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For NEET PG/FMGE/INI-CET/Undergraduates

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Mayur Arun Kulkarni

Preface

Dear Students,

As the heroine in a Hindi movie 'Dabangg' says "Thappad se darr nahi lagta sahab, pyar se lagta hai!"
Often my students walk up to me and say "Padhai se darr nahi lagta sir, lekin images se lagta hai!"

This left me thinking as to what I can do for all of you so that you can overcome this fear and be confident with X-ray/USG/CT/MRI images. Well, the best way out of a difficulty is through it – hence **ONE TOUCH RADIOLOGY** for you!

Why this Book?

Images are the soul of Radiology. Although so many of these being asked so frequently in your exams, there wasn't a single comprehensive reliable source of good images available for students even now. **ONE TOUCH RADIOLOGY** will be that source. You will find good quality, labeled, unambiguous images for your quick review and revision in this book.

Who is this Book for?

This book is for anyone who wants to learn and fall in love with Radiology. It is most relevant for those who are preparing for their NEXT/NEET-PG/INI-CET/FMG examinations. However, if you are an undergraduate student, carry it with you in your back-pack into your clinics and jump to Pneumothorax/ Pneumoperitoneum/Stroke when you get these cases and get the imaging part covered then and there.

How to use this Book?

This book has almost all the important images and relevant theory alongside it. But this is a concise book meant for quick review and not a descriptive textbook per se. Hence, I want you to use it along with your Online/Offline classes, like an add-on resource. Most of the images here are the same ones you will see in my Marrow modules as well as in my Offline classes. However, even if you have followed any other source – this book will help you with spotter images and high-yield theory part. Also, when you are studying Medicine/ Surgery/Orthopedics/Pediatrics/OB/GYN – keep this book handy so that you can go through the images of specific topics then and there.

How did I Write this Book?

Every topic/image/table used in this book is based on a detailed review of recent examination pattern and all the high-yield topics have been included in this book. This will be more than enough for all those who are preparing for NEXT/NEET-PG/INI-CET/FMGE.

My wife, Dr Kavita has been my pillar of support throughout this endeavor as during this period, she single-handedly played the role of both parents to Spruha and Hrida – two little angels in my life. No words can express my feelings for them. My parents have always blessed and pushed me to do better. Dr Swapnil Yewalkar, Dr Amit Shetty, Dr Saurabh Patil, Dr Tejas Mankeshwar, Dr Basavraj Biradar have made important contributions to this book. My Marrow family of all faculties and friends have an equal share of credit in my success.

Remember my dear friends – You are as Good as you think you are!

So, believe in yourself and give your best shot in whatever you do. And you will succeed for sure.

Let's Learn, Love and Rock Radiology together!

Love

Mayur Arun Kulkarni

Contents

LATEST QUESTION PAPERS

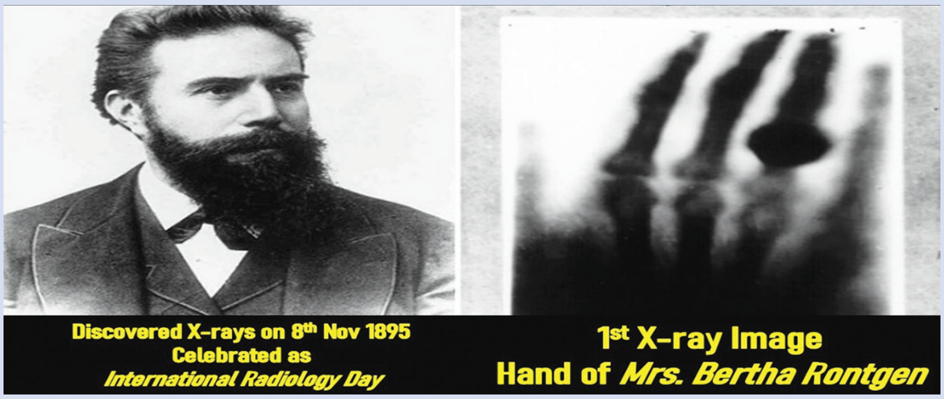
1. GENERAL RADIOLOGY

X-RAYS

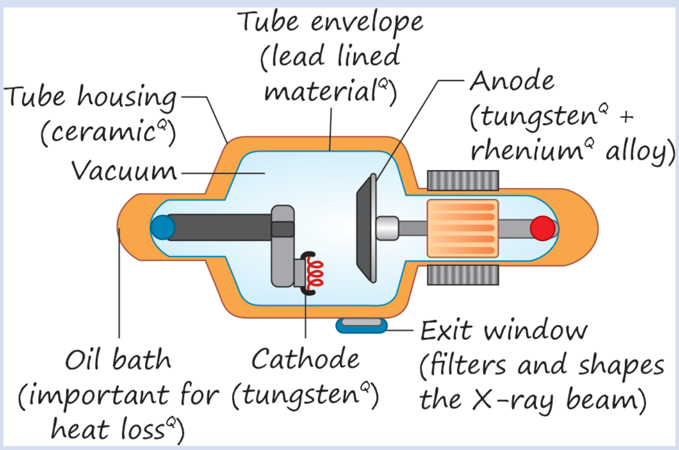
Radiation symbols		
International Radiation Symbol "The Trefoil"	X-ray Radiation Hazard	High Level Sealed Source Ionizing Radiation Symbol IAEA and SO — 2007
		

X-ray basics

Wilhelm Conrad Röntgen — Founding Father of Radiology



X-ray Tube — Structure



X-rays are a part of Electromagnetic spectrum[Q]

- Electromagnetic spectrum[Q]:
- All energy components are part of this spectrum.
- In increasing order of frequencies/energies this spectrum includes—radio waves (least frequency and energy),[Q] microwaves, infra-red, visible light, ultraviolet, X-rays and gamma rays (Maximum frequency and energy).[Q]
- All have same speed[Q]—speed of light—3×10^8 m/s
- All have same type of wave[Q]

X-ray specifics:

- Have relatively high frequency and high energy
- Wavelength = 0.01–10 nm
- Energy 100 eV – 100 keV

