



EDITION

RADIOLOGY

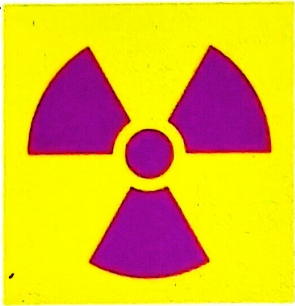
ED.08

# X-RAY FUNDAMENTALS : PART 1

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## INTRODUCTION

Symbols :



Trefoil: Radiation Hazard



X-ray radiation hazard



Sealed radiation source

Father of Radiology : Wilhelm Roentgen (Discovered X-rays in 1895).

International Day of Radiology : 8th November.

## Electro Magnetic (EM) Spectrum

00:13:10

Radio waves : micro waves : Infrared : Light : Ultraviolet : X-rays : Gamma rays

minimum

Frequency and energy

maximum

### Properties of em spectrum :

mass : Absent.

velocity :  $3 \times 10^8$  m/s (Speed of light).

Types of waves : Transverse (Crest and trough).

### Properties of X-rays :

Frequency : High.

Energy : High.

Origin : Extranuclear.

Wavelength : 0.01 to 10nm.

Energy content : 100 eV to 100 KeV.

Note: khanirfan0392@gmail.com

### 1. Atomic jargons :

	Proton number	Neutron number	Feature
Isotopes	Same	Different	Same element
Isotones	Different	Same	Different elements
Isobars	Different	Different	Same atomic mass number
Isomers	Same atomic number and weight		Different/unique Atomic energy

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2. Tungsten (W) :

- Transition metal : Component of X-ray tube.
- Atomic number : 74.
- Atomic mass number : 184.

**Radiation Units**

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	Conventional unit	S.I unit
Radiation exposed	Roentgen	Coulomb/kg (Charge/weight)
Radiation absorbed	Radiation absorbed dose (RAD)	Gray (Gy)
Absorbed dose equivalent	Radiation Equivalent in man (REM)	Sievert (Sv)
Radioactivity	Curie	Becquerel

Note : Radioactivity was discovered by Henri Becquerel.

# X-RAY FUNDAMENTALS : PART 2

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## Radiation effects

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### Determining factors :

- Duration } of exposure to radiation.
- Intensity }
- Sensitivity of tissues to radiation.

### Law of radio-biology/Law of Bergonie and Tribondeau :

Radiosensitivity  $\propto$  Tissues with  $\begin{cases} \text{Maximum undifferentiated cells.} \\ \text{Active mitosis.} \end{cases}$

most sensitive : **Bone marrow** > GIT > CNS/musculoskeletal system.

### Acute radiation syndromes :

#### Stages :

- Stage I : Prodromal (minutes to hours  $\rightarrow$  Nausea, vomiting, diarrhoea).
- Stage II : Latent (Hours to days).
- Stage III : manifest illness (Days to weeks).
- Stage IV : Recovery/death (Weeks to years).

#### Syndromes :

	Acute hematological syndrome	Acute GI track syndrome	Acute CNS syndrome
Threshold dose	1-2 Gy (Least)	6-10 Gy	20 Gy
manifestations	<ul style="list-style-type: none"> <li>• Pancytopenia</li> <li>• Hemorrhage</li> <li>• Infection</li> </ul> } Death	<ul style="list-style-type: none"> <li>• Malaise</li> <li>• Diarrhoea <math>\rightarrow</math> electrolyte imbalance</li> </ul>	<ul style="list-style-type: none"> <li>• <math>\uparrow</math> Intracranial tension</li> <li>• Circulatory collapse</li> </ul>

#### Types :

	Deterministic	Stochastic
Examples	<ul style="list-style-type: none"> <li>• Acute radiation syndromes</li> <li>• Cataract</li> <li>• Skin Damage</li> <li>• Sterility (Gonadal damage)</li> </ul>	<ul style="list-style-type: none"> <li>• Carcinogenesis</li> <li>• mutations/Chromosomal aberrations</li> </ul>
Onset	Acute to subacute	Chronic/Delayed
Threshold dose	Present	Not determined

Feedback

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Severity	Dose dependent	Dose independent
	Deterministic	Stochastic
Risk-Dose relationship	Non-linear with Threshold dose 	Linear with no threshold dose 

### Radiation Exposure

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#### Principle of Radiation Safety :

As Low As Reasonably Achievable (ALARA) :

while doing any X-ray based Ix (Radiographic/CT) ensure low exposure + maintain Quality.

