

RADIOLOGY

1

BASICS OF RADIOLOGY



Types of Radiation

00:00:55

1. Electromagnetic radiation - They travel as photons like light (Light is not used for imaging due to its poor penetration power)
 - X-rays
 - Gamma rays
 2. Particulate radiation
 - Alpha
 - Beta
 - Neutrons
- The above radiation are called Ionizing radiation

Damage and Penetration

00:01:51

PYQ: AIIMS 2018

- Damage and penetration are inversely related
- Gamma rays have the maximum penetration power out of alpha, beta, X-rays
- They go through the body with a higher penetration
- Gamma, with a maximum penetration causes minimum damage to the body
- Alpha, with a minimum penetration causes maximum damage to the body
- Damage caused: Alpha > beta > X-ray > Gamma
- Penetration caused: Gamma > X-ray > Beta > Alpha
- Decreased penetration means increased damage
- Alpha is the most damaging/most ionizing/maximum linear energy transfer (LET)
- The penetrating power of Neutrons > Gamma

No radiation in

00:03:39

- USG
 - Uses sound waves
 - FAST
 - Doppler: It is an ultrasound for the blood flow
- MRI
 - Uses Radio waves
 - MRCP (Magnetic Resonance Cholangio pancreatography)
- No radiation means non ionizing

Radiation is seen in

- X-rays (It is not produced from the nucleus of the atom)
 - It is used in radiography
 - CT scan (3D X-ray)
- Gamma rays
 - It comes from the nucleus of the atom
 - It is used in nuclear medicine
 - Nuclear medicine investigation modalities include
 - Scintigraphy
 - Radioisotope scan
 - PET
 - SPECT scan

Note:

- ERCP comes under contrast X-ray (Dye studies)
 - It has radiation exposure
 - We put an endoscope, it then goes to the duodenum and goes to the duct and contrast is put and X-ray images are taken
- Contrast X-ray for kidney, ureter, bladder is known as Intravenous Pyelogram

- HSG (Contrast X-ray for uterus and Fallopian tubes)
 - Hysterosalpingography
- LMP should be asked in a female before doing a CT. In this way, we rule out that there is no chance of pregnancy
- Rule of 10: Investigations that has radiation exposure should be done within ten days because its sure that there is no ovulation/fertilization/pregnancy during that time

Machine /Equipment identification

00:08:05

X-ray Machine

- This is a digital X-ray machine
- The advantage is that since we get a digital image, as soon as the technician clicks the X-ray beam that comes is detected by the electronic detector and we get the image on the screen
- It can be accessed by anybody in the hospital if we have the PACS system (Picture Archiving and Communication system)



USG

- It uses sound waves
- Sound wave frequency that is used is outside the human frequency audible range (MHZ)

PYQ: INICET 2021



CT vs MRI

- Tunnel is absent in CT machine (Image 1)
- In MRI machine, tunnel is present (Image 2)
- MRI is contraindicated in claustrophobic patients
- MRI can be done in Claustrophobic patients using sedation
- Unit to measure the strength of the magnet used in MRI - Tesla
- MRI is contraindicated with metallic foreign body, pacemaker, cochlear implant, knee implant
- Now MRI compatible implants are available
- The walls of the CT room are coated with Lead
- The walls of the MRI room have Faraday's cage
 - It is used in MRI room to prevent the disturbance from the outside radiowaves with the MRI radiowaves
- CT is always faster as it takes only 2 mins for CT brain whereas MRI brain takes 20 mins, hence CT is preferred in emergencies



Principles of Various Modalities

00:12:42

1. X-ray:

- X-ray tube is the source of X-ray
- Electrons come from cathode to anode
- Anode has Tungsten, the nucleus of the anode is positively charged and the incoming electron is negatively charged
 - These electrons get deflected by the anode nucleus
 - This is called as Brehmstrahlung radiation
- Other method of producing radiation is Characteristic radiation
 - It is characteristic of the material present in the anode

2. CT scan:

- X ray tube is present and it rotates around the patient taking images from all the angles
 - Continuous rotation is made possible by slip ring technology (Spiral CT)