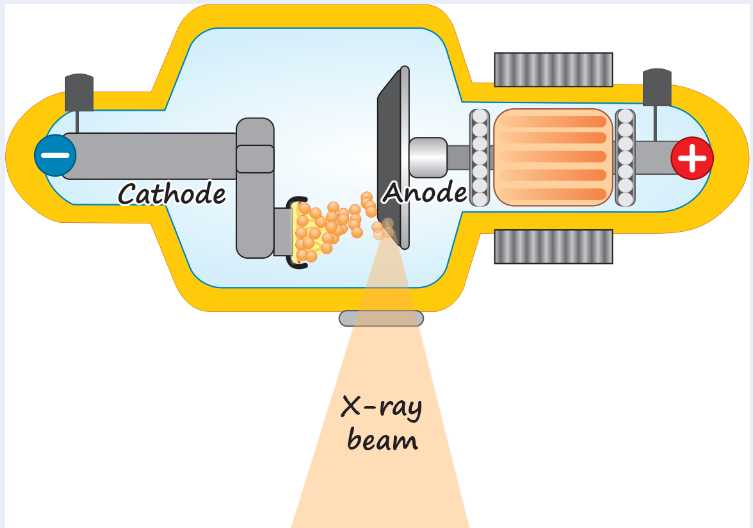
Tungsten:

- It is an important component of X-ray tube (Cathode filament)
- Symbol—W[Q]
- Atomic number—74[Q]
- Atomic mass number—184[Q]
- Classified as transitional metal[Q] in the periodic table

Contd...

X-ray basics

Electric current through cathode filament
↓
Cathode filament is heated
↓
Thermionic emission
↓
Cloud of electrons around cathode
↓
Electrons accelerated toward anode
↓
X-rays are produced

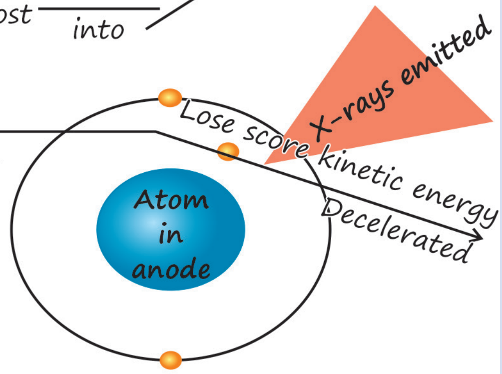


Mechanisms of X-ray Production

Continuous Spectrum—70–80%

Kinetic energy Converted / Lost into X-rays

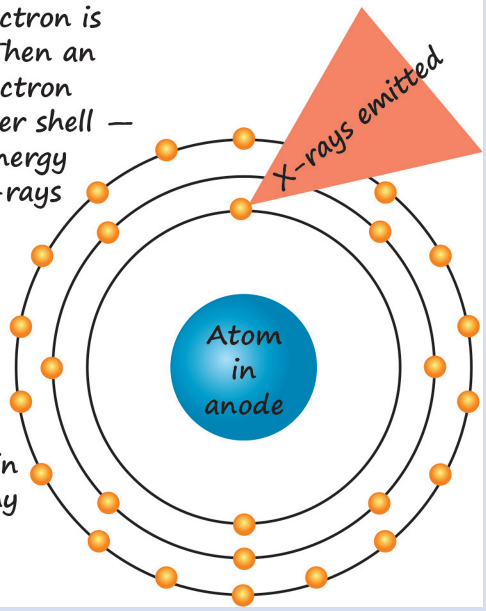
Accelerated electron is deviated/ decelerated when it comes close to nucleus of an atom in the anode



Characteristic Spectrum—20–30%

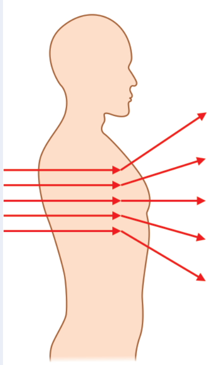
When electron hits inner shell electron — the inner shell electron is thrown out. Then an outer shell electron jumps to inner shell — losing some energy emitted as X-rays

Used in mammography



Interaction of X-rays with matter

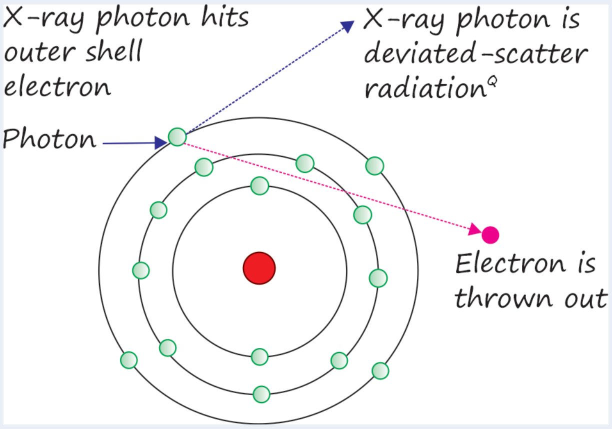
Occurs Inside the patient body



1. Compton effect — Overall most common
2. Photoelectric effect — Also seen in diagnostic radiology
3. Coherent scattering
4. Photodisintegration
5. Pair production

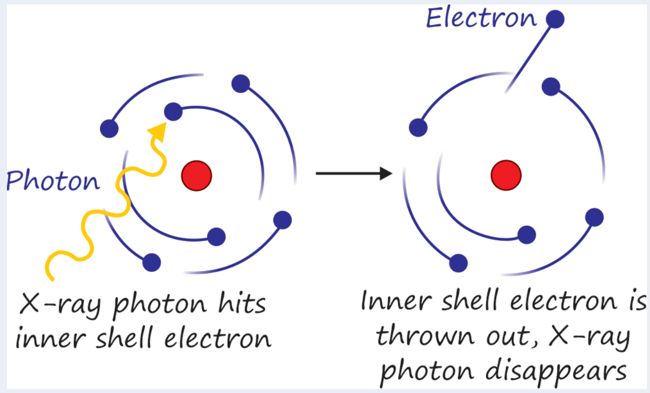
(3–5) Not seen in diagnostic radiology

Compton effect—Interaction of X-ray photon with outer shell electron[Q]



- Most common interaction of X-rays with matter[Q]
- It is a mid-energy phenomenon[Q]
- Most important outcome is scatter radiation[Q]. It causes image distortion, blurring and decreased diagnostic quality of the radiographic image
- Hence, to minimize scatter radiation, we try to minimize compton effect[Q]
- Minimizing compton effect—Using high energy X-rays[Q]

Photo-Electric Effect—Interaction of X-ray photon with inner shell electron[Q]



- Less common
- It is a low-energy phenomenon[Q]
- There is no scatter radiation[Q]—hence, image quality is better.
- Because there is no scatter radiation, we try to maximize photoelectric effect[Q]
- Maximizing photoelectric effect—
  - Using low energy X-rays[Q]
  - High atomic number target[Q]

Exposure Factors—Kilovoltage peak (kVp) and Milliampere second (mAs)

Kilovolt peak (kVp):

