Structured Notes According to

RADIOLOGY

Revision friendly **Fully Colored Book/Structured Notes**

For Best results, watch the video lectures along with reading notes

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In case of any discrepancy between book and videos, Dr. Nikita Nanwani's videos on PrepLadder should be considered.

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1 BASICS OF RADIOLOGY PART-1

Radiology or Radio-diagnosis deals with radiation involving investigations, nuclear medicine, and radiotherapy.

Types of Radiation

00:01:16

1. **Particulate Radiation**: Alpha (α) rays, Beta (β) rays and Neutrons
2. **Electromagnetic Radiation** (EMR): X-rays and Gamma (γ) rays

Ionizing power & penetration power

- Ionizing power is the amount of damage that occurs when DNA emits free radicals due to radiation.
- It is also known as Damaging power or LET (Linear Energy Transfer). PYQ: AIIMS 2018
- Ionizing power: Alpha (α) > Beta (β) > X-Rays > Gamma (γ) rays
- Penetration power: Neutrons > Gamma (γ) rays >Beta (β)rays >Alpha (α)rays
- Alpha particles have minimum penetration power. They stay in the body for maximum periods and then show effects.

Q. Which one has the highest penetrating power?

A. Alpha
B. Beta
C. Gamma
D. Neutrons

Ans: Neutrons have more penetration power than Gamma rays.

Types of Radiation

Ionizing

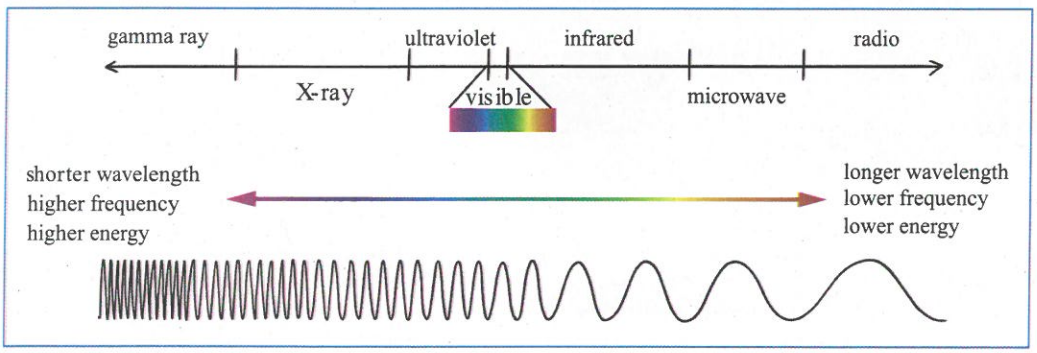
- **X-rays,** Radiography 3D X-rays (CT scan)
- **Contrast X-rays** - (Fluoroscopy-HSG, IVP, ERCP)
- **Gamma rays**, used in nuclear medicine – Scintigraphy, PET, SPECT

Non-ionizing

- **USG**
  - Doppler
  - FAST (Focused Assessment Sonography for Trauma)

PYQ: NEET PG 2021

- **MRI:** MRCP
- **Thermography**



Feature	EMR	Visible light
Energy	High	Low
Frequency (v)	High	Low
Wavelength (λ)	Low	High
Penetration	High	Low

- All EMR travel at the same speed.
- They have no charge and they do not get deflected by an electric field.
- Alpha particles are positively charged.
- Beta particles are negatively charged.

Recall: Speed of light 3×10^{8}m/sec.

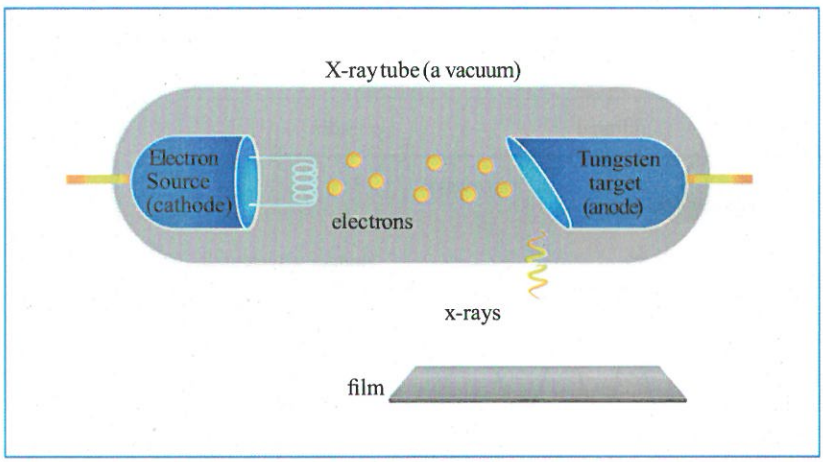
Feature	X-rays	Gamma rays
Energy	Less	High
Frequency (v)	Less	High
Wavelength (λ)	High	Less
Penetration	Less	High
Origin	Extranuclear	Nucleus

- Gamma rays are produced from the disintegration of the nucleus of radioactive isotopes.
- They are used in nuclear medicine.