3. Ultrasound:

- It is based on the principle of **Piezoelectric effect**
- In the probe, electricity is converted into sound by a crystal, which sends the sound into the patient's body, where it returns and is converted back into electricity.
- The crystal that we use is made up of Lead Zirconium Titanate which has the piezoelectric property

4. MRI

- o It is based on gyromagnetic property of moving protons.
- o Based on H+
- o NMR (Nuclear magnetic resonance) is the principle of MRI

5. PET

- o Positron Emission tomography
- o The principle of PET is annihilation coincidence circuit.
- o 18F-FDG is used in PET

Terminologies - Black and White

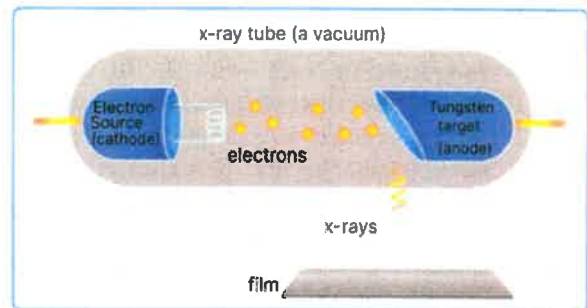
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	Black	White
X-ray	Radiolucent - air	Radiopaque - bones
CT	Hypodense	Hyperdense - bones, calcifications and acute hemorrhage
MRI	Hypointense	Hyperintense
Ultrasound	Hypoechoic Anechoic- clear fluid (Bile)	Hyperechoic

X-ray Tube Construction

00:19:02

- From the cathode, electrons come and goes towards the anode
- The electrons are produced at cathode by the process of Thermionic emission
- Cathode is made up of Tungsten (W)
- Anode is made up of Tungsten (W)
- X-ray tube should have vacuum
 - o No gas should be present so that it doesn't interact with the moving electrons in the X-ray tube
- X-rays are produced when the fast-moving electron beam is suddenly stopped.



Normal vs Mammography X-ray tube

00:19:48

- Mammography is the X-ray of the breast.
- We need a different machine in mammography because X-ray tube construction is different and different potential is needed



X-ray tube in mammography

- **Anode - Molybdenum**
 - o It has lower atomic number as compared to Tungsten in the normal X-ray tube
 - o X-rays that are produced are low energy X-rays (low kv)
 - o When the kv is low, it improves the contrast in the image (Microcalcifications can be identified)
- Machine has a compression plate
 - o For mammography, compression is a must
 - o That's why it is contraindicated in acute painful conditions like Abscess



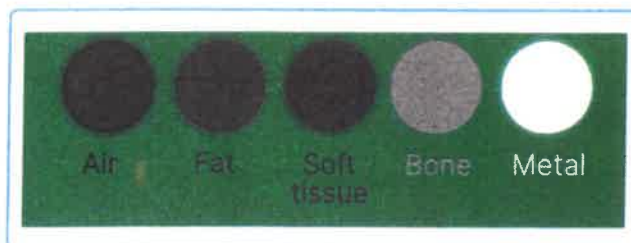
Contraindications of Mammography

- Breast abscess
- Young females
 - Young females with dense breast
 - In dense breast, white calcifications are not seen
- In a female with breast implant
 - If the breast is compressed, implant will rupture
 - In this case, MRI is done
 - Intracapsular rupture of the implant: Ruptured membranes are seen
→ **Linguine sign**

Five basic densities on X-ray

00:22:30

- Lesser the density, more the penetration of X-rays and more black the substance appears
- The air appears black - least dense.
- Metal appears white - most dense.
- Fat appears dark - less dense than water
- Air < fat < Water/soft tissue < bone < metal.
(Increasing order of density; Whiteness increases)
- Consolidation of lungs appear white
- Collapse of lung (no air) appear white
- Pneumothorax appears black



