

Radiology

Edition 8.5

Marrow

MARROW

Instructions

- Notes are to be used in conjunction with Marrow videos.

Please note:

- The information in this book has been printed based on the transcript of the Marrow videos. This book has to be used in conjunction with the Marrow videos and not as a standalone material.
- The information contained in this book is for educational purposes only. The content provided is not intended to substitute for professional medical advice, diagnosis or treatment.
- This book cannot be sold separately. It has been made available to only select eligible users who have an active subscription to Marrow videos.
- The text, images, slides, and other materials used in this book have been contributed by the faculty, who are subject matter experts. We have merely reproduced them as video transcripts in this book.
- The notes have been consciously designed in a way that is concise and revisable. To ensure this, we have intentionally added only the most relevant modules and images that are needed for you.
- Reasonable care has been taken to ensure the accuracy of the information provided in this book. Neither the faculty nor Marrow takes any responsibility for any liability or damages resulting from applying the information provided in this book.

All Rights Reserved

No part of this publication shall be reproduced, copied, transmitted, adapted, modified or stored in any form or by any means, electronic, photocopying, recording or otherwise.

Contents

Fundamentals of Radiology

X-Ray Fundamentals : Part 1	1
Electromagnetic (EM) spectrum • Radiation units	
X-Ray Fundamentals : Part 2	3
Radiation effects • Radiation exposure • Thermoluminescent dosimeter (TLD) badge	
X-Ray Production and Interactions	7
Atomic structure • Production of X-ray • Interactions of x-rays with matter	
CT Basics	9
USG Basics	10
Introduction to ultrasonography • Probes • Biological effects of ultrasound • Special applications of ultrasound	
MRI Basics	13
Magnetic resonance imaging (MRI)	
Contrast Media	15
Introduction • X-ray/CT contrast • Barium contrast • Iodine contrast • USG contrast • MRI contrast	
USG Interpretation	23
Introduction to USG • USG interpretations	
CT Interpretation	28
Basis of CT • Organ identification • Organ identification : abdomen & pelvis • Lesions seen on CT	

Radiotherapy and Nuclear Medicine

PET Scan	37
18-FDG (fluoro-deoxy-glucose) • Image formation in PET scan • Isotopes for PET scan : updates	
Systemic Radionuclide Imaging : Part 1	41
Technetium (tc) • Radionuclide imaging in infection/inflammation • Renal imaging • Cardiac imaging • Lung imaging	
Systemic Radionuclide Imaging : Part 2	45
GIT imaging : catheter angiography • GIT imaging : radionuclide studies • Skeletal imaging • Neck imaging • Miscellaneous imaging scans	

Radiotherapy	51
- Basics of radioactivity • Mechanism of action of radiotherapy • - Fractionated radiotherapy • Types of radiotherapy • Specialised applications • - Chemical modifiers • Radiotherapy specifics	
Systemic Radiology	
CXR Interpretation : Part 1	63
- Postero-anterior view • Antero-posterior view • Lateral view • Lateral decubitus view • - Oblique views • Lordotic views/apicogram	
CXR Interpretation : Part 2	68
Normal CXR • Incidental findings / variations	
Silhouette Sign : Basics	74
- Differential radiographic density theory • Sharp margins on X-ray • - Silhouette sign interpretation • Air bronchogram sign	
Silhouette Sign : Applications	77
- Important conditions with silhouette sign • Tuberculosis • COVID-19 pneumonia • - Interstitial lung disease (ILD)	
Pleural Abnormalities	84
Pleural effusion (PE) • Tension pneumothorax • Miscellaneous lung conditions	
Mediastinum and Lung Tumours	91
- Mediastinal mass lesions • Pneumomediastinum • Solitary pulmonary nodule (SPN) • - Lung tumors • Bronchiectasis, sarcoidosis & foreign body aspiration	
Congenital Heart Disease	98
Cyanotic congenital heart diseases • Acyanotic congenital heart diseases	
Acquired Cardiac Disease	102
- Mitral stenosis • Congestive heart failure • Pericardial effusion • - Pulmonary arterial hypertension • Aortic dissection • Aortic aneurysm • - Miscellaneous cardiac conditions	
Structural Anatomy of Brain	112
CT vs MRI • Normal imaging atlas	
Basics of Neuroimaging	117
CT brain • MRI brain	
Stroke Imaging	122
- Approach to stroke • Ischemic stroke • Cerebral venous sinus thrombosis (CVST) • - Global cerebral hypoperfusion (GCH) • Moya-moya disease • Hemorrhagic stroke • - Miscellaneous topics	
Head Trauma Imaging	129
- CT imaging guidelines for head trauma • CT interpretation protocol in head trauma • - Intracranial bleeds on CT imaging • Diffuse axonal injury • Skull fractures • - Intracranial bleeds on MRI	

