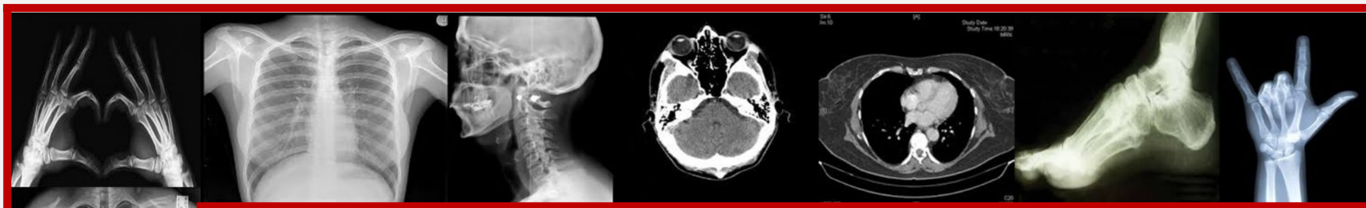
King Saud University

RADIOLOGY TEAM 434



Radiology Team

Lecture 1

Introduction to Radiology

Done and edited by:

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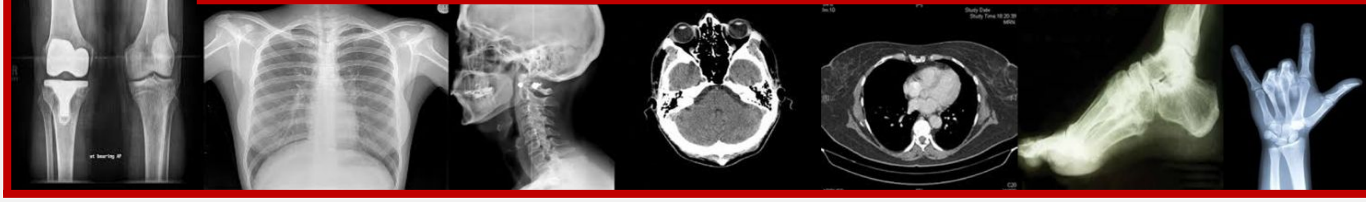
★ **Before starting, please check our Radiology editing file**

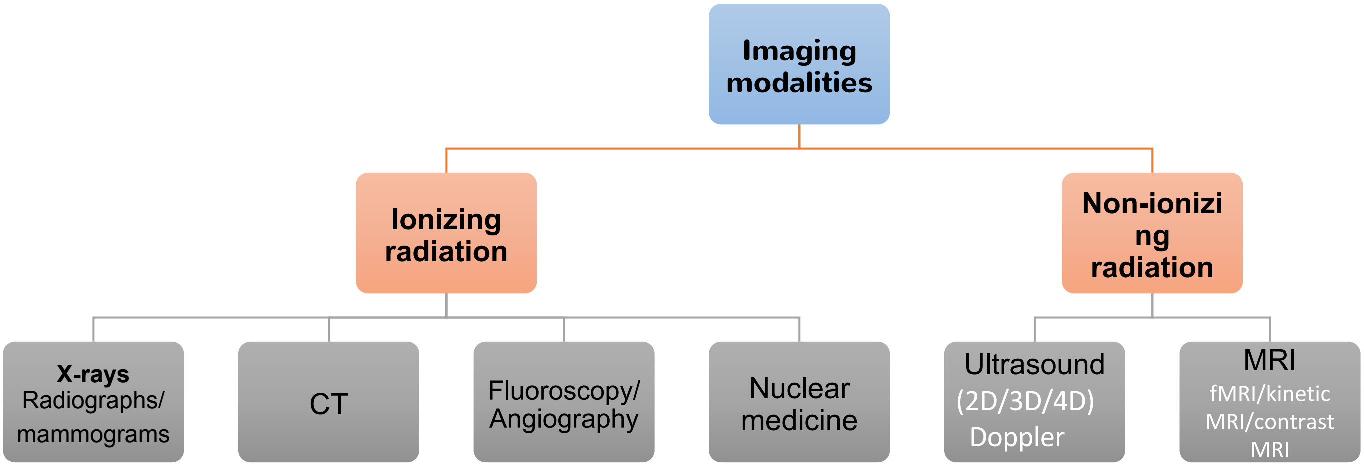


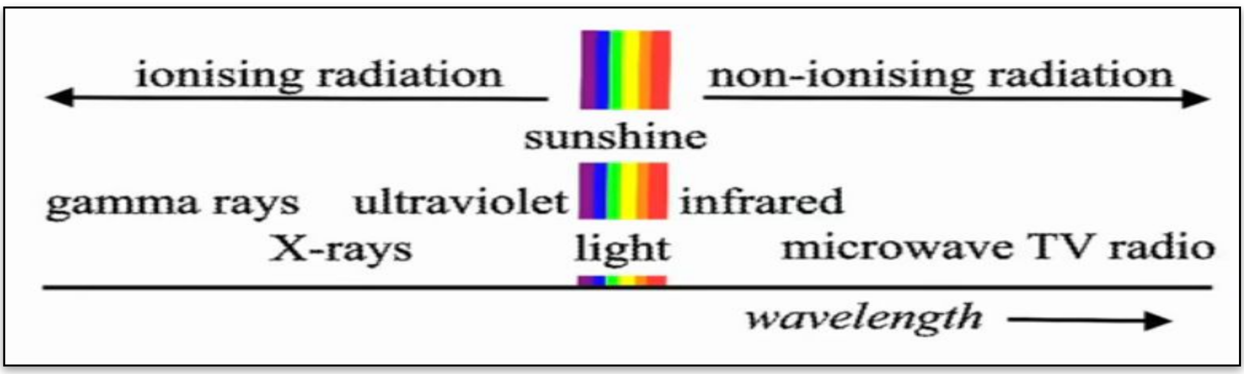
Color Index:

- Important
- Doctor's notes
- Explanations
- 433 & 432 TeamWork

Objectives

- Recognize various types of imaging studies.
- Discuss the mechanism for producing images with each modality.
- List the common indications for different imaging modalities.
- Describe the precautions for ordering imaging studies.





The line between ionized and non ionized is the visible light so the frequency of the waves determined which ionization and non-ionized radiation so any thing higher than the visible light considered as ionizing radiation and any thing less will be non-ionized.

Radiographic Terminology:

Radiology: Medical specialty in which x-rays, radium, and radioactive substances are applied in the diagnosis and treatment of the patient.