HU value

00:24:06

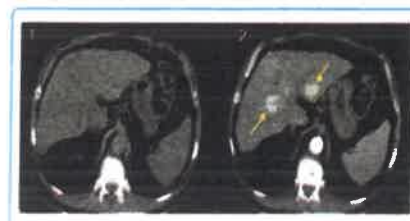
- HU value is used in CT scans
- HU - Hounsfield units after the name of Godfrey Hounsfield who invented the first CT machine
- HU value depends on the attenuation coefficient/ electron density of the substance
- When the attenuation coefficient is high, HU value is high.
- HU value of 0- reference substance - distilled water (Gray on CT)
- Negative value means less dense than water.
 - Air (-1000) and fat (-50 to -100)- black on CT
- Positive value means more dense than water.
 - Soft tissue, metal, bone (+1000)
- Air appears **jet black** on CT
- Fat is called as **dirty black** on CT
 - Fat containing lesion called Angiomyolipoma which is associated with Tuberous sclerosis
- Image 1: CT showing Metallic foreign body - streak artifact.
- Image 2: CT showing white - acute hemorrhage.
 - Hyperdense on Non contrast CT
 - Chronic hemorrhage- RBC lysis, the density decreases, it becomes hypodense
- Image 3: Kidney has the same density as of subcutaneous fat
 - Dirty black appearance
 - Fat containing Angiomyolipoma
- Image 4: Jet black colour surrounding the lung - Pneumothorax



NCCT vs CECT

00:28:47

- CECT (image 2) uses iodinated contrast that is given IV.
- **White aorta** helps to identify that this is a contrast scan
- When contrast is given, as compared to the normal liver, how these lesions take up contrast
 - Early contrast, more contrast -they appear more white
- In NCCT (Image 1), since the lesions have same density as that of the adjacent parenchyma, they get camouflaged hidden in the liver parenchyma



- It is important to give contrast incase any lesions are suspected.
- Indications for contrast
 - Lesion/Tumour
 - Infections /Inflammation
- Indications for NCCT
 - Calcifications
 - Renal stones: Urinary tract stones are calcified stones
 - Gall bladder stones: Non calcified and can be seen on USG
 - Acute hemorrhage
 - Chronic hemorrhage: SWI MRI-this picks up the hemorrhage hemosiderin well

CT vs MRI

- White skull bone cortex - CT (Image 1)
- Black skull bone cortex - MRI (Image 2)
- White outline that is seen is the outer most fat in the scalp
 - Fat appears white on MRI
- Knee image - The bone cortex is white → CT (image 3)
- Marrow containing fat appears black on CT and white on MRI (image 4)
- Always look for the bone cortex

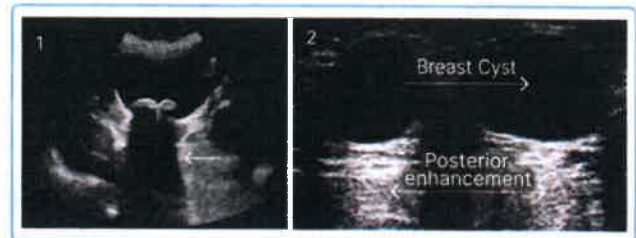
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Posterior Acoustic Shadowing and Enhancement

00:34:00

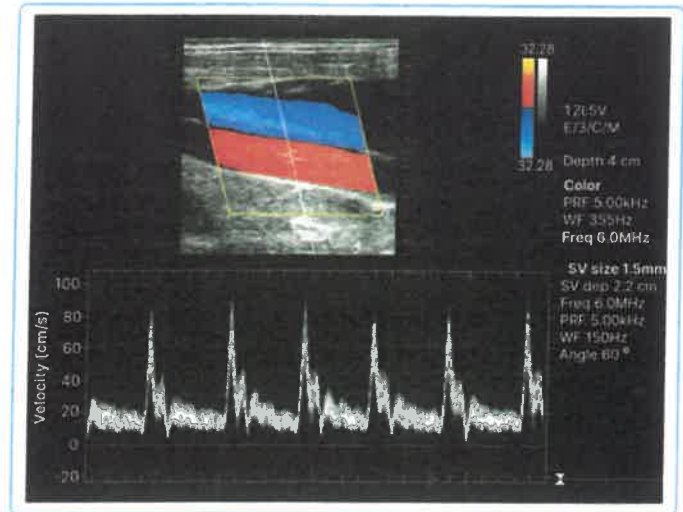
- Shadow appears black.
- Enhancement appears white.
- Posterior acoustic shadowing is given by (Image 1)
 1. Gall stones
 - Gall bladder appears black because the fluid is black on ultrasound
 - Gallbladder with stones → Sound reaches calculus → Sound reflected, so calculus itself is hyperechoic, hyperechoic → appears white.
 - Stones don't transmit any sound → No sound received behind stones → No sound echoed → It appears black → Posterior acoustic shadowing



