BASICS of

# COMPUTED TOMOGRAPHY IMAGING IN ONCOLOGY

*Lectures & Hand Out*

*FOR THE STUDENTS OF*

**HIGH INSTITUTE**
**OF APPLIED HEALTH SCIENCES**


*By*

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1ST EDITION

2025


# وما أوتيتم من العلم إلا قليلا

صدق الله العظيم

# إهداء

الى روح استاذنا الكبير و العالم الجليل

**الاستاذ الدكتور / ممدوح محفوظ**

علم الاشعة و معلم الاجيال

في مصر و الوطن العربي


تلميذك

أحمد مختار أبودهب

# ABOUT THIS HANDOUT

**ONCOLOGY IS A WIDE SECTOR OF MEDICINE THAT DEPENDS MAINLY IN IMAGING FOR DIAGNOSIS, SO THE FULL UNDERSTANDING & PRACTICING DIFFERENT TECHNIQUES OF SCANNING IS MANDATORY, WISH THIS HANDOUT TO MAKE IT EASIER.**

*The Author*

*Dr. Ahmad Mokhtar Hamed Abodahab*
*Sept 2025*

MY YOUTUBE

# Contents:



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CHAPTER 1

# INTRODUCTION TO IMAGING MODALITIES

## List of Imaging Modalities

- ✓ **X ray**
- ✓ **Ultrasonography & Doppler**
- ✓ **Computed Tomography (CT)**
- ✓ **Magnetic Resonance Imaging (MRI)**
- ✓ **Radio-isotope scan**
- ✓ **…… & Others**

**In Every modality you should know:**

- ➲ Basics of work
- ➲ Energy used
- ➲ Main Indications
- ➲ Contraindications
- ➲ Finding of main Pathologies

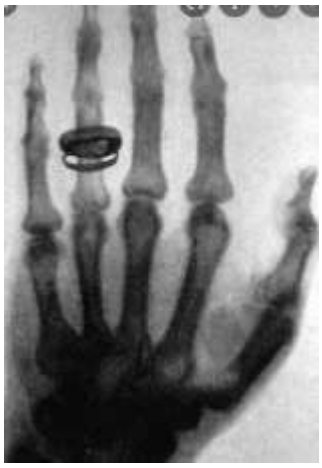
**Please, don't suggest any imaging modality for any patient unless you know the value of it for diagnosis of the case.**

# X – Ray

## Historical Hints :

- ✓ The oldest imaging modality
- ✓ Discovered by **William Rontegen** at **1895**
- ✓ The first X ray film was done for Rontegens' wife hand.

Wilhelm Conrad Röntgen



1st X ray Film

X Ray machine

## Basics of Work :

- **Energy used** : **X ray** , an ionizing radiation
- **X ray** is from its source (X ray tube) is penetrating objects & images are formed on film.
- **Bright object,** which absorb X ray & prevent it from reaching Film is described as **Radiopaque** (eg. Bone , metals, barium, stones …..etc )
- **Dark object,** which permeate X ray & passing it to Film is described as **Radiolucent** (eg. lung , air……etc )

## Contraindications :

- **Pregnancy**

  (Especially, early) , it can lead to **teratogenicity**.

- **Non indicated diagnosis ,**

  As you will expose patient to radiation without any benefit .

- **Contrast Hypersensitivity:** for X ray techniques using IV contrast as IVU.

## Indications :

X ray is a commonly used modality, & has many indications, such as diagnosis of:

- ✓ Fractures
- ✓ Foreign body inhalation or ingestion
- ✓ Basic Chest imaging
- ✓ Intestinal obstruction

- ✓ **Bone Tumors**
- ✓ Breast Imaging (Mammography)
- ✓ Urinary stones
- ✓ Perforated Gut

➲ **X ray techniques with Contrast** , as :

- **Barium studies** , for GIT (Barium Swallow, meal, enema)
- **IVU** (Intra venous Urography )
- **Vascular Imaging** (Angiography / Venography)
- T Tube Cholangiogram & Fistulograms

**Ionizing Radiation =** radiation that cause ionization of atoms exposed to it , so it has **hazards** on different organs espicially with higher doses of radiation & sensetive organs.

**Don't Forget**

. **X ray is mandatory** for diagnosis of any **Bone tumor**, even with using CT & MRI.

Portable X ray

Mammography

# Ultrasonography (US)

**Commonest used modality in daily work**

## Historical Hints :

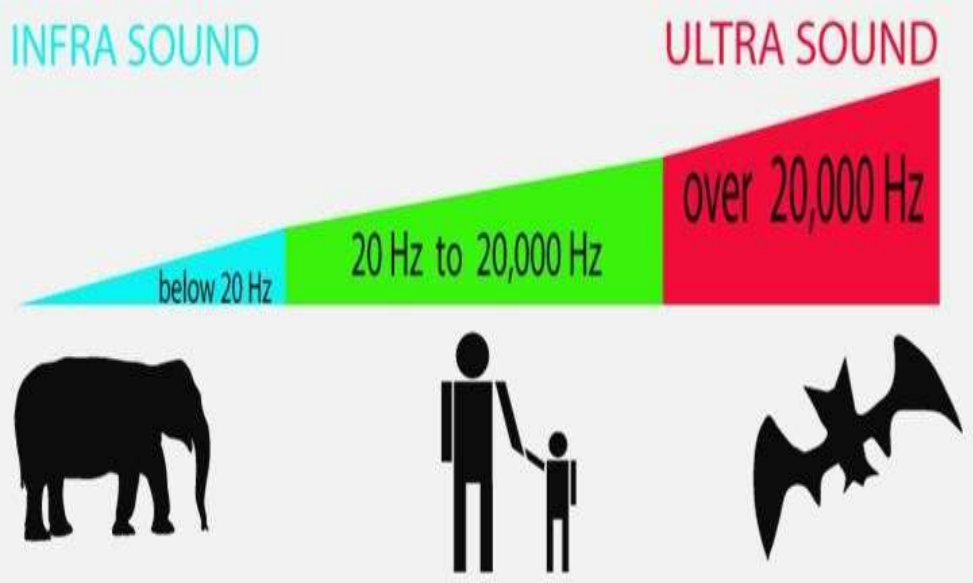
- The source of Idea of medical ultrasound is naval RADAR.
- Naturally, bats & dolphins are depending in US in hunting.

## Basics of Work :

- **Energy used** : Ultrasound (US) ,
- Ultrasound = Sound of frequency > 20.000 Hertz
- US waves are librated from probe (transducer) , penetrating patient tissues , reflected again

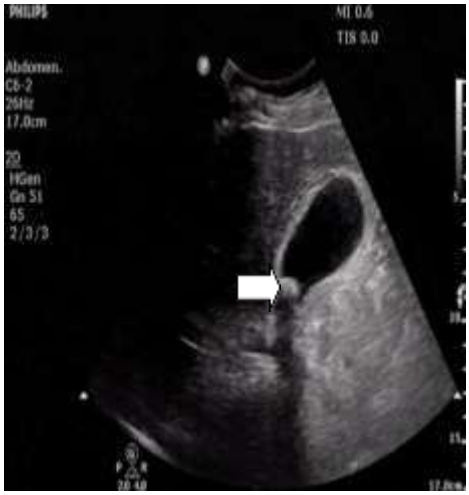
## Reporting terms:

- **Bright structures** = **Echogenic** or **Hyperechoic** (eg. Stones,fat)
- **Gray structures = Hypoechoic**
- **Dark Structures = Anechoic** (eg. Fluids)



## Advantages :

- Non expensive
- Non Ionizing
- Non invasive
- Real time imaging
- Diagnostic & interventional

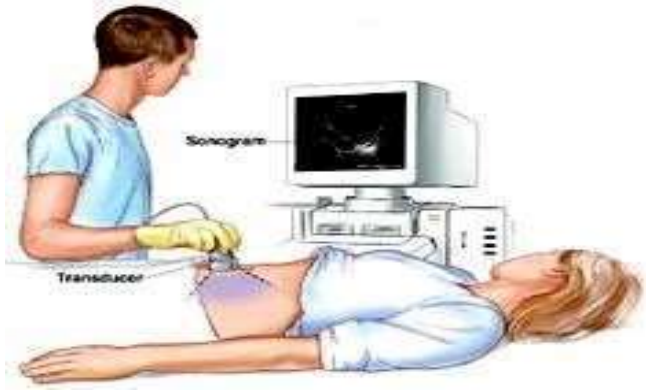


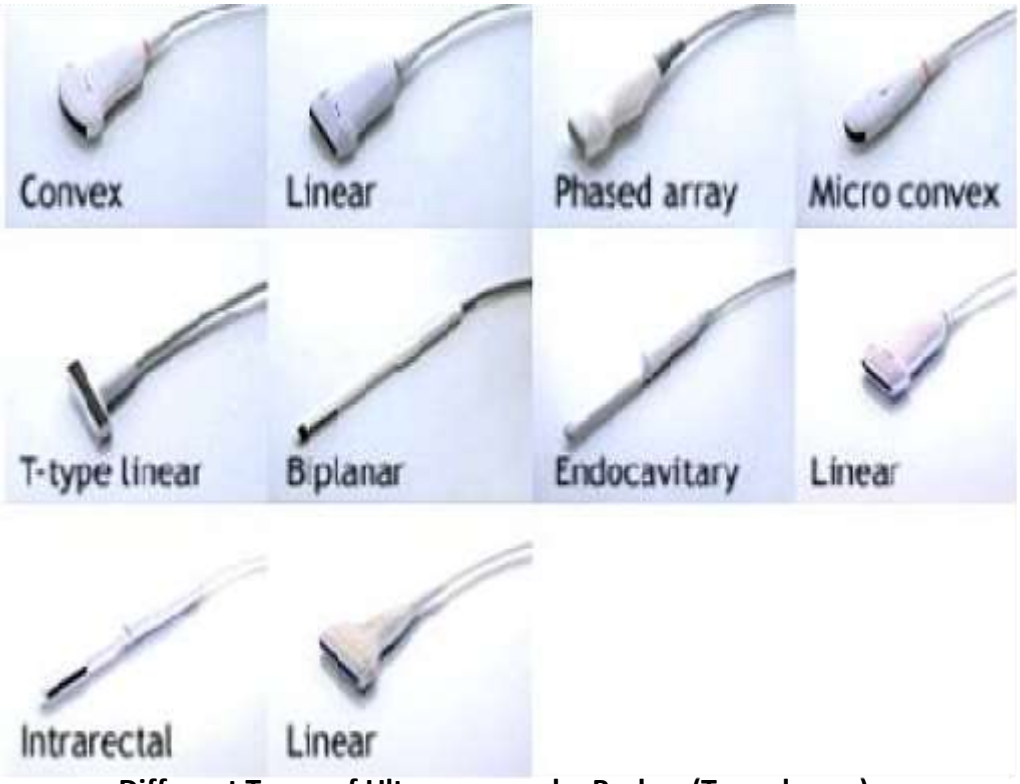
US image of Gall Bladder stone

## Indications :

US have **wide range of indications**, for most of body organs & systems such as:

- **Abdominal US** : trauma, acute abdomen , tumors scan ……etc
- **Chest US** : detection of small amount of effusion *(more sensitive than X ray)*
- **Trans-cranial US:** in infants before Ant. Fontanel closure.
- Neck, Breast, Obstetric , Scrotal , Trans-vaginal, Trans-rectal, soft tissue , ……..etc
- **Color Doppler** : for examination of Vascular system




**Different Types of Ultrasonography Probes (Transducers)**

## ✍ Limitations of US use :

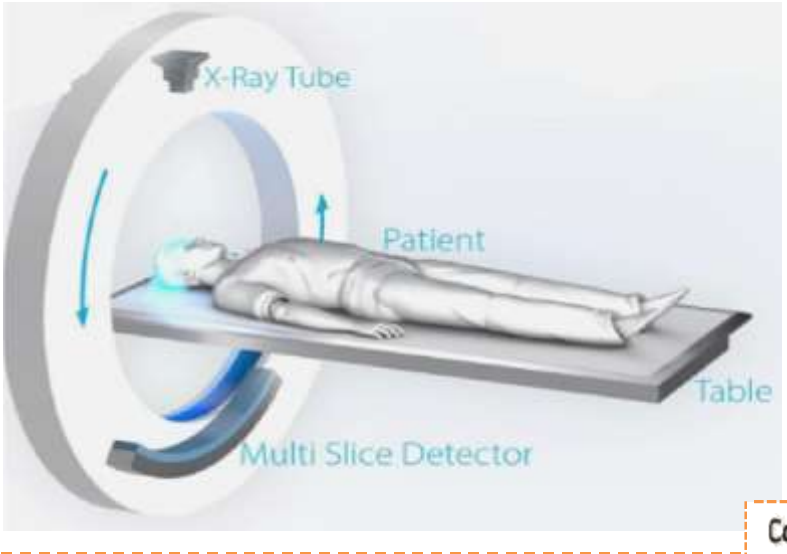
- **Gases**: Gases are scattering US waves → , masking organs below it (eg. Emphysema, Intestinal gases)
- **Bandages :** as casts & postoperative bandages
- **Non co-operation**: almost all radiological examinations need calm, co-operative patient.

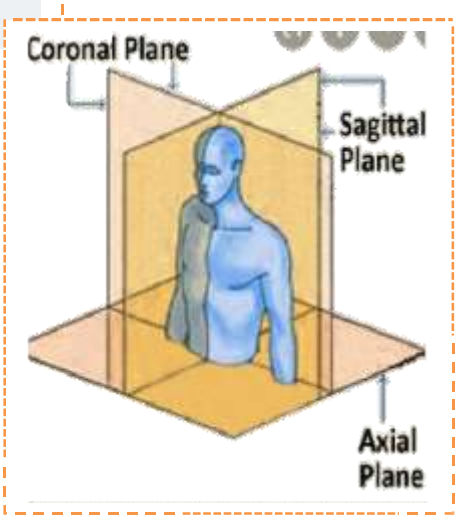
# Computed Tomography CT

## Basics of Work :

- **Energy used**: X ray , an ionizing radiation (higher Dose than X ray scans).

- **X-ray** is librated from **rotating X ray tube**, around patient penetrating body & received on X ray sensors, → send to CT control → images are formed as a cut sections (mainly Axial scans).

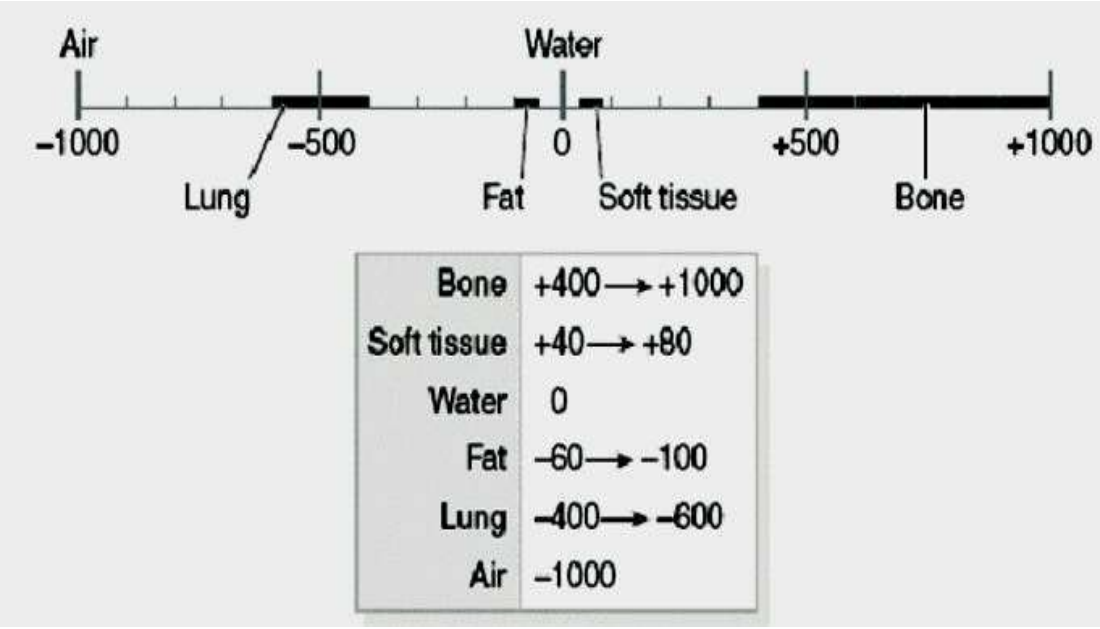


# ✍ CT terms:

- ✍ **Bright object,** *which absorb X ray* = **Hyperdense** (eg. Bone , metals, stones …..etc )
- ✍ **Dark object,** *which permeate X ray* = **Hypodense** (eg. , Fat , air……etc )

CT Densities of different structures is measurable, by the unit of **Hounsfield** (**Hu**) as described below :




| | |
|---|---|
| Bone | +400 → +1000 |
| Soft tissue | +40 → +80 |
| Water | 0 |
| Fat | −60 → −100 |
| Lung | −400 → −600 |
| Air | −1000 |

**Will BE DISSCUSSED LATER IN Details**

## Indications :

CT is usually indicated after **X ray** & **Ultrasonography** are not solving

the problem or reaching definite diagnosis , many indications of

CT such as :

- **Neuro Imaging :** Stroke, Trauma, Brain Tumors ,

  vascular lesions, congenital malformations…..etc

- **Chest imaging**: Infections, trauma, Tumors ……etc

- **MSK imaging**

- **Renal Imaging :** stones , tumors, congenital diseases ……etc

- **Trunk Imaging**

- **Vascular Imaging:** CT angiography for vascular diseases.

**Don't Forget**

**IV Contrast is mandatory for any CT brain for diagnosis or follow up of any BRAIN TUMORS.**

## Contraindications:

☒ **Pregnancy**: especially early (Patient or relative)

☒ **Contrast Hypersensitivity**


**X ray & CT**

**Are**

**Contraindicated**

**in Pregnancy**

**CT Machine**

# Magnetic Resonance Imaging MRI

## Basics of Work :

- **Energy used**: Magnetic Field + Radio Frequency
- Depending on **Magnetic Resonance Phenomena**
- **Reporting term** = Signal Intensity
  - ✓ Bright object = **Hyper intense**
  - ✓ Dark object = **Hypo intense**

### Summary of MRI Work Physics

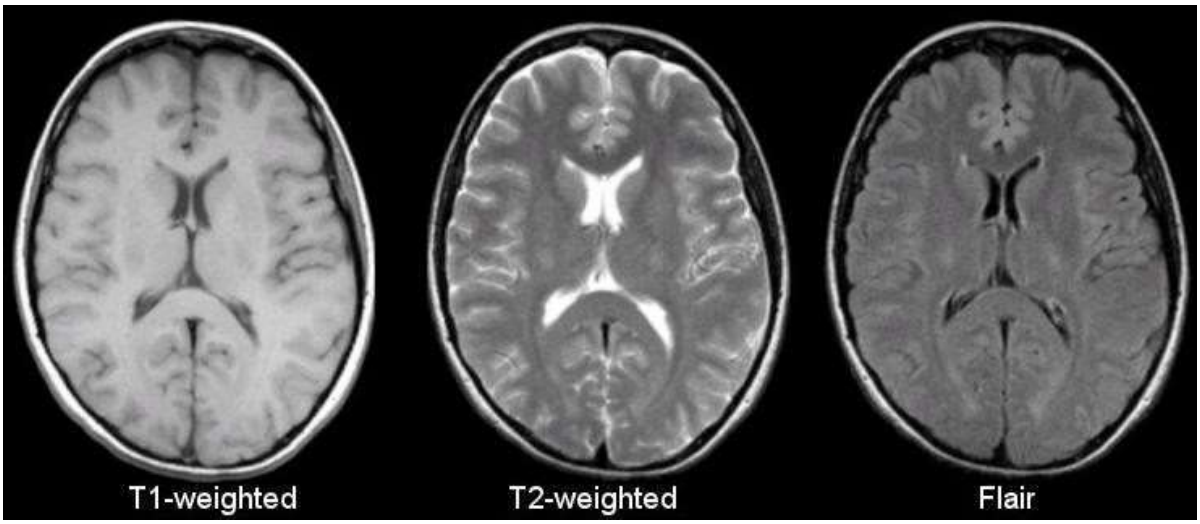
- Protons has **+Ve** charge.
- **H**ydrogen nucleus contains 1 **Proton**.
- Protons are rotating → Act as small magnet → Magnetic field around.
- **(Body net magnetization = near 0)** - Although all these H protons, as small magnets within the body , But due to direction of rotation is variable & against each others.
- **Magnet** → Uniting the direction of rotation of protons.
- **Coil** → **R**adio**f**requency **"RF"** → Change angle of protons by acquiring energy
- **"RF"** stop → Protons miss energy → apparatus receive energy & forming Image from

| Types of MRI | |
|---|---|
| • **According to shape:** | • **According to Magnet Type :** |
| ▪ Open<br>▪ Closed<br>▪ Dynamic<br>▪ Extremity | ▪ Permanent<br>▪ Electeric<br>▪ Super magnet |

## ⇨ Why to use Open MRI :

- For Cases of **Claustrophobia** & **Morbid Obesity.**


***MRI Sequences & appearance of different structures***




*Normal MRI in Different Sequences*

## Contraindications:

**Any Ferromagnetic material**

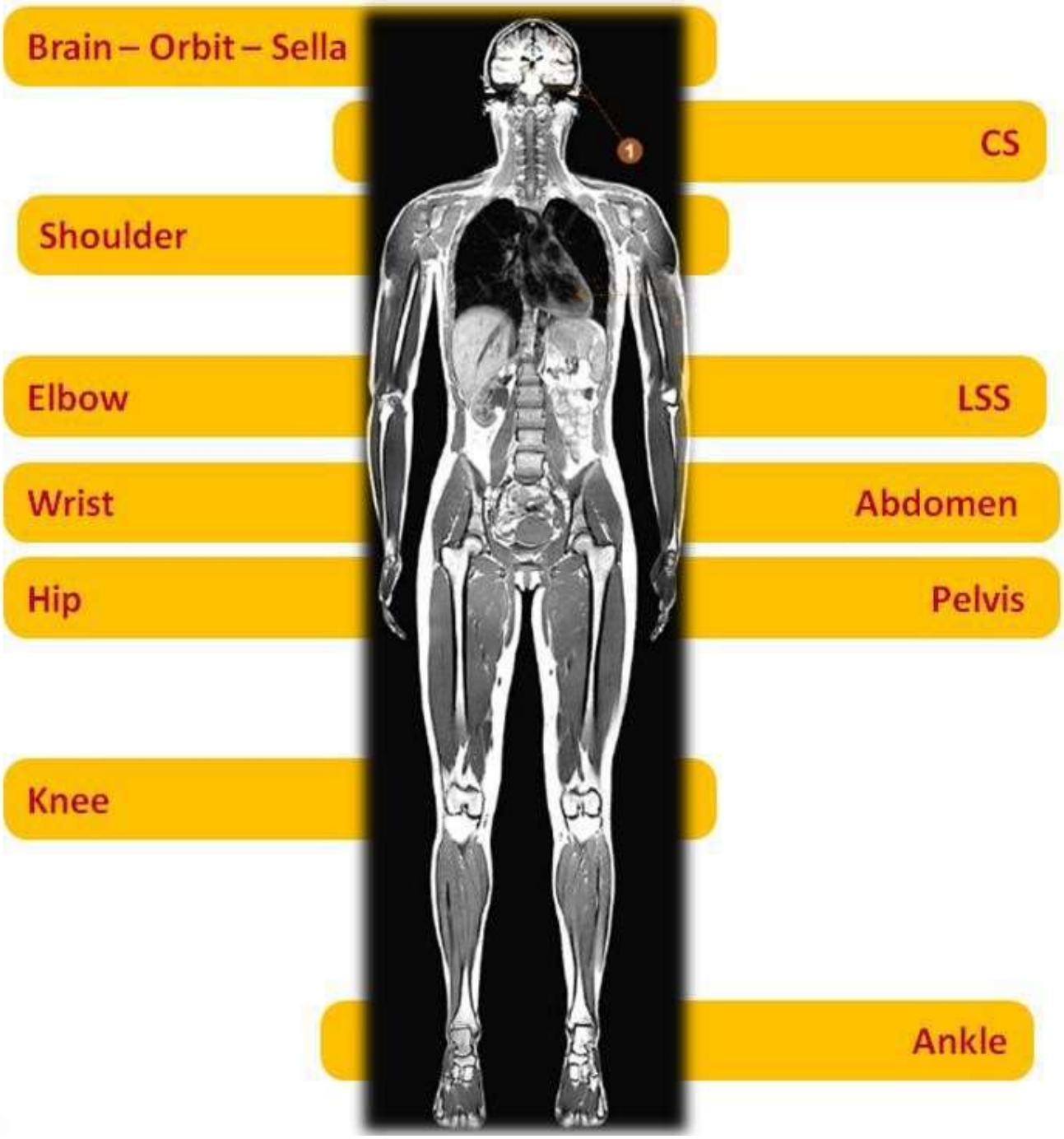
- ☒ Pacemaker (Fatal)
- ☒ Any Iron FB
- ☒ Contrast Hypersensitivity
- ☒ Fire arm / Vascular metallic clips