#### Hazard Levels :

	Types	Scans	Exposure values (mSv)
Danger	CT/PET/radionuclide studies (Highest exposure)	<small>khanirfan0392@gmail.com</small> PET Scan	25
		CT Abdomen	10
		CT Thorax	8
		Bone Scan	-
		CT Head/Brain	3.5
Warning	Diagnostic procedures (multiple exposure)	Barium Enema	7
		Intravenous urogram	-
		Barium meal follow through	-
		Barium meal	-
		Barium Swallow	-
		micturating Cystourethrography (MCU) : IOC for Vesico-ureteric Reflux	1.2
Safe	Spot radiographs (Exposure once/twice)	Lumbar Spine	1.0
		Abdomen X-ray	-
		Hip X-ray	-
		Skull X-ray	-
		Chest X-ray	0.02
		Limb/Joint X-ray	0.01 (least)

Barium Enema : In spite of high exposure → Safety maintained due to lead shield (Shielding of gonads).

**Guidelines :**

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International guidelines : Given by International Commission on Radiological Protection (ICRP) & International Commission on Radiation Units (ICRU)

		Public exposure	Occupational exposure
Effective Dose		1 mSv/year	<ul style="list-style-type: none"> <li>• 20 mSv/year or 50 mSv in any 1 yr.</li> <li>• &lt; 100 mSv in 5 years.</li> </ul>
Annual equivalent dose	Lens of Eye	15 mSv	150 mSv
	skin	50 mSv	500 mSv
Pregnant females		< 1 mSv	

Indian guidelines : Given by Atomic Energy Regulatory Board (AERB).

Same as international except occupational exposure → effective dose of 30 mSv in any 1 year provided < 100mSv in 5 years.

**Exposure Factors :**

Adjustments done on X-ray console based on image requirement.

	Tube potential (TP)	Tube current (TC)
Unit	Kilovoltage Peak (kVp)	milli-Ampere second (mAs)
To measure	Potential difference across cathode and anode tubes	Number of photons in X-ray beam (Film Blackening)
Determines	<ul style="list-style-type: none"> <li>• <math>\propto</math> Penetration</li> <li>• <math>\propto \frac{1}{\text{Image contrast}}</math></li> </ul>	<ul style="list-style-type: none"> <li>• <math>\propto</math> Image contrast</li> </ul>

**Thermoluminescent Dosimeter (TLD) Badge**

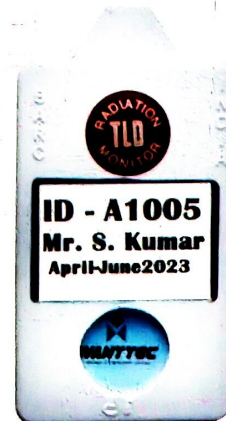
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Time duration : 3 months.

Application : To monitor occupational radiation exposure.

Composition : Phosphor crystals.

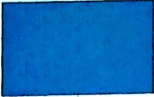
- Lithium Fluoride (LiF).
- Lithium Borate.
- Beryllium Oxide (BeO).



TLD Badge

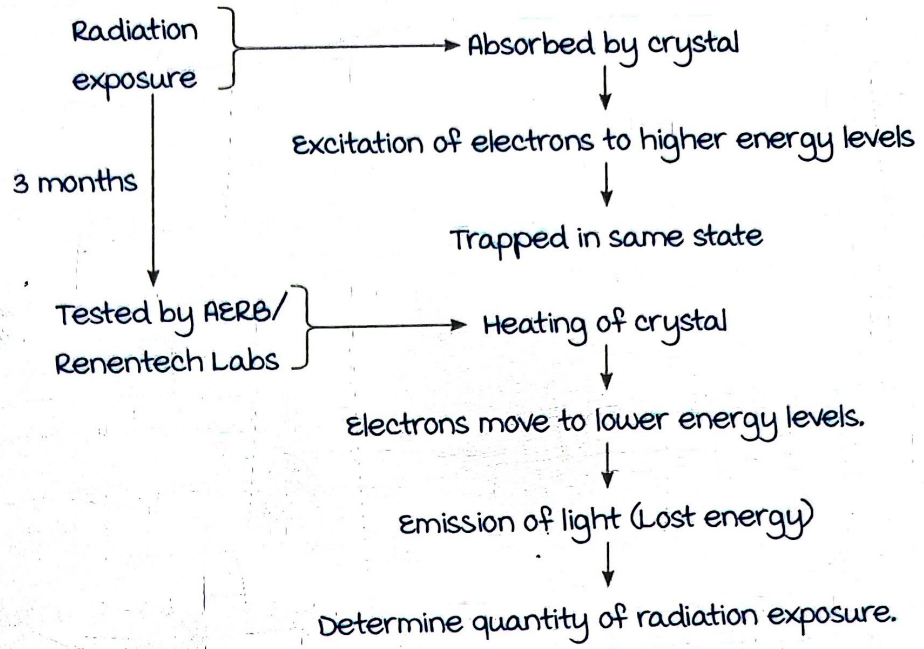
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### Fundamentals of Radiology

