT scans do. This radiation is harmful if there is repeated exposure.

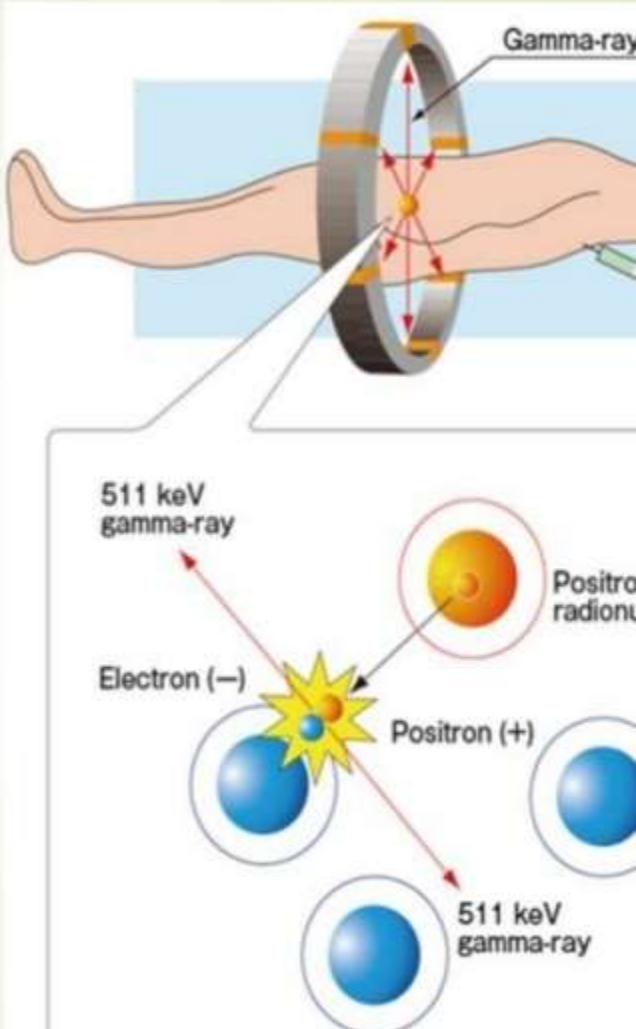
TESLA & GAUSS

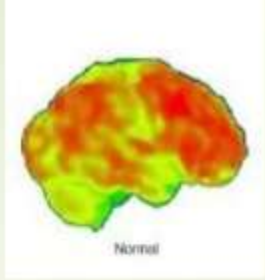
- MRI system is rated using a unit of measure known as a **tesla**.
- Another unit of measure commonly used with magnets is the **gauss** (1 tesla = 10,000 gauss).
- The magnets in use today in MRI systems create a magnetic field of 0.5-tesla to 2.0-tesla
- Most MRI systems use a **superconducting magnet**, which consists of many coils or windings of wire through which a current of electricity is passed,

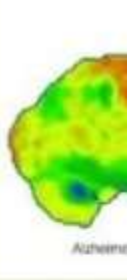
PET - POSITRON EMISSION TOMOGRAPHY

WHAT IS PET

- PET is Nuclear medicine functional imaging technique for metabolic processes/ functions in the human body.
- Positron emitting tracer is injected into the body which emits positrons causing annihilation that results two gamma rays.
- These rays are detected by opposing detectors.
- Then these signal is transfer to amplifier and other electronic circuit.



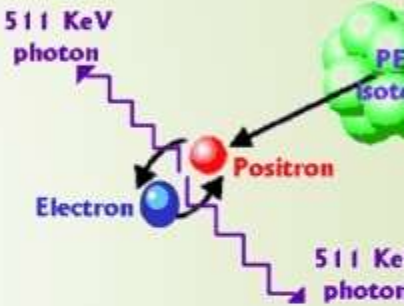


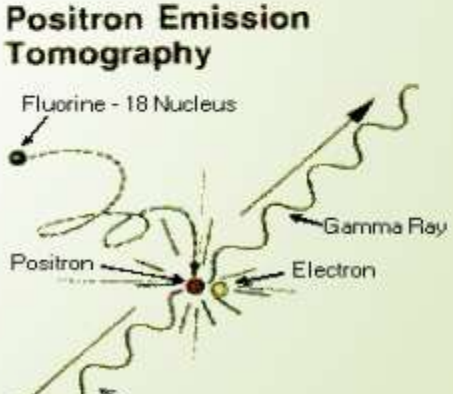


- The tracer may be injected, swallowed or inhaled, depending on which organ or tissue is being studied by the PET scan.
- The tracer collects in areas of your body that have higher levels of chemical activity, which often correspond to areas of disease. On a PET scan, these areas show up as bright spots.