Don't Forget

**MRI is large powerful Magnet**


Warning of Use seen at every MRI Unit

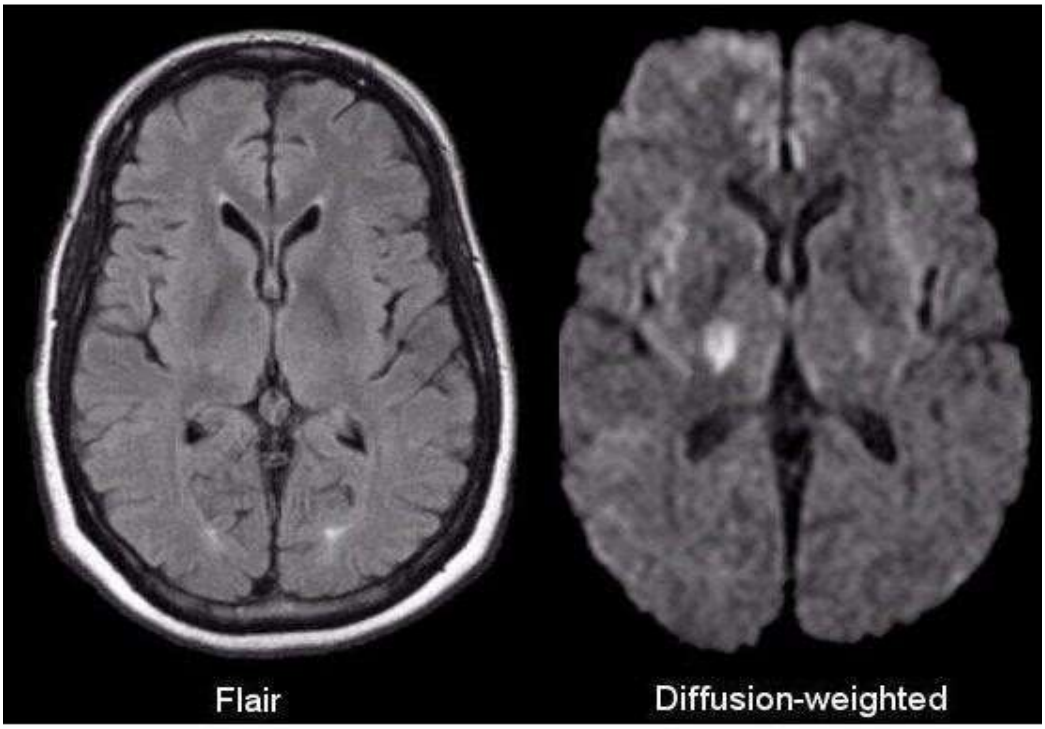
**Indications:** (Many organs, Many Systems)



## Hints about Indications:

✓DW (Diffusion Weighted MRI)

The fastest Method to detect Acute cerebral infarction.




Note the Acute Infarction Only Seen on DWI

## Advantages of MRI

- ✓ **Non Ionizing Radiation**
- ✓ **Non iodinated Contrast (Gadolinium)**
- ✓ **Best soft tissue differentiation** by **Multi Sequences**
- ✓ **Multi planner** : scan at any direction

**MRI** *Is*

**Multi planner**

**Multi Sequences**

## Disadvantages of MRI

- × **Expensive / Limited availability**
- × **Limited use in Lung / cortical bone Imaging**
- × **Ferromagnetic Contraindications**
- × **Long scanning time**

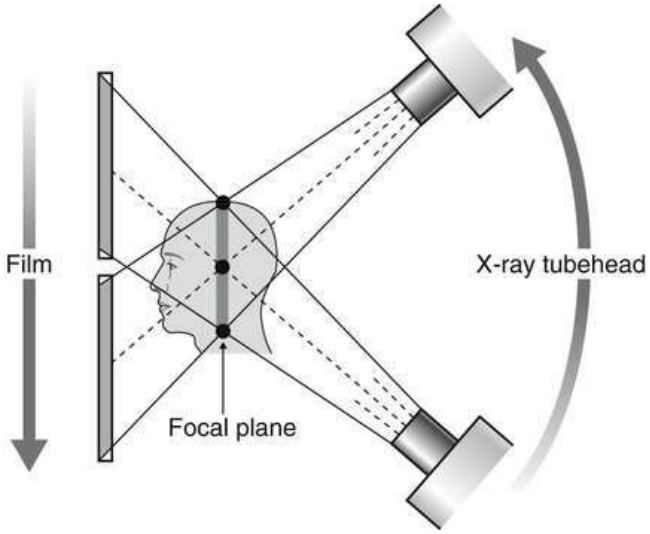
CHAPTER 2

# HISTORY OF CT

| Year | Development |
|---|---|
| 1924 | Johann Radon formulated the mathematical theory of tomographic image reconstruction. |
| 1930 | A. Vallebona constructed equipment and published 1st clinical body section imaging material. |
| 1963 | A. McLeod Cormack developed the theoretical underpinnings of CT scanning. |
| 1971 | 1st generation CT: commercial CT introduced by Sir Godfrey Hounsfield. |
| 1972 | EMI scanner was introduced as clinical system of cranial examination. |
| 1974 | 2nd generation CT. |
| 1975 | 3rd generation CT. |
| 1976 | 4th generation CT. |
| 1979 | Cormack & Hounsfield shared the noble prize in physiology or medicine. |
| 1980 | 5th generation cardiac CT. |
| 1989 | Single-row CT. |
| 1991 | Spiral CT was introduced. |
| 1994 | Double row spiral CT. |
| 1998 | Multidetector CT. |
| 2004 | 16 row spiral CT. |
| 2006 | Dual source CT introduced. |
| 2007 | 320 row spiral CT. |

- The history of the CT scan began in the 1960s with **Godfrey Hounsfield**
- Working with Allan Cormack, Hounsfield's invention created cross-sectional images of the brain (significant advancement from conventional X-rays).
- **October 1971** → The first patient was scanned in,
- **By 1972**, the commercial version was released,
- **1979** Hounsfield and Cormack earned the **Nobel Prize**

## Focal Plane Tomography




- X-ray source and the detecting film moved simultaneously along specific trajectories → .Early attempts to overcome the superimposition of structures
- This approach became known as planography or focal plane tomography.
- Key contributors: the French physician ***André Bocage***, Italian radiologist ***Alessandro Vallebona***, and Dutch radiologist ***Bernard George***.

- **In 1961**, neurologist William Oldendorf → approach to imaging structures inside the skull.
- He developed an experimental trial → record variations in radiodensity within a **test sample** (containing aluminum and iron nails) arranged around the center, mimicking the structure of a skull.
- Throughout the mid-20th century, the technique continued to evolve, → **sharper images** and allowing for **greater control** over the thickness of the examined cross-section.
- This progress was driven by the development of :

• **More complex, multidirectional devices** capable of moving in multiple planes and

• Achieving more effective blurring of out-of-focus structures.

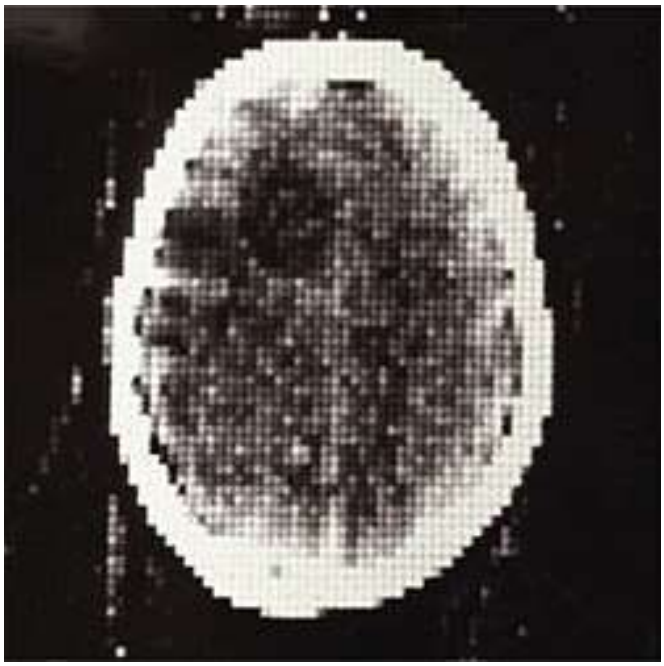
However, despite these advancements in focal plane tomography, its ability to image soft tissue remained highly limited due to poor contrast.

# Godfrey Hounsfield

The British electrical engineer Godfrey N. Hounsfield

- **1967**, The british electrical engineer **Godfrey N. Hounsfield**,, work on his own project (Based on his earlier radar research).→ detect objects **inside a structure** by sending beams through it from *different angles*.

- **On October 1, 1971**, the first patient—a woman with a suspected brain tumor—was successfully examined.



The first clinical CT scan, in October 1971 at **Atkinson Morley's Hospital in London** with Hounsfield's scanner

- Hounsfield described the method, scanner design, and operation in his landmark **1973 paper**.

Hounsfield, G. N. (December 1973). "Computerized transverse axial scanning (tomography). 1. Description of system". *The British Journal of Radiology*. **46** (552): 1016–1022. doi:10.1259/0007-1285-46-552-1016. ISSN 0007-1285. PMID 4757352.

FIG. 5.
Illustration of the patient in position.

FIG. 6.
X-ray control console.

- **After 1972**, several companies around the world began developing their own CT systems.
- **In 1977**, at least 17 companies were already active on the global market, → offering commercial CT scanners.
- Progress was driven by innovations in various fields, including :
  - X-ray tube optimization,
  - detector development,
  - faster data processing, and
  - advanced reconstruction algorithms.

These technological advancements defined the different "**generations**" of CT scanners, ranging from the **first** to the **fifth** generation.

- **Fan-beam CT devices**—known as third-generation scanners—have proven to be the most practical.

1973, *British Journal of Radiology*, *46*, 1016–1022

# Computerized transverse axial scanning (tomography): Part I. Description of system

G. N. Hounsfield

Central Research Laboratories of EMI Limited, Hayes, Middlesex

(*Received February, 1973 and in revised form July, 1973*)

ABSTRACT

This article describes a technique in which X-ray transmission readings are taken through the head at a multitude of angles: from these data, absorption values of the material contained within the head are calculated on a computer and presented as a series of pictures of slices of the cranium. The system is approximately 100 times more sensitive than conventional X-ray systems to such an extent that variations in soft tissues of nearly similar density can be displayed.

For many years past, X-ray techniques have been developed along the same lines, namely the recording on photographic film of the shadow of the object to be viewed. Recently, it has been realized that this is not the most efficient method of utilizing all the information that can be obtained from the X-ray beam. Oldendorf (1961) carried out experiments based on principles similar to those described here, but it was not then fully realized that very high efficiencies could be achieved and so, picture reconstruction techniques were not fully developed.

As the exposure of the patient to X rays must be restricted, there is an upper limit to the number of

Radiology (Ambrose and Hounsfield, 1973). A short account has also appeared in the *New Scientist* (*Technology Review*), 1972.

## PRINCIPLES OF THE METHOD

The aim of the system is to produce a series of images by a tomographic method as illustrated in Fig. 1. Each image shown at the bottom of the figure is derived from a particular slice.

In the actual equipment, the patient is scanned by a narrow beam of X rays. The X-ray tube, detectors, and collimators are fixed to a common frame, as shown in Fig. 2, those rays which pass through the head being detected by two collimated sensing devices (scintillation detectors) which always point towards the X-ray source. Both X-ray source and detectors scan across the patient's head linearly taking 160 readings of transmissions through the head as shown in scan 1 on the scanning sequence diagram (Fig. 3). At the end of the scan the scanning



Hounsfield, G. N. (December 1973). "Computerized transverse axial scanning (tomography). 1. Description of system". *The British Journal of Radiology*. **46** (552): 1016–1022. doi:10.1259/0007-1285-46-552-1016. ISSN 0007-1285. PMID 4757352.

## * Significance and Impact :

•**Pioneering Diagnostic Tool**: The EMI scanner was the first successful CT scanner and was a fundamental advance in neuroradiology.

•**Improved Diagnosis**: It significantly increased the accuracy of diagnoses for various brain conditions, including tumors, infections, and injuries.

•**Non-Invasive Approach**: The technique provided crucial diagnostic information without the need for invasive procedures, such as the hazardous injections of air or special liquids previously required.

•**Foundation for Modern CT Scanners**: Though technology has since advanced, the EMI scanner laid the foundation for today's advanced CT technology.

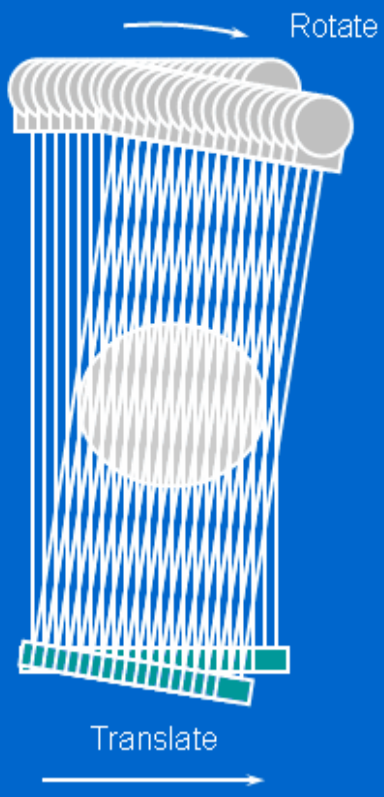
# CT Scanners Generations

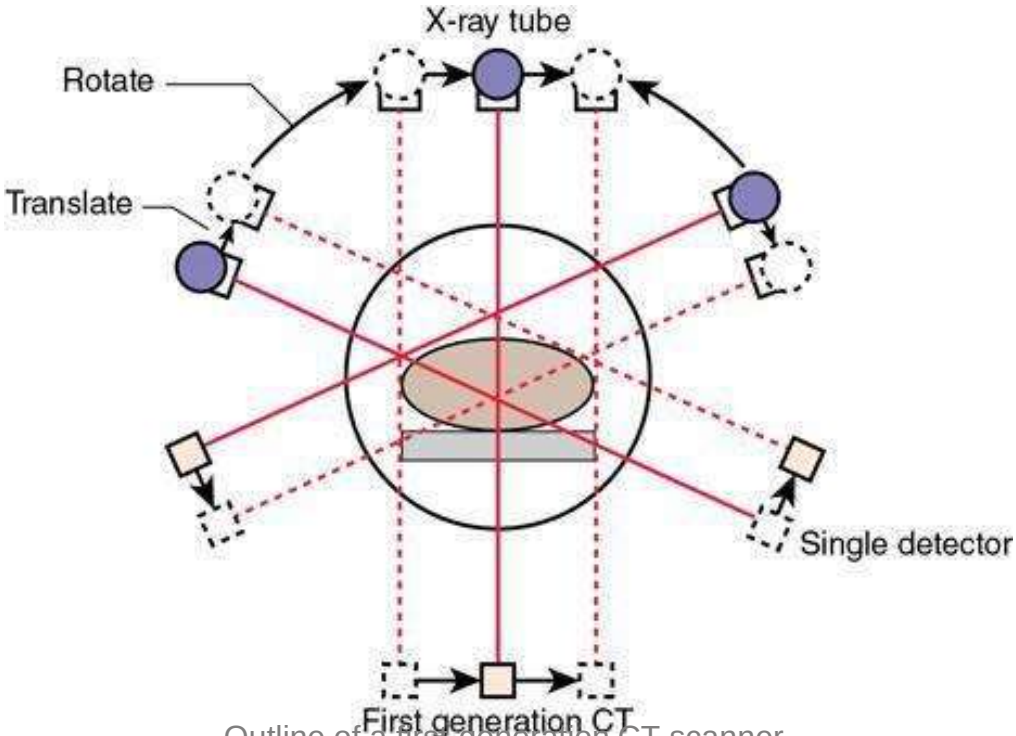
## First-generation scanners

- First-generation CT scanners—such as Hounsfield's *EMI Mark I* design
- The X-ray tube, typically operated at 120 kVp and 32 mA,
- emitted a **narrow pencil beam** aimed at a two-element detector (acquiring two 13 mm slices simultaneously),
- Detector consisted of sodium iodide (NaI) scintillators coupled to photomultiplier tubes.
- Both the **tube** and the **detector** moved linearly across the patient at a fixed gantry angle.
- After each traverse, during which 160 data points (two rows of 80 measurements at 1.5 mm intervals) were collected,
- the system rotated by 1° around the center of the bore and repeated the process,
- ultimately acquiring **180 projections** within **five minutes**.
- The detector required gain and offset calibration at the beginning of each linear pass.

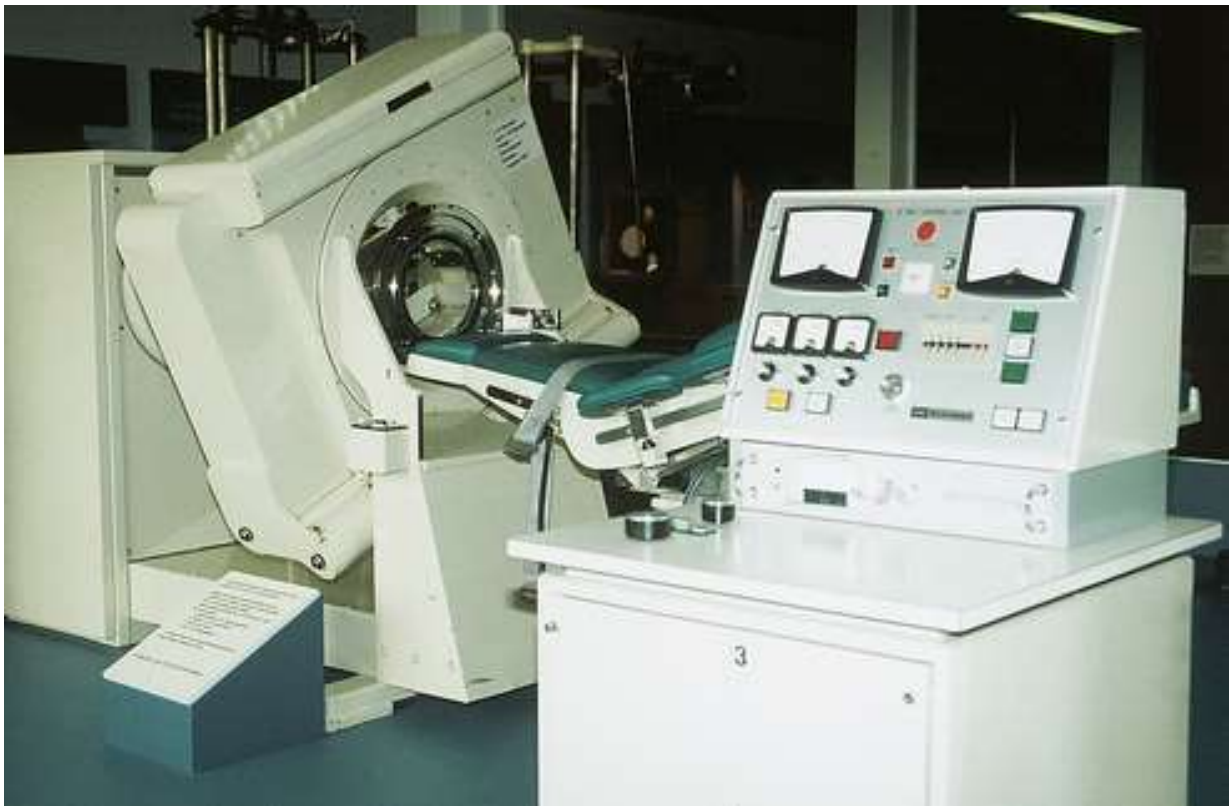
## First generation CT scanner

- Single detector
- Translate - rotate acquisition
  - Translates across patient
  - Rotates around patient
- Very slow
  - minutes per slice



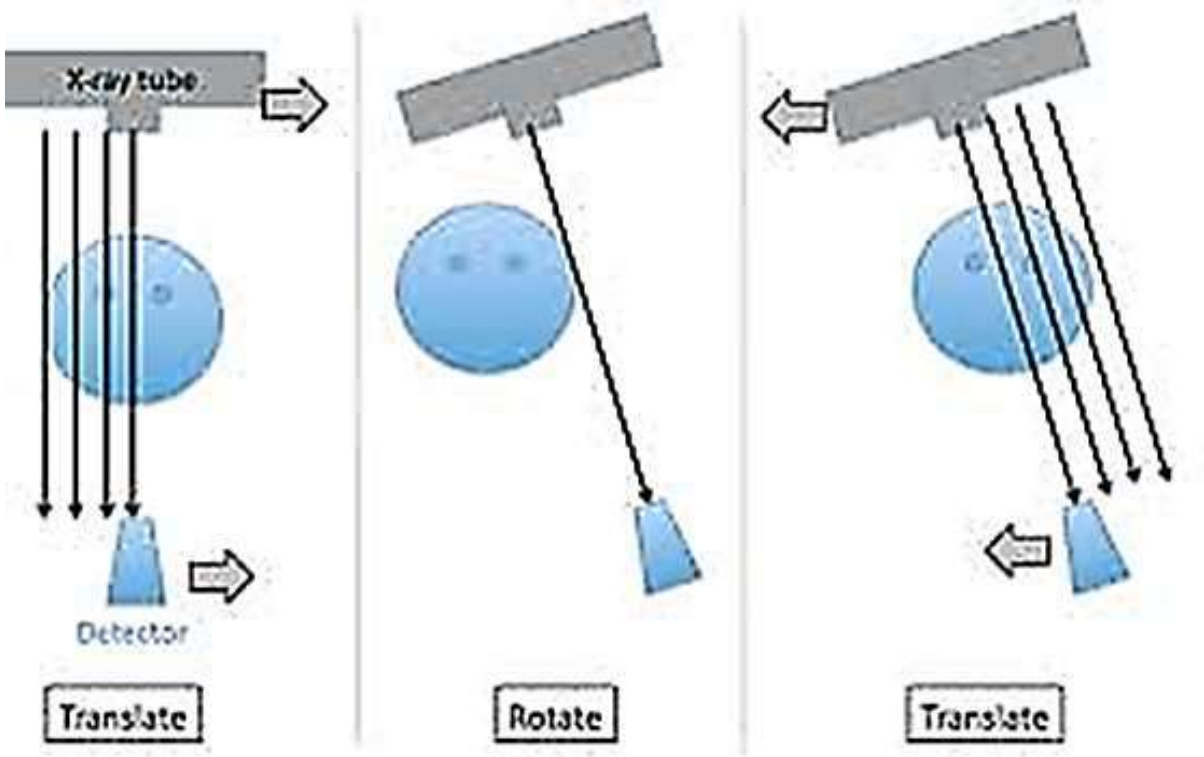




Outline of a first-generation CT scanner.