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# X-RAY PRODUCTION AND INTERACTIONS

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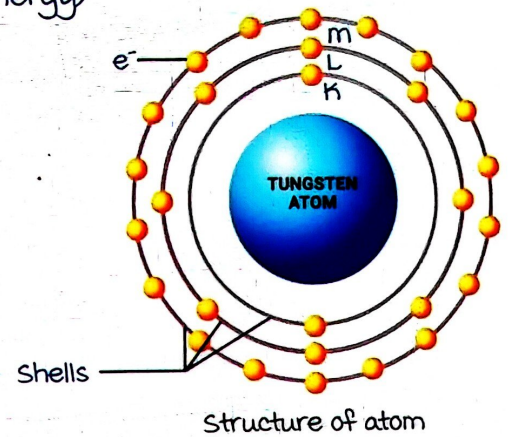
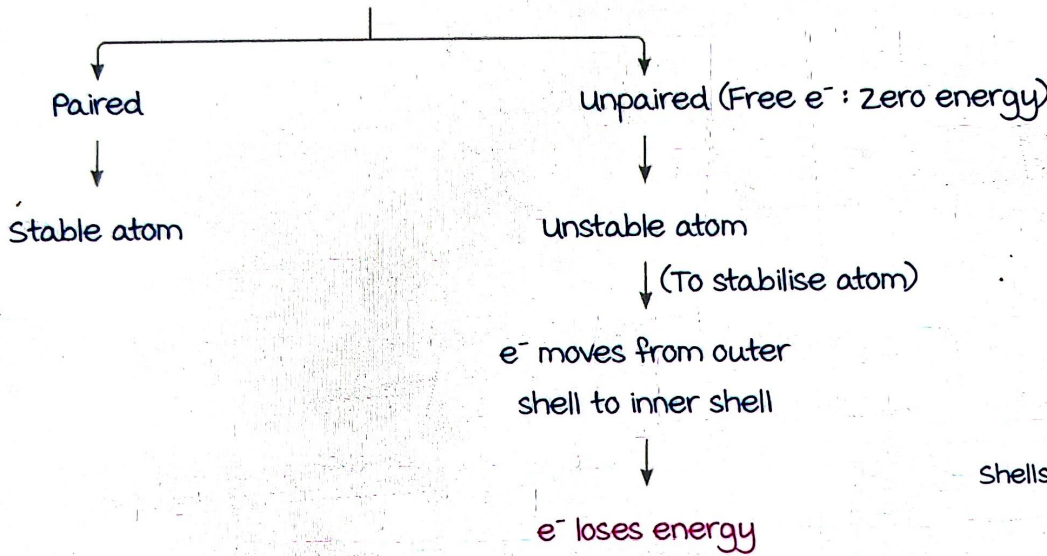
## Atomic structure

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Shells around atom :

Each shell has a **specific energy level**.