2. Renal stones
 3. Calcifications of bones
 4. Air
- Posterior acoustic shadowing is due to bad conductor of sound
 - Bile doesn't give shadowing because it is a good conductor of sound
 - Enhanced sound → more sound is echoed → it appears white
 - Posterior acoustic enhancement is seen with fluids (Image 2)
 - Cystic lesions
 - For e.g.: A patient with a breast lump is taken for ultrasound, the lesion appears jet black
 - The area behind the cyst appears white because of enhancement because of fluid transmission
 - Ultrasound helps to differentiate a solid vs cystic lesion
 - Posterior acoustic enhancement is seen in cystic lesion
 - Fluid appears black
 - So fluid is called as anechoic
 - The fluid is transmitting the sound but not producing any echo

Doppler

- Doppler is an ultrasound for the blood flow
- It is based on the principle of doppler shift
- Doppler shift is a change in frequency of sound by the moving blood
 - It shows colour in the doppler
- Colour in the colour doppler indicates the direction of the blood flow
 - Red indicates flow towards transducer
 - Blue indicates flow away from transducer
 - Mnemonic - **R**ed Tower (Towards) **B**lows Away (Away from the transducer)



Spectral Doppler

- Spectral doppler - Graph / Duplex doppler
- The velocity of the blood flow can be quantitatively measured

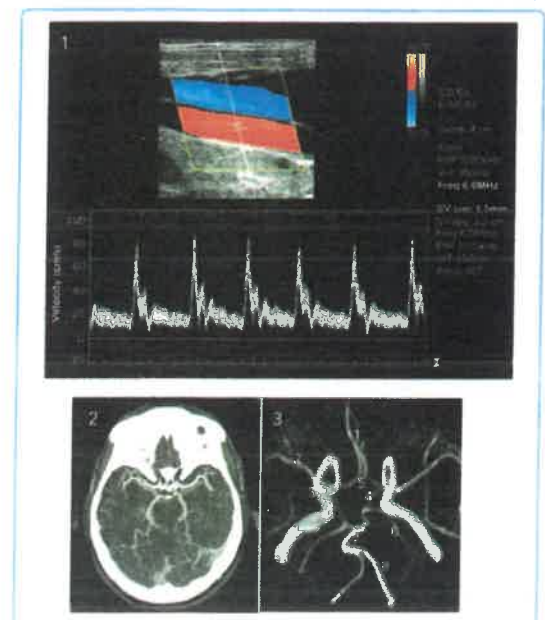
Elastography

- Elastography is the study of elasticity or loss of elasticity i.e., fibrosis
 - It helps to identify the malignant nodules of the thyroid (Image 3), liver fibrosis (cirrhosis)
- Pressure is given with probe and the values can be obtained in kPa.
- Black and white ultrasound is a B mode of ultrasound (Image 2)
- Orange colour ultrasound is a contrast enhanced ultrasound (CEUS) (Image 1)
- Contrast that we use in ultrasound is microbubbles
- CEUS is commonly used in liver lesion characterization
- The advantage of ultrasound contrast is the microbubbles get excreted by the lungs and not the renal excretion
 - So they are safe in renal failure
- Unlike the CT or MRI contrast that have renal excretion, ultrasound contrast can be given in renal failure