X-ray Production

00:13:55

- The sudden stopping of a fast-moving electron beam produces X-rays.
- The beam converts kinetic energy to 99% heat and 1% x-rays.
- X-rays were discovered accidentally by W.C. Roentgen on 8th November 1895 (International Day of Radiology).
- Anything unknown in mathematics is described as 'x.'
- These unknown rays were named X-rays.

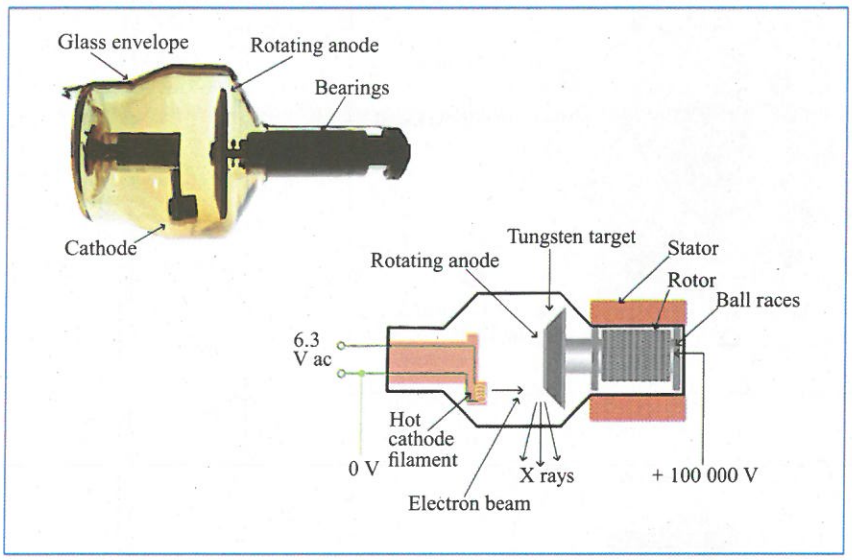


Working Principle

- A cathode (Filament) is an electron source that produces electron beams.
- The anode is a Tungsten target that stops electron beams.
- The electron beam travels from the cathode to the anode.
- Thermionic emission occurs at the cathode, where the cathode is heated to a high temperature, which emits electrons.
- Anode blocks the beam, and 1% of X-rays escape through the window onto a film.
- The remaining 99% of heat dissipation is by radiation.

Important Information

- Filament in the x-ray tube is made up of Tungsten (W, atomic number: 74)
- It has a high melting point.
- Nowadays, tungsten is added with Thorium.
- Anode is made up of tungsten and Rhenium.
- Nowadays, rotating anodes are used to avoid focal points as in stationary anodes.
- This increases the shelf-life of an anode.
- X-ray tubes are made up of Pyrex or ceramic or metal.



- Most anodes are rotatory which is most suitable and commonly used.
- **Stationary anodes:** Portable X-ray units
  - Emergency department
  - Dental clinics
- **Focusing cup (made of nickel):** Used to focus the beam that comes from the cathode as a straight line and prevents reflection
- Tungsten has the highest melting point, which is used as a cathode.

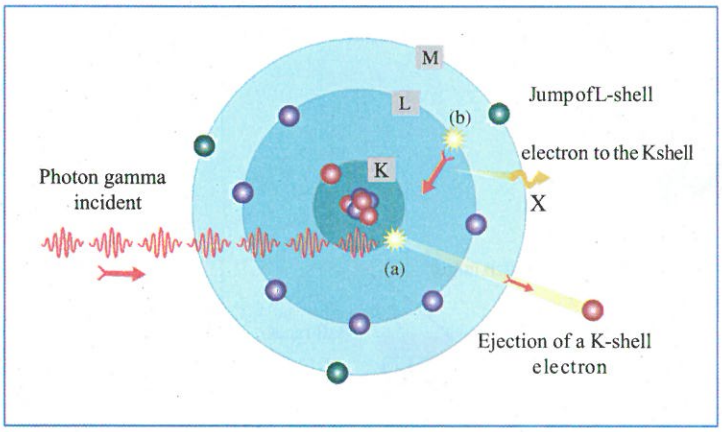
X- ray tube Components

- The glass envelope is made up of lead (Pb).
- The cathode is made up of Tungsten and Thorium.
- The anode is made up of Tungsten and Rhenium.
- The focusing cup is made up of Nickel.