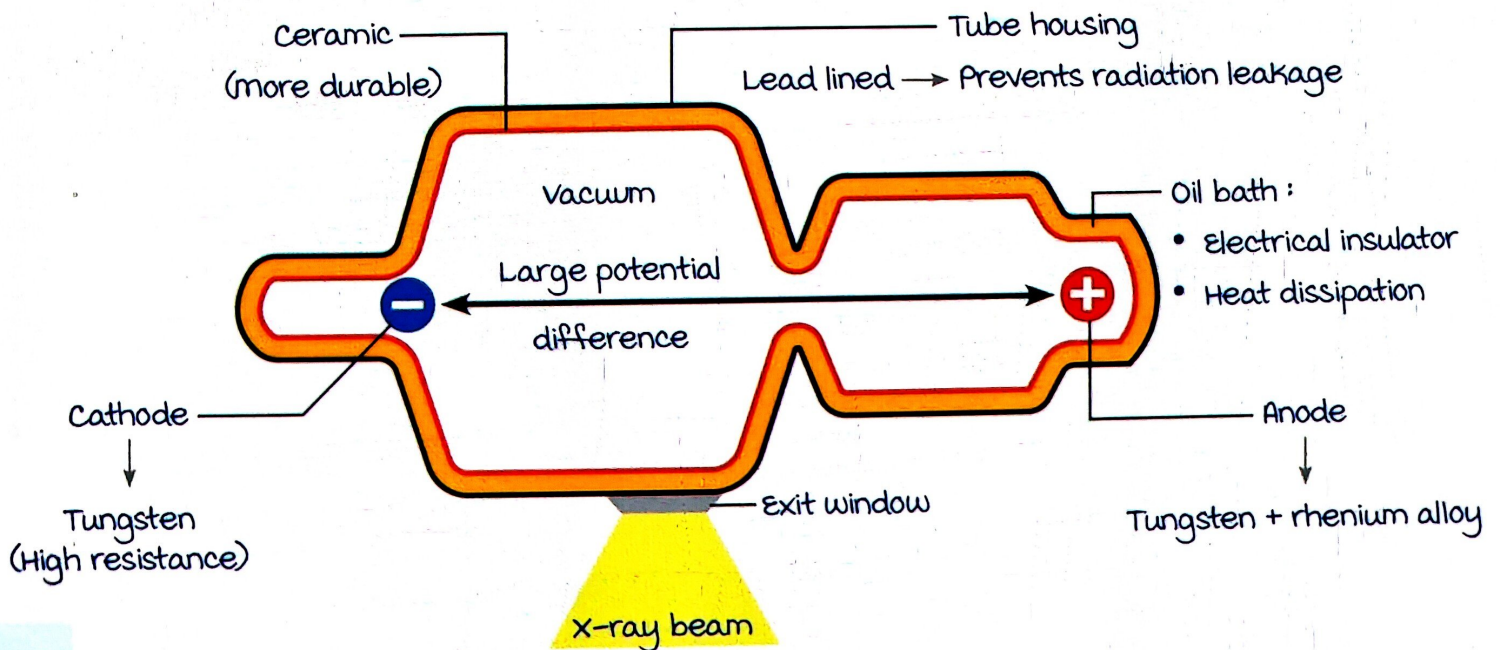
Electrons ( $e^-$ ) :



## Production of X-ray

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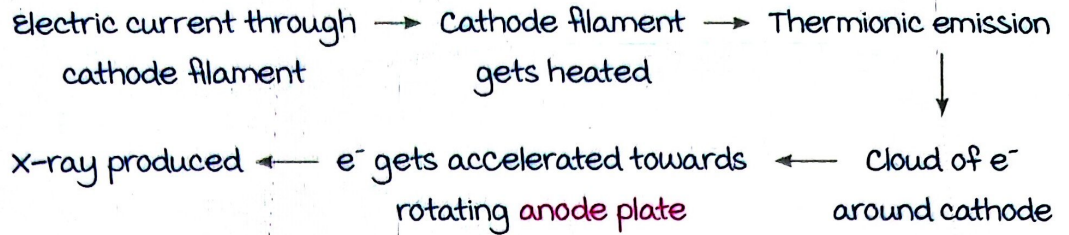
Structure of x-ray tube :





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**X-ray production :**



**mechanisms of X-Ray production :**

	Continuous spectrum	Characteristic spectrum
mechanism	Acceleration/deceleration of e <sup>-</sup>	Shifting of e <sup>-</sup> from outer to inner shell
Frequency of use	70-80% (m/c)	20-30%
Additional points	AKA Bremsstrahlung/ white breaking radiation.	used in mammography.

**Interactions of X-rays with matter**

00:19:27

	Compton effect (m/c)	Photoelectric effect
AKA	mid energy phenomenon	Low energy phenomenon
Interaction	X-ray photon & outer shell e <sup>-</sup>	X-ray photon & inner shell e <sup>-</sup>
Outcome :	↑ deviation of X-Ray more (↑ distortion)	Absent
• Scatter radiation	Low	Better
• Image resolution	↓ effect	↑ effect
• Desired level		

Note :

Other interactions (Not used) → Coherent scattering, photodisintegration, pair production.

# CT BASICS

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## Introduction :

Sir Godfrey Hounsfield :

- Founding father of CT technology.
- Invented 1<sup>st</sup> generation CT scanner : EMI.
- Awarded nobel prize along with Allan Cormack in 1979.

Tomography : modality of producing cross-sectional images of body.

## CT Room :

Equipment : Tomography machine + Computer.

Walls :

- Lined by **lead** → Prevent leakage of radiation.
- Thickness :
  - Lead : 1/16<sup>th</sup> inch.
  - Concrete : 4-6 inches.

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## Basic Principle :

The **internal structure** of an object can be **reconstructed from multiple projections** of that object.