- Voltage applied across the cathode and anode in the X-ray tube.
- High kVp—results in higher penetrating power of X-rays[Q]
- kVp also affects radiographic contrast–
  - Low kVp—high contrast[Q]—called short scale contrast[Q]
  - High kVp—low contrast[Q]—called long scale contrast[Q]

Milliampere second (mAs)[Q]

- Combination of:
  - mAmp[Q]—current passed through the cathode filament
  - Time[Q]—time of exposure
- Determines the number of X-ray photons[Q] in the X-ray beam
- Directly affects the contrast—increased mAs—increased contrast[Q]

RADIATION UNITS

Radiation exposure

- Conventional unit—Rontgen[Q]
- SI unit—Coulomb/Kg[Q]

Absorbed dose

- Conventional unit—Rad[Q]
  - Rad—stands for radiation absorbed dose
- SI unit—Gray[Q]

Absorbed dose equivalent

- Conventional unit—REM[Q]
  - Rem—stands for rontgen equivalent man
- SI unit—Sievert[Q]

Radioactivity

- Conventional unit–curie[Q]
- SI unit–Becquerel[Q]

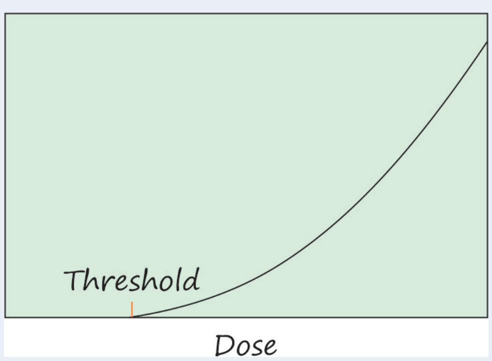
Acute radiation syndromes[Q]/Radiation sickness[Q]/Radiation toxicity[Q]	
Concept—Acute Radiation Syndromes (ARS)—Why do they occur in a particular order? **Law of Bergonié and Tribondeau[Q]: Basic Concept in Radiobiology** Whatever tissue/organ/region in the body has the maximum proportion of undifferentiated cells/cells in active mitosis will be more sensitive to radiation.	**Four stages of acute radiation syndromes** 1. Prodromal stage: Nausea vomiting-diarrhea stage—lasts from few minutes to hours 2. Latent phase: Lasts few hours to days 3. Manifest illness phase: Actual symptomatic stage—lasts from days to weeks 4. Recovery/Death stage: Lasts weeks to years

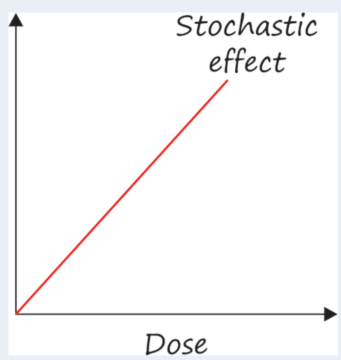
Acute hematological syndrome/ Bone marrow syndrome—1st clinical syndrome to occur	Gastrointestinal syndrome:	Cardiovascular[Q]/CNS syndrome[Q]:
Threshold dose: Around 1–2 Gray[Q]	• 2nd organ system affected • Threshold dose is 6–10 Gray[Q] • Symptoms are malaise, severe diarrhea, electrolyte imbalance	Threshold dose is around 20 Gray[Q]

DETERMINISTIC AND STOCHASTIC EFFECTS OF RADIATION

Smart-Work strategy tip: Remembering the various properties of these effects can be difficult. Hence, let us study them in a comparative manner. Also try to remember their examples first so that using those examples we can remember the individual properties.

	Deterministic effects	Stochastic effects
Examples	• Acute radiation syndromes[Q] (discussed above) • Cataract[Q] • Skin changes[Q]—Erythema, ulceration • Sterility[Q] • Radiation myelitis • Fibrosis • Teratogenesis/Fetal death	• Radiation induced carcinogenesis[Q] • Genetic mutations[Q] • Chromosome aberrations[Q]
Onset	Acute[Q] and subacute[Q] effects	Chronic effects[Q]
Threshold dose	Yes[Q]	No threshold dose[Q]
Severity of effect	Directly proportional to dose[Q]	Not related to dose[Q]
Risk of occurrence	Nonlinear relationship with threshold[Q]	**Linear relationship with no threshold (LNT)**





RADIATION EXPOSURE, PROTECTION AND GUIDELINES

Radiation exposures in various modalities

Modality	Radiation exposure in mSv	
PET	25	CT/PET/ Radionuclide studies
CT abdomen	10	CT/PET/ Radionuclide studies
CT thorax	8	CT/PET/ Radionuclide studies
Dynamic cardiac scintigraphy	6	CT/PET/ Radionuclide studies
Bone scan	4	CT/PET/ Radionuclide studies
CT head[Q]	3.5	CT/PET/ Radionuclide studies
Barium enema[Q]	7.2	Diagnostic procedures
Barium meal follow through	3	Diagnostic procedures
Barium meal	2.6	Diagnostic procedures
Barium swallow	1.5	Diagnostic procedures
MCU[Q]	1.2	Diagnostic procedures
Lumbar spine[Q]	1.0	Spot radiographs
Abdomen X-ray	0.7	Spot radiographs
Hip joint	0.4	Spot radiographs
Skull X-ray	0.06	Spot radiographs
CXR PA view[Q]	0.02	Spot radiographs
Limb X-rays[Q]/joint X-rays[Q]	<0.01	Spot radiographs

Permissible radiation exposure—recent guidelines

Recommended dose limits in planned exposure situations:

Type of Dose	Occupational exposure	Public exposure
Effective dose	20 mSv per year[Q], averaged over defined 5-year periods (100 mSv in 5 years) Or provision that the effective dose should not be exceeded 50 mSv[Q] in any single year with the total dose at end of 5 years should be <100 mSv.	1 mSv in a year[Q] A higher per year exposure may be allowed in a single year, provided that the average over defined 5-year periods does not exceed 1 mSv per year[Q]
Annual equivalent dose in:		
Lens of eye	150 mSv[Q]	15 mSv[Q]
Skin	500 mSv[Q]	50 mSv[Q]
Hands and feet	500 mSv[Q]	–
Pragnant radiation workers	After declaration of pregnancy – 1 mSv dose to the embryo/fetus should not be exceeded[Q].	