Diagnostic Imaging: Medical specialty in which x-rays, radium, radioactive substances, sound waves, and radio frequencies are applied in the diagnosis and treatment of the patient

Radiologist: Physician who applies any form of radiation in the diagnosis and treatment of disease.

Radiographer: Skilled person qualified by education to provide patient services using imaging modalities as directed by a physician qualified to order and/or perform radiographic procedures (X-ray Technologist).

Radiograph: a photographic record produced by x-rays through an object

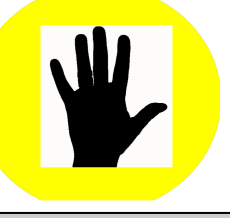
How we make radiographs ?

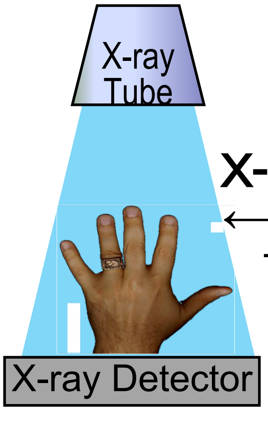
In old conventional cameras Light rays bounce off my hand and into my camera. We call the image:

- "Light-Ray"
- "Photograph" : Is the image of the light photons that bounce off my hand and into my image capture device.

And now take a deep breath… ☺

Imagine that you are in a dark room and you are holding a light source and this source is directed toward your hand, **what you will see in the wall?**
Correct! it is your hand's shadow and they call it "shadow graph"

1)"shadow-graph"	2)"Negative-graph"
	
Everywhere hand blocks the light is dark… Everywhere hand doesn't block the light is illuminated. Now, if we hang photographic film on wall we get… **"Negative-graph"**	Everywhere hand blocks light the film is *not* exposed and stays white… Everywhere hand doesn't block the light the film *gets* exposed and turns dark.



X-rays":
←Rays that pass thru the patient

The image→
is called a "Radiograph"

20^{th} Century: Images = Film

In 20^{th} century they first scan the patient and then → they process the film in the dark → allow the film to dry → then they call radiologist or other specialist to see the radiograph → and then send the film to the doctor → and the patient might take the film and it might get lost or damaged. And this process caused a "headache" to the radiology department because they must keep it in a special dry room and it take huge room in the hospitals

21^{st} Century: Digital Imaging

And now we have computer servers and these servers can save huge number of images and it just needs small room in the hospitals so we save very big space a lot of effort and people and the images will not be missed of damaged. The images will be in the computer and the radiologist can see the images online and even the doctor can see it too and if the patient want a copy we can give it to him in a CD and we still have a copy of that image. And now we have a backup server if any incident happen like fire and earthquake there will be a backup copy of these images so we will not loose the information

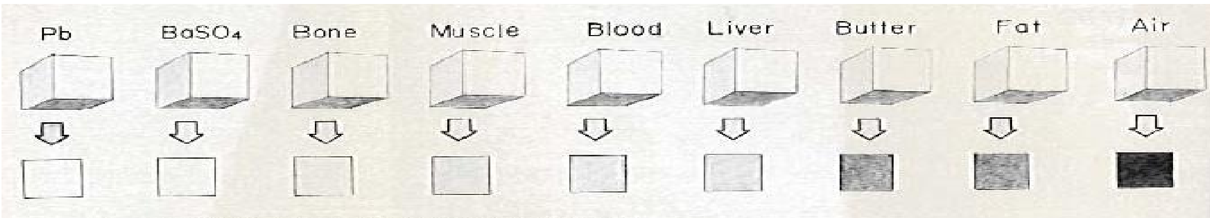
Before

Now

In x-ray : black coloration **(Radio-lucent)** is called (Lucency), white coloration **(Radio-opaque)** is called (opacity)

How do x-rays create an image of internal body ?structures

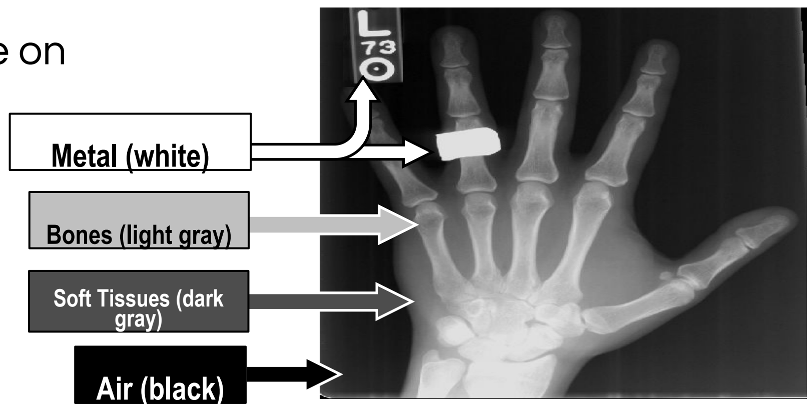
X-rays pass through the body to varying degrees → Higher atomic number structures block x-rays better, example bone → Lower atomic number structures allow x-rays to pass through, example: air in the lungs



:Radiographs are Limited can detect only four densities of tissue

All soft tissues look the same on radiographs:

- Muscles/Tendons
- Vessels/Nerves
- Organs/Blood

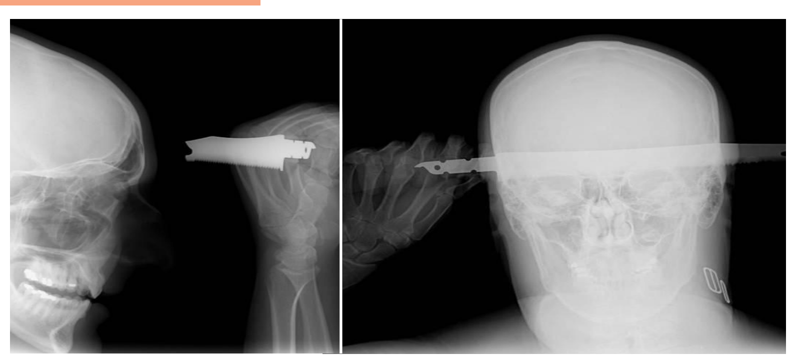


X-rays as Diagnostic Tool:

Can see:	Can't see:
-Bones	-Inside skull
▪Fractures	▪Can't see the brain
-Joint width, surfaces	-Inside joints
▪Arthritis	▪Can't see tears
▪Osteophytes	▪Ligaments, Tendons
▪Erosions	▪Menisci, Cartilage

NOTE:
From the most black to the most white:
1-Air
2- Fat
3- Soft tissue
4- Bone

Radiographs: 2D projection of 3D patient
Radiographs flatten everything
Can't tell what's in front, what's behind
With radiographs: NEED MULTIPLE VIEWS!
"One view = No views" one is not enough and it's useless.



