Radiology

Marrow Edition 8

MARROW

Instructions

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// ME821-PPL

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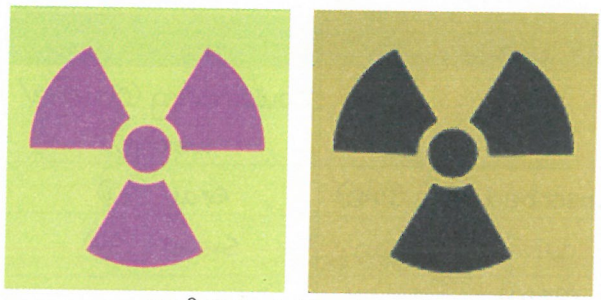
X-RAY FUNDAMENTALS : PART 1

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

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 : 3×10^8 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 :

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

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

2. Tungsten (W) :

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

Radiation Units

00:29:05

	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

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

Radiation effects

00:00:15

Determining factors :

- Duration
- Intensity

} of exposure to radiation.

- Sensitivity of tissues to radiation.

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

Radiosensitivity ∝ Tissues with → Maximum undifferentiated cells.
→ Active mitosis.

Most sensitive : Bone marrow > GIT > CNS/musculoskeletal system.

Acute radiation syndromes :

Stages :

Stage I : Prodromal (Minutes to hours → 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 tract syndrome	Acute CNS syndrome
Threshold dose	1-2 Gy (Least)	6-10 Gy	20 Gy
manifestations	• Pancytopenia • Hemorrhage • Infection } Death	• Malaise • Diarrhoea → Electrolyte imbalance	• ↑ Intracranial tension • Circulatory collapse

Types :

	Deterministic	Stochastic
Examples	• Acute radiation syndromes • Cataract • Skin Damage • Sterility (Gonadal damage)	• Carcinogenesis • Mutations/Chromosomal aberrations
Onset	Acute to subacute	Chronic/Delayed
Threshold dose	Present	Not determined

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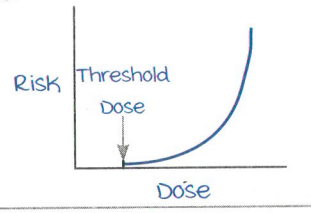
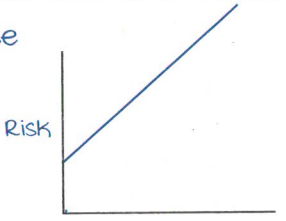
Severity	Dose dependent	Dose independent
	Deterministic	Stochastic
Risk-Dose relationship	Non-linear with Threshold dose 	Linear with no threshold dose 

Radiation Exposure

00:17:50

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)	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 : Inspite 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	• 20 mSv/year or 50 mSv in any 1 yr. • < 100 mSv in 5 years.
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	• $\propto$ Penetration • $\propto \frac{1}{\text{Image contrast}}$	• $\propto$ Image contrast

Thermoluminescent Dosimeter (TLD) Badge

00:37:26

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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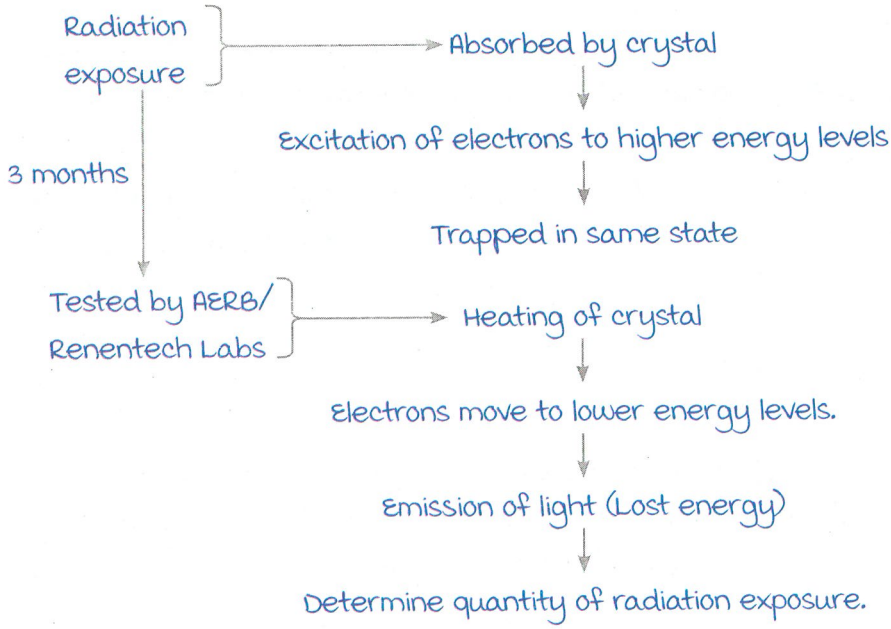
Principle :