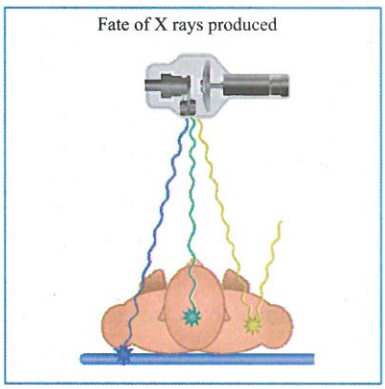
Bremsstrahlung vs Characteristic Radiation

00:25:57

- When an electron (negatively charged) beam travels toward the anode, the nucleus (positively charged) gets deflected and travels in a different direction.
- This is known as Bremsstrahlung radiation or braking radiation.
- Polyenergetic, continuous spectrum depending on the angle of deflection
- Characteristic radiation depends on the atomic number of the element.



Fate of X-rays Produced



A. Photoelectric Effect

- Similar to characteristic radiation.
- The beam ejects the innermost electron, which is replaced with the outer electron and then emits radiation.
- This is responsible for producing contrast in the X-ray film.
- The energy of the outer electron should be relative to the innermost electron.

B. Compton Effect

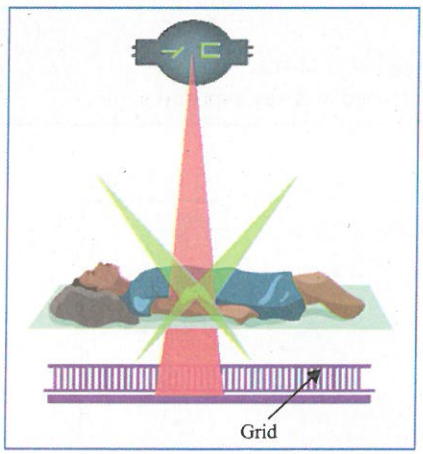
- The beam interacts with the outermost shell electron and ejects it.
- The remaining energy is converted to scatter radiation.
- The Crompton effect is bad.
- High energy X-ray photons interact with the outermost electron.

	Photoelectric Effect	Compton Effect
Shell	Innermost	Outermost
Energy	Low energy photon	High energy photon
Effects	Good, produces contrast on the films	Bad, produces scattered radiations on the film

- The X-ray beam is poly energetic.
- High-energy beams are helpful for high penetration.
- Low energy cannot penetrate the body; it stays in the body and is more damaging.
- A filter is placed between the X-ray tube and the patient.
- It is used to remove low-energy X-rays.
- A filter is made up of aluminum and copper.
- Thickness is 2.5 mm.

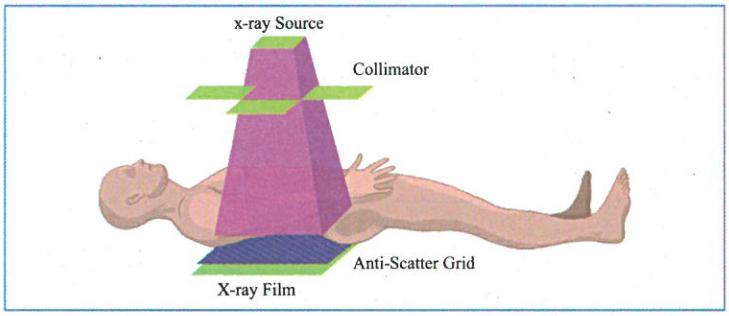
Important Information

- Lead is not used as a filter, as it stops all the rays.
- Filter is made up of a low atomic number of particles, which stops all the low-energy X-rays and permits high-energy X-rays.
- Scatter radiation (Compton effect) is also seen, which is bad.
  - The radiation may reach people surrounding it.
  - It may also interfere with X-ray film and reduce the film quality (blur or fog).
- To overcome this effect, a lead apron is given to the other person.
- **Lead apron protects from PE and Compton effects.**
- **Indian guidelines - thickness: 0.25mm, 0.5mm (most commonly used).**
- **International guidelines - thickness:0.5mm**
- **Gonadal sheet-0.5mm**



Scattered radiation can be reduced with the help of :

- **GRID**
  - It is placed between the patient and the cassette.
  - It is made up of lead and aluminum.
  - It blocks the scattered radiation, allowing primary radiation.



- **Collimator**
  - Beam limiting device.
  - It narrows the beam onto the patient.
  - It decreases the scattered radiation production.