Brain Tumors	137
Meningioma (extra-axial) • Glioma (intra-axial) • Vestibular schwannoma • Pituitary tumors • Craniopharyngioma • Tumors arising from posterior fossa • Retinoblastoma • Juvenile nasopharyngeal angiofibroma • Brain mets • Familial brain tumor syndromes • Sturge weber syndrome	
CNS Infections and Miscellaneous	145
Meningitis • Ring enhancing lesions • Miscellaneous CNS conditions • CNS spotters	
Conventional Procedures in Genito-Urinary Tract	153
Intravenous urography/pyelography • Micturating cysto-urethrography • GU tract cases	
Genito-Urinary Tract Imaging	160
Urolithiasis (renal calculi) • Nephrocalcinosis • Complications of obstructive uropathy • Genitourinary tuberculosis (GUTB) • Urinary bladder pathologies • Cystic renal diseases • Genito-urinary tract tumors • Renal artery pathologies	
Conventional Procedures in Git	170
Barium studies • Radiological studies of upper GIT cases • Radiological studies of lower GIT cases	
Git Imaging	178
Pneumoperitoneum • Intestinal obstruction • Volvulus • Miscellaneous GIT conditions • Abdominal trauma • Abdominal lymphoma	
Hepatobiliary Imaging	187
Multi-phasic hepatic contrast CT • Imaging of focal liver lesions • Biliary system imaging • Pancreas	
Obstetric and Gynaecology Imaging	195
Mullerian duct anomalies • Polyendocrine metabolic ovarian syndrome (PMOS) • Obstetric imaging	
Breast Imaging	201
Mammography • Breast carcinoma • BI-RADS V2025 • BI-RADS V2025 : Mammography and related updates • BI-RADS V2025 : Ultrasound & related updates • BI-RADS V2025 : MRI & related updates • BI-RADS V2025 : Categories	
Arthritis and Bone Infection	211
Rheumatoid arthritis • Seronegative arthritis • Other arthritic diseases • Infections	
Systemic Bone Disorders	218
Scurvy • Rickets • Hyperparathyroidism • Skeletal dysplasia • Slipped capital femoral epiphysis	
Bone Tumors	225
Distribution of bone tumors • Features of various bone tumors	
Musculoskeletal Trauma Imaging	230
Facial trauma • Cervical spine trauma • Upper limb trauma • Dorsal and lumbar spine trauma • Lower limb trauma • Pediatric bone trauma • Stress fractures	

X-RAY FUNDAMENTALS : PART 1

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

Introduction :

Symbols :



Trefoil: Radiation Hazard



X-ray radiation hazard



Sealed radiation source

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

International Day of Radiology : 8th November.

ElectroMagnetic (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 } 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).

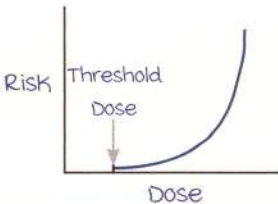
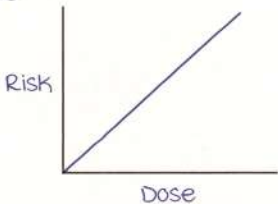
Syndromes :

	Acute hematological syndrome	Acute GI tract syndrome	Acute CNS syndrome
Threshold dose	1-2 Gy (Least)	6-10 Gy	20 Gy
manifestations	• Pancytopenia • Hemorrhage • Infection } Death	• malaise • Diarrhoea $\rightarrow$ Electrolyte imbalance	• $\uparrow$ 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

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

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

Guidelines :

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

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

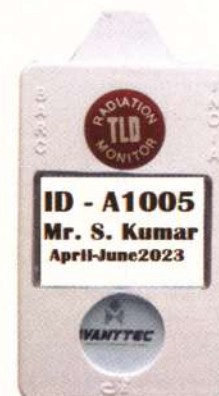
00:37:26

Time duration : 3 months.