In this image if you look at it think that somebody who is stab himself with knife but when you take another view which we call it lateral in x-ray you can see that the he is holding the knife in front but because in x-ray you can't differentiate between front you and back so that's why one image never enough

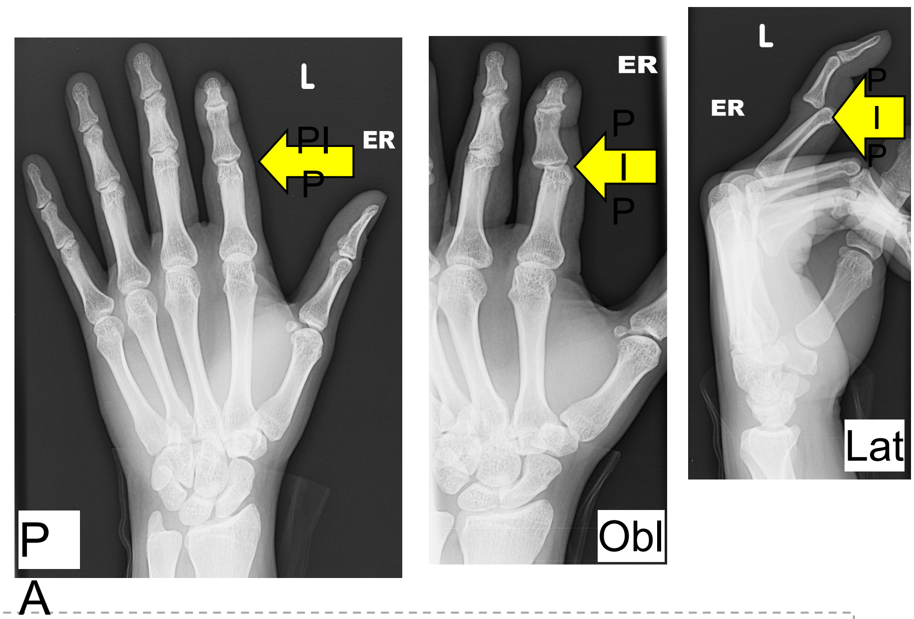
Continue Need Multiple Views…

Sometimes you can't see fracture in one view, you have to have multiple views with multiple directions to see the fracture it wasn't showing in this PA direction so when we ask patient to change position we could see fracture clearly .

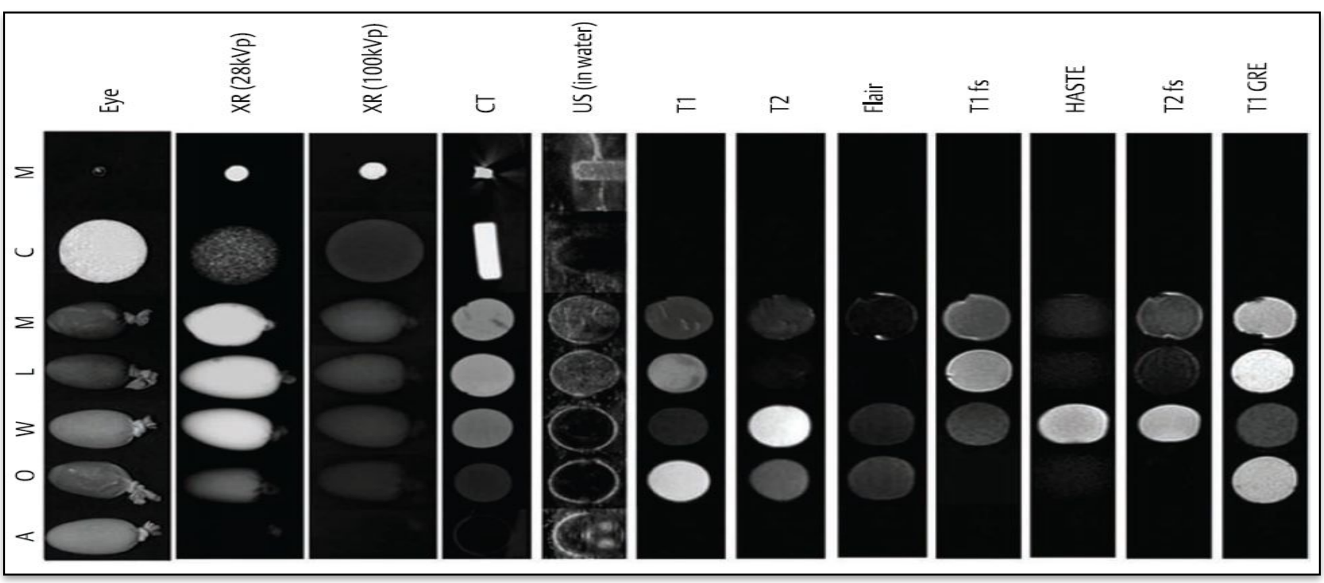
- Small finger

Not a subtle fracture
Fragment overlap each other so perfectly on PA view, are undetectable.

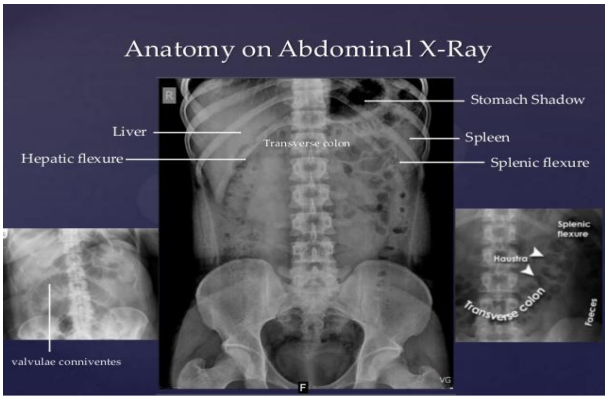
- Sometimes dislocation can't be seen in one direction