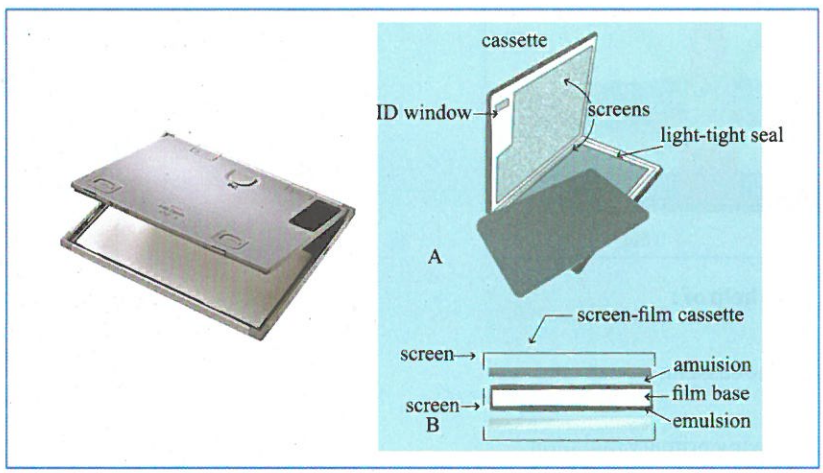
Factors to be considered

- **mAs**
  - Milliampere seconds is the unit of electric current.
  - Current is the flow of electrons.
  - Increase in mAs do not change the penetration power. It increases blackening (contrast) in the X-ray film.
- **KVP**
  - Kilovoltage peak is the unit for the potential difference between the cathode and anode.
  - KVP is directly proportional to the velocity of the X-ray beam and penetration power.
  - Increased penetration power may reduce the contrast of X-ray film.
  - In obese individuals, Kvp should be increased.
- **Distance** PYQ: NEET PG 2023
  - According to the inverse square law, the intensity reaching a point is inversely proportional to the square of the distance.
  - $I \propto 1/D^2$
  - For example, if the distance is 3, the intensity will be $1/9^{th}$

Important Information

- Contrast is the differentiation of black and white in the film.
- To increase the contrast of an X-ray film:
  - Kvp should be decreased
  - mAs should be increased
- In children, X-ray is taken from long distances to avoid higher intensity.
- ALARA (As Low as Reasonably Achievable) principle is used in X-ray exposures.

Conventional/ Film Screen Radiography 00:56:28



- It utilizes X-ray film. It is made up of an emulsion of silver halide (the maximum component is Silver Bromide).
- The coating may be single or double-sided.
- General X-rays are coated on both sides.
- A mammography x-ray is coated on a single side.
- The screen intensifies the effect of X-rays and increases the amplitude.
- These films are sensitive to light. Also, X-rays are taken in dark rooms.
- Film development takes about 45 minutes.

CR (Computed Radiography)

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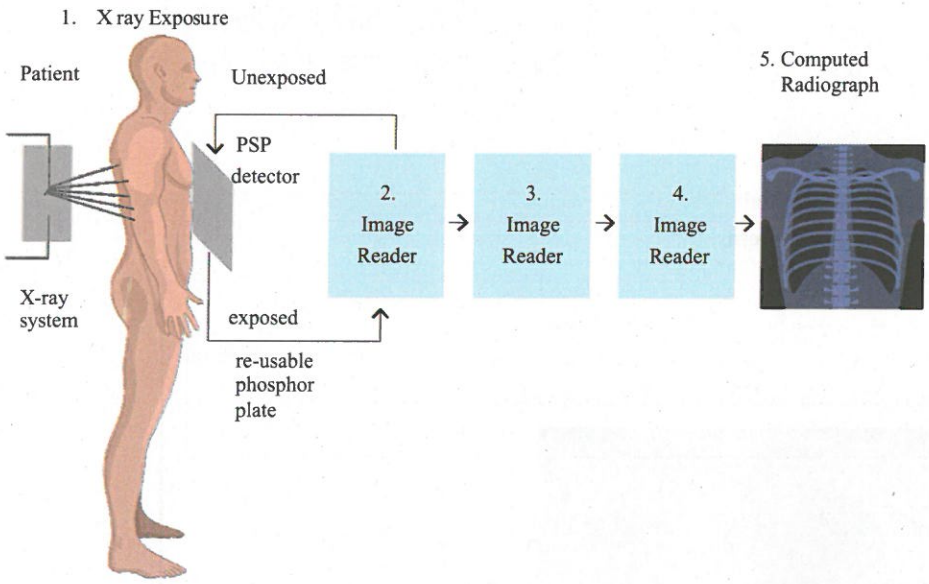
CR Image acquisition



- X-ray is sent to a computer for printing.
- The film is not used. Instead, a PSP (Photostimulable Phosphor) plate is used.
- A scanner, which reads PSP and sends images on a computer, is used in CR.
- Advantages of CR over Conventional radiography-
  - PSP can be reused.
  - The image is on the computer, editable.
  - A retake of an X-ray is not needed.
  - It can be shared online easily.
  - PACS compatible.