Application : To monitor **occupational radiation exposure**.

Composition : Phosphor crystals.

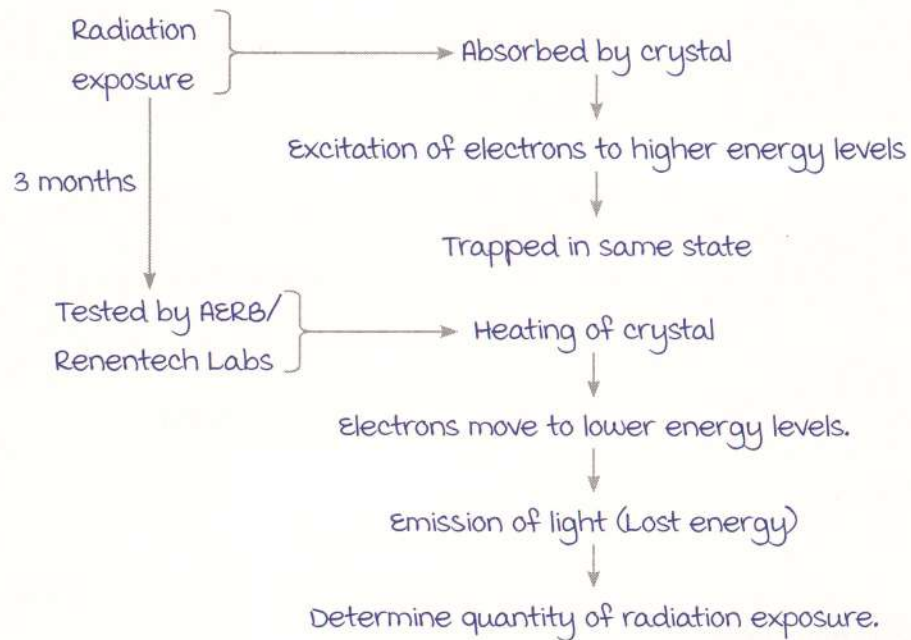
- Lithium Fluoride (LiF).
- Lithium Borate.
- Beryllium Oxide (BeO).



TLD Badge

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

Principle :



X-RAY PRODUCTION AND INTERACTIONS

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

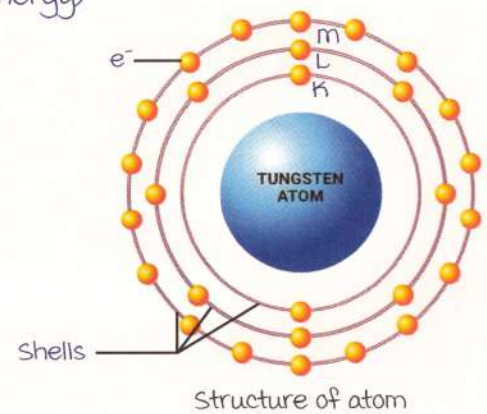
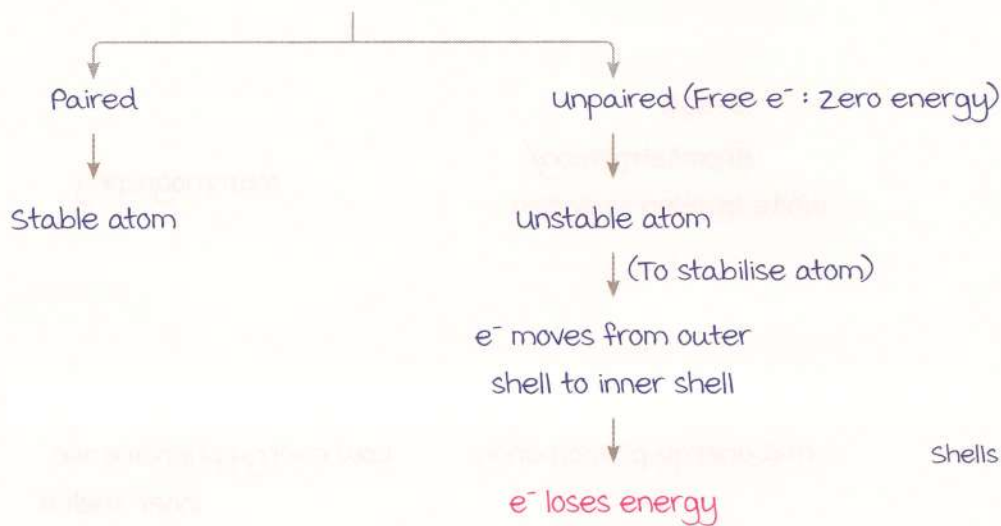
Atomic Structure