The ICRP and AERB guidelines are exactly similar with just one difference:

AERB–allows maximum exposure to occupational workers in any one year to be a maximum of **30 mSv**, provided that the total dose at end of 5 years should be <100 mSv

PYQ ALERT

Thermoluminescent dosimeter (TLD) Badge[Q]—NEET 2020 pattern question

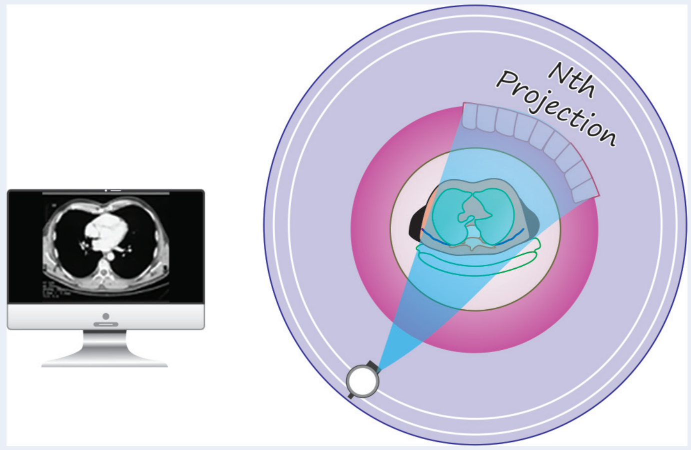
- Thermoluminescent dosimeter (TLD)[Q] is a passive radiation detection device that is used for personal dose monitoring or to measure patient dose.
- Composed of phosphor crystals[Q] [lithium fluoride (LiF)[Q], lithium borate ($Li_2B_4O_7$)[Q], beryllium oxide (BeO)[Q], and magnesium borate (MgB_4O_7)[Q]] that measure ionizing radiation primarily by trapping propagated gamma and neutron exposure.
- Incident energy is absorbed by some of the crystal's atoms thereby producing free electrons. Free electrons are trapped by the imperfect lattice structure of the crystal that is created due to doping impurities.
- The crystal is heated, the crystal vibrates to release the free electron back to its ground state. Trapped ionization is released as light, which is measured by photomultiplier tubes. This value is in ratio with the ionizing radiation captured by the phosphor, and represents the dosage administered to a person[Q], provided equipment was mounted properly.
- TLDs can measure doses between 0.01 mGy and 10 Gy[Q].

COMPUTED TOMOGRAPHY

Computed tomography is basically a fusion of two technologies:

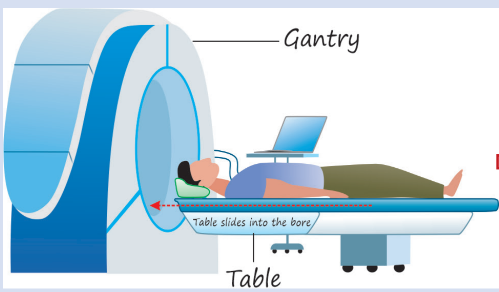
1. **Tomography**[Q]: X-ray-based imaging technique developed to acquire sectional images of the body.
2. **Computers**[Q]: Brought in to deal with the complex mathematical algorithms and iterations in the image reconstruction.

- **Father of CT technology**
- **Invented the 1st generation CT scanner/EMI scanner**
- **Hounsfield Unit Scale (HU scale/CT value scale)**
- **Awarded Nobel Prize jointly with Allan Cormack in 1979**

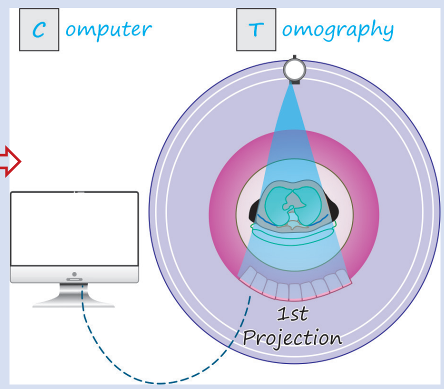


CT scan—basic principle: The internal structure of an object can be reconstructed from multiple projection of that object[Q].

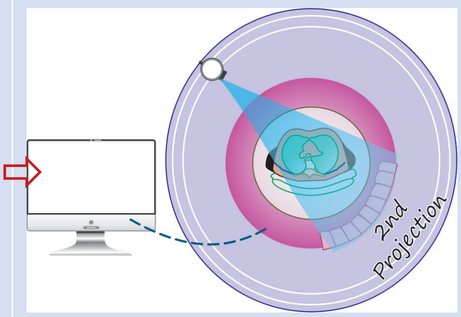
BASIC PRINCIPLE OF CT SCAN



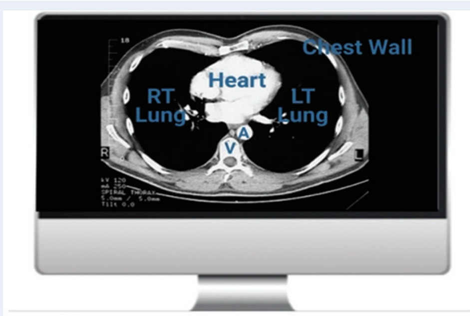
CT machine—has a gantry (tomographic unit) and tale (patient lies on this tale and it slides into the ore of the gantry)



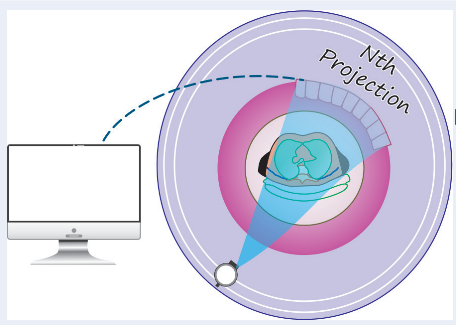
1st Projection data is obtained and transferred to computer



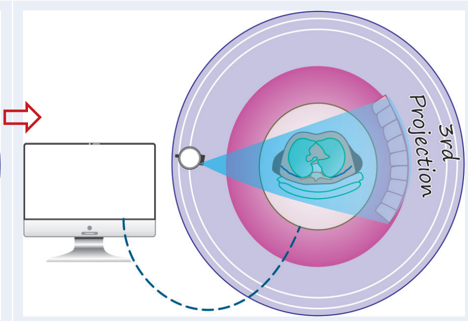
2nd Projection data is obtained (from a different angle) and transferred to computer



Computer reconstructs internal structure of body from all the projection data—using complex mathematical algorithms



Nth Projection is obtained—all from different angles around the patient and transferred to computer



3rd Projection data is obtained (from another different angles) and transferred to computer