DR (Digital Radiography)

01:03:46

- X-rays are emitted from X-ray tubes.
- Selenium or Cesium iodide is used as detectors.
- The image is available on the computer.
- Advantages of DR-
  - A PSP plate is not required.
  - Very quick
  - PACS compatible

MCQ

Q. PACS is an acronym for?

A. Portal Archiving & Common System
B. Planning Archiving & Communication System
C. Picture Archiving & Communication System
D. Photo Archiving & Computerized System

Position of an X-ray

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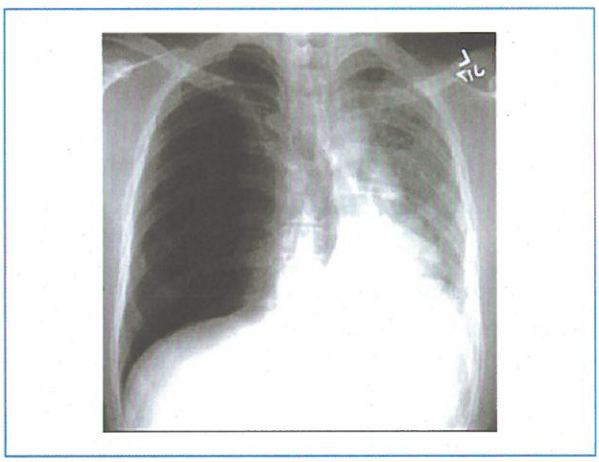
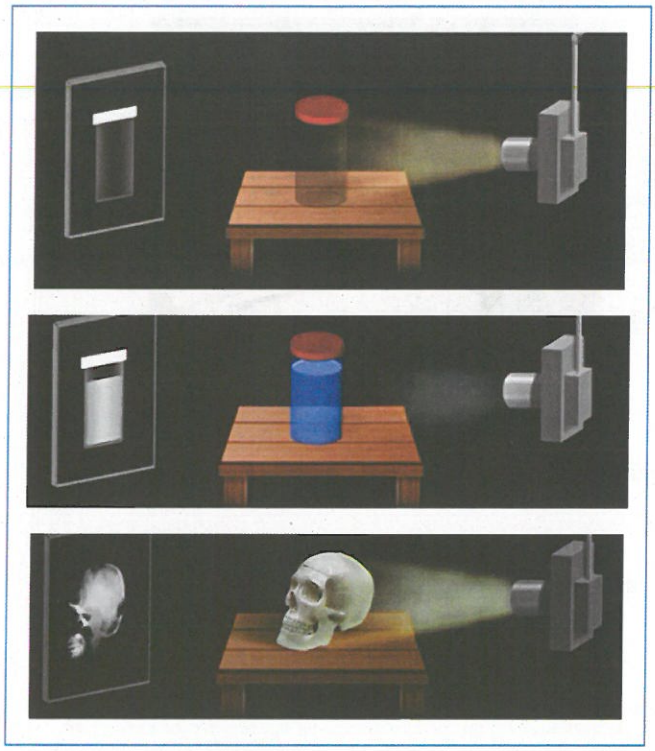
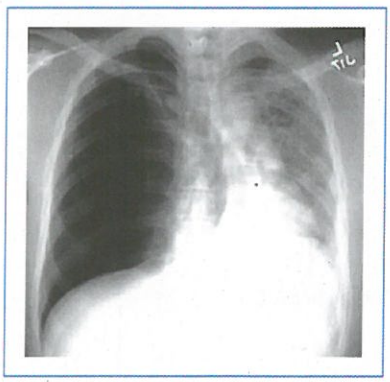


- Imagine the patient is standing in front of you.
- Your right side should be in line with the patient's left side, and vice-versa.

Black and White Principle in X-rays



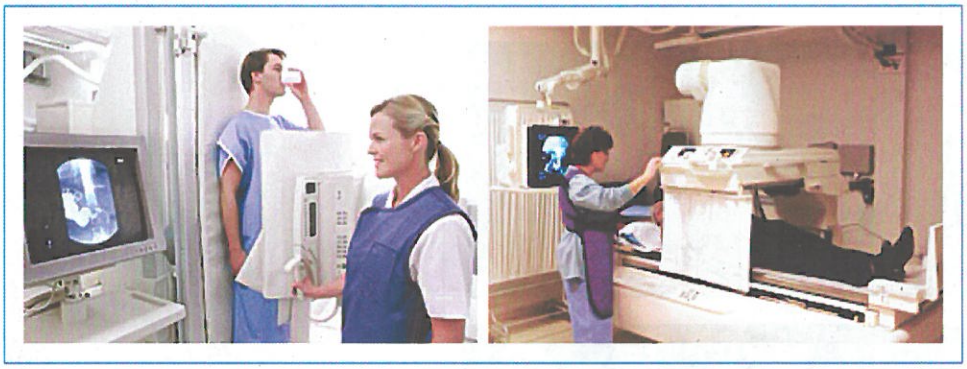
- X-rays passing through low densities (air) with maximum penetration appears black.
- X-rays passing through high densities (water/bone) with minimum penetration appears white.
- Bones cause maximum attenuation of X-rays.
- Increased penetration appears black.
- Decreased penetration appears white.