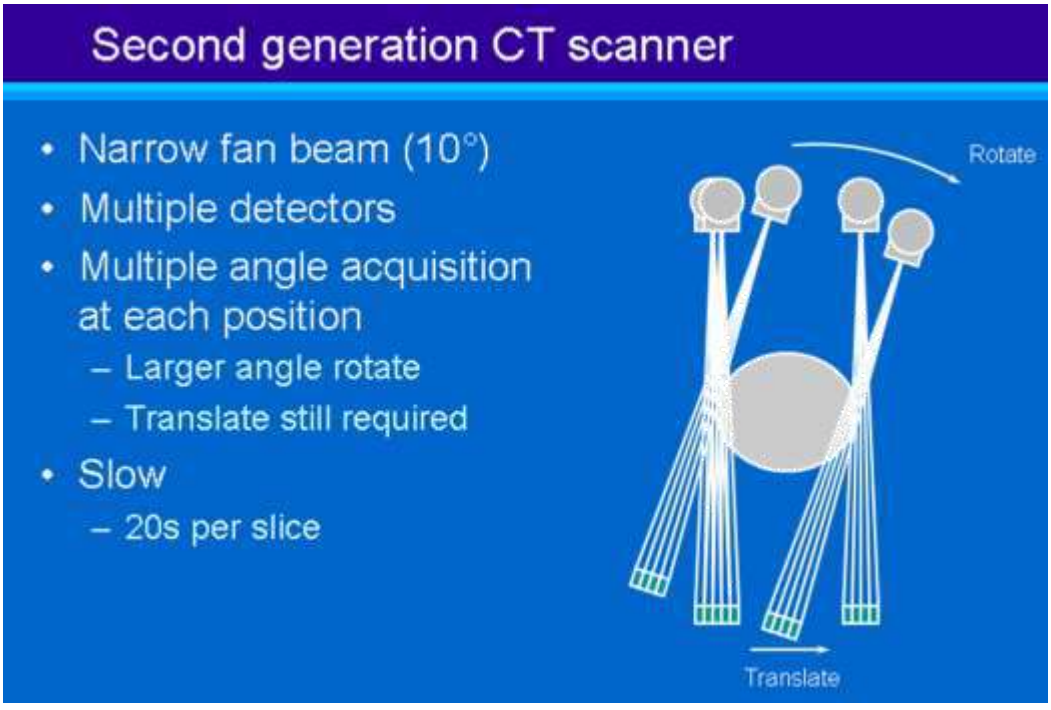
**First-generation EMI CT unit: dedicated head scanner.**

(Photograph taken at Reöntgen Museum, Lennep, Germany.)



# Second generation CT scanners

- **introduced in 1975 , with** Faster scan speeds, ← the **narrow pencil X-ray beam** was expanded into a **fan-shaped beam** & paired with multiple detectors—often more than ten.
- This configuration enabled the system to sample the object along several lines simultaneously, → significantly reducing the number of rotations required for image reconstruction.
- **Translate-rotate protocol** was still employed.
- In second-generation *CT ,* 30 detectors spanning over 10°,
- reduced scanning time to **just 20 seconds per slice** → fast enough to image certain body parts during a ***single breath-hold***.
- The rapidly growing market soon attracted serious competitors to EMI, including S*iemens*, H*itachi*, *GE*, and several smaller manufacturers,
- But ……. Still faster scanning was necessary.

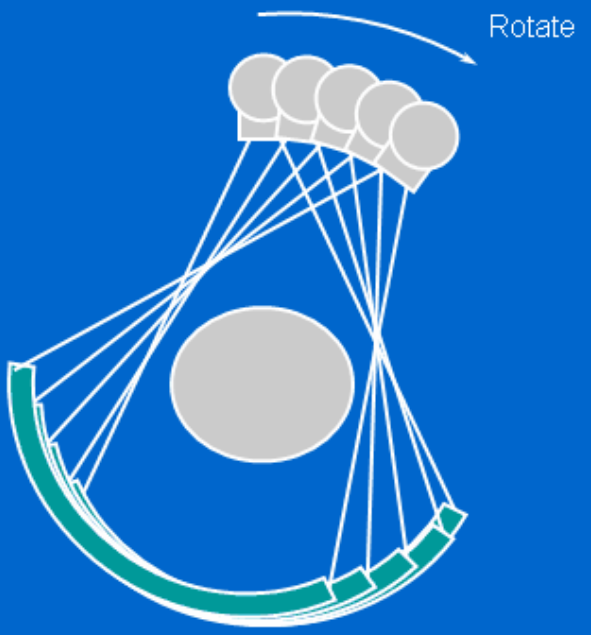


# Third-generation CT scanners



## Third generation CT scanner

- Fan beam
- Multiple (500 - 1000) rotating detectors
- Rotation only
  - no translation required
- Much faster
  - as fast as 0.5 s per rotation
- Most common modern scanner design

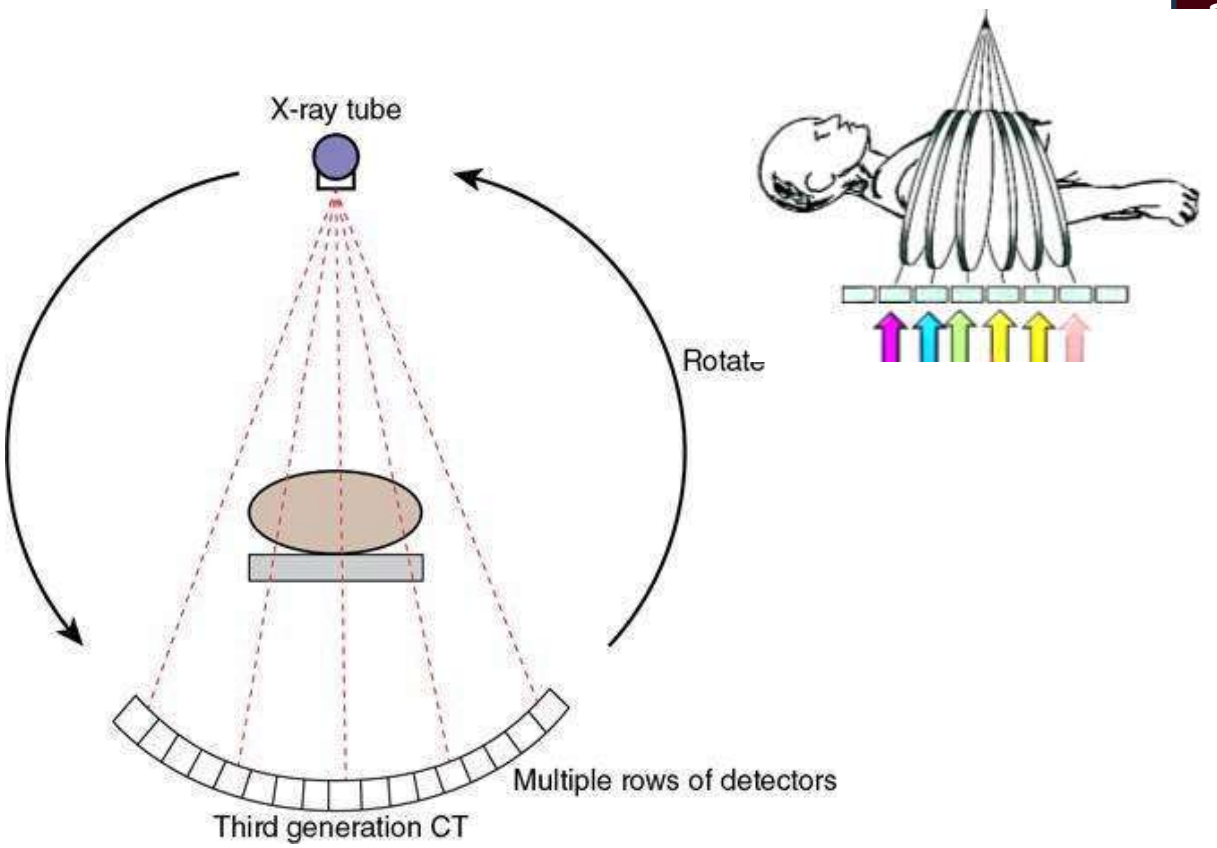



## Number of detectors and projections

Typically, for 3rd generation scanners:

650 - 900 detectors (per row)

1000 - 2000 projections per rotation





**FAN Shape Beam**

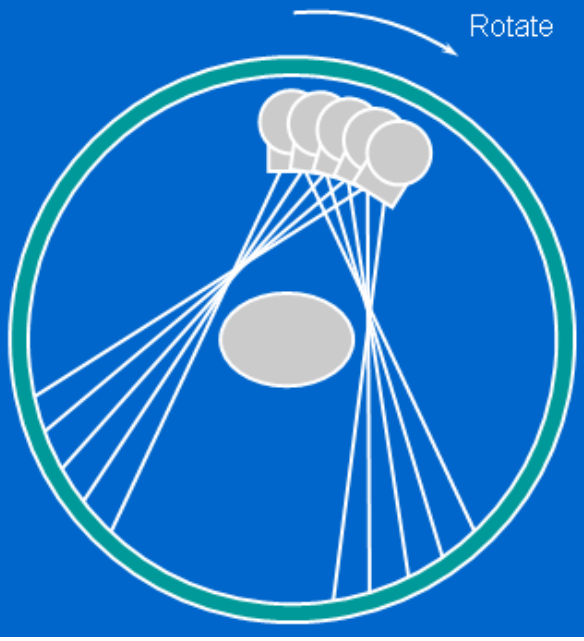


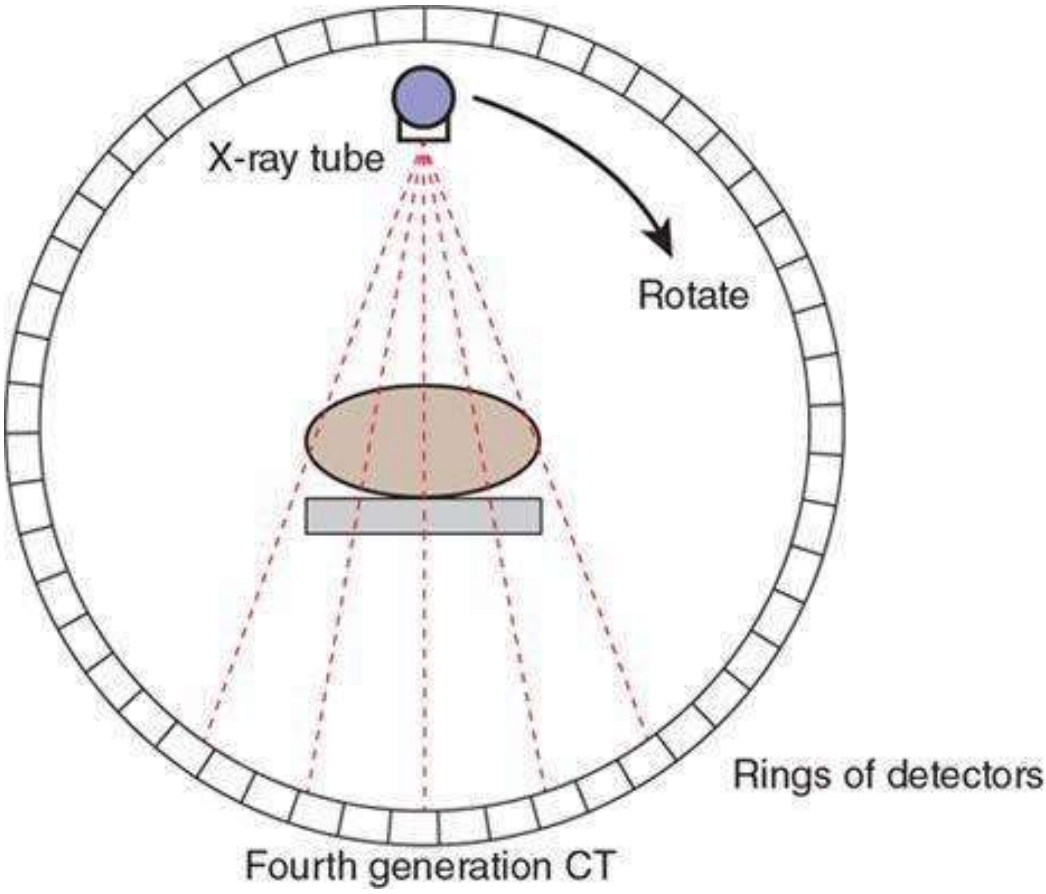
**Third Generation CT Machine in Sohag University Hospital (1993 – 2008)**

# 4th generation scanners

## Fourth generation CT scanners

- Fan beam
- Static detectors all round gantry
- Only tube rotates
- Avoids ring artefact problems of 3rd generation scanners

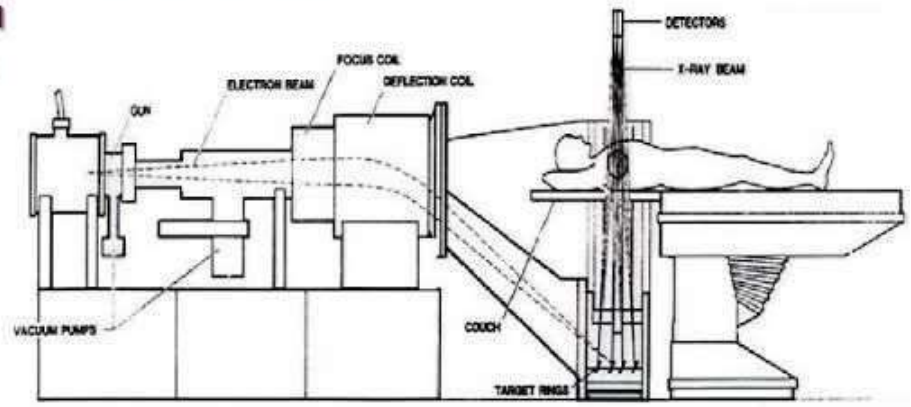


## 5th generation CT scanners 1981

### 5th generation: Electron Beam CT (EBCT)

- x-ray source is not x-ray tube but a focused, steered, microwave-accelerated EB incident on a tungsten target.
- It has no moving parts .
- Target covers one-half of the imaging circle; detector array covers the other half.
- Images in
- less than
- 50ms.




**Electron Beam CT (EBCT),**

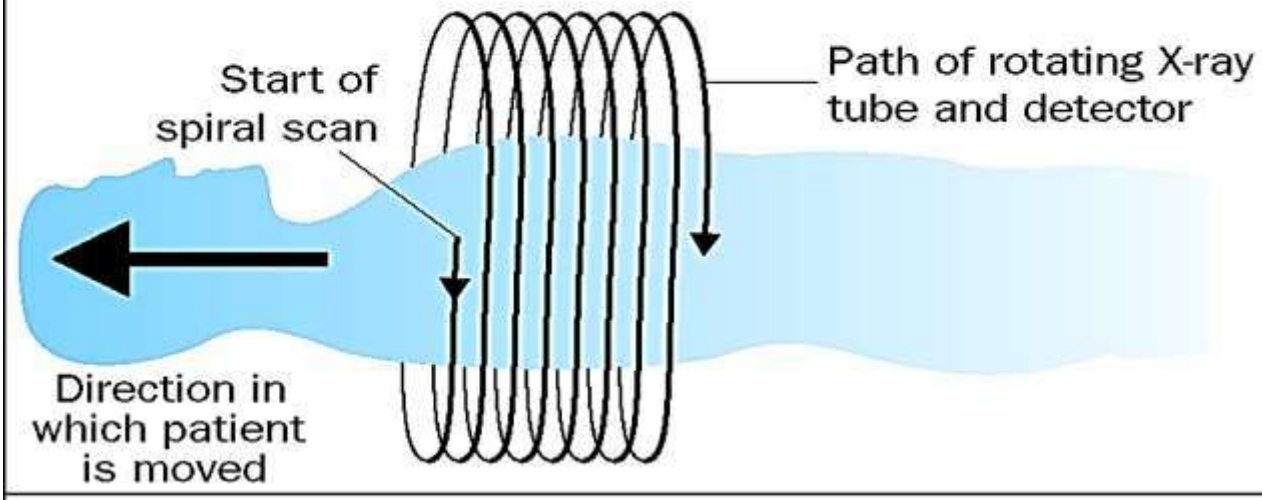
- This design was specifically optimized for cardiac imaging, as the heart's rapid motion makes it highly susceptible to motion artifacts.
- It enabled advanced applications such as coronary calcium scoring and other heart-related diagnostics.
- **EBCT** was also used for pediatric imaging, where patients often struggle with breath-holding or remaining still during scans.
- Only much later did modern CT systems, with multi-detector and dual-source technology, → achieve comparable temporal resolution, eventually displacing EBCT from the market.
- **Its decline was due to several limitations**: a large footprint, limited versatility for general imaging, high acquisition and maintenance costs, and lower spatial resolution compared to newer technologies.

2025

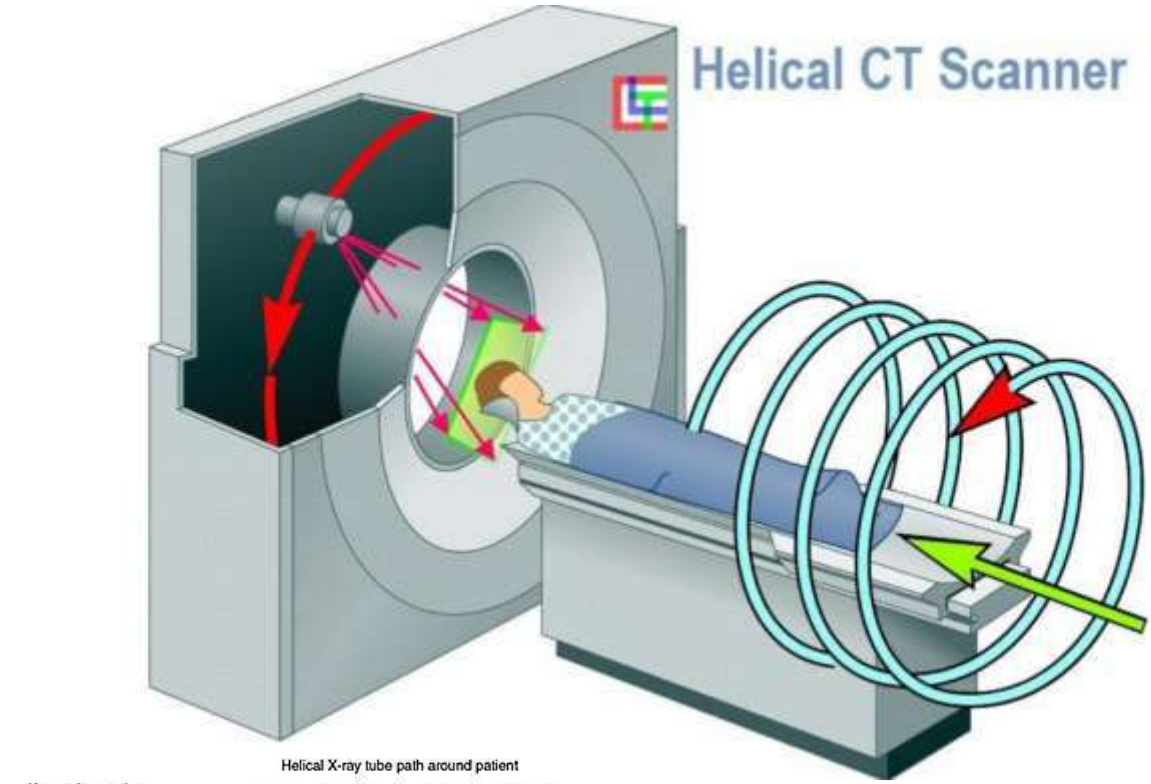
# Helical / Spiral CT 1990

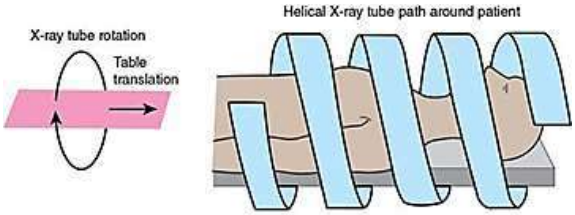
## Principles of spiral CT

Slip Ring Technology



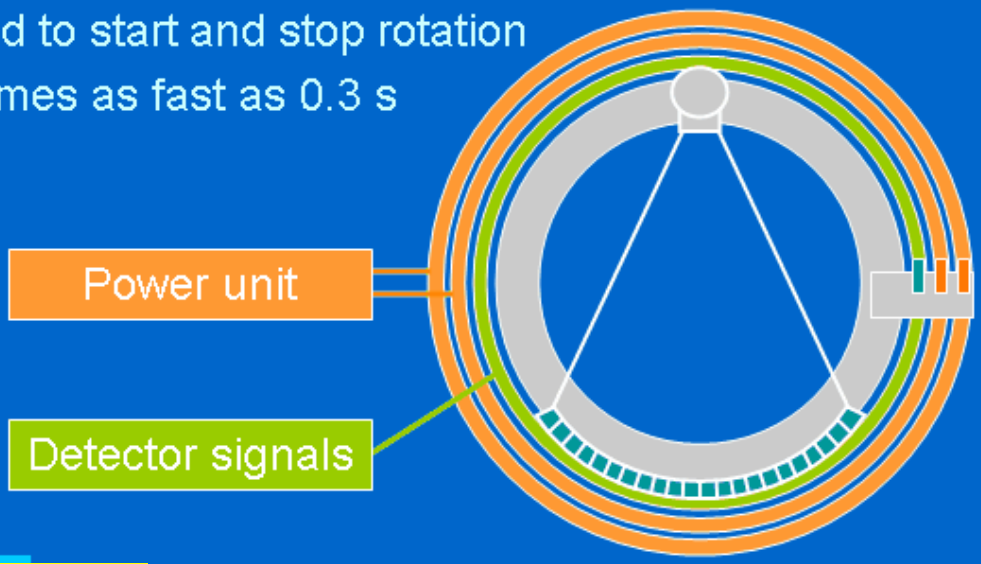

The patient is moved slowly through the gantry during continuous rotation of the X-ray tube. The pitch is the longitudinal distance the patient travels per tube rotation divided by the chosen thickness. For a table movement of 10 mm/s, a tube rotation of 1/s, and a slice thickness of 10 mm, the pitch is 1·0.