## Hounsfield unit/CT value scale :

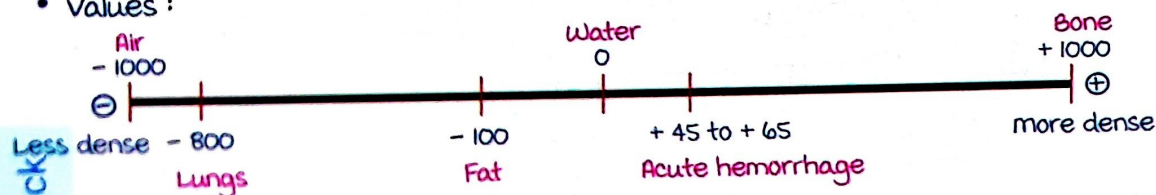
- Numerical value of tissues on CT scan.

$$HU_x = 1000 \times \frac{\mu_x - \mu_{\text{water}}}{\mu_{\text{water}}}$$

$HU_x$  : Hounsfield unit of tissue  
 $\mu$  : Linear attenuation co-efficient

- It is determined by electron density (Property of tissue determining appearance on CT scan).

- Values :





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# USG BASICS

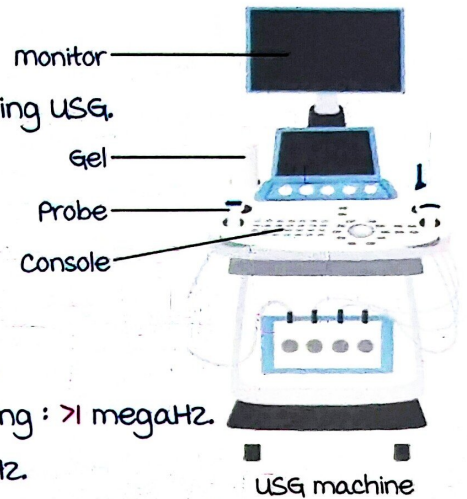
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## Introduction to Ultrasonography

00:00:38

Important historical details :

- Pierre Curie : Discovered piezoelectricity.
- Karl Dussik : First to attempt head imaging using USG.
- John Wild : Father of medical USG.
- Ian Donald : Father of obstetric USG.



Ultrasound waves :

- Ultrasound : Sound beam with high frequency.
- Ultrasound frequency used in diagnostic imaging : >1 megahz.

Note : Frequency values

- Ultrasonic : >20,000 Hz.
- Audible range : 20-20,000 Hz.
- Infrasonic : <20 Hz.

## Probes

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Principle :

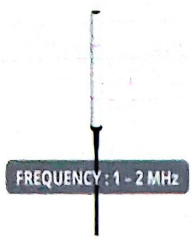
Frequency of ultrasound wave  $\propto \frac{1}{\text{Penetration of wave}}$

Types :

1. Pencil probe :

uses :

1. Trans-cranial Doppler (TCD) : Vascular imaging of brain.
2. Trans-cranial color scans (TCCS/duplex scans).



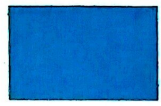
2. Convex/curvilinear probe : m/c used.

Use :

- Abdomen & pelvic USG.
- Obstetric USG.
- Obstetric doppler studies : Blood flow evaluation in
  - umbilical artery.
  - Fetal MCA.
  - uterine artery.




Feedback



----- Active space -----

3. Linear probe :

Flat surface 

Use : Small part imaging of

- Neck, thyroid, breast, scrotum, joints.
- Swelling on body surface (Eg. : Lipoma, ganglion cysts).
- Peripheral vascular dopplers.

FREQUENCY : 7.5 - 12 MHz

4. Endoluminal probe :



Use :

- Transvaginal sonography probe.
- Transrectal USG for prostate imaging.
- T&E (Trans-esophageal echocardiography) : To evaluate prosthetic valves.
- Endoscopic ultrasound probes.
- Endovascular probes.

FREQUENCY : >10 MHz

5. UBM probe :

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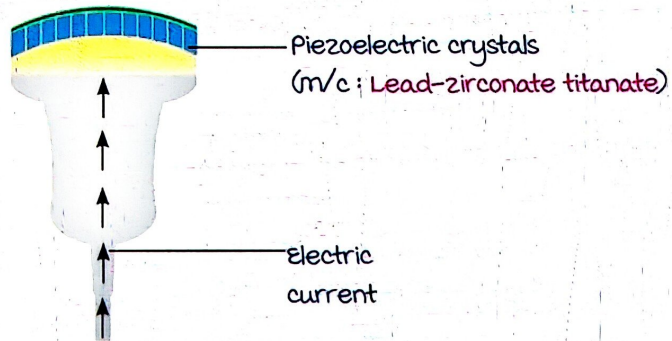
Use :

- Ultrasound biomicroscopy of the eye : For ophthalmic imaging.