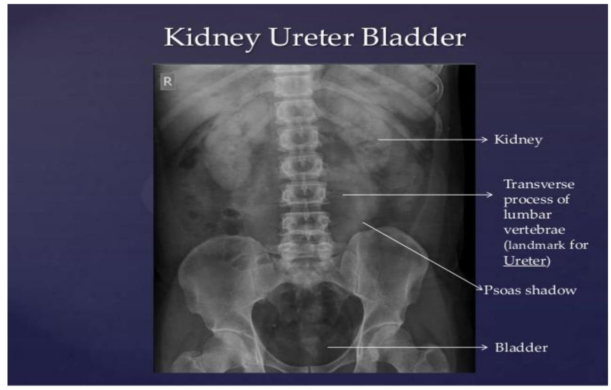


This pic Showing how different tissues or different substances and how it shows in different modalities (x-ray,CT,MR,US..) **this is for your knowledge** ☺

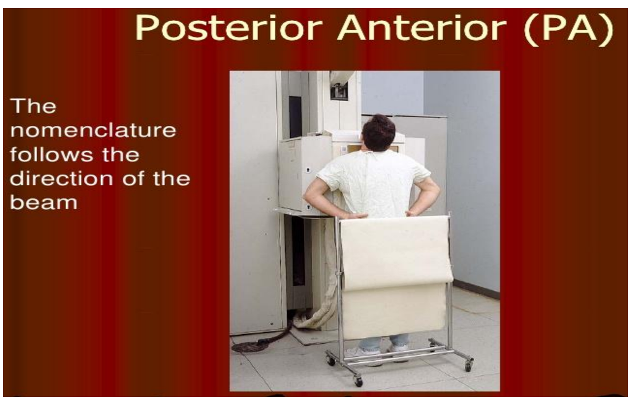


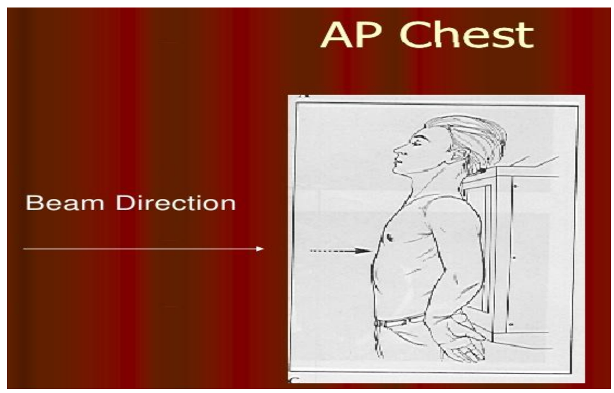
A: air; O: oil; W: water; L: liver; M: muscle; C: calcium; M: metal



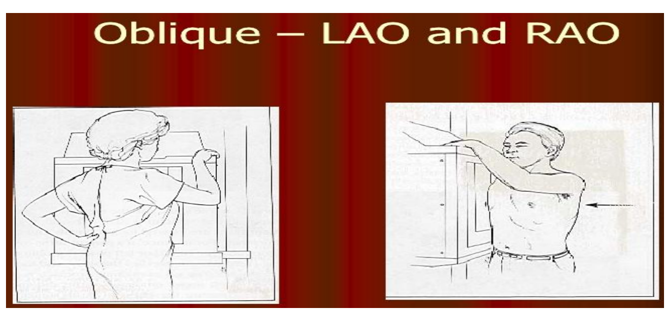


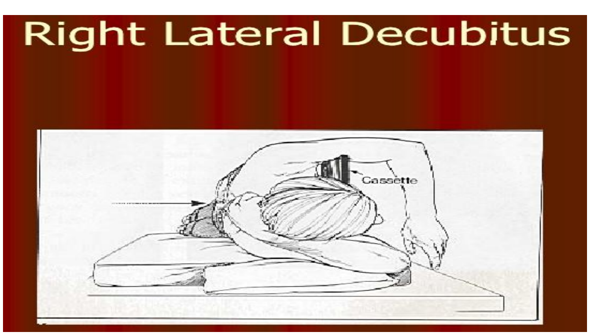
X-ray not very helpful in soft tissues so in this images you see lots of things look the same and the worse is sometimes can be covered behind ribs so you can't see behind the bones that's why sometimes we use contrast which material has very high density so the patient swallow this contrast and then we can see inside the bowel and we can see the stomach

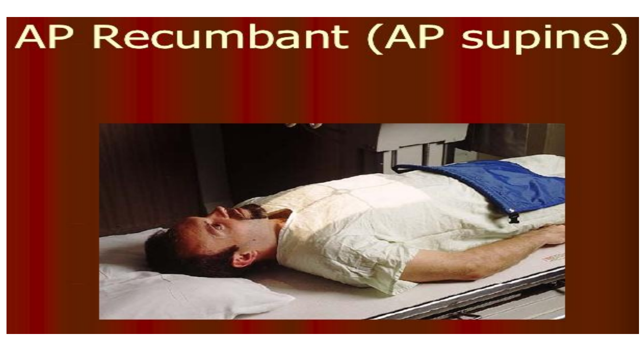




In PA position beam comes from posterior and the film will be in the anterior, It depends where is the bone for example you want to see a specific tissue try to make it in front the bone to get the images better.





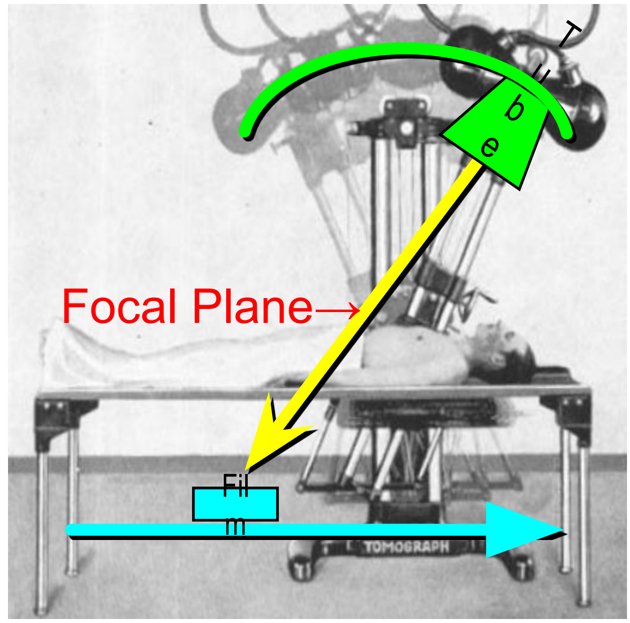


Tomography: Small step forward

Not Computed

To overcome flat 2D nature of radiographs…

- Structures in the Focal Plane → are in **focus**.(where focus the structure of interest)
- Structures out of focal plane are **blurred out**.
- At best, we got blurry pictures.(we will get most of the pic blurry **except** the structure in the focal plane)
- Long exposures = high radiation.
- **Can't use this to see the brain** ☹