- On X-ray
  - Pneumothorax (air) - Black
  - Pleural effusion (water)- Grey/White
  - Calcification (bones)- White
- On CT scan (3D X-ray)
  - Pneumothorax (air) - Black
  - Pleural effusion (water)- White
  - Calcification (bones)- White

Fluoroscopy

01:13:54

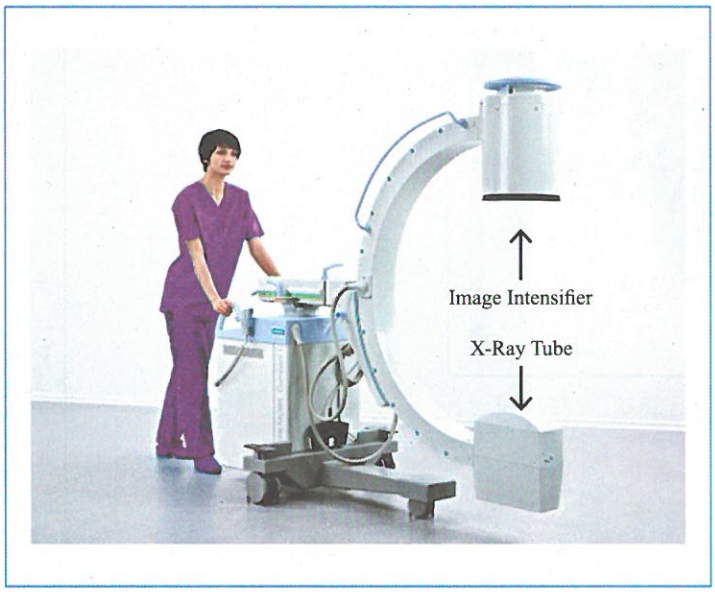


- A video or movie or cine X-ray.
- It is used for moving structures.
  - Blood-DSA (Digital Subtraction Angiography)
  - GIT peristalsis- Barium- motility
  - Cardiology
  - Diaphragmatic palsy- Paradoxical movement of the diaphragm.
  - C-arm in ortho OT
  - ERCP

Important Information

- Paradoxical movement of diaphragm can be observed on M-mode USG.
- Radiation exposure is high in Fluoroscopy compared to X-ray.
- Interventional radiologists have high exposure to radiation.

C-arm



- It is a C-shaped machine with an X-ray tube and image intensifier.

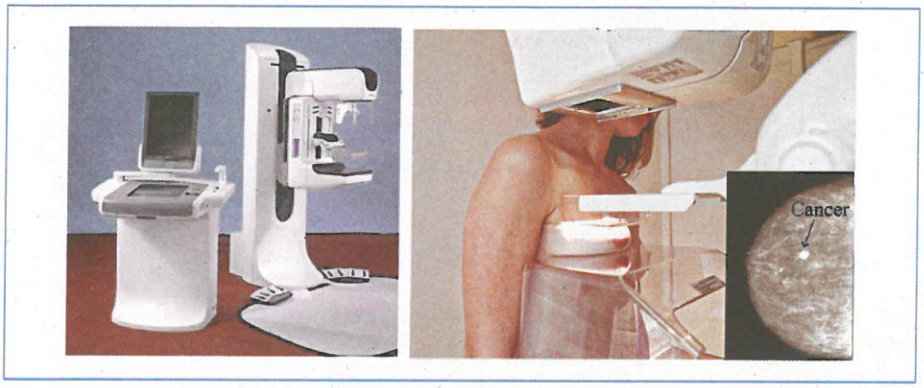
Important Information

- Image intensifiers are used in Fluoroscopy to convert images into a video on the screen.
- Image can be white or inverted (white structures on X-ray may appear black on Fluoroscopy).

- The patient is given a barium swallow: for esophageal studies.
- Real time X-ray imaging with high radiation exposure