X-RAY PRODUCTION AND INTERACTIONS

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Atomic structure

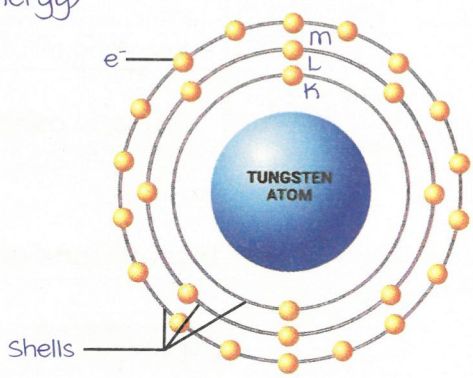
00:00:18

Shells around atom :

Each shell has a specific energy level.

Electrons (e^-) :

- Paired → Stable atom
- Unpaired (Free e^- : Zero energy) → Unstable atom → (To stabilise atom) → e^- moves from outer shell to inner shell → e^- loses energy

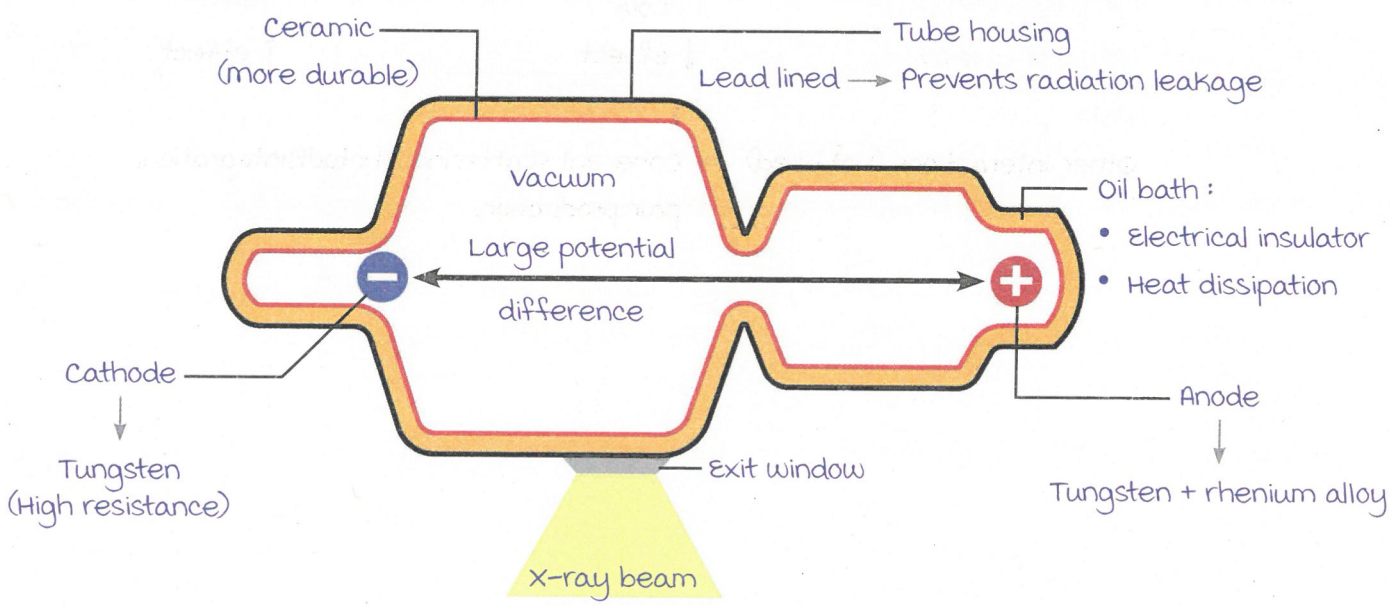


Structure of atom

Production of X-ray

00:08:20

Structure of X-ray tube :