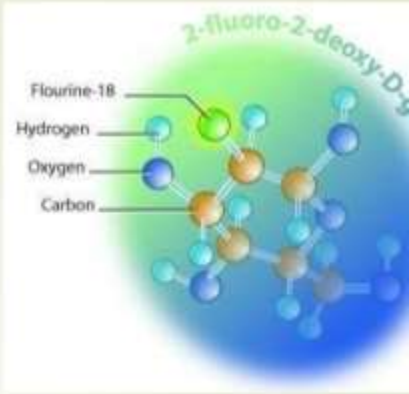
What is a POSITRON & How it produced GAMMA RAYS

- A Positron is an anti-matter electron, it is identical in mass but has an apposite charge of +1.
- Positron can come from different number of sources, but for PET they are produced by nuclear decay.
- The positron will encounter an electron and completely converting all their masses into energy.
- This is the result of two photons, or gamma rays





Tracer in PET

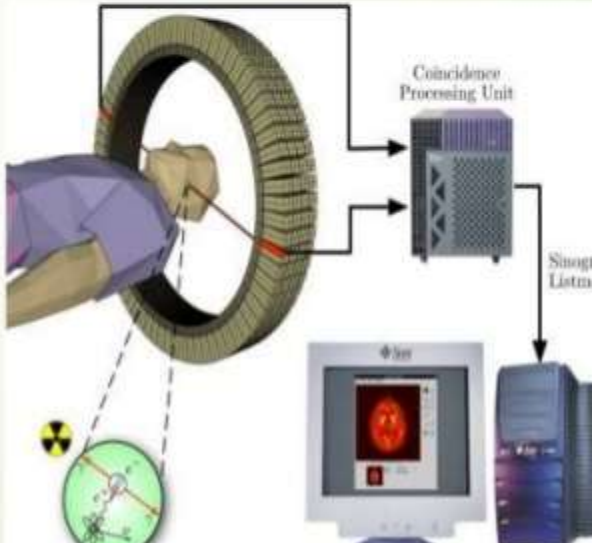


Special form of substance such as glucose in injected in body is FDG (Flouro-dehydroxy glucose) that collects in cells that are using a lot energy such as cancer cells

Why glucose ?

When radio pharmaceutical inserted in body. Body consume energy in the form of glucose

Tumor has high rate of consumption



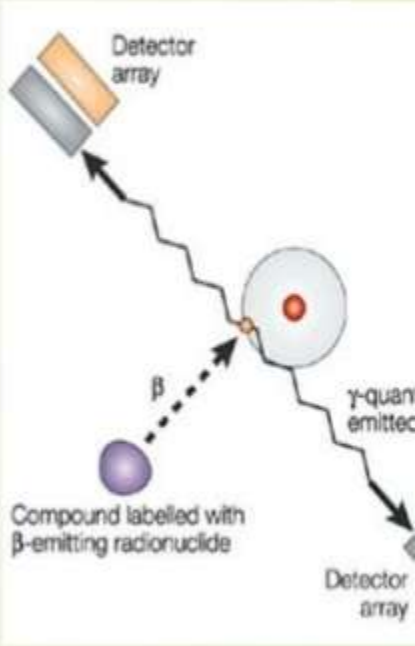
WHAT ARE THE PRIMARY FUNCTIONS OF THE PET SCANNER?

- Detect and Stage a Cancer (Earlier than CT / MRI)
- Determine whether a Cancer has spread throughout the body
- Find the place in the body where the Cancer first started (primary site)
- Make decisions on whether the Cancer can be removed surgically
- Make decisions about treatment plans
- Assess the effectiveness of a treatment plan, such as chemotherapy
- Show the difference between a scar tissue and an active Cancer tissue
- Determine if a Cancer has recurred after treatment
- Evaluate brain abnormalities such as Tumors
- Useful in evaluating some heart diseases

SINGLE-PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)

SINGLE-PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)

- Nuclear medicine tomographic imaging technique using gamma rays.
- Detect single photons emitted by radionuclide tracers
- Determine the origin and direction of emitted gamma
- Reconstruct 3D images of the source or anatomy
- Used as a diagnostic tool to image tumors, disease, and perform bone scans
- The images reflects functional information about patients similar to that obtained with PET



- The technique requires delivery of a gamma-emitting radioisotope (a radionuclide) into the patient, normally through injection into the bloodstream.

SINGLE-PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)

- a nuclear medicine tomographic imaging technique using gamma rays. It is very similar to conventional nuclear medicine planar imaging using a gamma camera (that is, scintigraphy). However, it is able to provide true 3D information. This information is typically presented as cross-sectional

- The technique requires delivery of a gamma-emitting radioisotope (a radionuclide) into the patient, normally through injection into the bloodstream.

PRINCIPLE OF SPECT

- SPECT imagers have gamma camera detectors that can detect the Gamma-ray photons emitted from the tracers that have been injected into the patient.
- The cameras are mounted on a rotating gantry that allows the collimated radiation detectors to be moved in a tight circle around a patient
- In SPECT, projection data are acquired from different views around the patient.
- The 3D images are computer generated from a large number of projection images of the body recorded at different angles.

(Gamma rays are a form of light that moves at a different wavelength than visible light)

SPECT/ PET

SPECT	PET
SPECT imaging is inferior to PET less resolution and sensitivity	Superior to SPECT
Lower cost	Very expensive
uses gamma emitting radioisotope (tracer) – half-life around 6h	uses positron emitting radioisotope (tracer) - half-life 75 seconds
SPECT radio tracers are cheaper	SPECT radio tracers are expensisve

ADDING CT TO SPECT AND PET (SPECT/CT & PET/CT)

- The incorporation of a CT scanner with a gamma camera for combined SPECT/CT or PET/CT imaging is designed to give anatomic with other than functional

- Innovative hybrid technology seamlessly integrates the functional images of advanced SPECT with the precise anatomical detail of multi-slice high-resolution CT.

THANK YOU

Next Lecture: 08/07/2020

Topic: Diagnostic X-Ray and X-Ray Related Special Investigations