Computed Tomography: Giant leap forward

Johann Radon

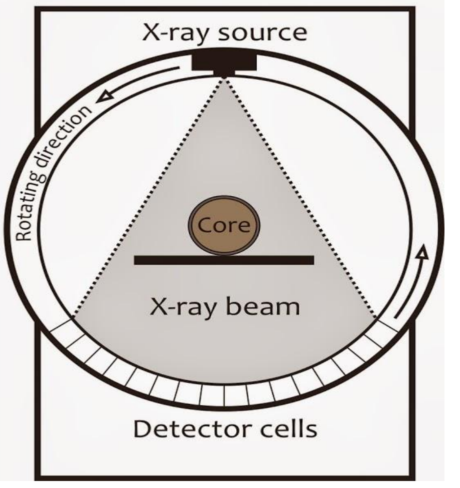
This handsome mathematician proved that we can get an image of 3D object by taking an infinite number of 2D projection images of the object and reconstruct (rebuild) them.

BUT at that time there was no main-frame computers ☹

❖ 2 years after computer invention, Godfrey Hounsfield a British electrical engineer developed **EMI brain scanner. And by using this scanner we can see through the skull into the brain. "Hounsfield Units"** is the scale we use to measure CT density

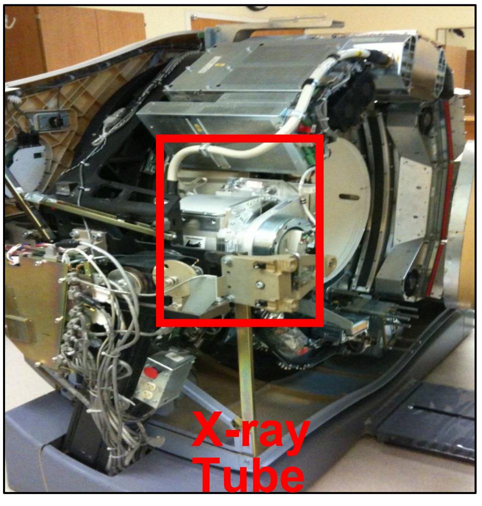
How CT works ?

By rotating X-ray tube with the X-ray detector and the patient will go through these rays then we will have something like “slices” so each one is an image and we reconstruct these images to have other images from different views, Which are 3D images.



How it looks like ?

Inside CT Scanner

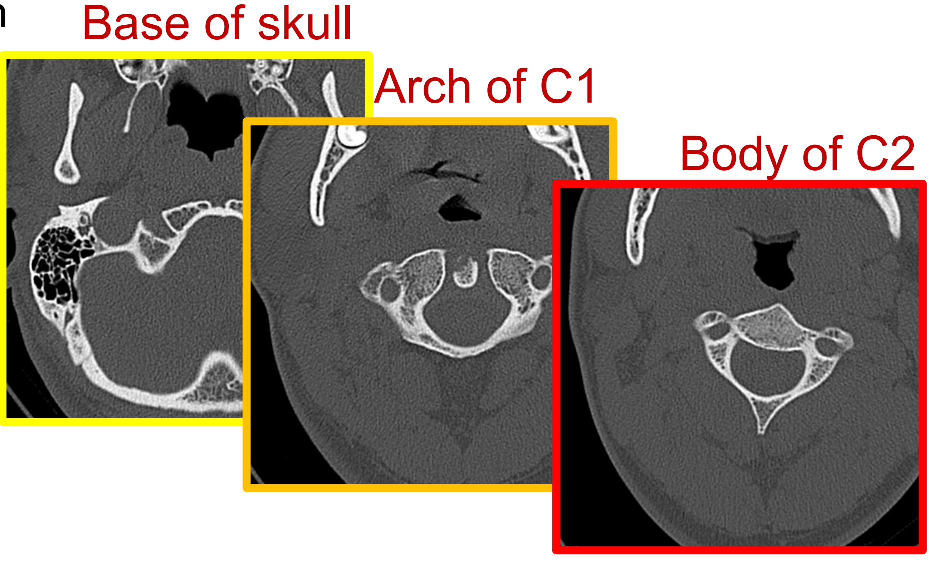


Outside CT Scanner

Computed AXIAL Tomography

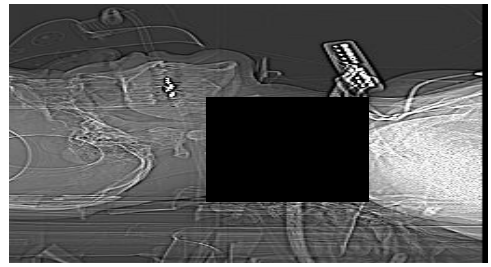
Axial Plane: The axial plane passes through the body from anterior to posterior and divides it into superior and inferior sections.

- Top to Bottom

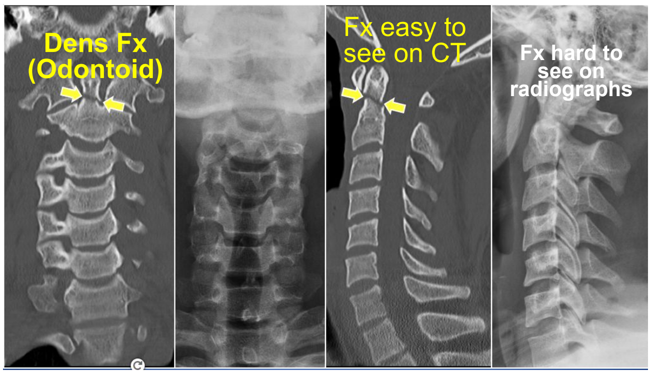


Computed **VOLUME** Tomography

Thin, continuous slices = Solid volume of data
Can reformat data:
Any 2-D plane (Coronal, Sagittal, Oblique)* Even in 3-D!