Mammography

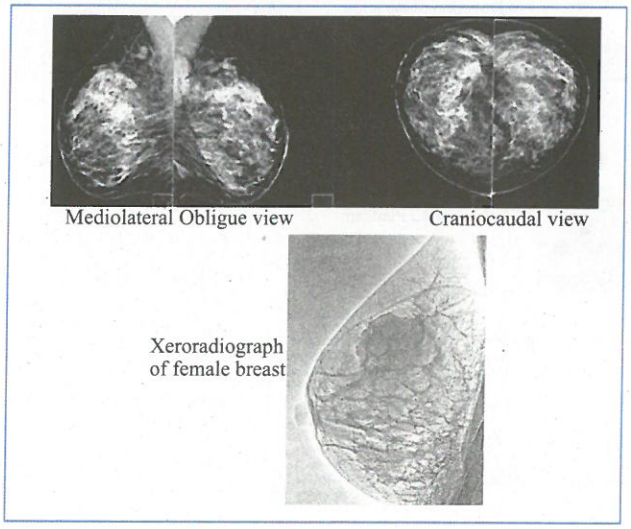
01:21:58



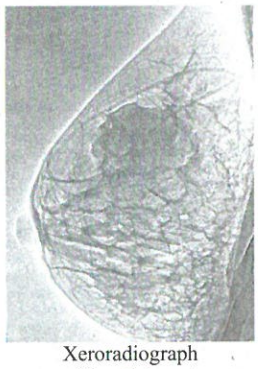
- It has compression plates, and breasts are placed on them.
- It is a low Kvp X-ray.
- In Mammography, the anode is made up of Molybdenum/Rhodium, the filter is also made up of Molybdenum, and the window is made up of Beryllium.
- X-rays penetrate breasts vertically and enter a detector.
- Compression is a must for better penetration and uniformity of breasts.
- C/I in acute, painful conditions (mastitis, breast abscess)
- It helps in the early detection of breast cancer.
- It is preferred over chest X-ray because of its benefits.
- Radiation exposure in Mammography (0.4msv) is more than in a chest x-ray (0.02msv). Mammography is still preferred because of its benefits rather than the risks.

Important Information

- Mammography in young females gives a white image; because the have dense breasts.



- The left side of the patient should be in line with your right side.
- Two perpendicular views are taken:
  - CC (Craniocaudal)
  - MLO (Mediolateral Oblique) view: axillary lymph nodes are also seen
- This gives a 3D orientation about the pathology.
- For example, AP and lateral views are taken for clarity in a fracture.



Xeroradiograph of female breast

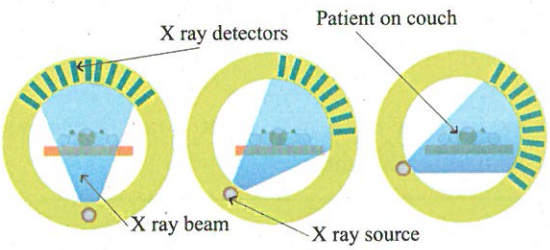
- Xeromammographiy/Xeroradiography
- Xero (dry) radiograph is taken for breasts.
- It uses a silicon plate.
- No film development or chemicals are used.

CT Basics

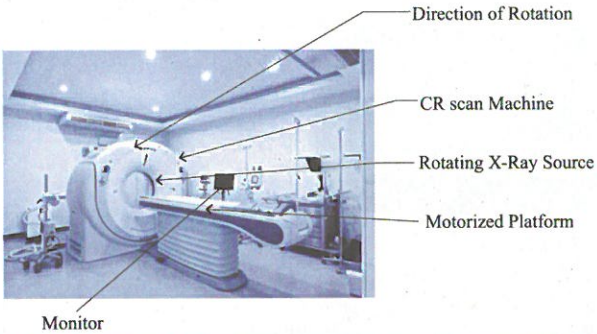
01:33:50

PYQ: FMGE 2019

- CT (Computed Tomography), 3D X-rays due to rotating X-rays tubes.