FREQUENCY : 50 MHz

Internal structure of USG probe :



Biological Effects of Ultrasound

00:14:13

Thermal effects :

mechanism :

Body tissues attenuate (block) some ultrasound waves

Energy of attenuated waves absorbed by tissues

Heats up tissues : Therapeutic application → Thermal ablation of tumors

Thermal index :

$$\text{Thermal index} = \frac{\text{Power of ultrasound produced from probe}}{\text{Power required to increase tissue temperature by } 1^{\circ}\text{C}}$$

Thermal index for —   
 → Soft tissue :  $TI_s$    
 → Bone :  $TI_b$

Feedback

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**mechanical effects :**

mechanism : Alternating change in pressures compressions &amp; rarefactions

Sudden rarefaction expansion at air-fluid interface.

Eg. : Lungs, bowel loops

Tissue damage (microcavitation)

mechanical index :  $< 0.9$  to prevent physical damage.**Special Applications of Ultrasound**

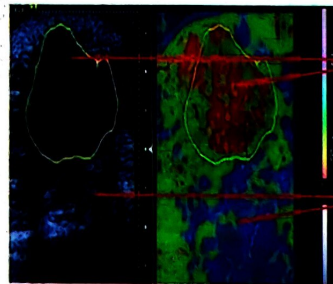
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## 1. Elastography :

- To determine elasticity/hardness of tissues.
- Types :
  - Strain elastography : manual application of pressure.
  - Shear wave elastography : Pressure applied through the ultrasound beam.

## 2. High Intensity Focused Ultrasound (HIFU) :

- Focused thermal ablation technique.
- Uses : Treatment of
  - Liver metastasis.
  - Uterine fibroids.
  - Breast lesions.



malignancies (Hard) : Appears dark

Normal tissues (Soft) : Appears light

Color map

## 3. Contrast enhanced ultrasound : uses microbubbles.

## 4. Spatio-temporal image correlation (STIC) : 3D cardiac imaging of fetus.

## 5. A mode of ultrasound :

- Special mode used for the eye : A scan.
- Graph represents various surfaces reflecting the sound beam.



A scan

# MRI BASICS

----- Active space -----

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## Magnetic Resonance Imaging (MRI)

00:01:00

### History :

Felix Bloch : Discovered nuclear magnetic resonance (NMR).

- Nucleus behaves like a magnet and has a magnetic field.

Raymond Damadian :

- Produced 1<sup>st</sup> NMR image (Of rat tumor).
- Produced 1<sup>st</sup> MRI image of human body (Using the 1<sup>st</sup> superconducting NMR scanner).

Paul Lauterbur : Developed 2D tomographic MR image.

Peter Mansfield : Developed 1<sup>st</sup> image of human finger using field gradient for slice selection.

### Basic principle :

Gyromagnetic property of hydrogen nucleus.

### Contraindications :

Absolute C/I : Interference/effect of magnetic field → Fatal consequences.

1. **metallic foreign body in eye.**
2. Cardiac pacemaker.
3. Cochlear implants.
4. Ferromagnetic hemostatic CNS aneurysm clips.

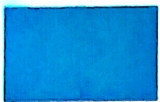
### Relative C/I :

1. Claustrophobia : Fear of closed spaces.
2. Insulin pumps.
3. Nerve stimulators.
4. Prosthetic heart valves (Before formation of granulation tissue).
5. 1<sup>st</sup> trimester of pregnancy (Speculated that noise of MRI may cause future hearing impairment)

### Note :

- Fixators
- External (Eg. : K-wire) : C/I for MRI.
  - Internal (Steel/titanium) : Safe for MRI.

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### Fundamentals of Radiology

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- Angioplasty stent :  
Formation of granulation tissue over stent (6-8 weeks post-placement)

↓  
Immobilisation of stent

↓  
**Safe for MRI**

- Anterior cruciate ligament (ACL) screw :  
magnetic but implanted deep within bone (immobile) → **Safe for MRI.**

### Faraday's cage :

Prevents action/interference of MRI magnet on outside devices & vice-versa : **Shielding.**

Wooden panels wrapped with copper wires



Faraday's cage

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# CONTRAST MEDIA

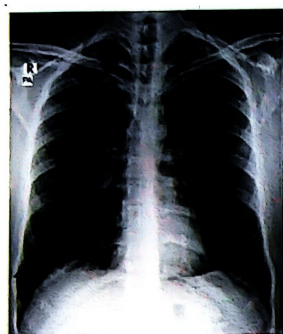
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## Introduction

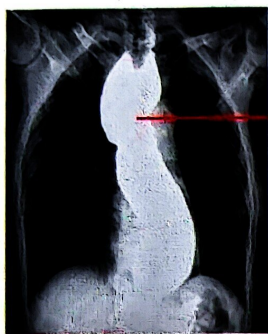
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### Definition :

Contrast media is an agent used to enhance appearance of organ/tissue in body.