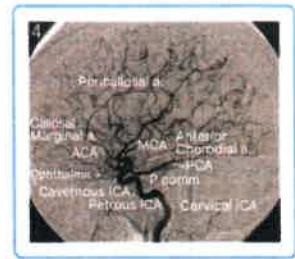


Investigations for Vascular Pathologies

- Vascular pathologies are Thrombosis, Embolism, Blood vessel aneurysm, Aortic dissection
- In these conditions, Doppler can be used
- Doppler (Image 1) is the first investigation for peripheral vessels where the vessels can be easily accessed by ultrasound
- Doppler is done to a patient with intermittent claudication
- Image 2:
 - White bone is seen
 - IV contrast is given
 - This is CT angio
 - CT angio is faster than MR angio
 - It is preferred in emergency conditions like Aortic dissection, Pulmonary embolism
- Image 3: White blood vessels are seen and white bone is not seen
 - This is MR angio
 - MR angio can be done with or without contrast
 - This can be done in Renal failure where contrast cannot be given



- Image 4: The angiography where the blood vessels appear black is DSA (Digital Subtraction Angiography)
 - Its not necessary that DSA is always black
 - DSA can be black or white
 - It is done by Fluoroscopy (video X-ray can show the contrast black or contrast white)
 - Contrast is given by Intrarterial technique
 - It is more invasive investigation
 - This is the gold standard investigation
- The advantage is that as it goes inside the artery
 - If any pathologies like a thrombus, it can be removed
 - Aneurysm: Coiling can be done (Embolising the aneurysm)
 - Other treatment for Aneurysm is clipping



00:46:31

IOC - General Principles

- 1. Air - CT**
 - Pneumothorax
 - The air is a bad conductor - so no USG.
 - The air does not give signal - so no MRI.
 - Wherever there is air, CT is done
- 2. Fluid - Ultrasound**
 - It appear black and anechoic
- 3. Calcification - CT**
 - Appear white
- 4. Soft tissue - MRI**
 - Soft tissues are Muscles, ligaments, cartilage, nerves
 - ACL tear in the knee
 - Meniscal tear in the knee
- 5. Cortex - CT**
- 6. Bone marrow - MRI**
- 7. Medical device positioning: Chest- X-ray**
 - E.g.: Pacemaker
 - Central line ET tube
- 8. Vascular pathologies**
 - Doppler is used for screening/first investigation
 - IOC: CT Angio
 - Gold standard investigation is DSA
 - CT Angio is the best investigation for Aneurysm than DSA
 - CT angio gives the true size of the aneurysm because it will be able to see the thrombosed parts also
 - That's why preoperatively, CT Angio has to be done

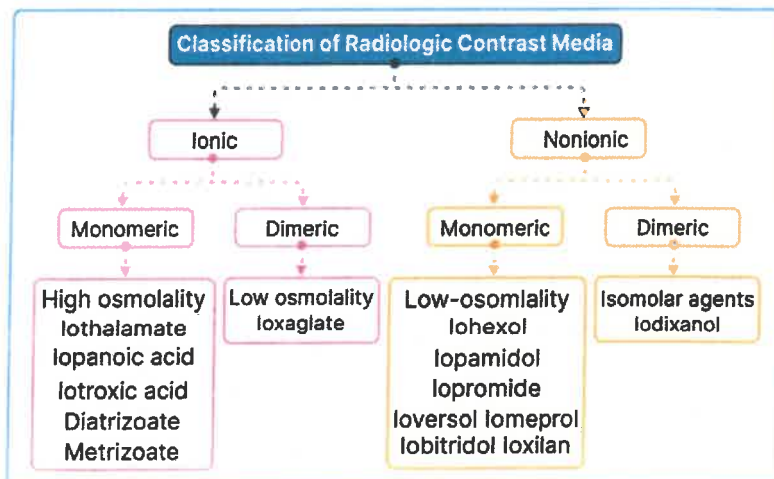
Contrast Media

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- Contrast helps in better evaluation, visualization
- Positive contrast - makes it appear white
 - Examples: Iodinated, Gadolinium, Barium
- Negative contrast - make appear black.
 - Eg: Air
- Iohexol
 - Iodinated contrast
 - Water soluble contrast
 - It is used wherever it is X-ray wherever contrast is needed
 - Contrast X-rays like HSG, IVP, CECT
 - The most commonly used is Iohexol