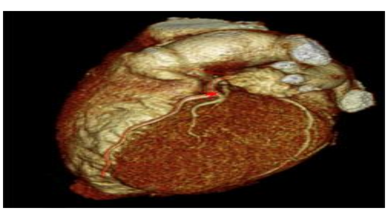
Multi-Planar Reformat

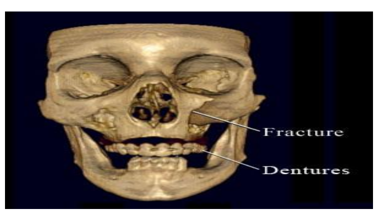


- **•Coronal Plane**
  - –Front to Back
  - –Like AP view
- **•Sagittal Plane**
  - –Left to Right
  - –Like a Lateral view

Multi-Planar Reconstruction

can be used to reconstruct images in orthogonal planes (coronal, sagittal, axial or oblique, depending on what the base image plane is). This can help to create a visualization of the anatomy which was not possible using base images alone.





NOTE:
In CT we use the word
(Dense):
1- Hyper –dense.
2- Iso-dense (iso =in between).
3- Hypo-dense.

Why CT is so great ?

- **Can see fractures otherwise missed**
  Cervical spine, pelvis
- **Can see the brain!**
  Strokes, bleeds, tumors "Hemorrhage always hyper dense"
- **Can see organs (lungs, liver, bowel)**
  Tumors, trauma, acute/chronic diseases
- **And now with ultra-fast, multi-slice…**
  - Can scan the heart in a single beat!
  - Can see coronary arteries, pulmonary emboli
- **Some hospitals have CT scanners in the ER**

*coronal= view from front , Sagittal= view from side, axial= view through patient

Problems with CT

- **Usually requires IV contrast**
  - Because of the possible side effects, e.g. allergic reactions and extravasation: leakage of contrast into surrounding tissues
  - 1% patients are allergic to CT contrast
  - Can affect renal function
- **Can't see structures inside joints**
  - Knee: •Menisci, •Ligaments, •Cartilage
  - Shoulder: •Rotator Cuff, •Labrum
  - Spine: •Disks, •Spinal Cord (We can't see spinal cord unless if there is calcification)
- **Costs more than radiographs**

High Radiation Dose

Normally we are exposed to low level of radiation every day, which is called "background radiation"

- **Ave background dose ≈ 2.4mSv/year.**
- When we use chest radiograph we will expose the patient ≈ **0.06mSv** ≈ 1 week of background radiation.
- When we use chest CT we will expose the patient **≈ 7.0mSv** ≈3 YEARS of background radiation. in one exposure of CT as you are having 3 background radiation " الاشعاع الي بالجو".

***What is radionuclides ?** An unstable form of a chemical element that radioactively decays, resulting in the emission of nuclear radiation

- **In earth**: naturally occurring radionuclides is Uranium-238, potassium-40
- **In atmosphere**: Radon-222 (from U-238)
- 2nd leading cause of lung cancer after smoking
- **In space**: cosmic rays
- Airline crews are more exposed to cosmic rays, doubling their background exposure

Advantages of CT	Disadvantages of CT
• Eliminates overlapping densities • Excellent resolution • Excellent for detecting intracranial bleeding • Excellent in the neck, chest and abdomen • Excellent for evaluating fractures	• More expensive than x-ray and ultrasound • Much more radiation • Dense bone (petrous ridge for example) and metal cause severe artifacts

Radionuclide imaging
(Nuclear Medicine)

Why nuclear medicine ?!

Because it is not only a radiological diagnostic method, we can use it for treatment !

- Developed after World War II
- Research on nuclear bomb byproducts

  Fission Uranium-235 → Iodine-131

  They found that there is weaker isotopes (agents) then the ones used in nuclear bomb that can help us in medicine

What are the agents that can be used in radionuclide imaging ?

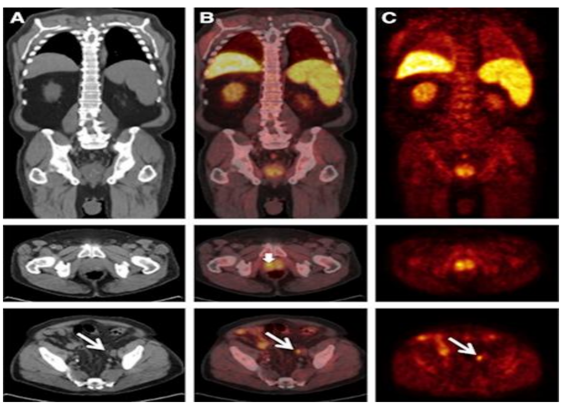
1- Iodine	2-Technetium
•Naturally occurring element •Rare on Earth (47th abundant) •Rare in Humans (<0.05%) •Taken up by Thyroid Gland •Made into Thyroid Hormone •Used in X-ray contrast dye •Naturally occurring Iodine not radioactive BUT Iodine-131 is **HIGHLY** radioactive •Emits **β-particles** which is Much more damaging than **γ-rays** • Accumulate in and destroys Thyroid tissue • Nuclear Reactor Fallout → Hypothyroid • Take Iodine pills to block I-131 from Thyroid • Useful for treating Thyroid Cancer • Now they developed more agents to accumulate in specific tissues, emit **low-energy γ-rays.**	• Radiopharmaceuticals • Not naturally occurring • 1936: First element to be artificially produced **Technetium-99m** • Ideal Imaging Agent Short half-life (6 hours) • After 24 hours 94% gone • Emits **γ-rays** • γ-rays pass out of the patient without accumulating • Good energy for gamma-camera detection • Dual-head cameras: Image γ-rays emitted front & back

- **Nuclear medicine: (Bone scan)**
- Was used a lot before CT & MR
  - ✓ Shows bone pathology earlier than radiographs
- Nowadays, seldom used for focal lesions
- We *still* use Nuc Med Bone Scans for:
  - ✓ Looking for bone metastases in *entire body*
    - ➢ Breast Cancer
    - ➢ Prostate Cancer

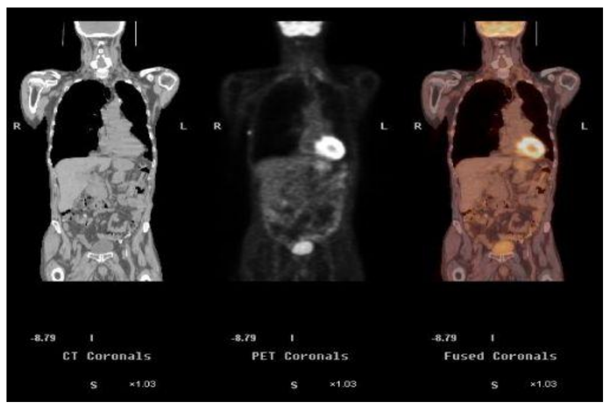
❖ Nuclear Medicine: PET/CT

- ❖ Most recent innovation in Nuc Med
- ❖ **PET**: Positron Emission Tomography
- ❖ Uses agents with *very* short half-lives
    - ✓ Flourine-18 (100 min)
    - ✓ Oxygen-15 (2 minutes)
    - ✓ Made onsite with cyclotron
- These agents are taken up by tumors, metastases → **Well shows abnormal FUNCTION**
- Combined with CT (Computed Tomography) → **Well shows underlying ANATOMY**
- Used for staging cancer patients

CT PET PET/CT



CT PET PET/CT



Why does it accumulate in one structure more then another one?