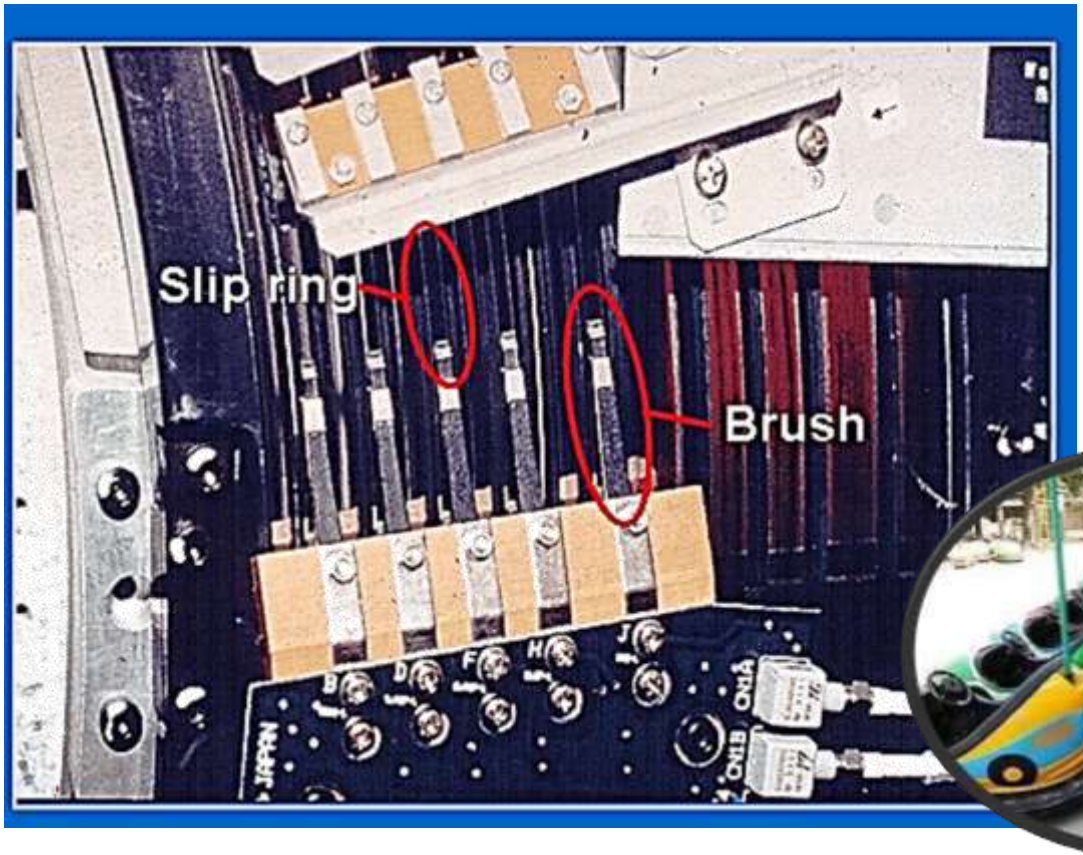



## Slip rings

- Slip rings introduced in 1990 allowed continuous rotation
  - Power and signals transmitted to rotating gantry using 'brushes' on static rings
  - no need to start and stop rotation
  - scan times as fast as 0.3 s

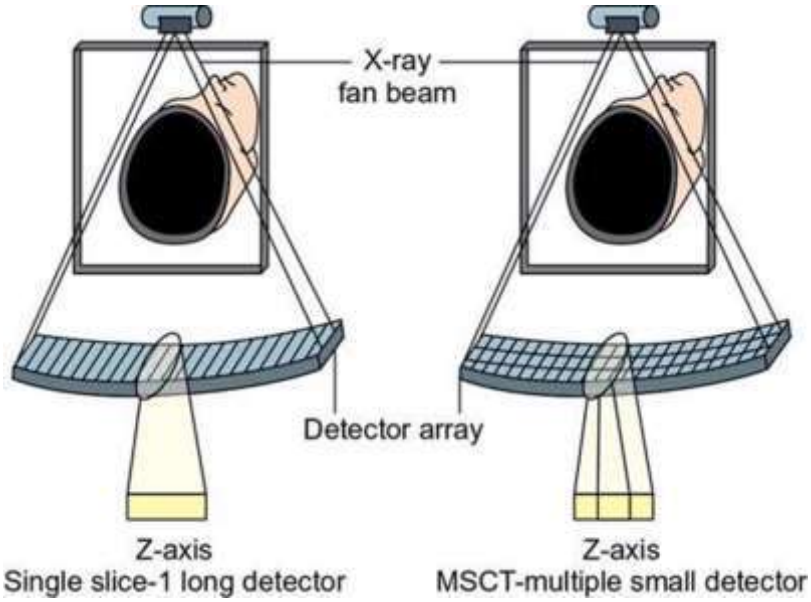



**Slip Ring Technology**



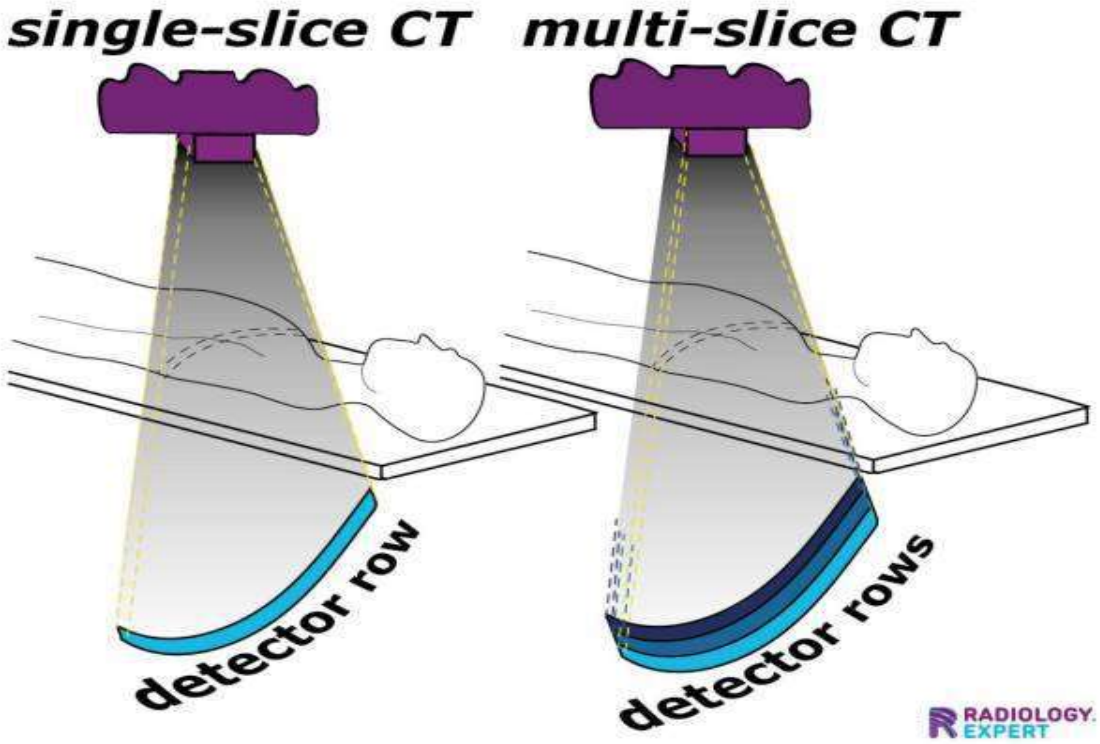

توصل الكهرباء بالتلامس مما يتيح حرية الدوران (مثل فكرة عربة الملاهي)

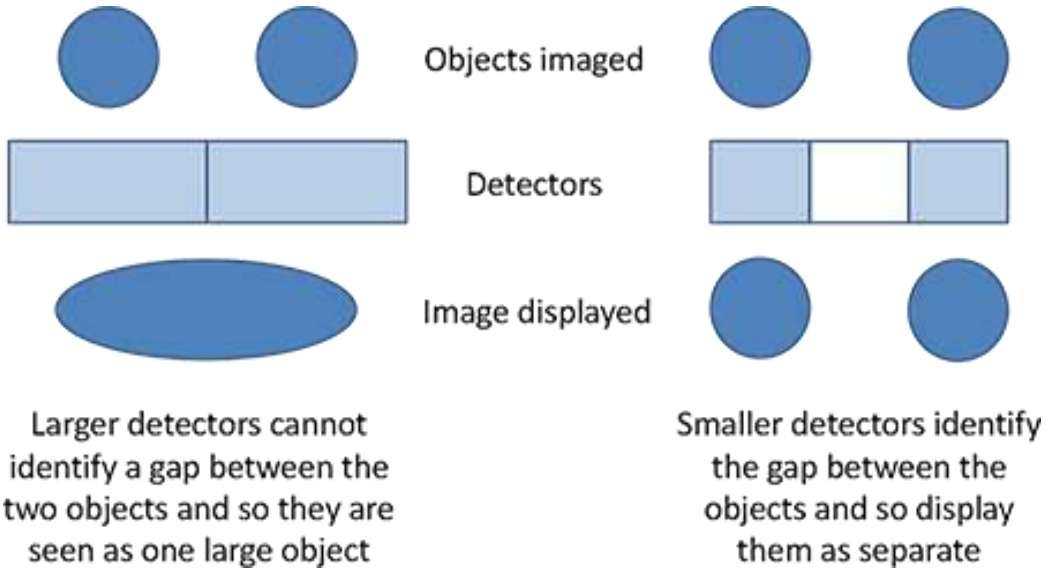
# Multi Slice CT

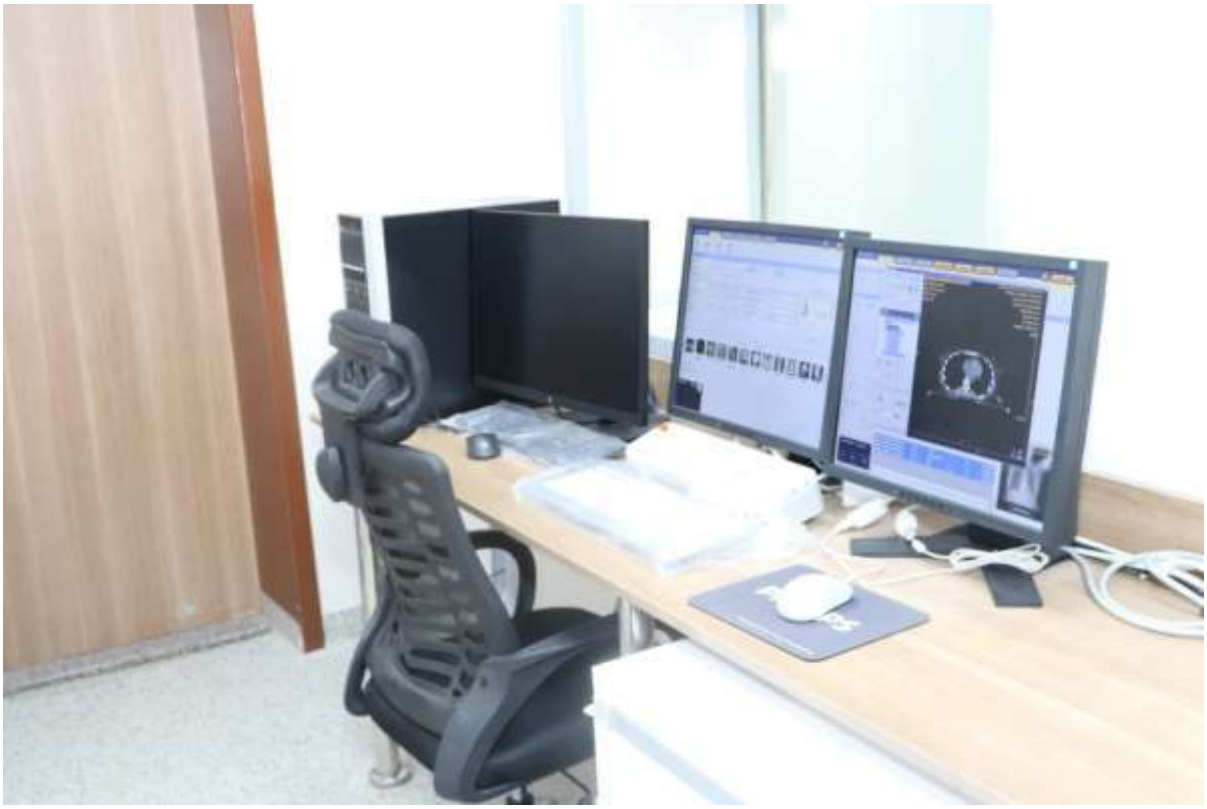



- Starting in the 1990s,
- CT detector technology transitioned from xenon ionization chambers to solid-state detectors.
- These new detectors used powdered scintillators (such as $Gd_2O_2S$) coupled with photodiodes to convert light into electrical signals.
- This advancement offered significantly higher quantum efficiency (>90%) and enabled more compact designs with improved spatial resolution.

The combination of **Helical scanning** and **Multi-slice technology** → acquisition of very thin slices, → makes isotropic voxel reconstruction possible.
This means that anatomical data can now be viewed from any angle without distortion (multiplanar reconstruction), → allowing the extraction, analysis, and visualization of accurate **3D models** of the scanned structures.


single-slice CT
multi-slice CT
detector row
detector rows
RADIOLOGY EXPERT


Objects imaged
Detectors
Image displayed
Larger detectors cannot identify a gap between the two objects and so they are seen as one large object
Smaller detectors identify the gap between the objects and so display them as separate

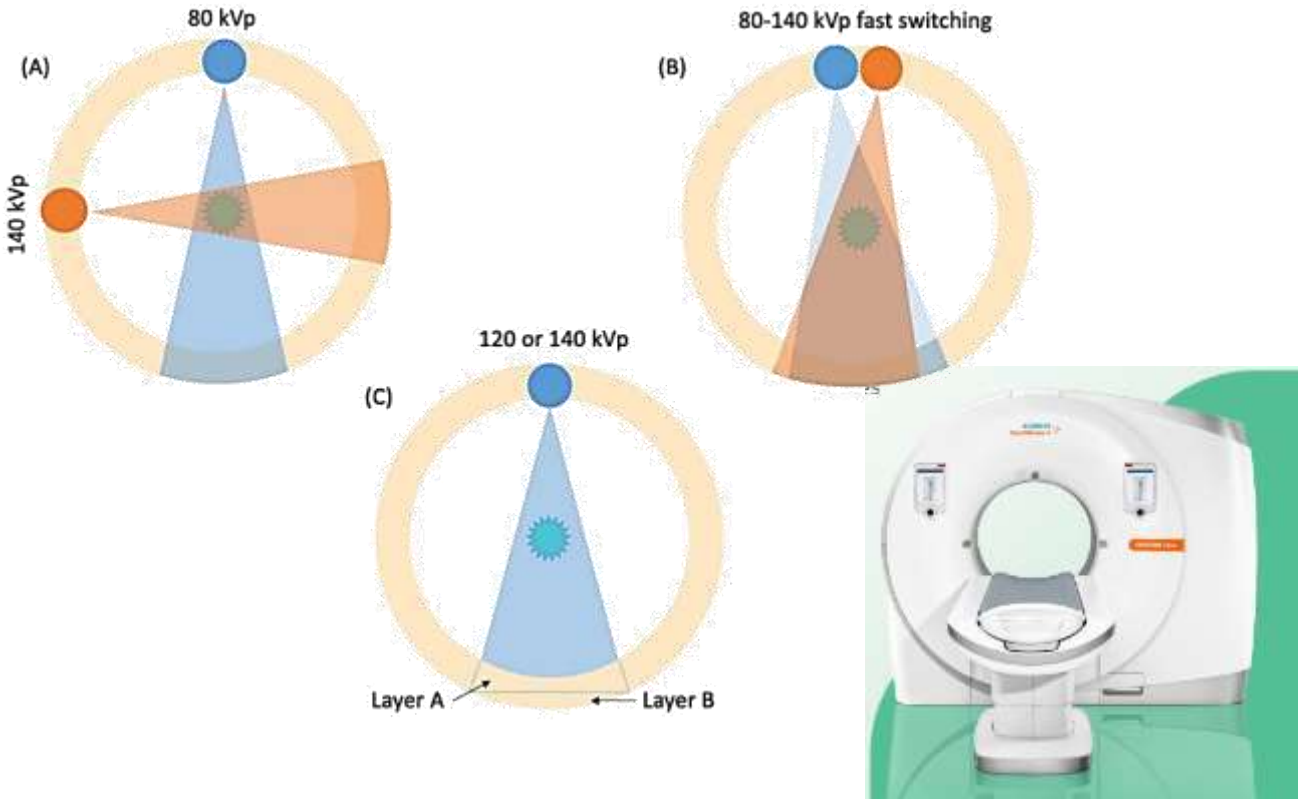


**Multi-slice CT Machine**
**in Sohag University New Hospital**

# Dual-Source and Dual-Energy CT CT



In **2005**, Siemens introduced the *SOMATOM Definition*, a scanner equipped with two X-ray tubes and two detectors mounted 90° apart on the gantry, each operating at different energies.



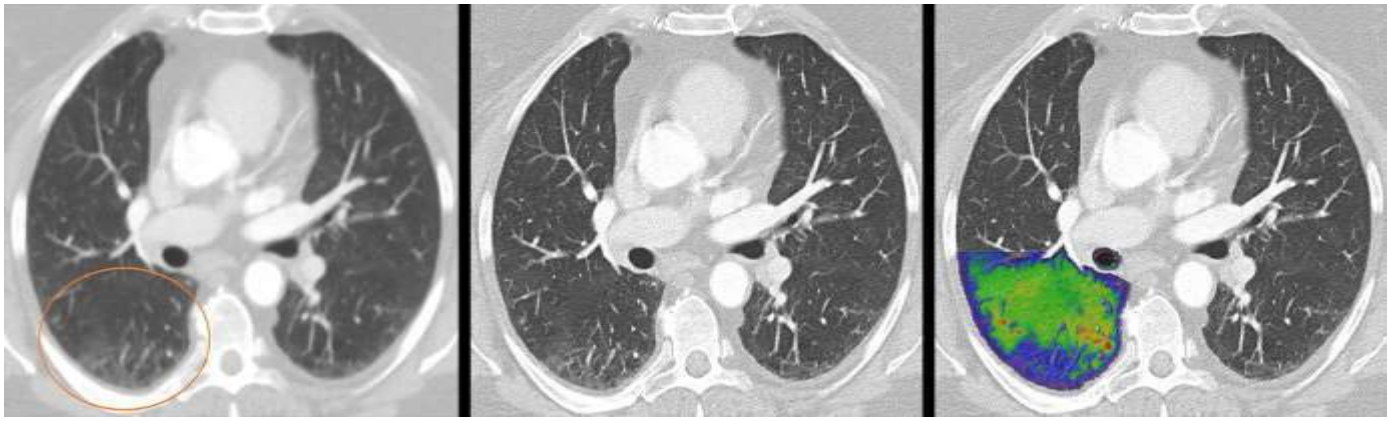

- is a newer CT technology that uses **two different X-ray energy levels** to distinguish materials that appear similar on standard single-energy scans.
- By measuring how materials attenuate X-rays at these different energy levels, →DECT can create detailed material maps, differentiate tissues, identify substances like calcium or iodine, and generate virtual **monochromatic images**, → improving diagnostic accuracy and offering personalized treatment planning.

# Photon-Counting CT

- In 2021 Siemens Healthineers introduced the first photon-counting CT scanner *NAEOTOM Alpha* equipped with two *Vectron* X-ray tubes and two *QuantaMax* detector arrays acquiring 144 slices
- The latest advancement in CT detector technology is the development of photon-counting detectors.

**Photon-Counting CT (PCCT):** is an advanced CT technology that uses specialized semiconductor detectors to directly count individual X-ray photons and measure their energy, providing clearer images with reduced noise and artifacts.

- These systems use semiconductor materials such as cadmium telluride (CdTe) to directly convert absorbed X-ray photons into electrical charges, with the signal strength proportional to the energy of the photon.
- CdTe is composed of high atomic number elements, making it highly effective at absorbing X-rays and offering excellent detection efficiency.
- Its relatively large bandgap of 1.5 eV also allows operation at room temperature with minimal thermal noise.



**Lung imaging** Photon-counting CT allows visualization of detailed structures (centre) with simultaneous functional imaging (right). For comparison, a conventional CT image is shown on the left.

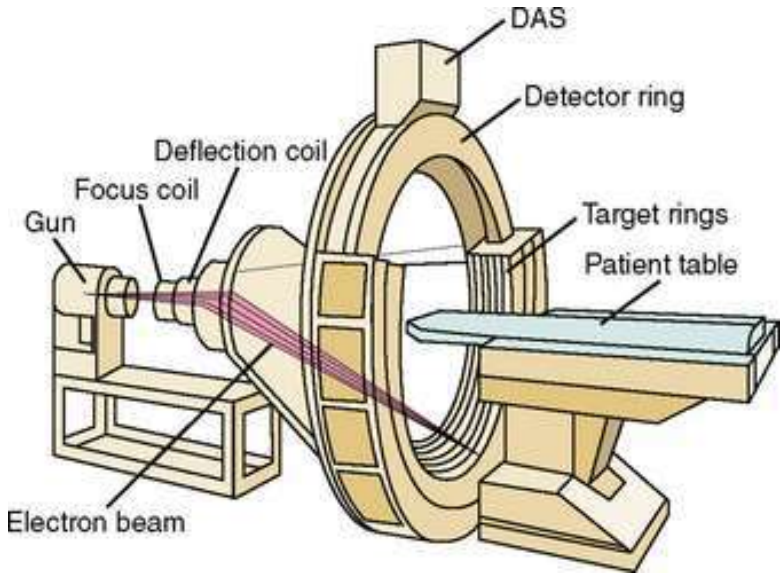
**Technique**:

- X-ray photon → absorbed in the CdTe crystal via the photoelectric effect—energy→ is transferred to an electron, → ionizes atoms and generates electron-hole pairs.

- Charge collection electrodes separate these charges, and after amplification, the resulting signal is sorted into energy bins based on pulse height. → This enables ***every photon*** to be individually counted and classified by energy at ***each pixel***. As a result, photon-counting
- CT reaches an even **better performance** than dual-energy CT at material decomposition, and improves overall signal-to-noise ratio and dose efficiency.