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X-ray production :

Electric current through cathode filament → Cathode filament gets heated → Thermionic emission → Cloud of e^- around cathode → e^- gets accelerated towards rotating anode plate → X-ray produced

Mechanisms of X-Ray production :

	Continuous spectrum	Characteristic spectrum
Mechanism	Acceleration/deceleration of e^-	Shifting of e^- 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^-	X-ray photon & inner shell e^-
Outcome : • Scatter radiation • Image resolution • Desired level	↑ deviation of X-Ray more (↑ distortion) Low ↓ effect	 Absent Better ↑ effect

Note :

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

CT BASICS

Introduction :

Sir Godfrey Hounsfield :

- Founding father of CT technology.
- Invented 1st 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 : 1/16th inch.
  - Concrete : 4-6 inches.

Basic Principle :

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

Hounsfield unit/CT value scale :

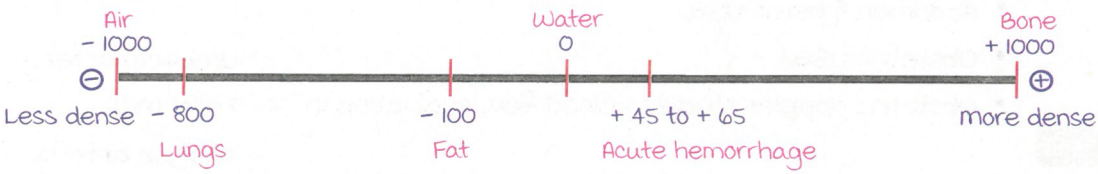
- Numerical value of tissues on CT scan.

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

HU_x : Hounsfield unit of tissue

μ : Linear attenuation co-efficient

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



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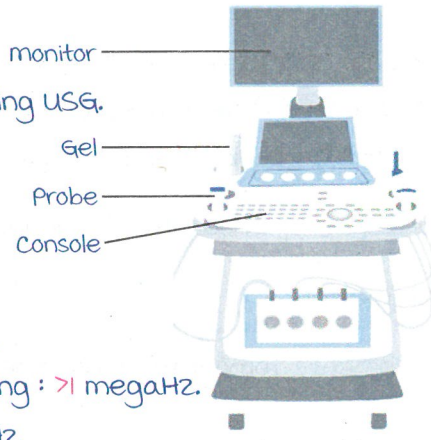
USG BASICS

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.



USG machine

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.

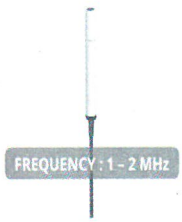
Probes 00:06:54

Principle :

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

Types :

1. Pencil probe :

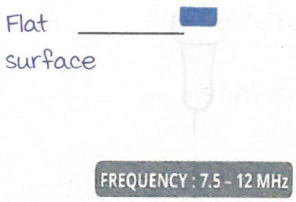


Uses :
1. Trans-cranial Doppler (TCD) : Vascular imaging of brain.
2. Trans-cranial color scans (TCCS/duplex scans).

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.

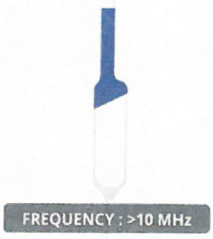
3. Linear probe :



Use : Small part imaging of

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

4. Endoluminal probe :



Use :

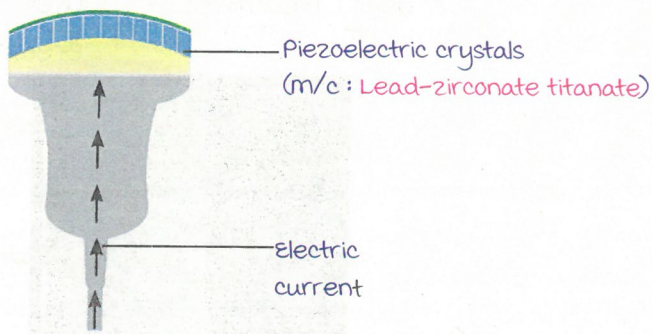
- Transvaginal sonography probe.
- Transrectal USG for prostate imaging.
- TEE (Trans-esophageal echocardiography) : To evaluate prosthetic valves.
- Endoscopic ultrasound probes.
- Endovascular probes.

5. UBM probe :

Use :

- Ultrasound biomicroscopy of the eye : For ophthalmic imaging.