We all know that tumor and some organs (thyroid) has more blood supply then other organs so it will uptake the agent more then others → its appearance

Ultrasound:

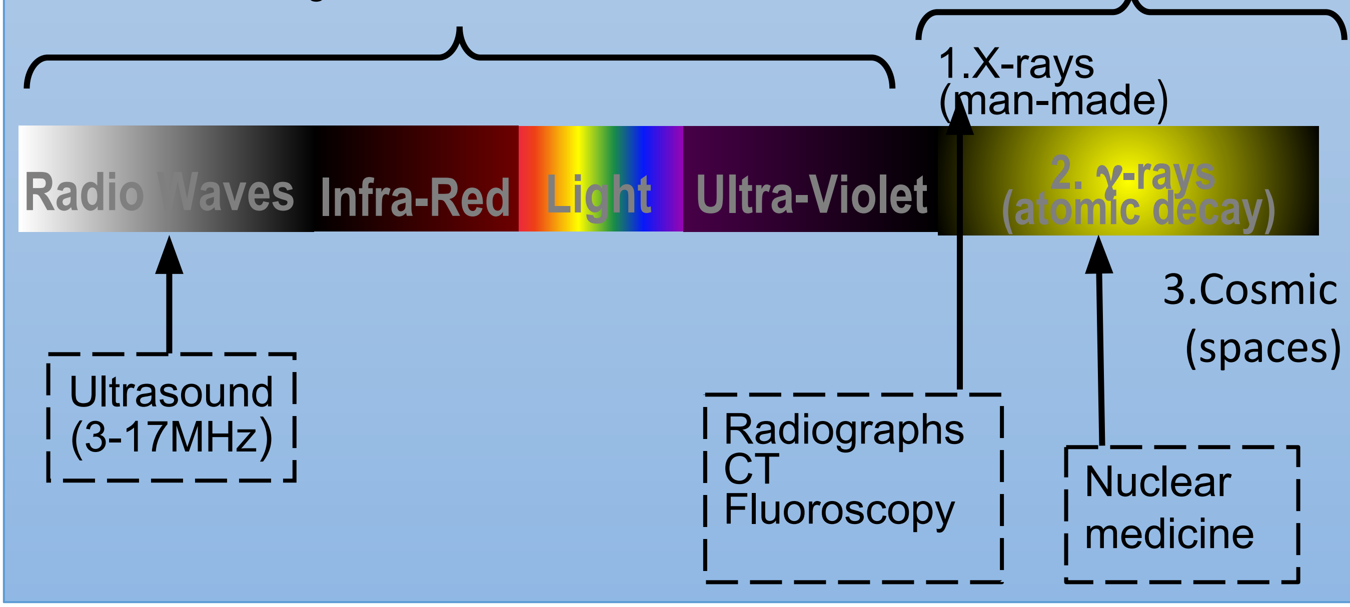
History of Ultrasound:

- Developed after World War II
- Based upon **SONAR**
  - "**SO**und **N**avigation **A**nd **R**anging"
    - Sound wave sent out
    - If sound hits an object
    - get reflected back
    - Measure time for the reflected echo to return
    - Multiplying the time by speed of sound = distance from the object
  - Works best in water because it transmits sound well

Sonography "Ultrasound":

- Uses radio waves (Not X-rays, γ -rays)
- Non-ionizing Radiation

▪ Ionizing Radiation



Diagnostic Ultrasound

- Ultrasound is sound waves with frequencies which are higher than those audible to humans (>20,000 Hz).
- Ultrasonic images also known as sonograms are made by sending pulses of ultrasound into tissue using a probe.
- The sound echoes off the tissue; with different tissues reflecting varying degrees of sound.
- These echoes are recorded and displayed as an image to the operator

*الموجات الفوق صوتية تعتمد على ممناعة الموجة وليس الكثافة مثل السوائل مافيه ممناعة فراح يخترقها و بيان أسود

Image interpretation:

White areas:

- Represent "echogenic" structures, which transmit & **reflect** sound waves
- Soft tissues, fat, vessels, nodes, masses.

Black areas:

- Represent areas that are "anechoic"
- Fluid: transmit but **does not** reflect sound waves

Grey:

Helps widen the representative scale of black/white "brightness"

Lines:

Occur at boundary of two markedly different tissue reflectors **"boundary of organs"**

Tissue characteristics of Ultrasound:

Air : near total reflector (scatter reflector)

Fluid: near total propagator (no reflection)

Bone: near total reflection

Soft tissue: partial reflection, partial propagator

- reflects every time tissue impedance changes – every interface
- ideal for ultrasound images

:Sonography Useful for

- Tissues that contain/surrounded by water
- Abdominal organs
- Gall bladder (Gall Stones)
- Kidneys (Kidney Stones)
- Blood vessels
- Blood clots (DVT: Deep Venous Thrombosis)
- Imaging without Ionizing Radiation
- Pelvic organs
- Uterus, Ovaries
- Testes
- Babies (Newborn)
- Babies… before birth
- Obstetric Ultrasound

1: in radiology, a measure of how much detail a device can print or display.

Advantages

- No radiation
- Portable
- Instantaneous (real time)
- Excellent for cysts and fluid
- Doppler ultrasound is excellent to assess blood flow
- Excellent for newborn brain, thyroid, gall bladder, female pelvis, scrotum, pregnancy.

Disadvantages

- Does not work well in large or obese patients
- Resolution[1] less than CT and MRI.
- Air or bowel gas prevents visualization of structures.