**Parameters:**

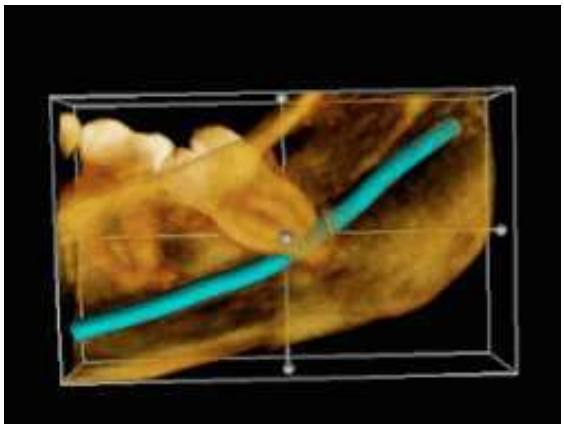
- (6cm collimation width)
- Gantry rotation time down to **0.25s**



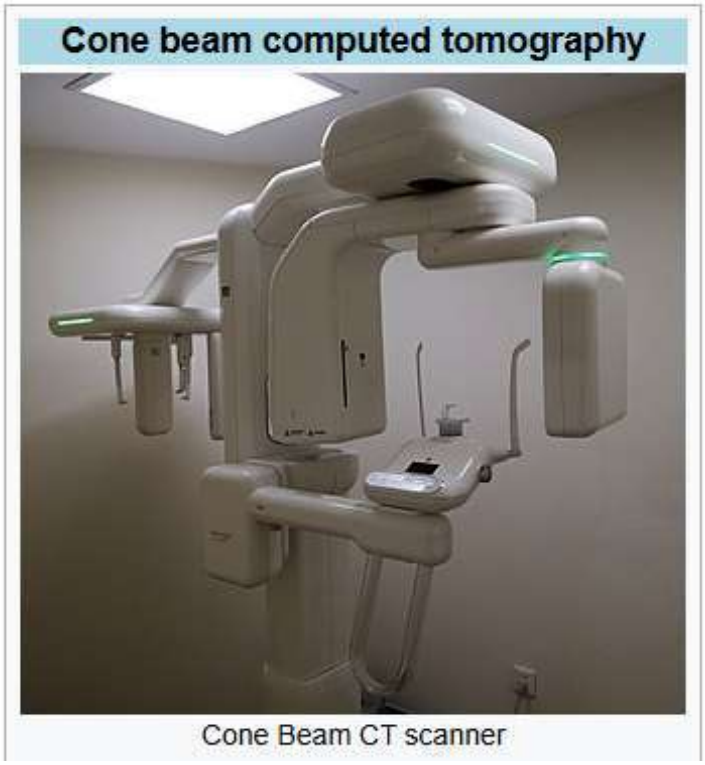
# Cone-Beam CT 1998

- **Cone beam computed tomography** (or **CBCT**, also referred to as **C-arm CT**, **cone beam volume CT**, **flat panel CT** or **Digital Volume Tomography** (DVT))
- is a medical imaging technique consisting of X-ray computed tomography where the X-rays are divergent, forming a cone **used in dental imaging.**

- CBCT has become increasingly important in treatment planning and diagnosis in :
  - implant dentistry,
  - ENT,
  - orthopedics,
  - and interventional radiology (IR),

Impacted wisdom tooth seen on CBCT



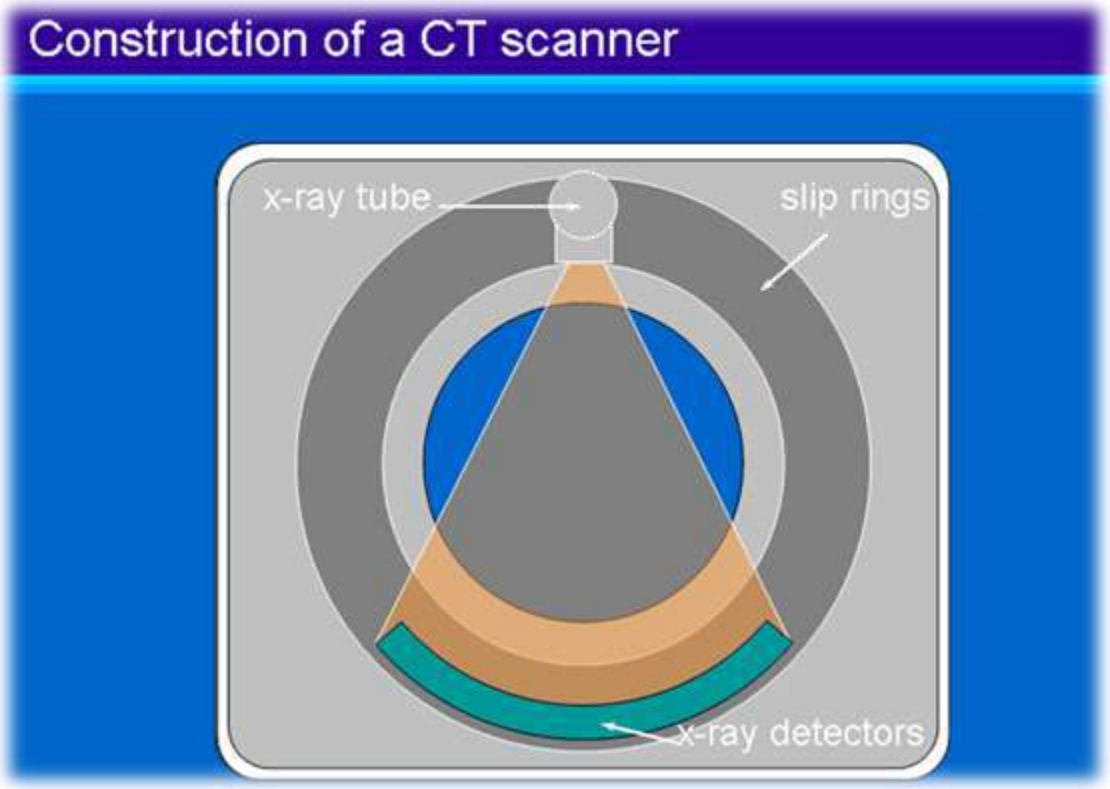

Cone Beam CT scanner

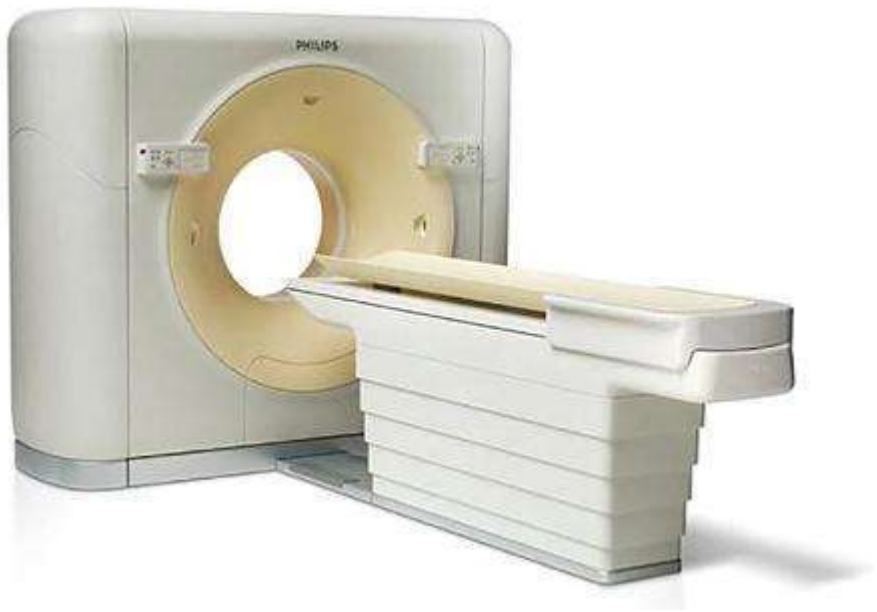
# CHAPTER 3

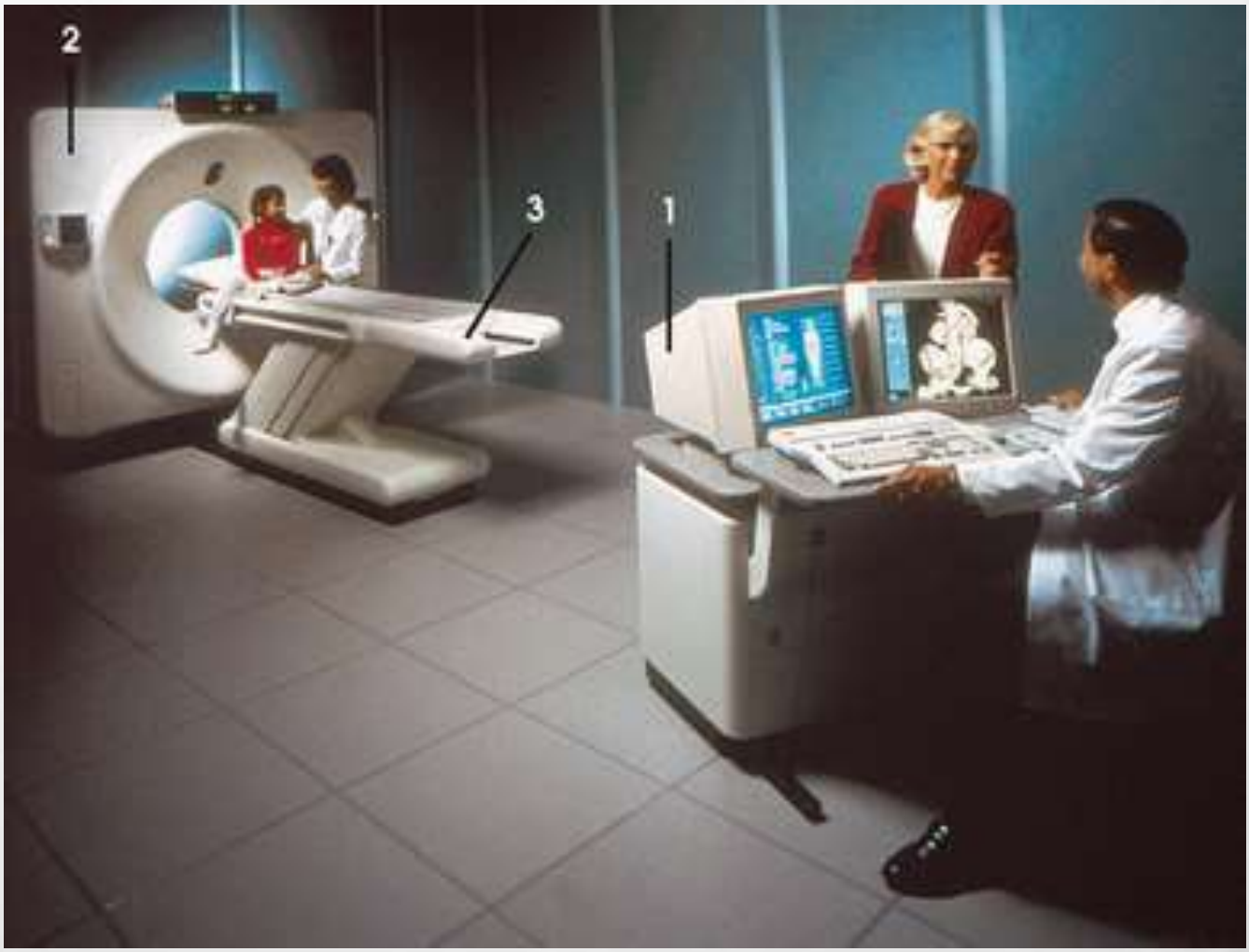
# BASICS OF CT WORK

Simply CT is composed of :

- Rotating **X-ray tube** , as a source of CT
- Rows of **detectors** , receiving X-ray after it passed through the body
- Computer unit receive data and forming image.






**Components of a CT scanner:**

*1,* computer and operator's console;

*2,* gantry;

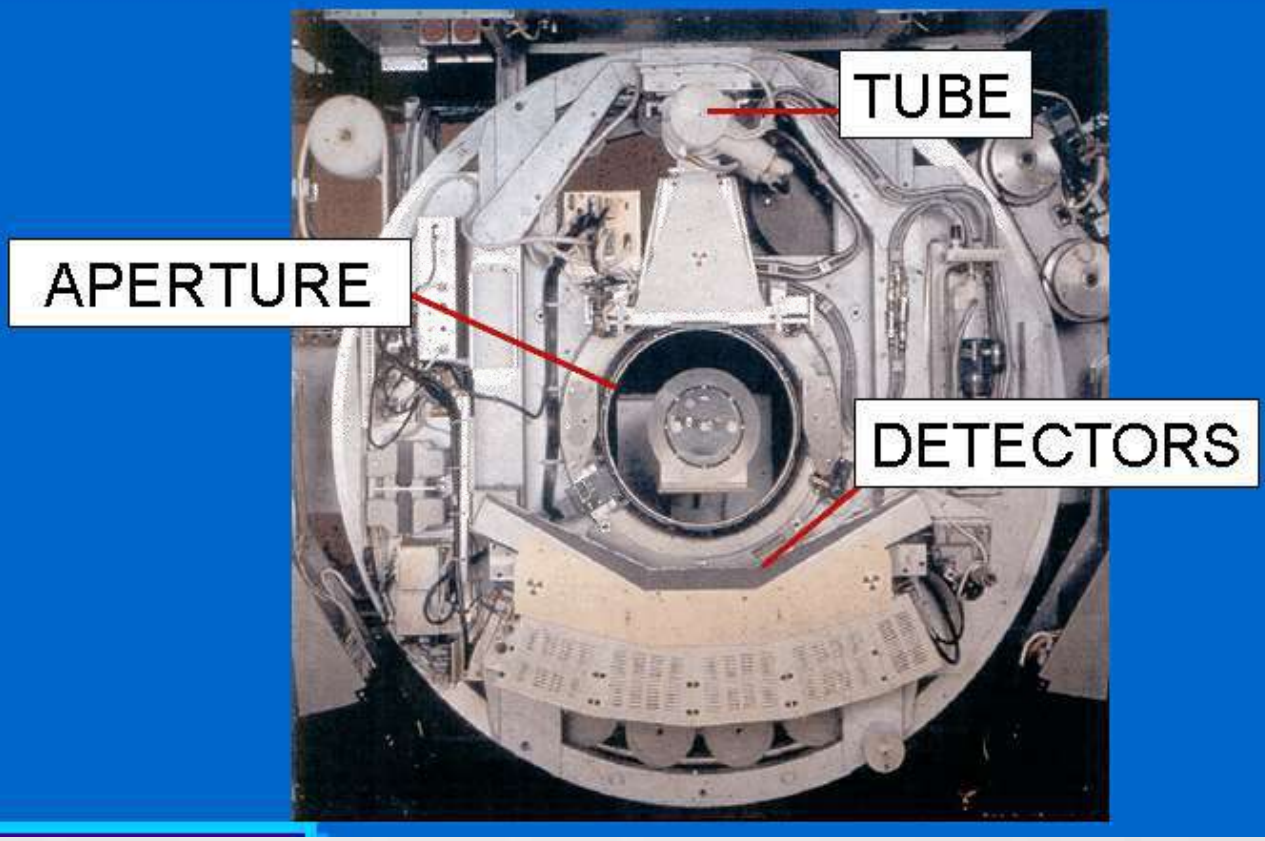
*3,* patient table.

(Courtesy GE Medical Systems, Waukesha, WI.)

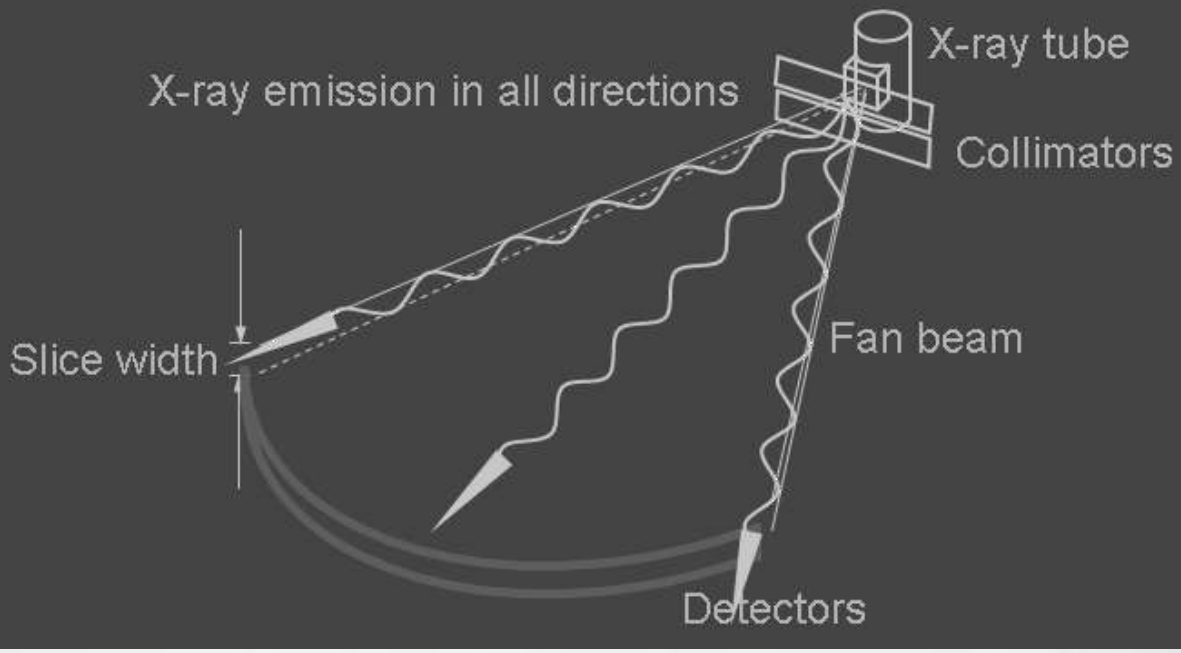
**CT operator's console**, workstation for three-dimensional image manipulation, and power injector control panel.


**CT Injector**

## In practice

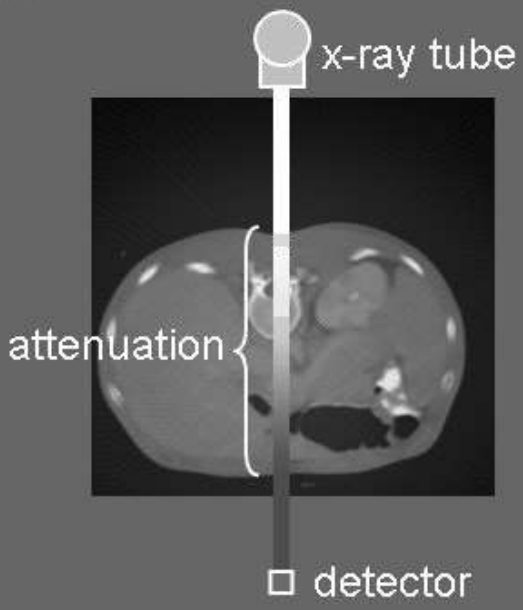


## Data acquisition



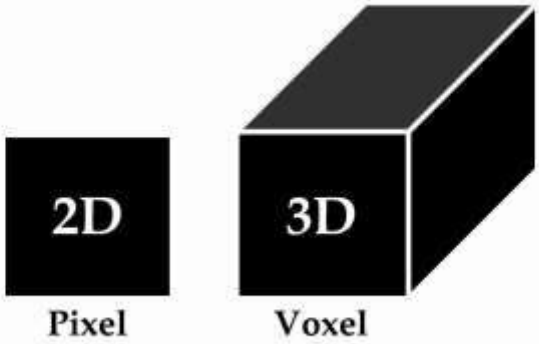

## What are we measuring?

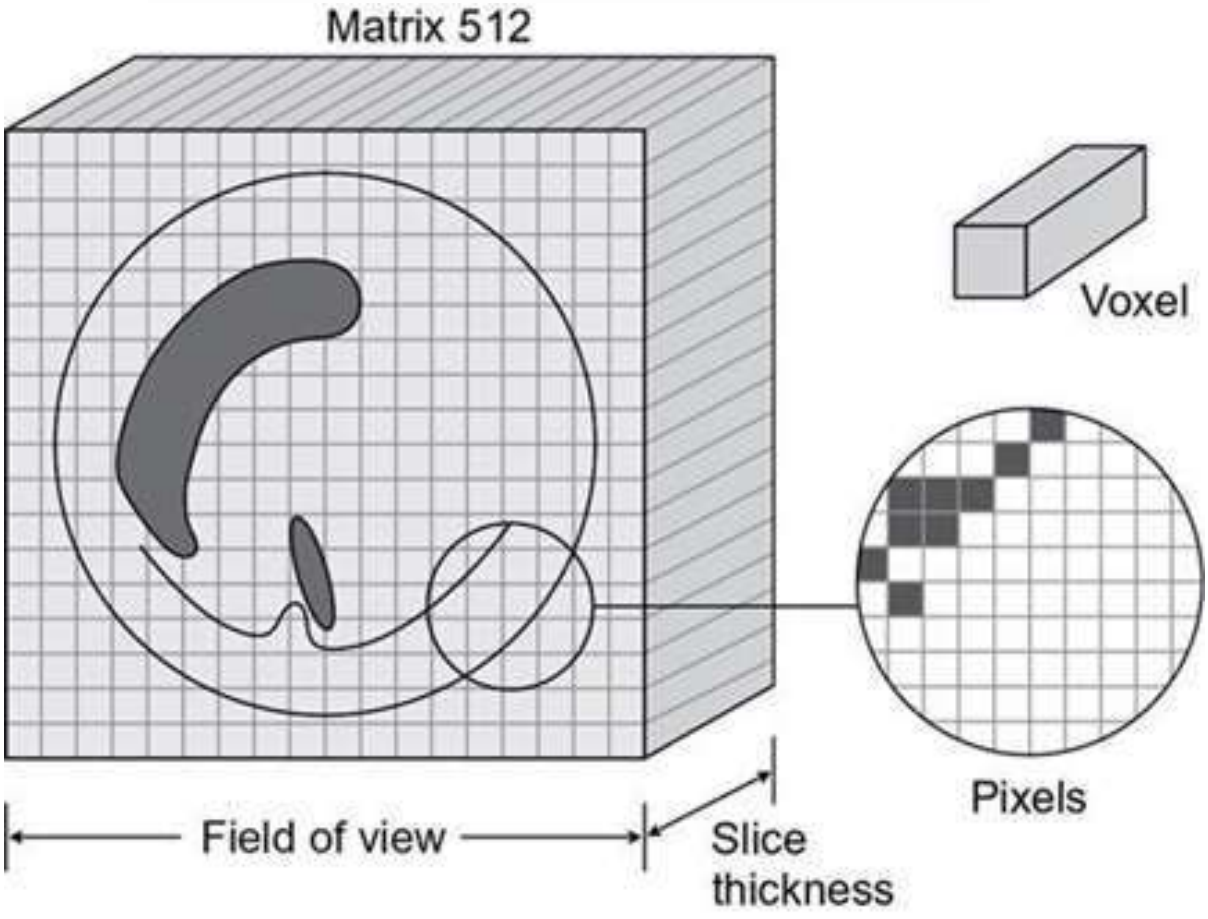
- The average linear attenuation coefficient, μ, between tube and detectors
- Attenuation coefficient reflects the degree to which the x-ray intensity is reduced by a material