Plain chest X-ray



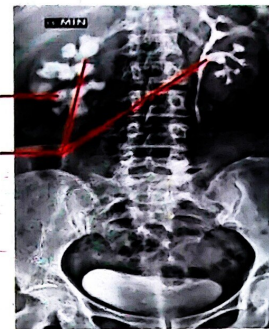
Barium enhanced contrast study

Esophagus



Plain X-ray abdomen :

Hydronephrosis  
Opacification of renal pelvicalyceal system



Iodine (IV route) enhanced contrast study

### Contrast media :

Based on Radiological modalities

X-ray/CT scan

- Barium
- Iodine

USG

Stabilised microbubbles

MRI

Gadolinium (Gd) : m/c

## X-ray/CT Contrast

00:05:00

### TYPES :

Based on appearance :

		Principle	Examples
Positive Contrast	<p>Barium Swallow study</p>	Block/attenuate more X-ray compared to adjacent tissues ↓ Appears <b>white</b> (Similar to bone)	<ul style="list-style-type: none"> <li>• Barium</li> <li>• Iodine</li> </ul>
Negative Contrast	<p>CECT abdomen</p>	Block/attenuate less X-rays compared to adjacent tissues ↓ Appears <b>Black</b>	<ul style="list-style-type: none"> <li>• Air</li> <li>• Water</li> <li>• mannitol : Hyperosmolar → Draws water into gut lumen.</li> </ul>

Note : Double contrast : Barium enema (Infusion of barium followed by air).



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**BARIUM :**

Atomic number : 56.

Dosage form : High/low density barium sulphate suspension (Insoluble in water).

**Advantages :**

Inert compound (Inside bowel lumen) :

- No irritation/damage to mucosa.
- Does not interfere with digestion.
- Does not get absorbed.

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**Contra indications :**Absolute : **Perforation** (Causes severe chemical peritonitis).

Relative :

- Small bowel obstruction (SBO).
- Hypersensitivity.
- Recto-vaginal/vesico-vaginal fistula.
- Left sided colonic obstruction : Excessive stasis → Barium converts into fecoliths.

**Applications :**

Bowel studies.

## 1) Barium swallow :



To evaluate :

- Oropharynx.
- Esophagus.
- Gastro-esophageal junction.

## 2) Barium meal :

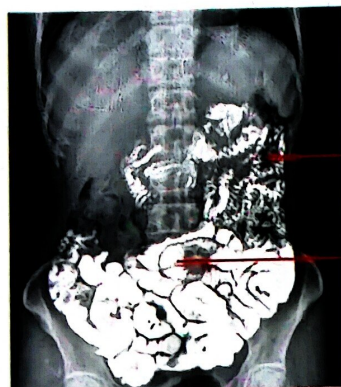


To evaluate :

- Stomach.
- Proximal duodenum.

## 3) Barium meal follow through :

To evaluate : Small bowel.



Feathery appearance of jejunal loop,

Featureless appearance of ileum (in central abdomen)

## 4) Barium enema :

To evaluate : Large bowel.

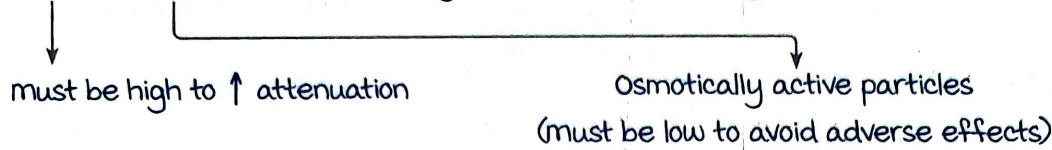


**IODINE :**

Water soluble contrast.

Atomic number : 53.

Iodine/Particle (I : P) Ratio : Ideally I : P ratio should be high



**Types of Iodinated Contrast :**

	High Osmolar	Low Osmolar		
	Ionic monomers	Ionic Dimers	Non-Ionic monomers	Non-Ionic Dimers
Features	-	-	<ul style="list-style-type: none"> <li>m/c used contrast</li> <li>Chemically stable : low adverse effects.</li> </ul>	<ul style="list-style-type: none"> <li>Iso-Osmolar contrast</li> <li>Safest</li> <li>High cost</li> </ul>
I : P Ratio	3 : 2 (Worst)	6 : 2	3 : 1	6 : 1 (Best)
Examples	Salts of Diatrizoic Acid : <ul style="list-style-type: none"> <li>Trazografs</li> <li>urograffin</li> <li>Angiograffin</li> <li>Gastrograffin</li> <li>urovision</li> <li>uro video</li> </ul>	<ul style="list-style-type: none"> <li>Ioxaglic Acid</li> <li>Iocarmic Acid</li> </ul>	<ul style="list-style-type: none"> <li>Iohexol (Omnipaque) : m/c</li> <li>Iopamidol</li> <li>Ioversol</li> <li>Iopromide</li> </ul>	<ul style="list-style-type: none"> <li>Iotrol</li> <li>Iotrolan</li> <li>Iodixanol</li> </ul>

**Contrast Induced Nephropathy (CIN) :**

Diagnostic criteria : ↑ S.creatinine of :

- >25%/Per injection value
  - 0.5mg/dL absolute increase
- } within 48-72 hrs of i.v contrast.