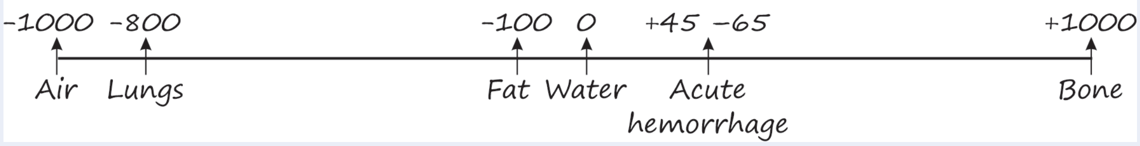
CT scan Miscellaneous

Hounsfield unit (HU) scale/CT value scale

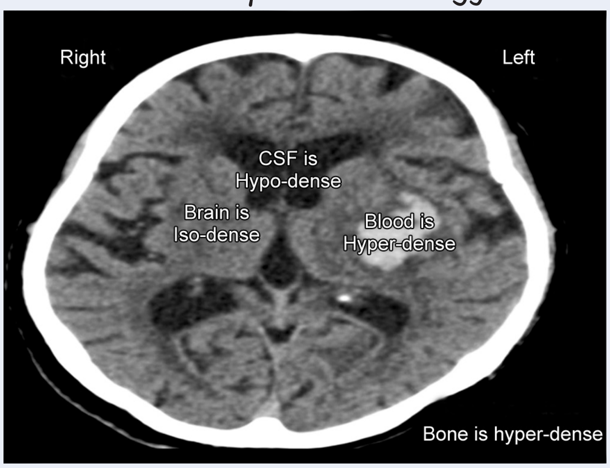
Each tissue in the body is allotted a numerical value – it is "HU/CT value"

$$\text{HU Value} = 1000 \times \frac{\mu_x - \mu_w}{\mu_w}$$

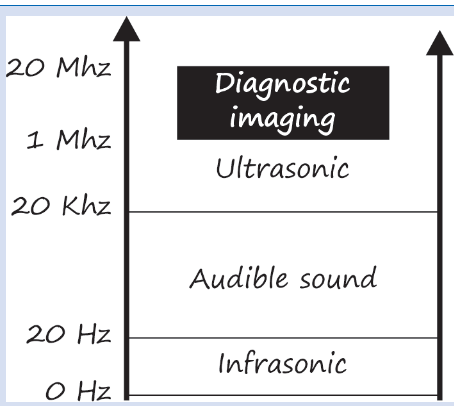
- μ_x = Linear attenuation coefficient of a tissue "x"
- μ_w = Linear attenuation coefficient of water
- Main determinant of linear attenuation coefficient of a tissue is its desnsity[Q]

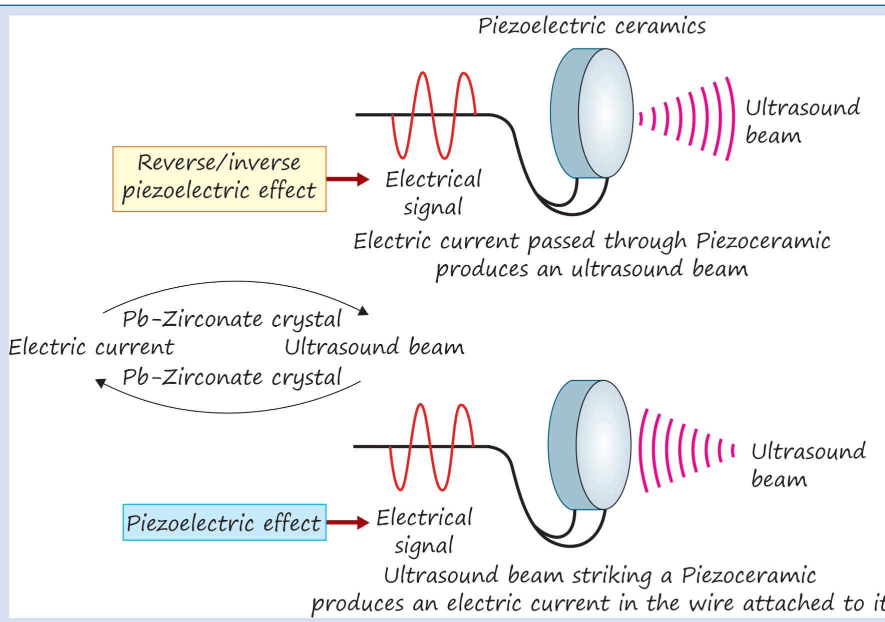


CT descriptive terminology



ULTRASOUND IMAGING





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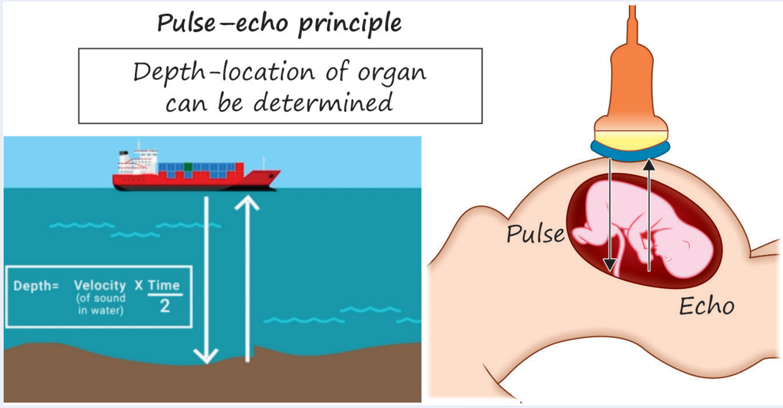
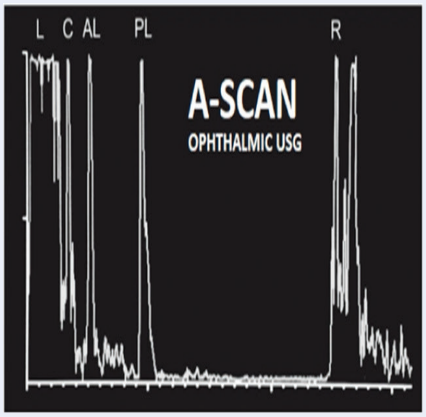
Pulse-echo principle

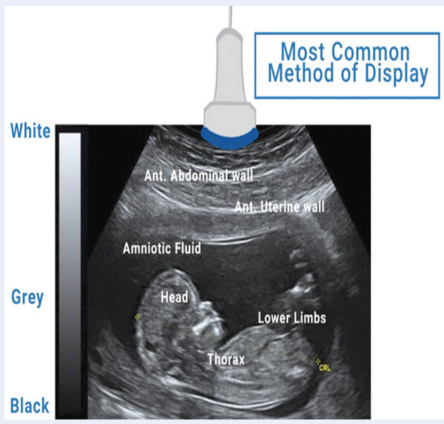


Sound emitted by probe (pulse)
↓
Hits an organ in the body and is reflected back (echo)
↓
Received by probe