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 :

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

Thermal index for → Soft tissue : TI_s.
→ Bone : TI_B.

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

Mechanical effects :

Mechanism : Alternating change in pressures compressions & rarefactions

↓

Sudden rarefaction expansion at air-fluid interface.
Eg. : Lungs, bowel loops

↓

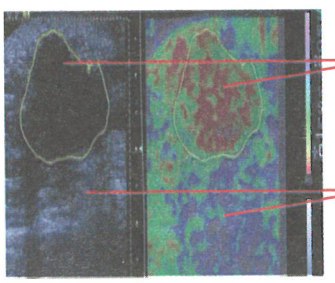
Tissue damage (microcavitation)

Mechanical index : <0.9 to prevent physical damage.

Special Applications of Ultrasound

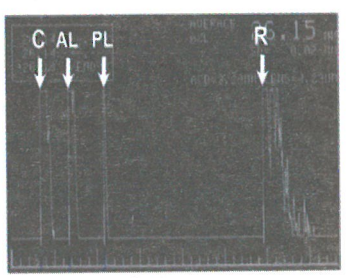
00:18:38

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.



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

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 1st NMR image (Of rat tumor).
- Produced 1st MRI image of human body (using the 1st superconducting NMR scanner).

Paul Lauterbur : Developed 2D tomographic MR image.

Peter Mansfield : Developed 1st 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. 1st 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.

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

- 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

CONTRAST MEDIA

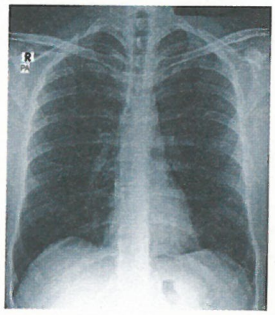
----- Active space -----

Introduction

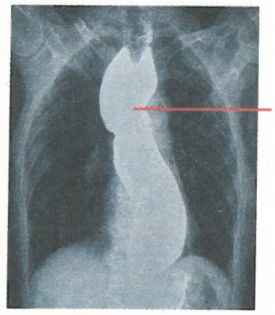
00:00:25

Definition :

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

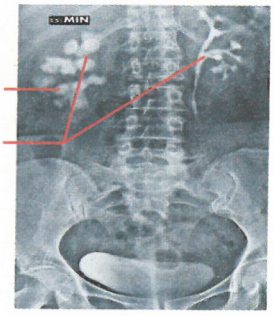


Plain chest X-ray



Barium enhanced contrast study

Plain X-ray abdomen :



Iodine (IV route) enhanced contrast study

Contrast media : Based on Radiological Modalities

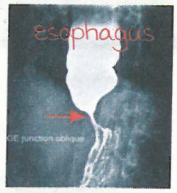
- X-ray/CT scan
  - Barium
  - Iodine
- USG
  - Stabilised microbubbles
- MRI
  - Gadolinium (Gd) : m/c

X-ray/CT Contrast

00:05:00

TYPES :

Based on appearance :

		Principle	Examples
Positive Contrast	 Barium Swallow study	Block/attenuate more X-ray compared to adjacent tissues → Appears white (Similar to bone)	• Barium • Iodine
Negative Contrast	 CECT abdomen	Block/attenuate less X-rays compared to adjacent tissues → Appears Black	• Air • Water • Mannitol : Hyperosmolar → Draws water into gut lumen.

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

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

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.

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 :

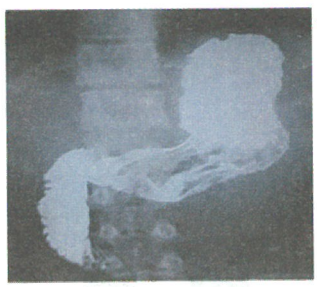
Bowel studies.

1) Barium swallow :

To evaluate :

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

2) Barium meal :

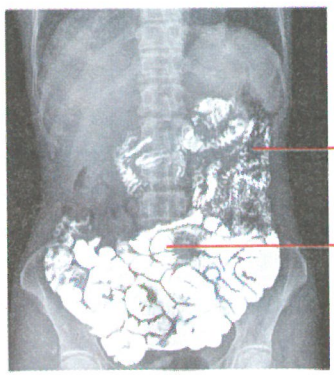


To evaluate :

- Stomach.
- Proximal duodenuml.

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.