# Image Reconstruction

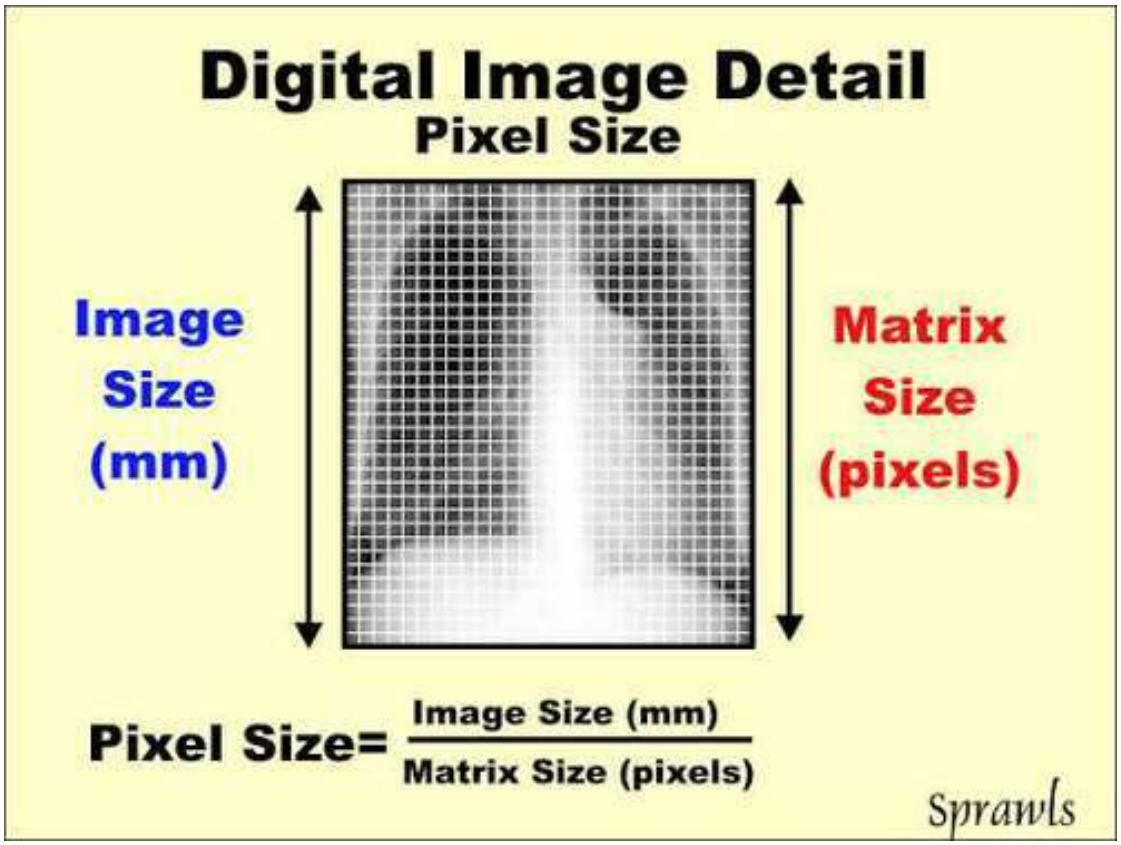
| PIXELs | VOXELs |
|---|---|
| picture elements | volume elements |
| tiny squares (2D) | tiny cubes (3D) |
| building blocks making up a slice | building blocks making up a chunk (many slices stacked together) |



What's in the pixel value?
Anything! Depends on the imaging modality.

| MODALITY | PIXEL VALUE |
|---|---|
| camera / webcam | visible light reflected by objects |
| CT | Hounsfield Unit / CT Number |
| PET | radiotracer uptake |

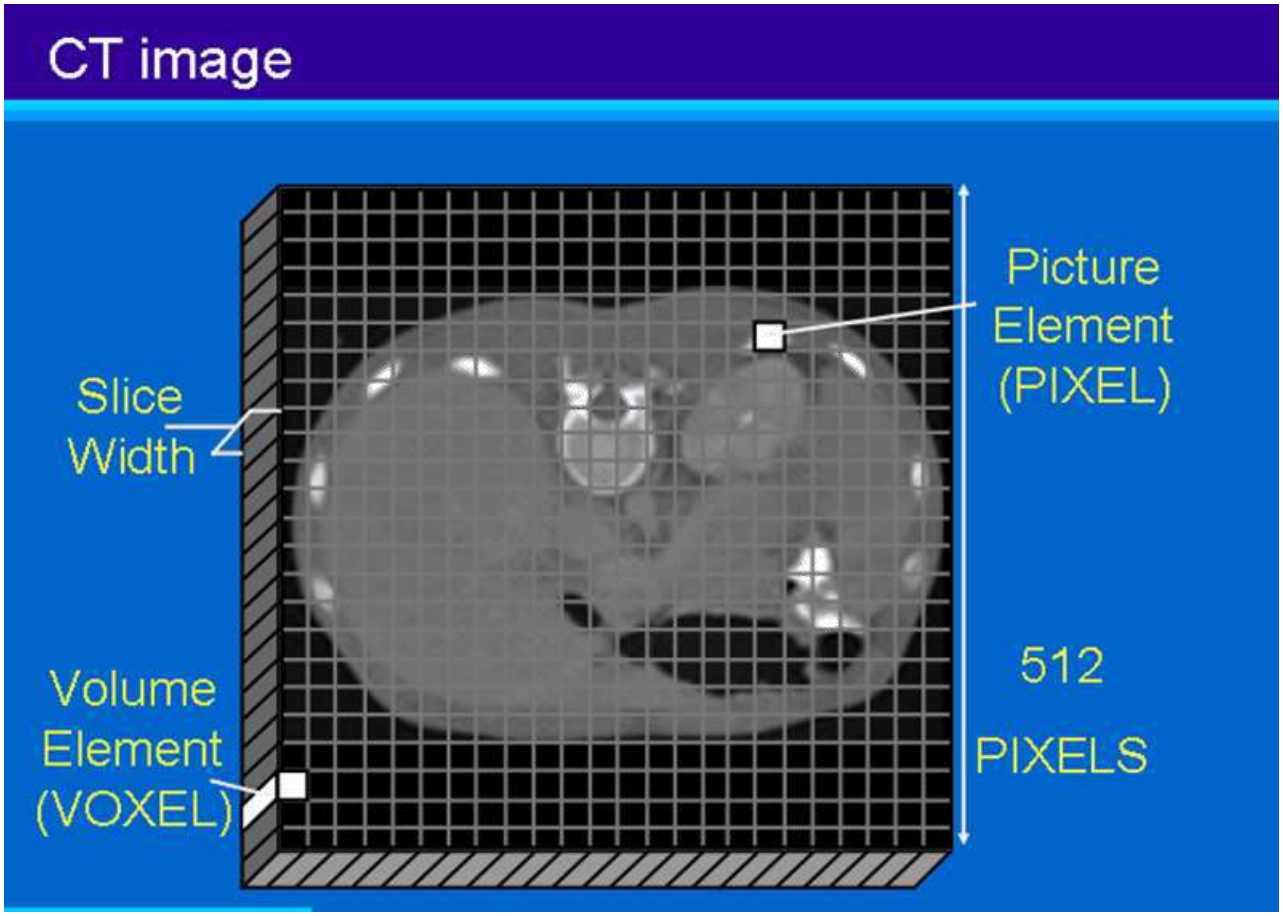


## Image Reconstruction



The Computer system receive data and forming image filtering it and improve image quality.

- The mechanism of image formation in CT depends on the receptors measuring the X-rays coming through a slice of the patient in different positions.
- The slice through which X-rays pass is divided into tiny blocks known as **voxels** or volume elements.
- The reading of any one receptor is a **measure of the attenuation** in different voxels along the path of a particular ray.
- Attenuation measurements are used to quantify the fraction of radiation removed in passing through a given amount of specific material of thickness.



## CT numbers

- Each **pixel** of the image matrix contains a number
- It represents the **X-ray attenuation** in the corresponding voxel of the object.
- This number represents the **CT number** which is actually a measure of the average linear attenuation coefficient (μ), between tube and detectors.

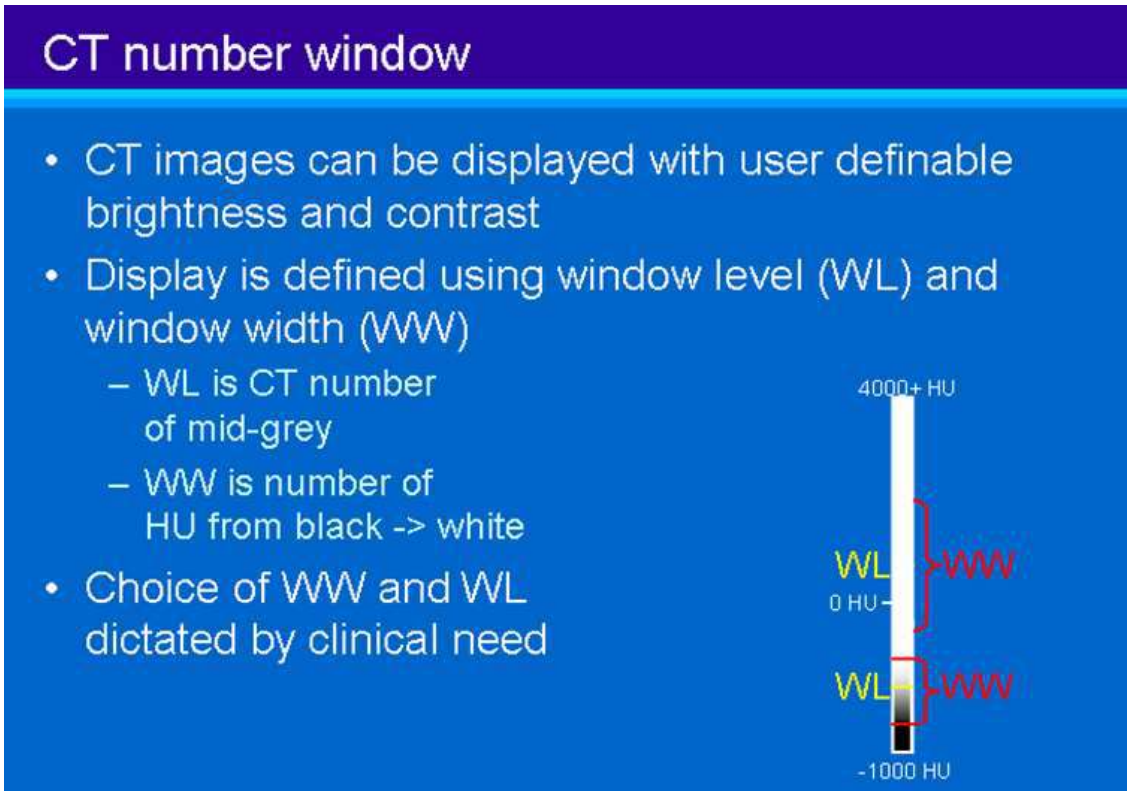
**Attenuation coefficient =** the degree to which the X-ray intensity is reduced by a material that is being imaged. The linear attenuation coefficient (μ) of each voxel is determined by

١.Voxel composition

٢.Voxel thickness

٣.Quality of the radiation beam

The computer calculates linear attenuation coefficient of each pixel and further converts it to new digital number which is known as CT number.



## Average Hounsfield units (HU) for selected substances

| Tissue | CT Number (HU) |
|---|---|
| Bone | +1000 |
| Liver | 40-60 |
| White mater | -20 to -30 |
| Grey mater | -37 to -45 |
| Blood | 40 |
| Muscle | 10-40 |
| Kidney | 30 |
| CSF | 15 |
| **Water** | **0** |
| Fat | -50 to -100 |
| Air | -1000 |

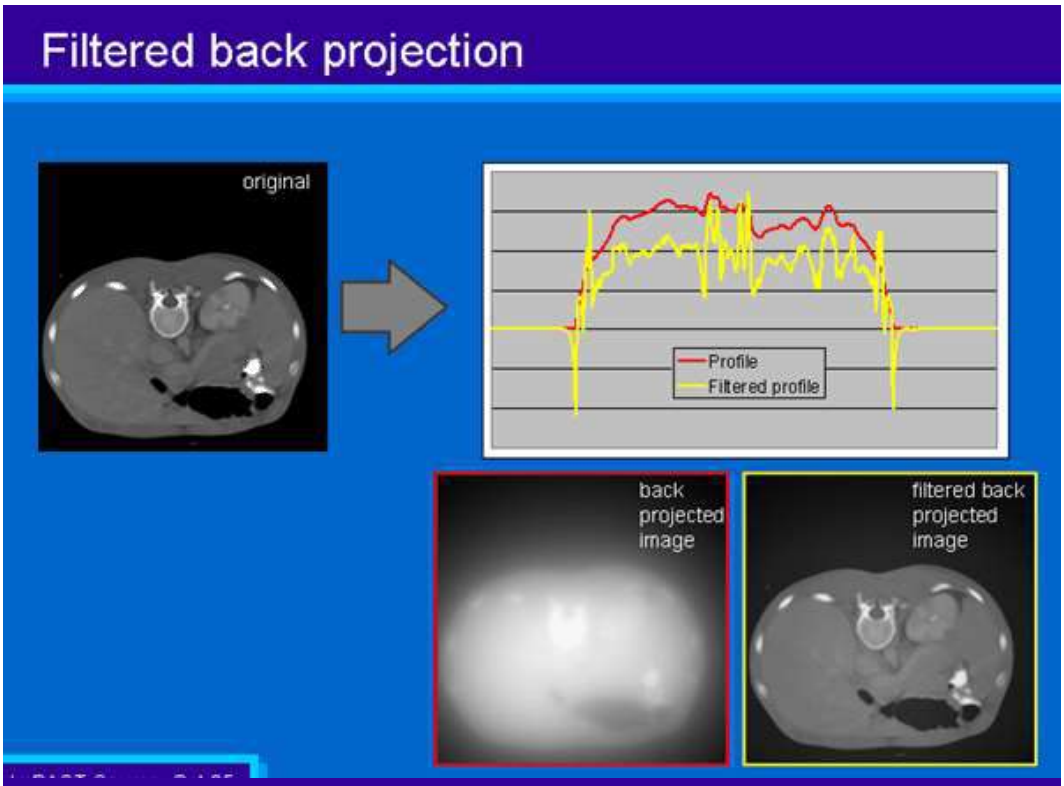
## WINDOW WIDTH AND WINDOW LEVEL

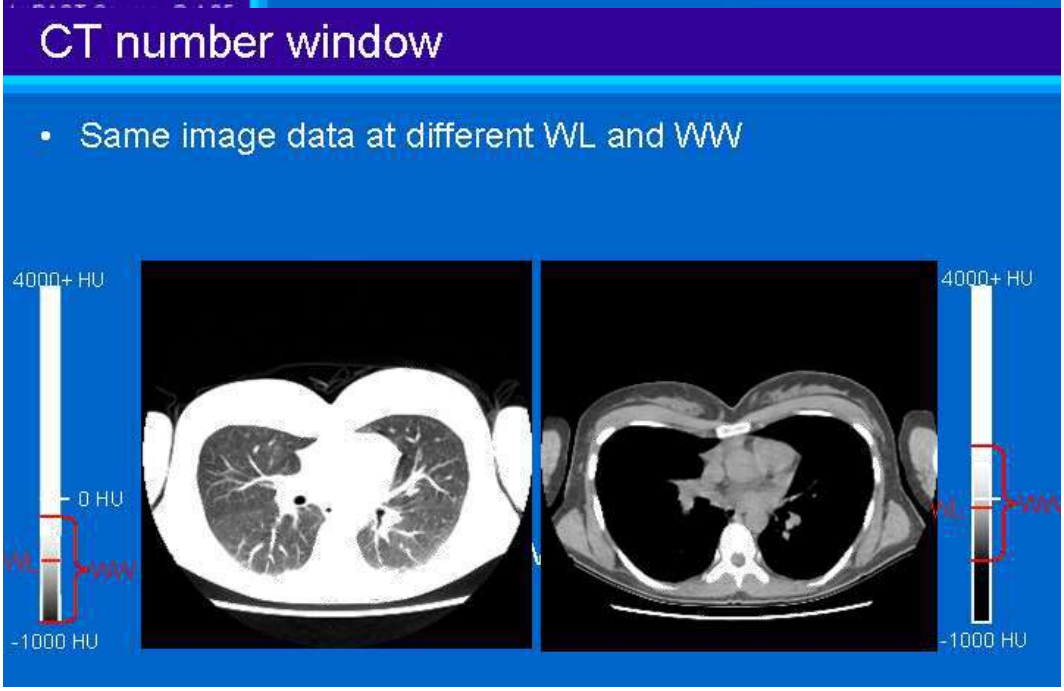
| CT Examination | Width | Level |
|---|---|---|
| Brain | 190 | 50 |
| Skull | 3500 | 500 |
| Orbits | 1200 | 50 |
| Abdomen | 400 | 35 |
| Liver | 175 | 45 |
| Mediastinum | 325 | 50 |
| Lung | 2000 | -500 |
| Spinal Cord | 400 | 50 |
| Spine | 2200 | 400 |

## Reconstruction process

The computer reconstructs an image, a matrix of μ-values for all voxels in a slice perpendicular to the rotation axis.

**Thousands of equations** are required to calculate the linear attenuation coefficients of all the pixels in the image matrix. In order to achieve this task at a fast speed without compromising the accuracy, various reconstruction algorithms are used.



**The number of photons per pixel** is dependent on many factors:

(a) **Quantity and quality** of **X-ray beam** which in turn depends on mAs and kVp, respectively

(b) **Detector efficiency**:

The number and efficiency of detectors

(c) **filtration**:

Number of photons absorbed in the path of the beam

(d) **Pixel and voxel** size

(e) **Scan time**

**In traditional (CT), a high number of photons, approximately 10,000 photons per pixel, are typically required to minimize noise and ensure a sufficient signal-to-noise ratio in the image.**

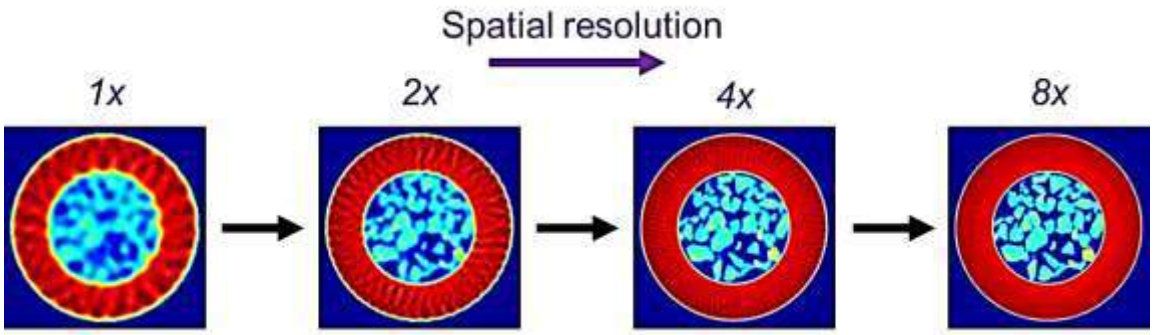
## CT Resolution

- Resolution has two components; **spatial** and **contrast** resolution.
- These two parameters are related to one another
- Also related to the radiation dose absorbed by the detector (i.e. quantum mottle/noise).

(a) **Spatial Resolution**

Spatial resolution = the ability of an imaging system to differentiate between two closely placed objects.

- The factors which determine high contrast spatial resolution include scanner design (size of focal spot of X-ray tube, size of detector, magnification), computer reconstruction and display.
- *Spatial resolution is a function of pixel size;* ***smaller pixel size*** *confers better spatial resolution.*
- ***Thinner slice thicknesses*** *also allow better spatial resolution,* → *thus spatial resolution is also affected by voxel size.*
- *Anatomical details that do not lie totally within a slice thickness may not be resolved completely, thereby producing the partial volume averaging artefact.*




*Spatial = مكاني

(b) **Contrast Resolution**

Contrast resolution = ability to distinguish one soft tissue from another irrespective of size or shape.

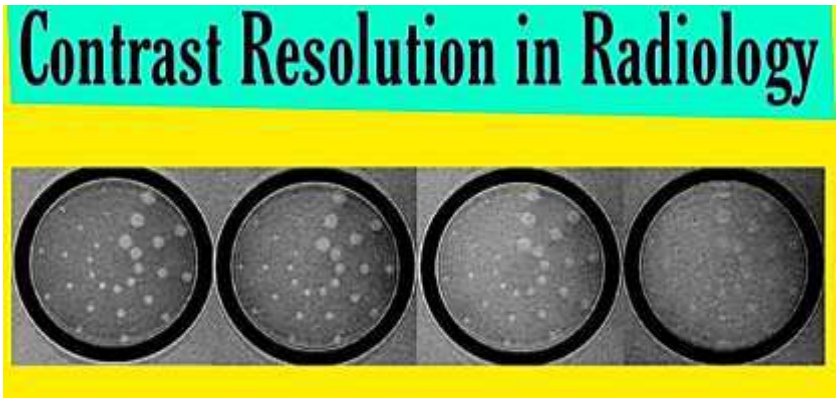
- It may also be defined as the ability of an imaging system to display an image of an object that is only marginally different in density from its adjacent tissue.

- *The absorption of X-rays in tissue is characterized by the X-ray linear attenuation coefficient, which is a function of* ***X-ray energy*** *and the* ***atomic number of the tissue****.*

- *In CT, absorption of X-rays by the patient is determined also by the mass density of the body part.*

- The ability to image low-contrast objects with CT is limited by the size and uniformity of the object and by the noise of the system.

- Hence while imaging a low contrast body part like abdomen, the noise in the system has to be kept low, whereas imaging of high contrast structures like lung accepts a higher noise in the system while preserving anatomical information. Use of iodinated contrast media is another method of enhancing the contrast within the system.