Organ limitation

(it can't penetrate air nor bone so we can't use it for brain or lung)

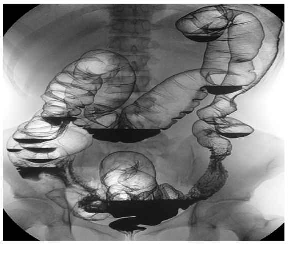
Fluoroscopy:

- Utilizes X-Rays
- Real-time imaging
- Utilizes image intensifier *
- Involves use of contrast agents

X-ray can be static or can be also dynamic we can take many x-rays "images" during patient movement for example to see dynamic movement or to see bowel for example patient can swallow some type of contrast and then we create images by many x-ray we call this **fluoroscopy.**

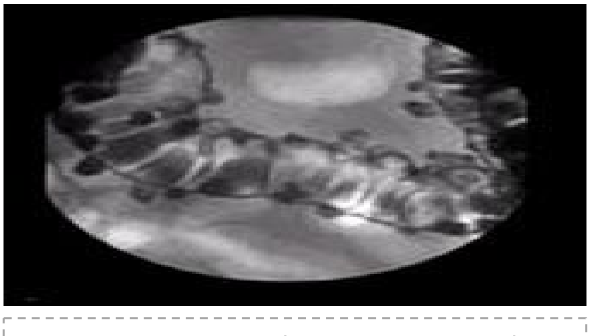
Main Uses of Fluoroscopy:

- Gastrointestinal Imaging
- Genitourinary Imaging
- Angiography very important use
- Other
- Intraoperative
- Foreign body removal
- Musculoskeletal



Single Contrast vs Double Contrast:

Single Contrast (Barium Enema)



Double Contrast (Barium Enema)

* It shows x-ray not very sharp or very high, so we need very low amount of radiation because contrast it self has high density.

Magnetic Resonance Imaging (MRI):

- MRI doesn't rely on X-rays to see projected shadows of patients, unlike radiographs, CT & fluoroscopy.
- MRI sees tissues based upon sub-atomic characteristics (magnetism).

- Proton nucleus of Hydrogen has small magnetic field that can be used to detect tissues containing hydrogen.

How MR Scanner Works:

▪ Magnet

- Aligns spins of protons in hydrogen nuclei

- Align in direction of magnetic field, B_o

▪ Coil (antenna)

1) Sends RF pulse to flip spinning protons

▪ After RF pulse is off, protons realign to B_o

▪ As protons realign, resonate RF energy.

2)Measures strength of resonant RF echo

▪ At a specific time, T_E, "Echo Time"

Steps 1&2 repeated many times / image slice

▪ At a specific "Repetition Time", T_R

Simply, hydrogen atoms(protons) in water molecules and lipids:
1. magnetism affects all protons causes them to line up in one direction
2. magnets can be switched on and off to change the direction of the magnetic field
3. whenever the water molecule spin around they give a light radio wave
4. MRI machine can detect it
5. show it as images.

Tesla(T): Measure Magnetic Field Strength

- Earth's magnetic field:
- 30 μT (3×10^{-5} T)

- Typical refrigerator magnet:
- 3 mT (3×10^{-3} T)

- High Field MRI scanner:
- 1.5 – 3 T
- 1,000 times the strength refrigerator magnet
- 100,000 times the Earth's magnetic field

*numbers not for memorization!

*B0 = main magnetic field

MRI: Need Multiple Sequences

T1 shows Fat best

Most normal anatomy surrounded by fat

In essence, T1 shows anatomy best

T2 shows Fluid best

Most pathology contains fluid (edema)

In essence, T2 shows pathology best

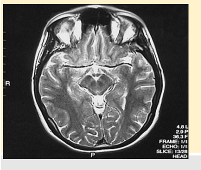
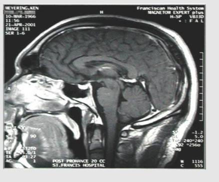
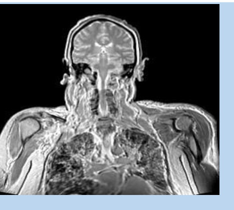
Fat-suppression makes fluid more conspicuous

PD "proton density" shows Dense Stuff best

Good for meniscus and tendon tears

Used mostly for MRI of joint pain

MR Applications:

Part of the body	Applications	Images
Neuro-imaging	• Excellent tool due to high soft tissue contrast resolution • Abundant water content of CNS allows for imaging soft intracranial tissue	 MRI Axial, T2-Weighted
Head and Neck imaging	• Multi-planar capability allows for monitoring extent of disease • Differentiating subtle soft tissue boundaries of head and neck	
Body Imaging: Thorax	mediastinal, hilar, chest wall abnormalities	
	Limited lung imaging due to artifacts	
	New advances in breast imaging	
	Potentials for cardiac MRI with coronary MR angiography	MRI Breast Imaging
MSK Imaging	High sensitivity for neoplastic, inflammatory, and traumatic conditions of bone and soft tissue • T1-weighted---fluid collections and abnormalities in fatty marrow • T2-weighted---lesions in both marrow and soft tissue	

Advantages & disadvantages of MRI:

Advantages

1. No overlapping artifact
2. Excellent resolution
3. Very good at detecting fluid

4. Excellent for imaging the brain, spine and joints
5. No radiation
6. Multiple imaging tests within the same study (T1, T2, IR, GE)

Disadvantages

1. Very expensive
2. Patients cannot have a pacemaker or ferromagnetic material
3. Slower to acquire images (approximately 45 minutes)

•**Note**: now mostly metals are MRI compatible (we can do MRI in that case) Can we do MRI For a pregnant patient? Yes, but only after the first trimester

Note:

- MRI contrast may cause nephrogenic systemic fibrosis when we give it to chronic renal failure patient
- Metallic Pacemaker is contraindicated in MRI, Titanium is fine
- Claustrophobia is a relative contraindication in MRI
- MRI contrast: You have to take precaution if there is renal impairment
- CT contrast: You have to take precaution if there is renal impairment or allergy

	X-ray	US	CT	MRI
Black coloration	Radiolucent	Hypo-echoic	Hypo-dense	Hypo-intense
White coloration	Radiopaque	Hyper-echoic	Hyper-dense	Hyper-intense

MCQs

- 1 Dark grey in x-ray images represents?

A. Bones
B. Metal
C. Air
D. Soft tissue

- 2 What is the organ that couldn't be seen in the tomography but can be seen in Computed tomography (CT)?

A. Heart
B. Brain
C. Lungs

- 3 The boundaries of the organs in ultrasound represented as:

A. Lines
B. white
C. Black
D. Grey

- 4 Proton density (PD) in MRI shows ….. best?

A. Fat
B. Fluid
C. Dense stuff

1.D 2.B 3.A 4.C