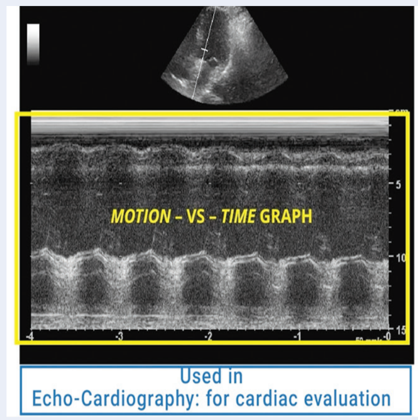
In methods of display of ultrasound



A-mode



B-mode



M-mode

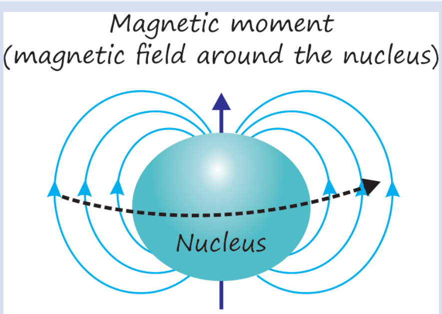
MRI BASICS

MRI Magnet—is a Superconducting Magnet[Q]

The magnetic field is generated by a current, which runs through a loop of wire. Surrounded with a coolant, such as liquid helium, to reduce the electric resistance of the wire. At 4 Kelvin (-269°C) electric wire loses its resistance. Thus producing a permanent magnetic field.

Basic Principle of MRI

"Human MRI is based on Gyromagnetic property[Q] of Hydrogen nucleus"



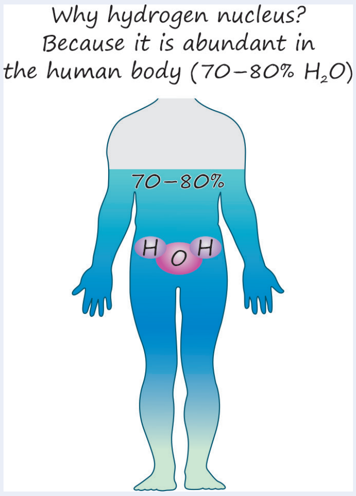
Whenever a charged particle moves in space–it creates a magnetic field around it

Gyromagnetic property:

- The nucleus of an atom rotates around itself.
- Because the nucleus is charged (+ve charge) this rotation creates a magnetic field around the nucleus.
- This creation of magnetic field (magnetic moment) around the nucleus created due to its rotation is called ***Gyromagnetic property***[Q].

Contd...

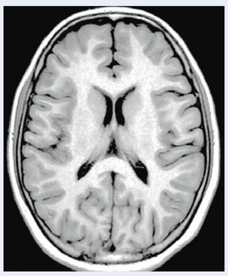
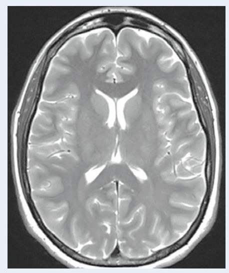
"Human MRI is based on Gyromagnetic property[Q] of Hydrogen nucleus"



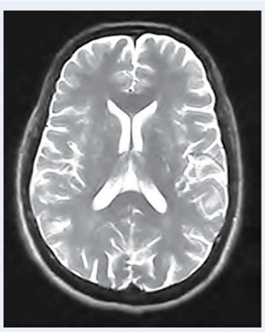
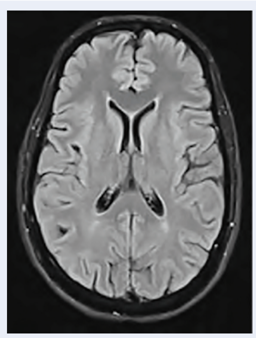
Why Hydrogen nucleus?

- Hydrogen has the highest Gyromagnetic ratio—suggests a strong gyromagnetic property.
- Hydrogen is very abundant in the human body (70–80% of body weight is formed by water)
- Hence, if we measure the signal arising from Hydrogen nuclei in the body—it will be a very strong signal—thus creating an excellent Image.

MRI Image Basics

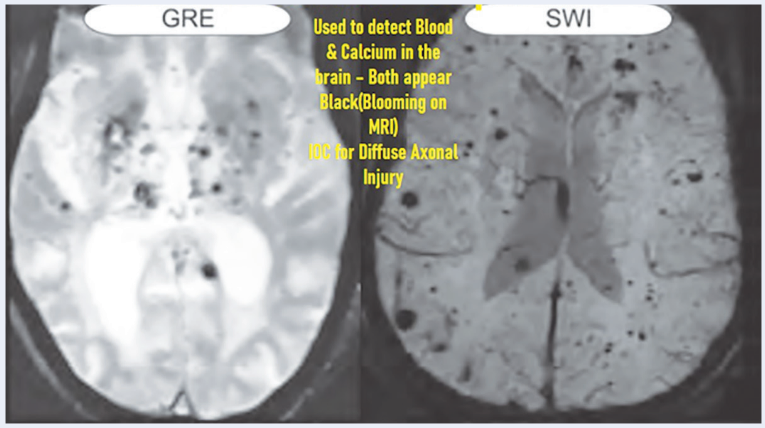
T1W	T2W H_2O is Bright on T2W images
	

CSF signal intensity	T1W CSF is Hypointense (Black)	T2W CSF is Hyperintense (White)
Gray matter and white matter	Anatomical image – So white matter appears white, gray matter appears gray.	Appearance of gray and white matter is opposite to their names

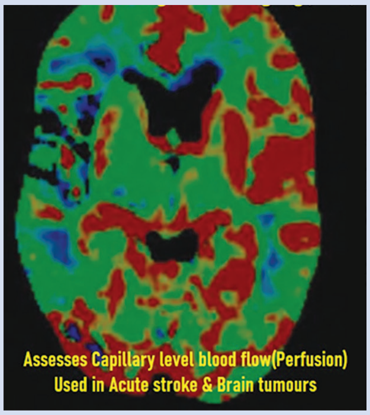
T2W	Fluid attenuated inversion recovery (FLAIR)
	
CSF/Water: Hyperintense Gray-White matter appearance (Opposite to their names) • Gray matter is hyperintense • White matter is hypointense	**CSF/Water:** Hypointense–Fluid signal is attenuated[Q]-hence the name: • Gray matter is hyperintense • White matter is hypointense
Better for depiction of pathology	Can detect even the smallest of lesions