## Detector type

### XENON

Pressurised xenon gas

↓

Ionisation

↓

Signal

### SOLID STATE

Scintillation

↓

Photon capture

↓

Light

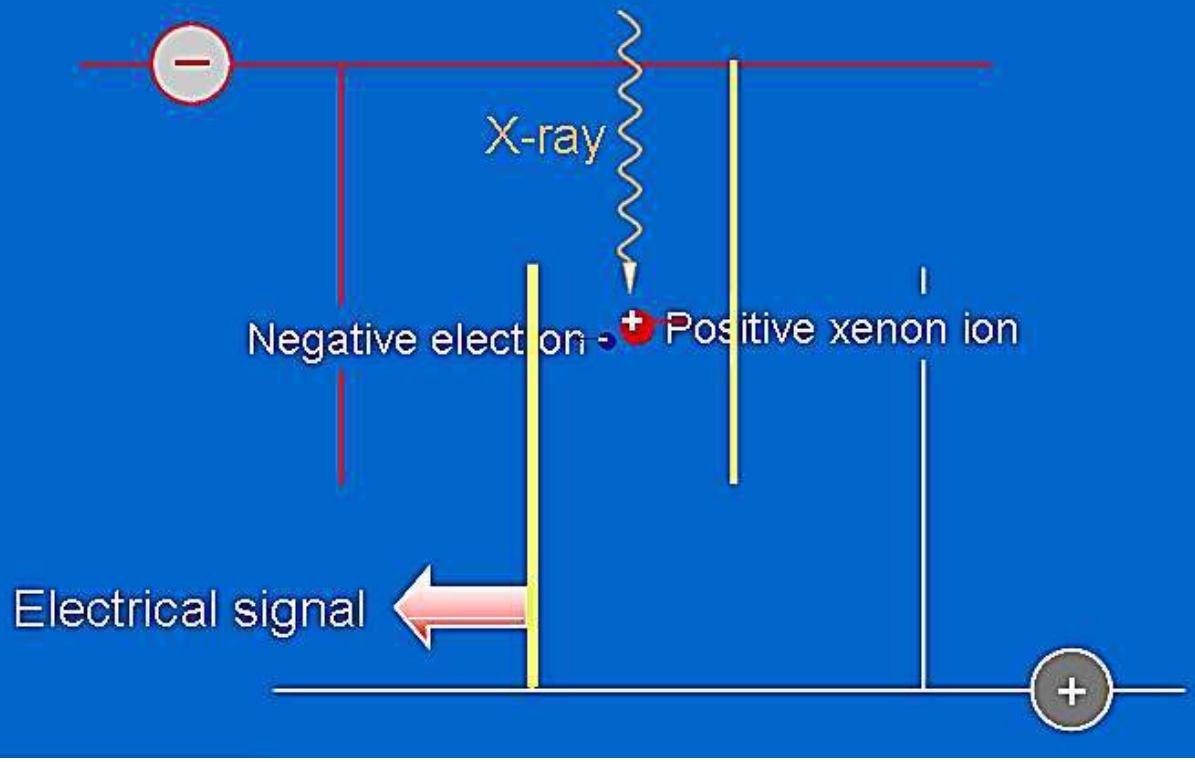
↓

Photo-diode

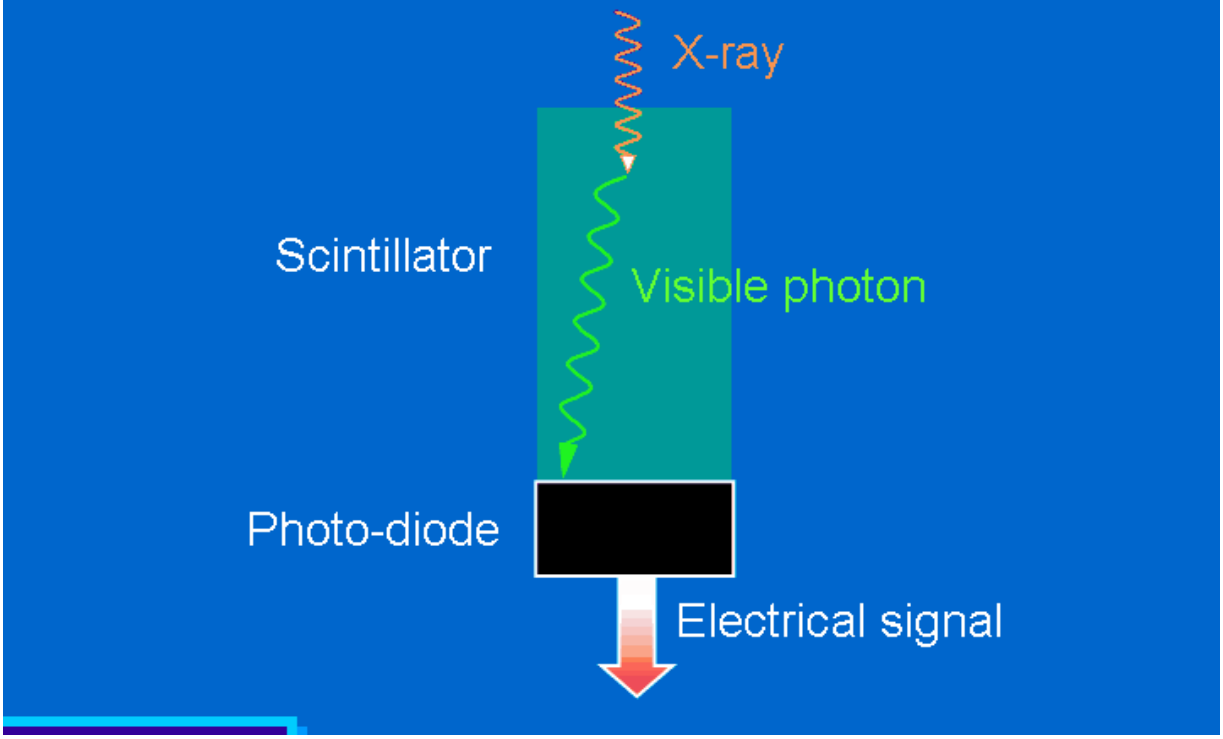
↓

Signal

## Xenon detectors



## Ceramic scintillators

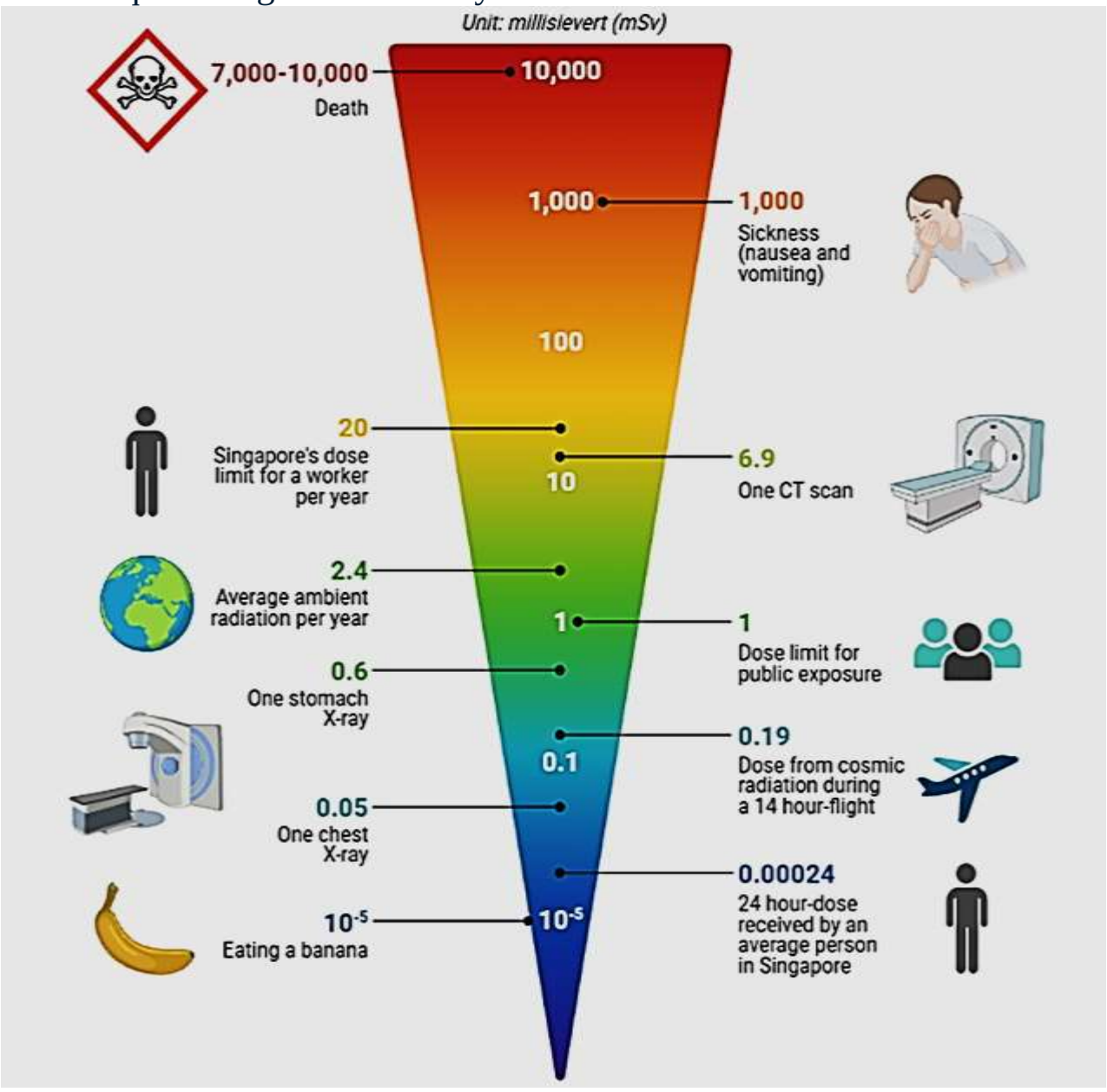


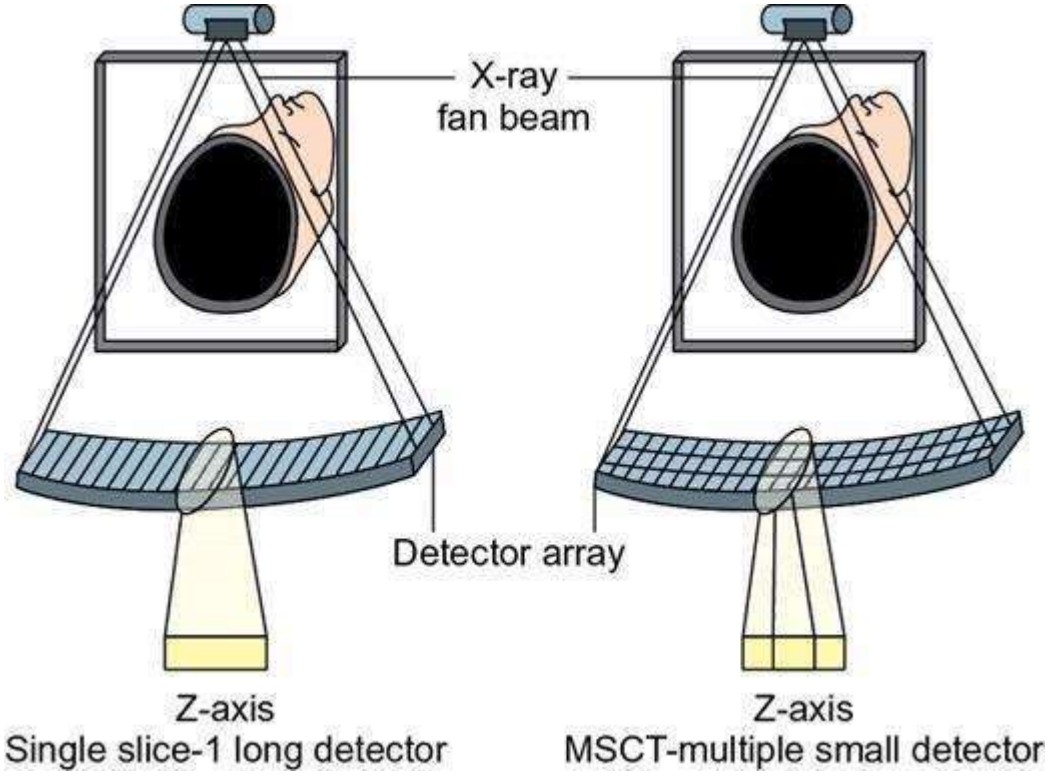

## Xenon vs. solid state

- Xenon - Single detector chamber sub-divided by electrodes
- Solid state - Detector array made up of individual elements

## Image Quality and Radiation Dose

- High quality image generation is indispensable for obtaining maximum diagnostic information from the CT images used in medical imaging.
- The discernibility of diagnostically important structures in a CT image defines image quality.
- **High quality images** usually use higher radiation dose to the patient.
- Should understand image quality assessment tools in CT to optimize low radiation dose in a way that it is consistent with image quality of adequate diagnostic efficacy.






## Advantages of MDCT

١.Faster and simultaneous acquisition

٢.Reduced scanning time

٣.Reduced gantry rotation time (0.5–0.8 s)

٤.Rapid table translation

٥.Larger anatomical coverage

٦.Better tube loading capacity

### Two essential features of MDCT technology

١.Improved scan speed

٢.Isotropic imaging

# CHAPTER 4

# CT ARTIFACTS

# CT Artefacts

- **Artifact: Unreal image abnormality or distortion**
- Artifacts are commonly encountered in clinical CT and may obscure or simulate pathology.
- There are many different **types of CT artifacts**, including :

- Noise,
- Ring,
- Motion,
- Metal artifacts.

- Pseudo-enhancement
- Cone-beam,
- Helical,
- Beam hardening
- Scatter,

- Methods for reducing noise and out-of-field artifacts may enable ultra-high resolution limited field of view imaging of tumors and other structures.

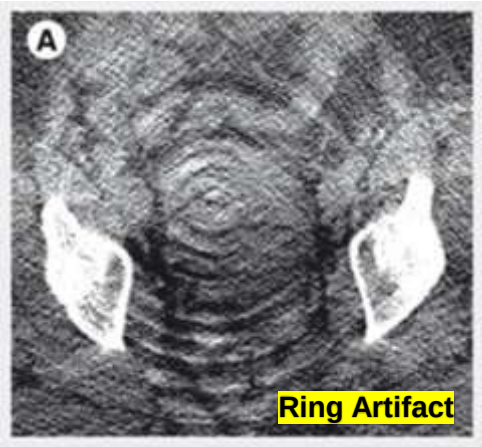
**For Ideal CT Image:**

- High radiation dose, → high photon counts,
- monochromatic x-rays,
- infinite detector resolution,
- perfect detectors,
- No motion and
- No scatter,

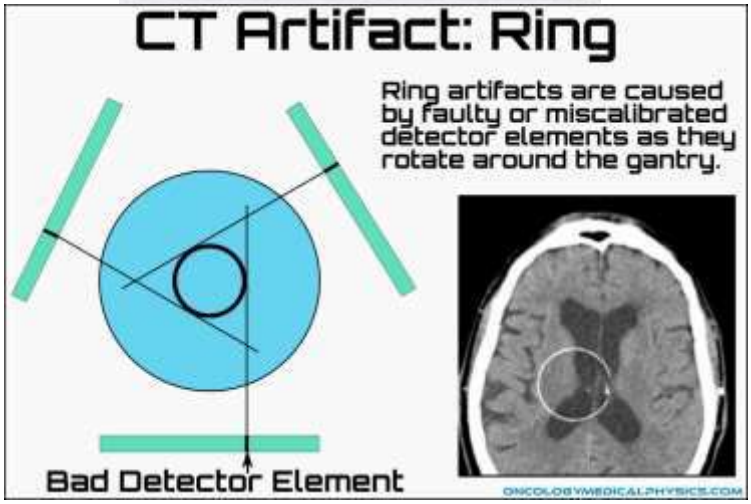
→ CT images would be a **perfect**.

If any of those conditions are not met, → **artifacts will occur**.

## 1- Ring artifact




- A mis calibrated or defective detector → a bright or dark ring centered on the center of rotation.
- This can sometimes simulate pathology.
- *Usually*, **recalibrating the detector** → is sufficient to fix this artifact,
- *occasionally* the detector itself needs to be replaced.

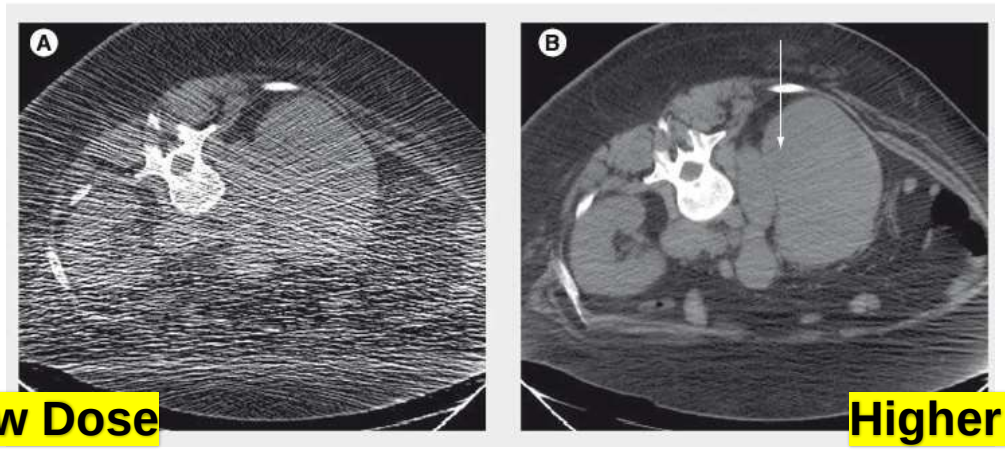



## 2- Noise

- Poisson noise is due to the statistical error of low photon counts → random, thin, bright & dark streaks that appear preferentially in the direction of greatest attenuation.
- With noise:

➔ **High-contrast objects**, such as <u>bone, may still be visible</u>,

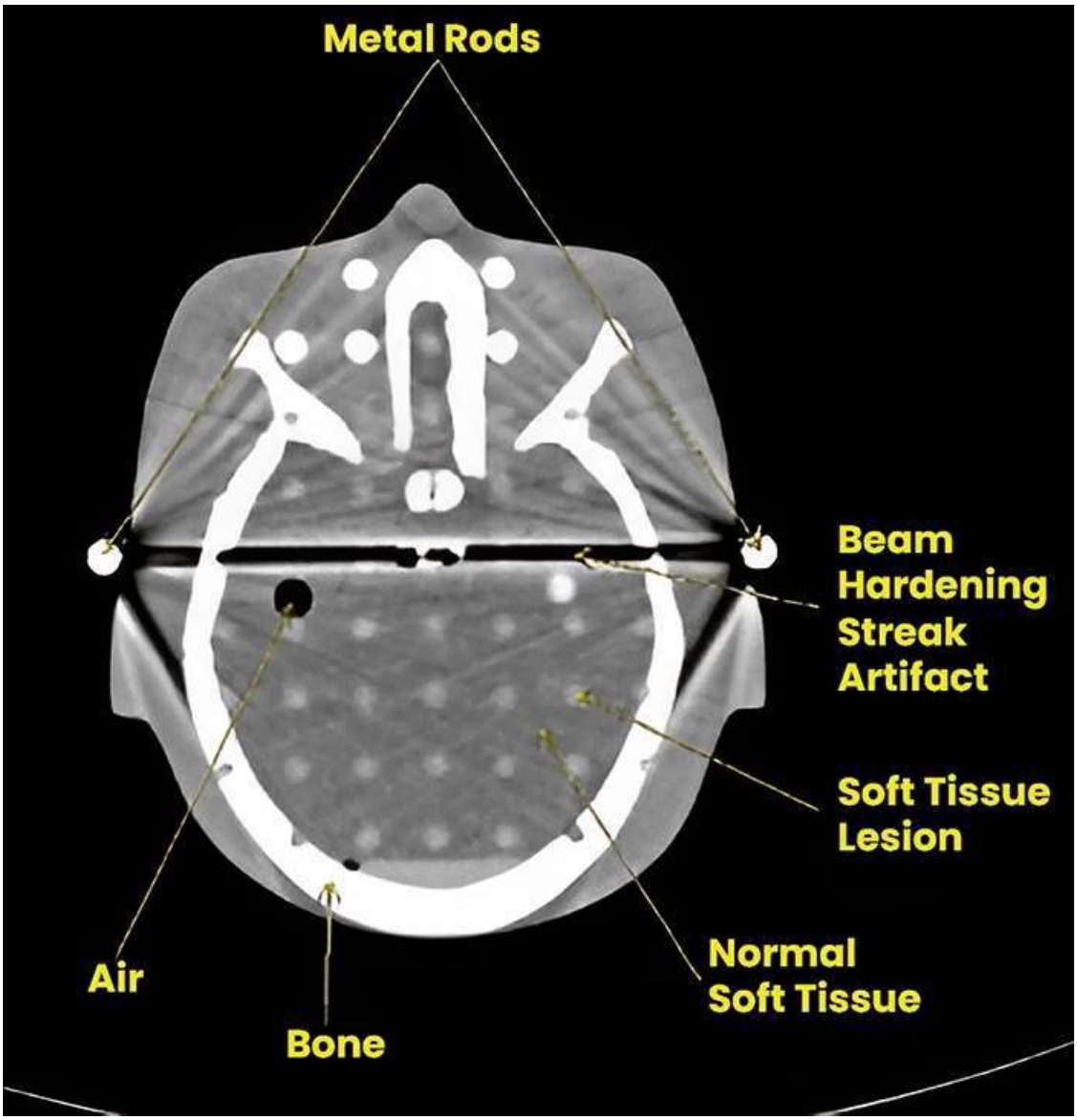
➔ **Low-contrast soft-tissue** boundaries may be obscured




**Low Dose** **Higher dose**

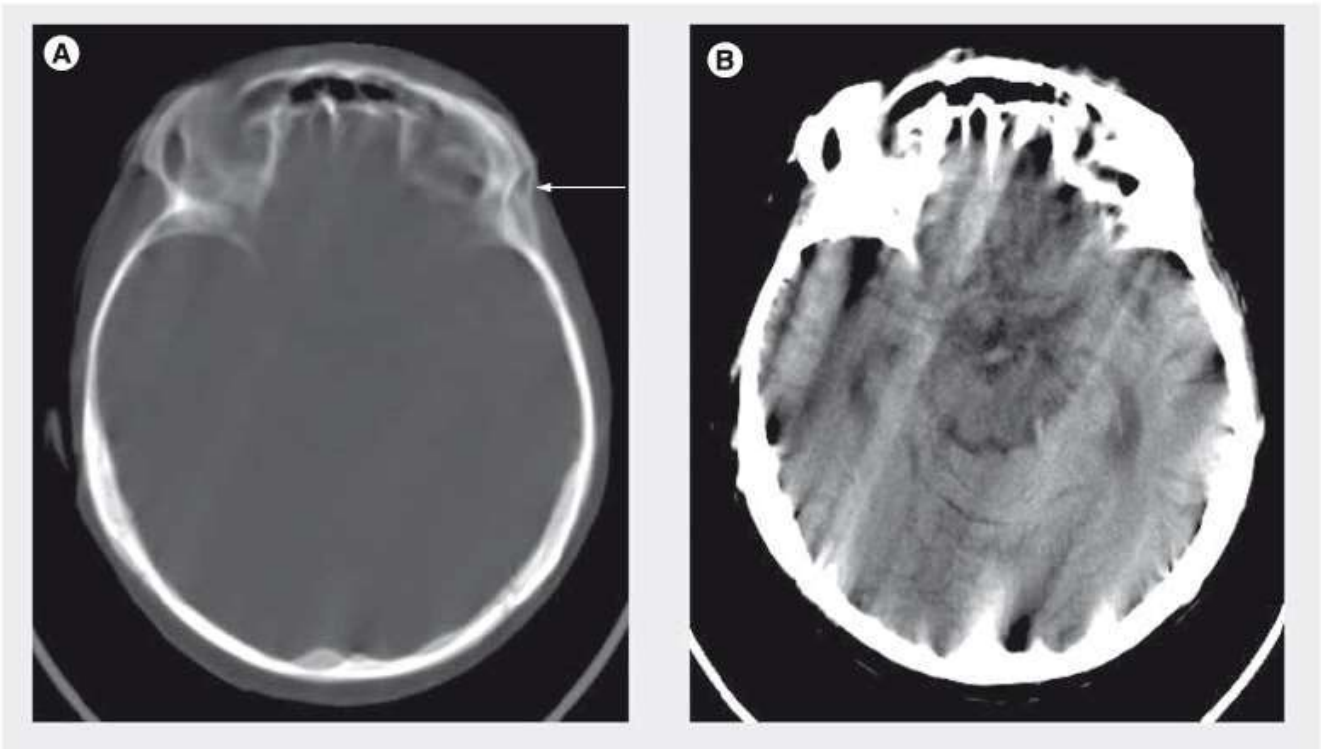
## 3- Beam Hardening & Scatter

- Beam hardening and scatter are different mechanisms
- Both produce **Dark streaks** between **two high attenuation objects**, such as *metal, bone, iodinated contrast or barium*.
- They can also produce ***dark streaks along the long axis*** of a single high-attenuation object.
- **Bright streaks** are seen adjacent to the dark streaks.
- These artifacts are a particular problem in the posterior cranial fossa and with metal implants.