**Pathology :**

- Direct injury to proximal convoluted tubule.
- Free radical mediated injury.
- Vaso constriction.

**Laboratory markers :**

- S. creatinine (most important).
- S. Cystatin C.
- Estimated GFR (eGFR) <60 mL/min.
- Plasma neutrophil gelatinase associated lipocalin (NGAL).

**Risk Factors :**

- Pre-existing Chronic Kidney Disease (CKD) : most important.
- Elderly age.
- Diabetes mellitus.

Feedback

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- Anemia
- Hypovolemia/Dehydration.
- multiple myeloma.
- metabolic Syndrome.

management :

- Self limiting condition : monitor fluids and electrolytes.
- Hemodialysis (Rare).

Prevention : Pre-contrast

- Renal Function Tests : To rule out CKD.
- Hydration.
- Bicarbonate therapy.
- N-Acetyl Cysteine.
- Vitamin C.
- Rosuvastatin.

Contraindications :

- Renal impairment.
- Hyperthyroidism.
- Ongoing radio-active iodine therapy.
- Undergone I-123 based radionuclide scan.
- H/o hypersensitivity/anaphylactic reaction.

USG Contrast

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MICROSCOPIC GAS BUBBLES :

Principle :

Normal Ultrasound waves :

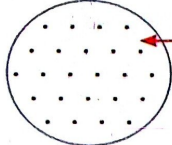
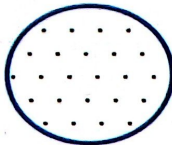
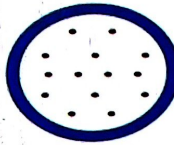
Compression : ↑ pressure.

Rarefaction : ↓ pressure.

On Contrast :

Creates back scattering of ultrasound beam during rarefaction.

Classification :

	1st Generation	2nd Generation	3rd Generation
Stability	Least (Absent shell → Disintegrates before reaching target organ)	moderate	Highest (m/c used)
Gas	Air	Air	Nitrogen/Polyfluorocarbon/SF6
Shell	None	Protein	Protein/Lipid/Polymer
	 <p>Tiny microscopic bubbles</p>		

**Applications :**

Tissue specific contrast :

Organs : Liver, Spleen, Pancreas.

Contrast materials : **Levovist** (m/c), Sonovist, SonoZoid.

Vascular contrast :

I.V injection : To assess blood flow.

Contrast materials: Albunex, Infuson.

**MRI Contrast**

00:36:20

**Types :**

Based on net magnetic vectors of patient's body of particular tissue.

	1. T <sub>1</sub> Relaxation agents	2. T <sub>2</sub> Relaxation agents
Principle	Shortening of T <sub>1</sub> relaxation time ↓ Bright on fat suppressed T1w image	Shortening of T <sub>2</sub> relaxation time ↓ Dark on T2w Image
Examples	<b>Gadolinium</b> (m/c) : c/I in pregnancy. • magnevist : Gd-DTPA • Omniscan : Gd-DTPA-BMA	<b>SuperParamagnetic Iron Oxide (SPIO)</b> : uptake by Kupffer cells (Liver) in focal nodular Hyperplasia (FNH) → ↓ Intensity on image

3. Hepatocyte specific agents : manganese containing contrast material.

- Gd-manganese DPDP.
- Gd-BOPTA.
- mangafodipir trisodium.
- Gad-EOB-DTPA.

**Nephrogenic Systemic Fibrosis (NSF) :**

Pathology :

- In Renal failure patients → ↓ Renal excretion of Gd

↓  
Transmetallation :

Free Gd ion deposited in body (Extremities, muscle, chest wall)

↓  
Induce Inflammatory reaction (Subcutaneous edema, firm indurated plaques)↓  
Irreversible fibrosis (Joint contractures, deformities, respiratory difficulty)

- Toll like receptors (TLR) type 4 and 7 involved in pathogenesis.

Etiology : Gadolinium containing agents

- Omniscan (**Gadodiamide**) : (Banned).
- magnevist (Gadopentetate dimeglumine): and m/c.
- Optimark (Gadoversetamide).

Feedback