MRI image gallery

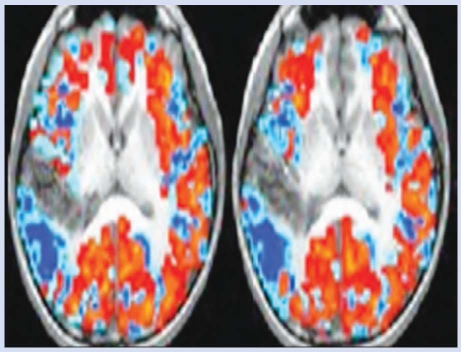
Short Tau inversion recovery (STIR)



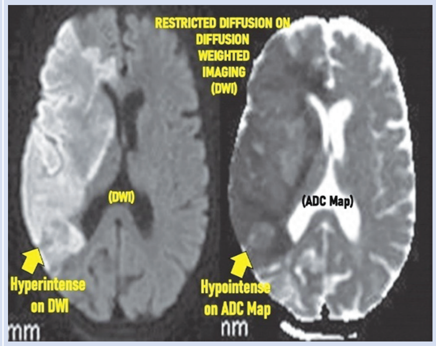
Blood sensitive sequences



Perfusion weighted imaging (PWI)

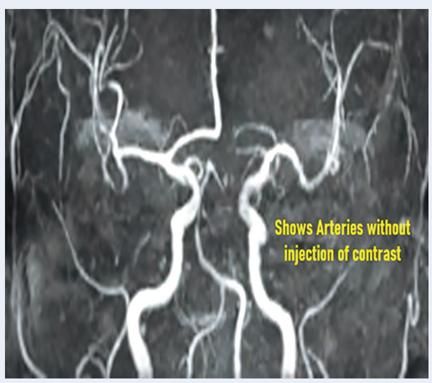


Functional MRI/Bold–Blood Oxygen Level Dependant Imaging Fat MRI acquisition–to detect functional centers of the brain

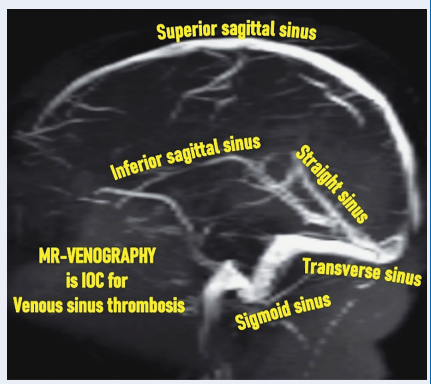


Diffusion weighted imaging (DWI)

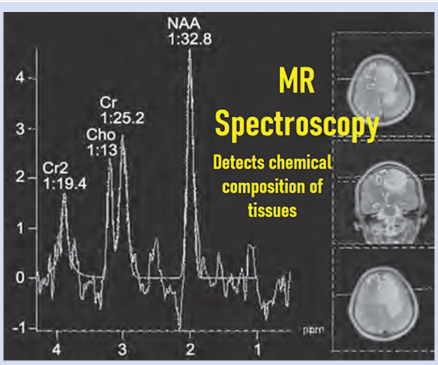
Proton density (PD) image

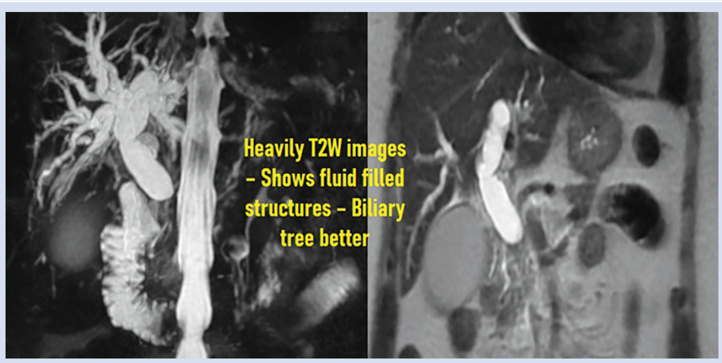


TOF–MRA: Time of flight MR angiography



MR-Venography





Magnetic Resonance Cholangio-Pancreaticography (MRC)

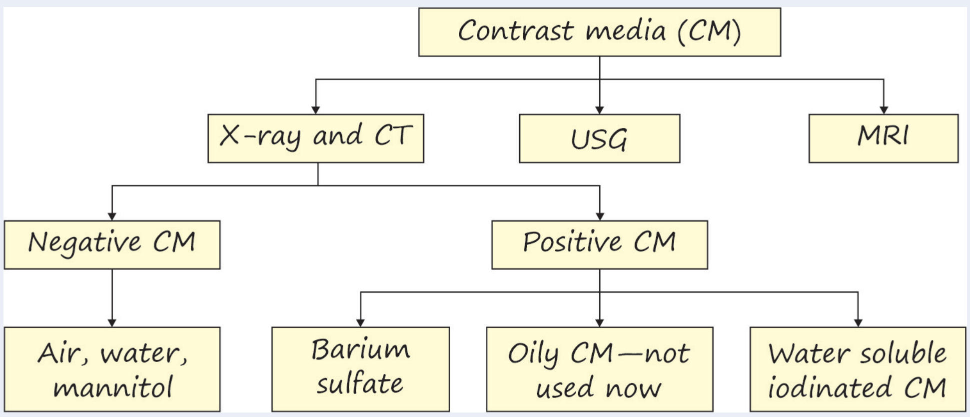
CONTRAINDICATIONS FOR MRI[Q]

Absolute contraindications[Q]: • *Cardiac pacemaker* • *Metallic foreign body of eye* • *Ferromagnetic hemostatic aneurysm clips in CNS* **Relative contraindications[Q]:** • *Cochlear implants* • *Claustrophobia*	• *Insulin pumps/Nerve stimulators* • *1st trimester pregnancy* • *Epidural catheters/CNS Ventricular catheters* • *Spinal fixation devices* • *Feeding tubes* • *Prosthetic heart valves* • *Orthopedic external fixators*
Faraday Cage[Q]—*is a shielding box used all around the MRI room to shield out stray electromagnetic interference. Made up of wood panels wrapped with copper[Q].*	

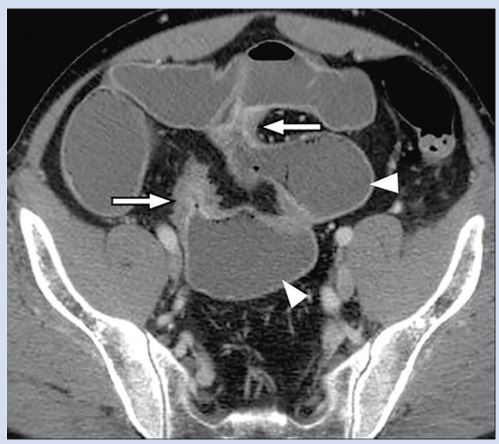
CONTRAST MEDIA

Definition: *Any agent that is used to enhance the appearance of a particular structure/organ in the body.*

Classification



Positive CM
- *Attenuate more X-rays than soft tissues—hence, appear whiter*
- *Examples – Barium sulfate and Iodinated media*



Negative CM
- *Attenuate less X-rays than soft tissues—hence, appear blacker*
- *Examples – Air, water, mannitol*

Barium – *Used as Barium sulfate ($BaSO_4$) suspension[Q]*

Why? – *Inert*
- *No damage/irritation to bowel mucosa*
- *Not absorbed*
- *No interference with normal digestion/absorption*

Contd...