00:00:18

Shells around atom :

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

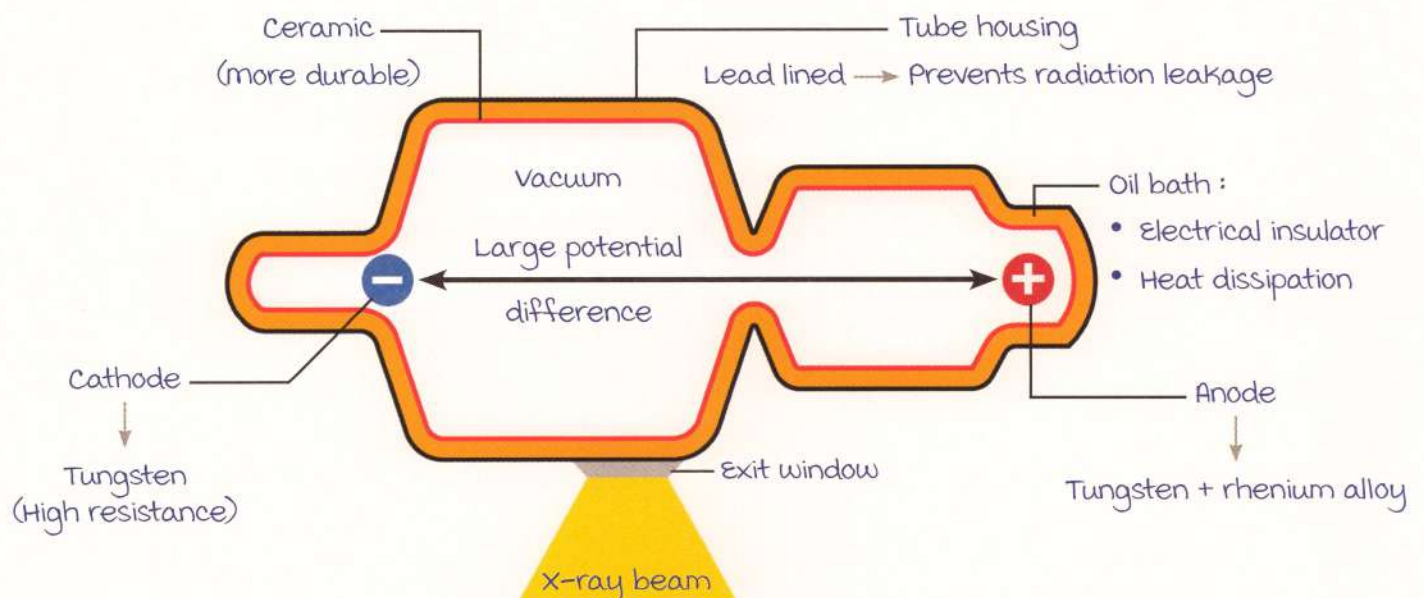
Electrons (e^-) :



Production of X-Ray

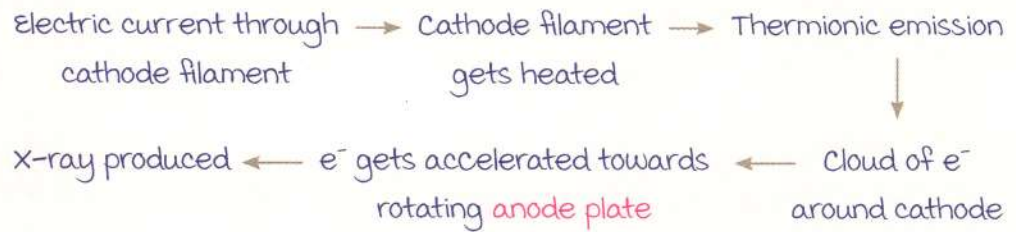
00:08:20

Structure of x-ray tube :



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

X-ray production :



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 braking 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 :	↑ 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

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

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.