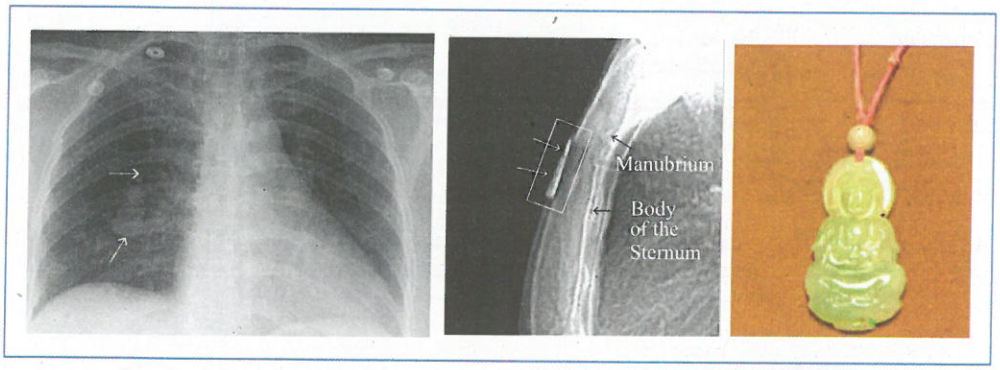


CT scanner with the X ray source and detectors shown in three positions

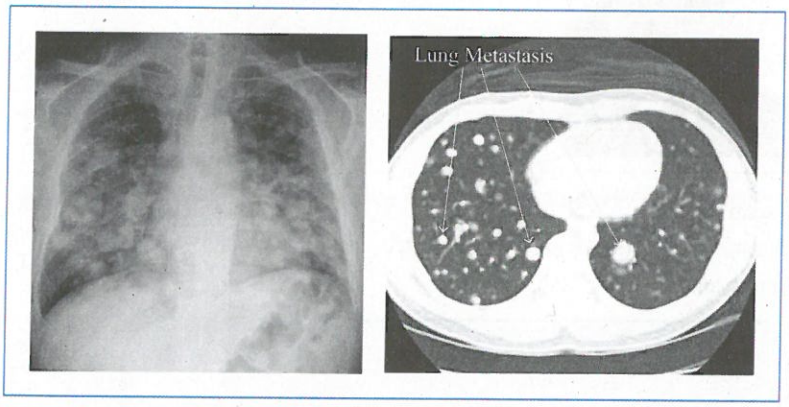


- Images are taken from various angles.
- The gantry has an X-ray tube and a detector.
- The table goes in, and an X-ray tube rotates around the table.
- The most commonly used CT scan is 3rd generation CT scan.

- The distance the table moves for every gantry rotation is known as pitch.
- Pitch is inversely proportional to the image's quality and the radiation dose.



- In AP/PA view, the object resembles a nodule inside the lung parenchyma.
- In lateral view, the object appears outside the body.
- Hence, two perpendicular view are required to evaluate the exact position of the object.



- The opacities of a lung cancer patient may look clumsy.
- If a cross-sectional view is taken, we can identify the placement of opacities.

X-ray	CT Scan
Initial, quick	Best choice
Cheap	Costly
Investigations may be incomplete.	Helps in the final diagnosis, completes investigation.

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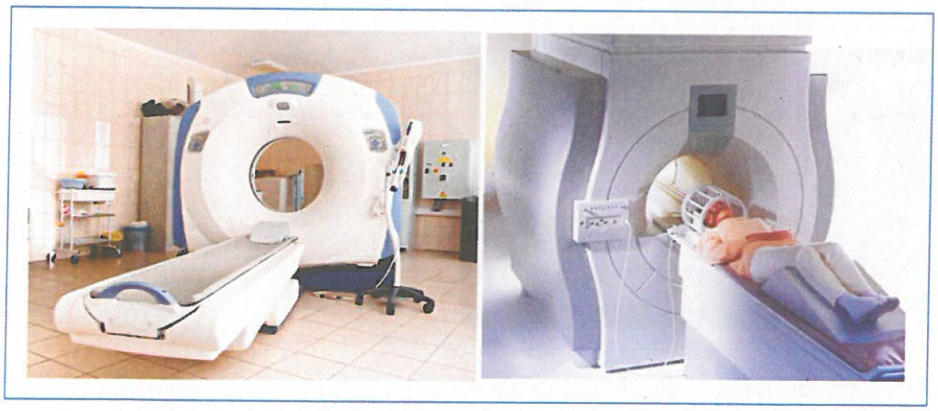
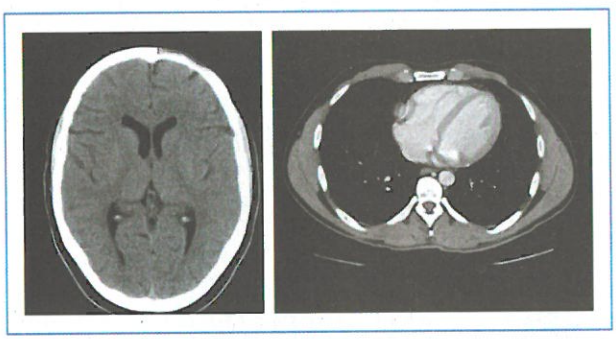


CT Scan	MRI Scan
Single loop	Long tunnel
Pressure injector (for contrast) is present	Pressure injector is absent (metallic objects are not allowed)
Preferred by claustrophobic patients	Not preferred by claustrophobic patients
Radiation exposure is present	Radiation exposure is absent
Quick results (5-10 minutes)	Time - consuming (30-40 minutes)
Preferred in emergency conditions	Not preferred in emergency conditions

- Godfrey Hounsfield invented the CT scan.
- Hounsfield units (HU) are based on the attenuation (stopping) of the X-rays.
- It depends on the radio density of the substance.

Important Information

- Distilled water has zero HU value.
- Positive and negative HU values are given based on the density compared with water.
- Bones have a high positive HU value (+1000).
- Air has a high negative HU value (-1000).
- Soft tissues (+40)
- Metals have HU values more than bones (maximum white).
- Oil is less dense than water.
- Fats have negative HU values (-10 to -100).
- HU values of acute hemorrhage are 50-70 (positive)
- Chronic hemorrhage has negative values.
- In a CT scan, black is considered as hypodense and white is considered as hyperdense.



- In the above scans, the bone cortex appears white and the fat appears black.