Absolute contraindication: Perforation causes severe chemical peritonitis – may be fatal.

Relative contraindications: Hypersensitivity, left sided colonic obstruction. Vesicovaginal/Rectovaginal fistulas

Where? – It is used for bowel evaluation

Barium study	Used for
Barium swallow	Cricopharynx – Esophagus – Gastroesophageal junction
Barium meal	Stomach and Proximal duodenum
Barium meal follow-through	Small bowel
Barium enema	Large bowel

Iodine to particle ratio: Concept

Iodine – Numerator – Determines attenuation – Should be as high as possible

Particles – Denominator – Determines osmolarity – Should be as low as possible

Hence overall the I/P ratio must be as high as possible[Q]

Iodinated contrast materials

Renal excretion	Iodinated contrast media			
Osmolarity	High osmolar	Low osmolar		
Subtypes	Ionic monomers	Ionic dimers	Nonionic monomers	Nonionic dimers
Iodine: Particle ratio:	3:2	6:2	3:1	6:1
Examples	Trazograf Urografin Angiografin, Gastrografin Thalmic acid (conray), Urivision, Urovideo	Ioxaglic acid, Iocarmic acid	Amipaque, iohexol/omnipaque Iopamidol, Ioversol Iopromide	Iotrol, Iotrolan, Iodixanol

Contrast Induced Nephropathy (CIN)

Diagnostic criteria: Impairment of renal function, measured as

- 25% increase in serum creatinine from baseline[Q] or
- 0.5 mg/dL (44 µmol/L) increase in absolute serum creatinine value[Q]
- Within 48–72 hours[Q] after intravenous contrast administration(following contrast exposure, serum creatinine levels peak between 2 and 5 days and usually return to normal in 14 days)

Markers of CIN:

- Serum creatinine[Q] – as described in in diagnosis
- Estimated GFR (eGFR)[Q] (estimated GFR [eGFR] <60 mL/min/1.73 m^2) – predictive marker of CIN
- Serum Cystatin C levels[Q]
- Plasma neutrophil gelatinase-associated lipocalin (NGAL), also known as human neutrophil lipocalin, is an early predictive biomarker

Contd...

Risk factors:	Prevention of CIN:
Most important risk factor – Pre-existing Chronic kidney disease[Q] • Elderly age • DM • Metabolic syndrome • Anemia • Hypovolemia/Dehydration • MM **Treatment of CIN** • Supportive Rx – sufficient in most cases. • Hemodialysis[Q] – rarely needed—can efficiently remove contrast from the blood stream	• Precontrast Renal function tests • Precontrast hydration using IV normal saline[Q] – is most important step • N-Acetyl cysteine [Q] –sulfhydryl groups that act as antioxidants and free radical scavengers High dose statins[Q] – Rosuvastatin • Bicarbonate therapy[Q] • Statins - Rosuvastatin

MRI contrast agents

T_1 Relaxation agents[Q]	T_2 Relaxation agents[Q]	Liver specific contrast agents
• **Gadolinium compounds**[Q]: Most commonly used MRI contrast medium[Q] • **Paramagnetic substances**[Q]: Affect the magnetic properties of adjacent molecules Act as extracellular contrast agent cause shortening of T_1 relaxation time[Q]—hence, appear bright on T1W MRI[Q] • **FDA approved agents:** ▪ Gd-HP-DO3A-Gadoteridol/ProHance ▪ Gd—DTPA—Magnevist ▪ Gd—DTPA—BMA—Omniscan	Superparamagnetic iron oxide (SPIO)[Q]/Ultrasmall—SPIO (USPIO)[Q]— undergoes selective phagocytosis by reticuloendothelial system cells[Q] (Kupffer cells)[Q] Uptake causes hypointense appearance on T2W images[Q] Specific for FNH—shows around 60–70% signal loss on T2W images[Q] Hepatic adenomas show only 15–20% signal loss.	Manganese—DPDP[Q] Gd—BOPTA[Q] Gd—EOB—DTPA[Q]

Nephrogenic systemic fibrosis (NSF)/Nephrogenic fibrosing dermopathy

- In renal failure patients
- Associated gadolinium compounds:
  - Omniscan/Gadodiamide[Q]—Most commonly implicated
  - Magnevist/Gadopentetate dimeglumine[Q]—2nd most common
  - OptiMARK/Gadoversetamide[Q]
- Subcutaneous edema and firm, indurated, erythematous skin plaques—progress to flexure contractures with restricted movements – progressive condition with no Rx.

Toll-like receptors (TLR)[Q] - TLR4 and TLR7 – involved in pathogenesis

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About the Author

Mayur Arun Kulkarni, *MD, DNB (Radiology)* popularly known as Dr MAK, is currently holding the position of Director, Shree Diagnostics, Pune, Maharashtra. He specializes in Fetal medicine and Women's Imaging, and is a Clinical Radiologist at heart. With more than 14 years of experience in practicing Radiology, he has authored a couple of books on Radiology — Conceptual Review of Radiology, 4th Edition and Radiodiagnosis & Imaging, 1st Edition. Besides, he has also published numerous papers in national and international journals of repute.

The author has been teaching the students preparing for NEET/FMGE/INI-CET entrance examinations for more than 13 years and is known for his Conceptual and Clinically-integrated teaching style. His videos on Marrow-Edition 7 are widely appreciated by students across the country. The author is the pioneer of RAD-IMAGINE Interactive Animation that has enthralled thousands of students and made them fall in love with the subject of Radiology. A staunch advocate of Integrated clinical approach to learning, his videos are a visual, conceptual and intellectual treat for students! He is highly admired by the students for his simplified teaching and conceptual anecdotes.

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