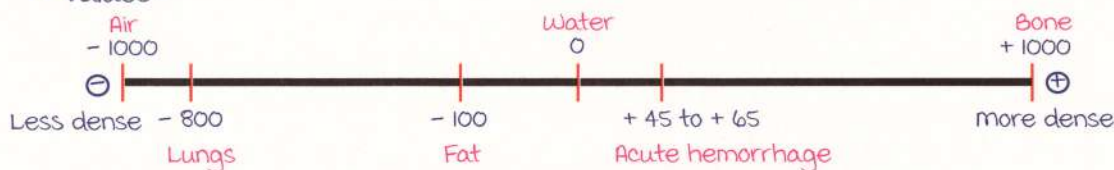
$$HU_x = 1000 \times \frac{\mu_x - \mu_{\text{water}}}{\mu_{\text{water}}}$$

HU_x : Hounsfield unit of tissue

μ : Linear attenuation coefficient

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

- Values :



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

USG BASICS

Introduction to Ultrasonography

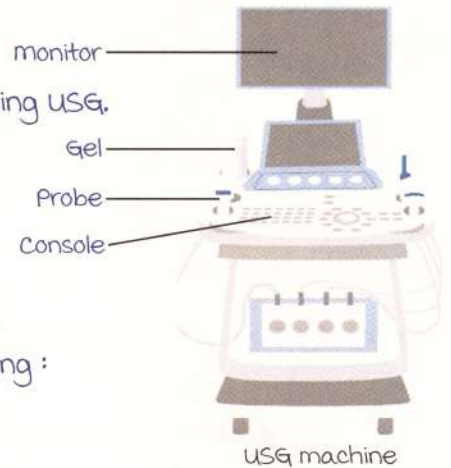
00:00:38

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.

ultrasound waves :

- ultrasound : Sound beam with high frequency.
- ultrasound frequency used in diagnostic imaging :
 >1 MHz.



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).

FREQUENCY : 1 - 2 MHz

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.

FREQUENCY : 3.5 - 5 MHz

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

3. Linear probe :

Flat
surface

FREQUENCY : 7.5 - 12 MHz

Use : Small part imaging of

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

4. Endoluminal probe :



FREQUENCY : >10 MHz

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 :

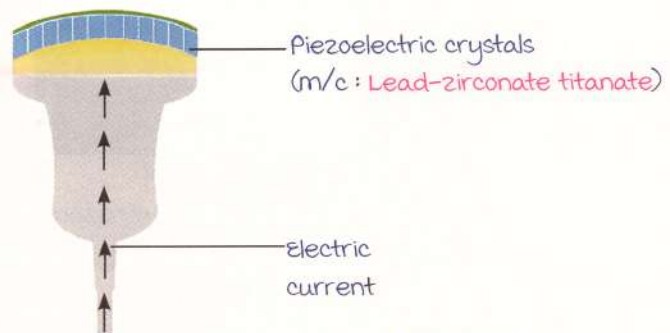


FREQUENCY : 50 MHz

Use :

- Ultrasound biomicroscopy of the eye : For ophthalmic imaging.

Internal structure of USG probe :



Biological Effects of Ultrasound

00:32:18

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 :

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

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)

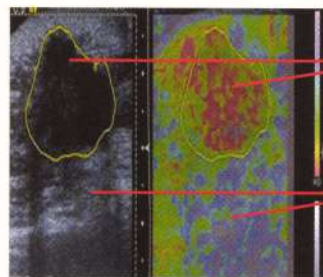
mechanical index : <1.9 to prevent physical damage.

Special Applications of Ultrasound

00:36:40

1. Elastography :

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



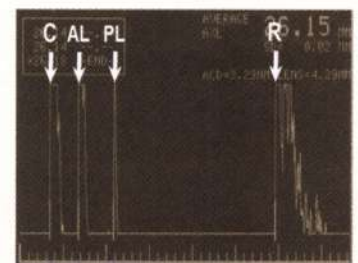
Color map

2. High Intensity Focused Ultrasound (HIFU) :

- Focused thermal ablation technique.
- uses : Treatment of
 - Liver metastasis.
 - uterine fibroids.
 - Breast lesions.

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 -----

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)
6. Epidural catheters

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

Note :

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