- Iohexol is a low osmolar contrast and is renal safe
- Most common side effect - Anaphylactoid reaction which are not IgE mediated
- KFT/RFT is done before giving the contrast
- Since it has renal excretion, Renal function should be normal
- GFR can be evaluated by Serum creatinine
- Serum creatinine should be normal before giving contrast otherwise contrast induced nephropathy can occur
- Gadolinium
 - It is a contrast used in MRI
 - It has magnetic properties
 - It is a non iodinated contrast
 - Nephrotoxic
 - T1 weighted MRI
 - Gadolinium is a paramagnetic substance.
- Sonovue
 - This is the ultrasound contrast
 - These are Microbubbles of sulfur hexafluoride gas
 - These are excreted from the body via lungs
 - Safe in renal failure
- Barium
 - Barium sulfate is the contrast
 - It is given via oral route or rectal route
 - It is for GIT only
 - It is not given via IV because it is water insoluble
 - Barium is contraindicated in Perforation
 - In Perforation, iodinated contrast is used
 - If Barium goes out through perforation, it will go into the peritoneal cavity causing Peritonitis
- The patient is drinking Barium and the image can be seen on the TV screen directly
- This comes under Fluoroscopy
- Fluoroscopy means video X-ray done for moving structures like GIT
- All the barium studies come under Fluoroscopy
- Fluoroscopy has more radiation exposure
 - Wearing the lead apron is important because radiation exposure is very high



- Diatrizoate
 - The brand name: Gastrografin
- Non ionic dimer is Iodixanol
 - This is contrast that is isosmolar (**Mnemonic:** iso nodi = non ionic dimer contrast)

- Ionic monomers are high osmolar (**Mnemonic: IM high**)
- Rest of the groups are low osmolar
- Ionic dimer: Ioxaglate

Radiation Units

00:58:40

- The sequence of events is:
 - Exposure to radiation.
 - Absorption of radiation.
 - Effect of radiation on the body
 - Damage to the tissue depends on tissue sensitivity and the type of radiation
- The unit that is dependent on the type of radiation is the equivalent dose
- The unit that depends on the sensitivity of the tissue is Effective dose
- All the conventional units begin with R.
- SI units don't begin with 'R'
- **RAD** is the unit of radiation absorbed dose (Conventional)
 - **GRAY** is the SI unit of radiation absorbed dose
 - **Mnemonic: RED → GRAY**
- **REM** is the conventional unit of Equivalent dose
 - **SIEVERT** is the SI unit of Equivalent dose
- **REM** is the conventional unit of Effective dose
 - **SIEVERT** is the SI unit of Effective dose
- Exposure
 - Roentgen is the first person who discovered X-ray.
 - **Roentgen** is the conventional unit
 - **Coulomb/kg** is the SI unit
 - Exposure means ionization.
 - Ionization means the creation of ions- positive and negative ions or the charge.
 - The SI unit for charge - Coulomb.
- Unit for radioactivity
 - Conventional unit- **Curie**
 - SI unit: **Becquerel**.
- 1 Gray = 100 Rad
- 1 SV = 100 Rem

DOSE	CONVENTIONAL UNITS	SI UNITS
EXPOSURE DOSE	ROENTGEN	COULOMB/KG
RADIATION ABSORBED DOSE	RAD	GRAY
EQUIVALENT DOSE	REM	SIEVERT
EFFECTIVE DOSE	-	SIEVERT

Examination	Typical effective dose (mSv)	Equivalent number of chest X-rays	Equivalent length of background exposure
X-ray			
Limbs and joints (except hip)	<0.01	<0.5	<1.5 days
Chest (single PA)	0.02	1	3 days
Skull	0.07	3.5	11 days
Lumbar spine	1.3	65	7 months
Hip	0.3	15	7 weeks
Pelvis	0.7	35	4 months
Abdomen	1.0	50	6 months
IVU	2.5	125	14 months
Barium meal	3	150	16 months
CT head	2.3	115	1 year
CT chest	8	400	3.6 years
CT abdomen or pelvis	10	500	4.5 years