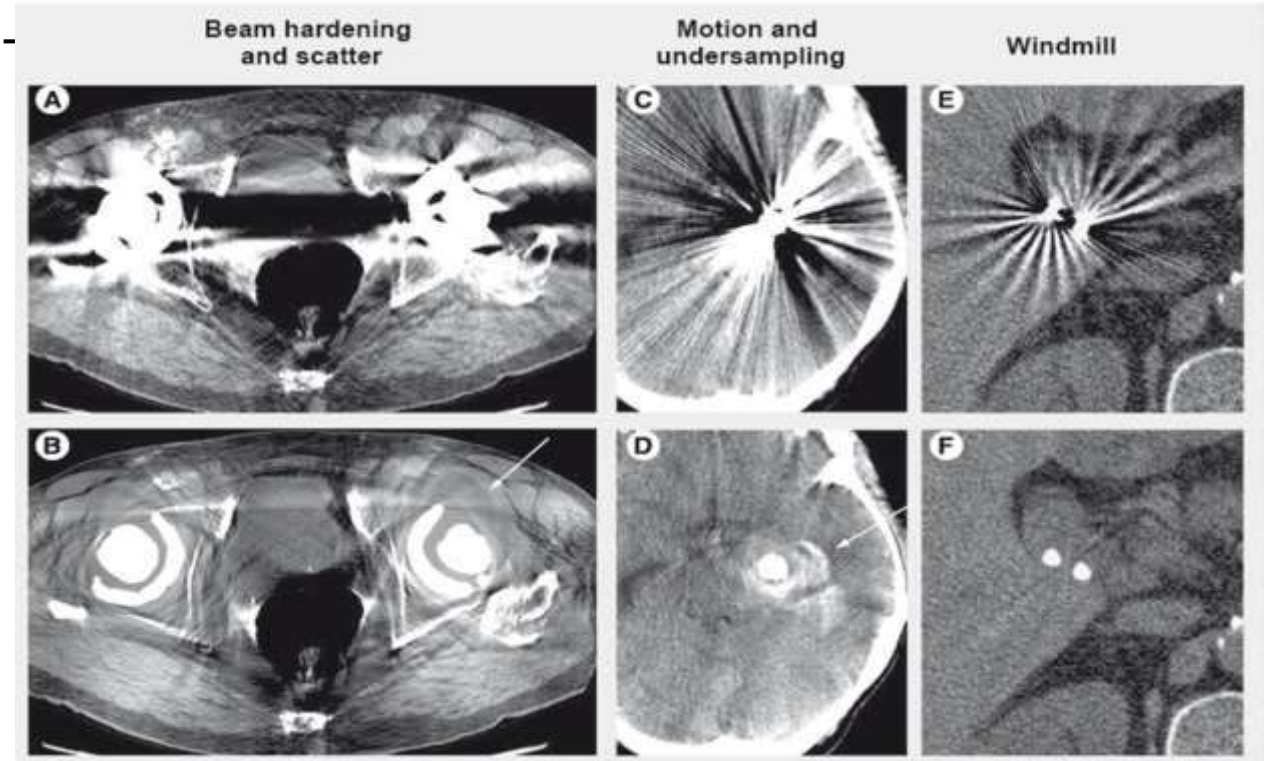
## 4- Motion Artifact

- Motion (patient, cardiac, respiratory or bowel) → **blurring** and **double** images.
- **Faster scanners** → reduce motion artifact (patient has less time to move during the acquisition). This can be accomplished with **faster gantry rotation** or **more x-ray sources**.
- **More detector rows** → allow a greater volume to be imaged in a single gantry rotation, thus → increasing the distance between step-off artifacts from motion on coronal or sagittal reformats.
- **Rigid body motion artifacts** (mainly a problem with head CT,) can be reduced using special reconstruction techniques.



## 5- Metal Artifact

- Metal streak artifacts are extremely common,
- seen in 21% of scans.
- They are caused by multiple mechanisms, related to :
  - **Metal itself** **or** - **Metal edges**.
- **The metal itself:** causes beam hardening, scatter effects and Poisson noise. Beam hardening and scatter → **dark streaks** between metal with surrounding bright streaks
- **The metal edges:** cause streaks due to under sampling, motion, cone-beam and windmill artifacts.
- Metal artifacts are more with **high atomic number metals**, such as iron or platinum, and less with **low atomic number metals**, such as titanium.
- In some cases (i.e., **dental fillings** on head CT scan), → patient positioning or gantry tilt can angle the metal outside of the axial slices of interest.
-

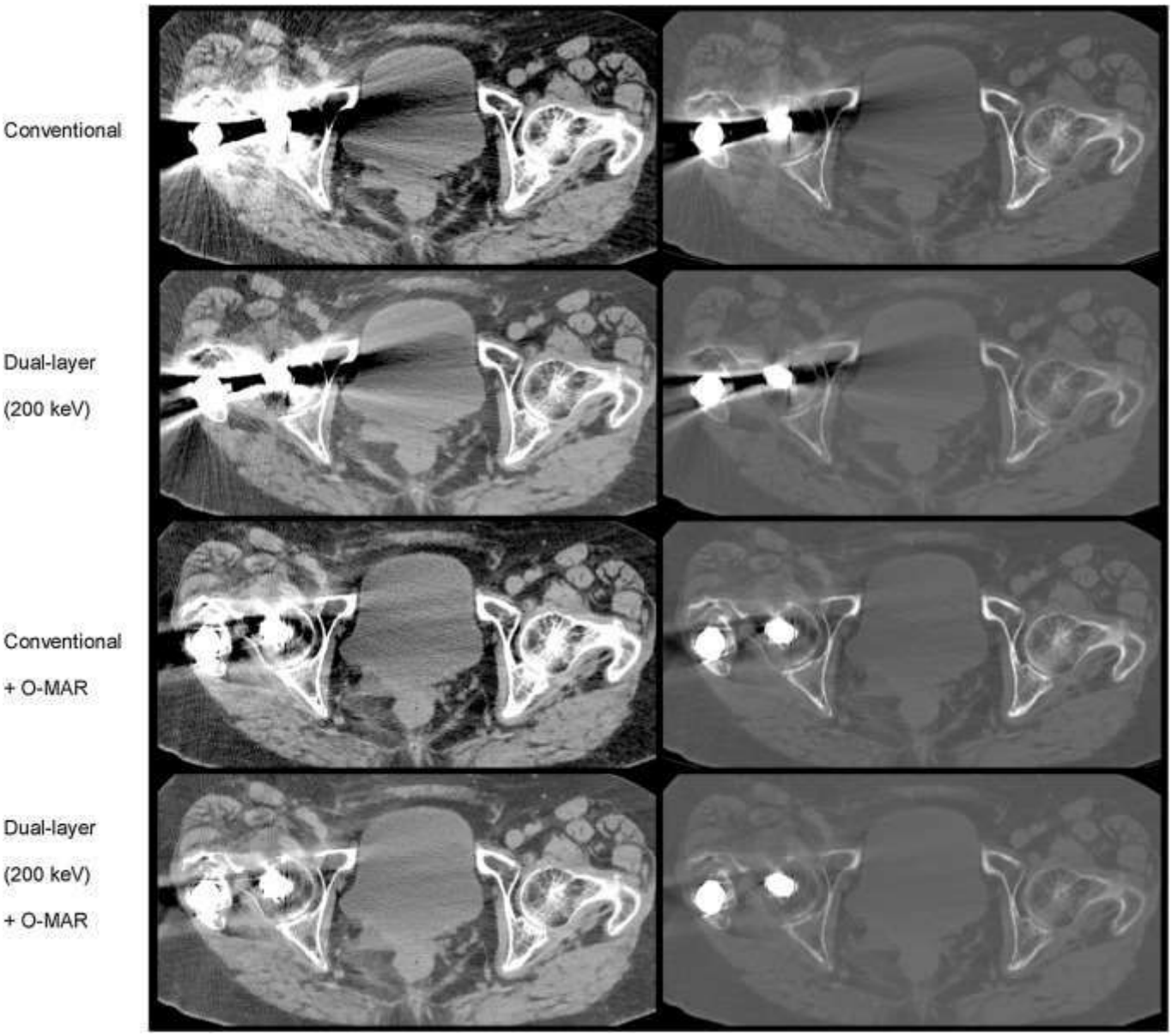


## Metal Deletion Technique:

- Computerized tomography (CT) algorithm that reduces metal artifacts by modifying and replacing the corrupted data in the projection images

Several techniques have been proposed for metal artifact reduction

**It reduces many different types of metal artifacts, and can reveal new findings**.



## Patient Related Artifacts:

**١.Metallic artefacts**

**٢.Incomplete projection:** This is due to the incomplete inclusion of the body part in the scan field. This results in incomplete information reaching the detectors which eventually produces streaking and shading artefacts.

- **It can be reduced by** complete inclusion of body part, increasing the **FOV (Field of View)** and removal of extra parts from field of view for, *e.g. keeping the arms above head while scanning the chest to avoid their incomplete inclusion in the scanning field.*

**٣.Patient motion:** Voluntary (as MSK Movements) or involuntary as cardiac respiration. .

**In pediatric patients and coronary angiography, the usage of cardiac gating for are a methods of reduction of patient motion artefact .**

# CHAPTER 4

# CONTRAST MATERIALS

# What is Contrast ?

**A material given to enhance visualization of a lesion or structure**

## Contrast

## Positive

**i.e. Opaque**

Most of Contrast

## Negative

**i.e. Lucent**

Air or Cos

# Contrast

## Routes of Administration

- Oral
- IV
- Rectal

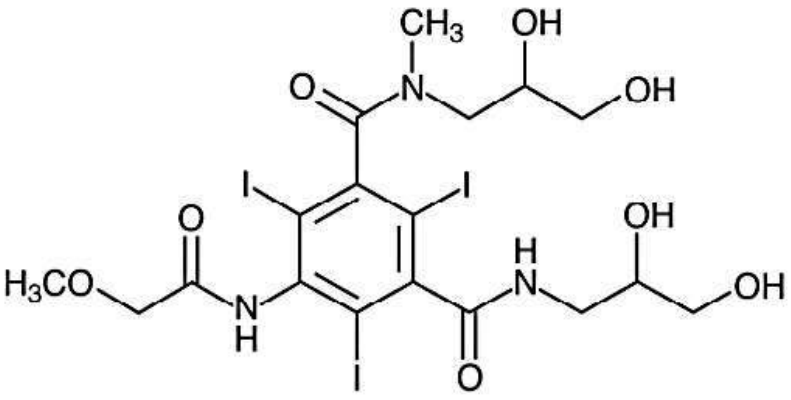
| Types of contrast media | | | | |
|---|---|---|---|---|
| **Contrast** | **Trade name** | **Ionic/Non-ionic** | **Iodine content** | **Osmolarity** |
| Diatrizoate | Gastrografin | Ionic | 300mg/ml | 1550 |
| Ioxaglate | Hexabrix | Ionic | 320mg/ml | 580 |
| Ultravist | Iopromide | Non-ionic | 300mg/ml | 607 |
| Optiray | Ioversal | Non-ionic | 300mg/ml | 651 |
| Isovue 370 | Iopamidol | Non-ionic | 370mg/ml | 796 |
| Omnipaque 300 | Iohexol | Non-ionic | 300mg/ml | 672 |
| Ioxilan 350 | Oxilan | Non-ionic | 350mg/ml | 695 |
| Iotrol 300 | Iotrolan | Non-ionic | 300mg/ml | 310 |
| Visipaque 320 | Iodixanol | Non-ionic | 320mg/ml | 290 |


# CT Contrast Materials


# CT Contrast Composition

## Iodine

Iopromide has the following structural formula:




## ICM = Iodinated Contrast Material

# I C M

## INDICATIONS AND USAGE

### 1 Intra-Arterial Procedures

- **Arteriography:** Cerebral and peripheral in adults
- **Coronary & Cardiac** CT imaging in adults

& in pediatric patients aged **2 years and older**

### 2 Intravenous Procedures

- **Excretory urography :** in adults and pediatric patients aged 2 years and older
- **Contrast Enhanced Computed Tomography (CT)** of :
  - the head and body (intrathoracic, intra-abdominal, and retroperitoneal regions)
  - For the evaluation of **neoplastic** and non-neoplastic lesions in adults and **pediatric patients** aged **2 years and older**
- **Contrast mammography** to visualize known or suspected lesions of the breast in adults, as an adjunct following mammography and/or ultrasound

# I C M

## DOSAGE & ADMINISTRATION

## 1 Important Dosage and Administration Information :

**• ULTRAVIST is for intra-arterial or intravenous use only and must not be administered intrathecally**

**Specific concentrations and presentations of ULTRAVIST are recommended for each procedure.**

• **INSTRUCTIONS OF USE:**

- **Hydrate patients**, prior to and following the administration.

• Individualize the volume, concentration, and injection rate according to the specific **dosing tables**

• **Visually inspect** for particulate matter and/or discoloration, whenever solution and container permit.

**➔ Do not administer it if particulate matter (including crystals) and/or discoloration is observed or if containers are defective.**

• **Use aseptic technique** for all handling and administration .

• **Warm :** to body temperature before administration.

• It can be used with **0.9% Sodium Chloride** Injection in a power injector.

**➔ Do not mix or inject ULTRAVIST in intravenous administration lines containing other drugs or total nutritional admixtures**.

• **Discard any unused portion** remaining in the single-dose container following initial use.

**Table 1: Recommended Concentrations and Volume of ULTRAVIST to Administer per Single Injection for Selected Injection Sites of Intra-Arterial Procedures in Adults**

| Imaging Procedure | | Cerebral Arteriography | Peripheral Arteriography | Coronary Arteriography and Left Ventriculography | Visceral Angiography and Aortography |
|---|---|---|---|---|---|
| Concentration (mg Iodine per mL) | | 300* | 300* | 370* | 370* |
| Intra-Arterial Injection Sites | Carotid Arteries | 3 mL to 12 mL | - | - | - |
| | Vertebral Arteries | 4 mL to 12 mL | | | |
| | Aortic Arch Injection (four vessel study) | 20 mL to 50 mL | | | |
| | Subclavian or Femoral Artery | - | 5 mL to 40 mL | - | - |
| | Aortic Bifurcation (distal runoff) | | 25 mL to 50 mL | | |
| | Right Coronary Artery | - | - | 3 mL to 14 mL | - |
| | Left Coronary Artery | | | 3 mL to 14 mL | |
| | Left Ventricle | | | 30 mL to 60 mL | |
| | Aorta and Major Abdominal Branches | - | - | - | Individualize a volume approximately equal to the blood flow and related to the vascular and pathological characteristics of the specific vessels being studied. |
| Maximum Total Dose | | 150 mL | 250 mL | 225 mL | 225 mL |

*Use single-dose vials or pharmacy bulk package.

| Table 2: Recommended Concentrations and Volume of ULTRAVIST for Intravenous Procedures in Adults | | | | |
|---|---|---|---|---|
| Imaging Procedure | Excretory Urography | Contrast Computed Tomography | | Contrast Mammography |
| Concentration (mg Iodine per mL) | 300* | 300‡ | 370‡ | 300‡ or 370‡ |
| Excretory Urography | 1 mL/kg body weight | - | - | - |
| CT of Head | - | 50 mL to 200 mL | 41 mL to 162 mL | - |
| CT of Body - Single Phase Contrast<br>Bolus Injection<br>Rapid Infusion | - | 50 mL to 200 mL<br>100 mL to 200 mL | 41 mL to 162 mL<br>81 mL to 162 mL | - |
| CT of Body – Multiple Phase Contrast | - | 50 mL to 200 mL total volume<br>Phase 1: 100% contrast,<br>Phase 2: 20% to 60% contrast,<br>using a power injector suitable for simultaneous injection of contrast and 0.9% Sodium Chloride Injection | 41 mL to 162 mL total volume<br>Phase 1: 100% contrast,<br>Phase 2: 20% to 60% contrast,<br>using a power injector suitable for simultaneous injection of contrast and 0.9% Sodium Chloride Injection | - |
| Contrast Mammography | - | - | - | 1.5 mL/kg body weight using a power injector at 2 mL/second to 4 mL/second |
| Maximum Total Dose | 100 mL | 200 mL | 162 mL | 150 mL |

*Use single-dose vials or pharmacy bulk package.
‡Use single-dose vials, pharmacy bulk package or imaging bulk package.

### 2.4 Recommended Dosage in Pediatric Patients Aged 2 Years and Older

The recommended doses in pediatric patients aged 2 years and older are shown in Table 3.

**Table 3: Recommended Concentrations and Volume per Body Weight of ULTRAVIST for Cardiac Chambers and Related Arteries, Excretory Urography, and Contrast Computed Tomography in Pediatric Patients Aged 2 Years and Older**

| Imaging Procedure | Intra-arterial | Intravenous | |
|---|---|---|---|
| | Cardiac Chambers and Related Arteries | Excretory Urography | Contrast Computerized Tomography |
| Concentration (mg Iodine/mL) | 370* | 300* | 300‡ |
| Volume (mL/kg body weight) | 1 to 2 | 1 to 2 | 1 to 2 |
| Maximum Total Dose (mL/kg) | 4 | 3 | 3 |

*Use single-dose vials or pharmacy bulk package.
‡Use single-dose vials, pharmacy bulk package or imaging bulk package.



**The safety & effectiveness of ULTRAVIST in younger than 2 years of age have not been established.**

**ULTRAVIST is not approved for use in patients younger than 2 years of age**

### 3 DOSAGE FORMS AND STRENGTHS

ULTRAVIST injection is a clear, colorless to slightly yellow, odorless solution available in two concentrations:

300 mg Iodine per mL available as

- 50 mL, 100 mL, 125 mL, and 150 mL in single-dose vials
- 200 mL and 500 mL in pharmacy bulk packages
- 200 mL and 500 mL in imaging bulk packages

370 mg Iodine per mL available as

- 50 mL, 100 mL, 125 mL, and 150 mL in single-dose vials
- 200 mL and 500 mL in pharmacy bulk packages
- 200 mL and 500 mL in imaging bulk packages

# I C M .

## Hypersensitivity Reactions

Hypersensitivity Reactions can cause **life-threatening** or **fatal** hypersensitivity reactions including :

- Anaphylaxis.
- Manifestations include respiratory arrest,
- laryngospasm,
- bronchospasm,
- angioedema,
- and shock

**Most** severe reactions develop **shortly** after the start of injection (e.g., within 1 to 3 minutes), but **delayed reactions** can also occur.

- There is **increased risk of hypersensitivity** reactions in patients with a history of previous reaction to a contrast agent and known allergic disorders

(that is, bronchial asthma, allergic rhinitis, and food allergies), or other hypersensitivities.

- **Premedication** with **antihistamines** or **corticosteroids** does not prevent serious life-threatening reactions, but may reduce both their incidence and severity.
- **Obtain a history** of allergy, hypersensitivity, or hypersensitivity reactions to iodinated contrast agents and have emergency resuscitation equipment and trained personnel available prior to contrast administration.
- **Monitor** all patients for hypersensitivity reactions.

# I C M

## WARNINGS AND PRECAUTIONS

**ULTRAVIST is not approved for intrathecal use.**

**1- Risks Associated with Intrathecal Use Intrathecal administration**, even if inadvertent, can cause :

- Death,
- Convulsions,
- Cerebral hemorrhage,
- Coma,
- Paralysis,
- Arachnoiditis,
- Acute renal failure,
- Cardiac arrest,
- seizures,
- Rhabdomyolysis,
- Hyperthermia,
- Brain edema.

**2- Acute Kidney Injury**, including renal failure:

- may occur after administration of contrast.
- **Risk factors include**:

- Preexisting Renal Insufficiency,
- Dehydration,
- Diabetes mellitus,
- Congestive heart failure,
- Advanced Vascular disease,
- Elderly age,
- Concomitant use of **nephrotoxic** or **diuretic** medications,
- Multiple myeloma or other paraproteinemia,
- **Repetitive** and/or **large doses** of contrast.

**So…….**

= Use the **lowest necessary dose** of contrast in patients with renal impairment.

= **Hydrate patients** prior to administration.

= **Do not use** laxatives, diuretics, or preparatory dehydration prior to administration.

## 3 Cardiovascular Adverse Reactions:

Contrast → increases the circulatory osmotic load → induce acute or delayed hemodynamic disturbances.

*Esp. in patients with congestive heart failure, severely impaired renal function, combined renal and hepatic disease, or combined renal and cardiac disease*,

- More when repetitive and/or large doses are administered.

-**Fatal cardiovascular reactions** have occurred mostly within **10 minutes** of ULTRAVIST injection; Like :

- **Cardiac arrest** : the main feature was.
- **Hypotensive collapse** and **shock**.
- **Cardiac decompensation**,
- **Arrhythmias**, and **Myocardial ischemia** or infarction can occur during coronary arteriography and ventriculography.
- **Pulmonary edema** in patients with heart failure.

- Use the **lowest necessary dose** of ICM in congestive heart failure patients.
- always have emergency resuscitation equipment and trained personnel.
- Monitor all patients for severe cardiovascular reactions.

**Deaths from the administration of iodinated contrast agents range from 6.6 per 1 million (0.00066 %) to 1 in 10,000 patients (0.01 %).**

## 4- Thromboembolic Events:

- Serious, & in some cases fatal,
- thromboembolic events → **myocardial infarction** and **stroke**
- Risk of thromboembolic events can be influenced by:
  - length of procedure,
  - catheter and syringe material,
  - underlying disease state, and
  - concomitant medications.

**To decrease thromboembolic events**, :

- Use meticulous (accurate) angiographic techniques and
- Minimize the length of the procedure.
- Avoid **blood remaining** in contact with syringes containing iodinated contrast agents, which increases the risk of clotting.
- Avoid angiography in patients with homocystinuria because of the risk of inducing thrombosis and embolism.

## 5- Thyroid Dysfunction in Pediatric Patients :

- Thyroid dysfunction (**hypothyroidism** or **transient thyroid suppression**) has been reported after both **single** exposure and **multiple exposures** to iodinated contrast media (ICM) in pediatric patients 0 to 3 years age.

### Risk Factors :

- Younger age,
- very low birth weight,
- prematurity,
- underlying medical conditions affecting thyroid function,
- admission to neonatal or pediatric intensive care units, and
- congenital cardiac conditions

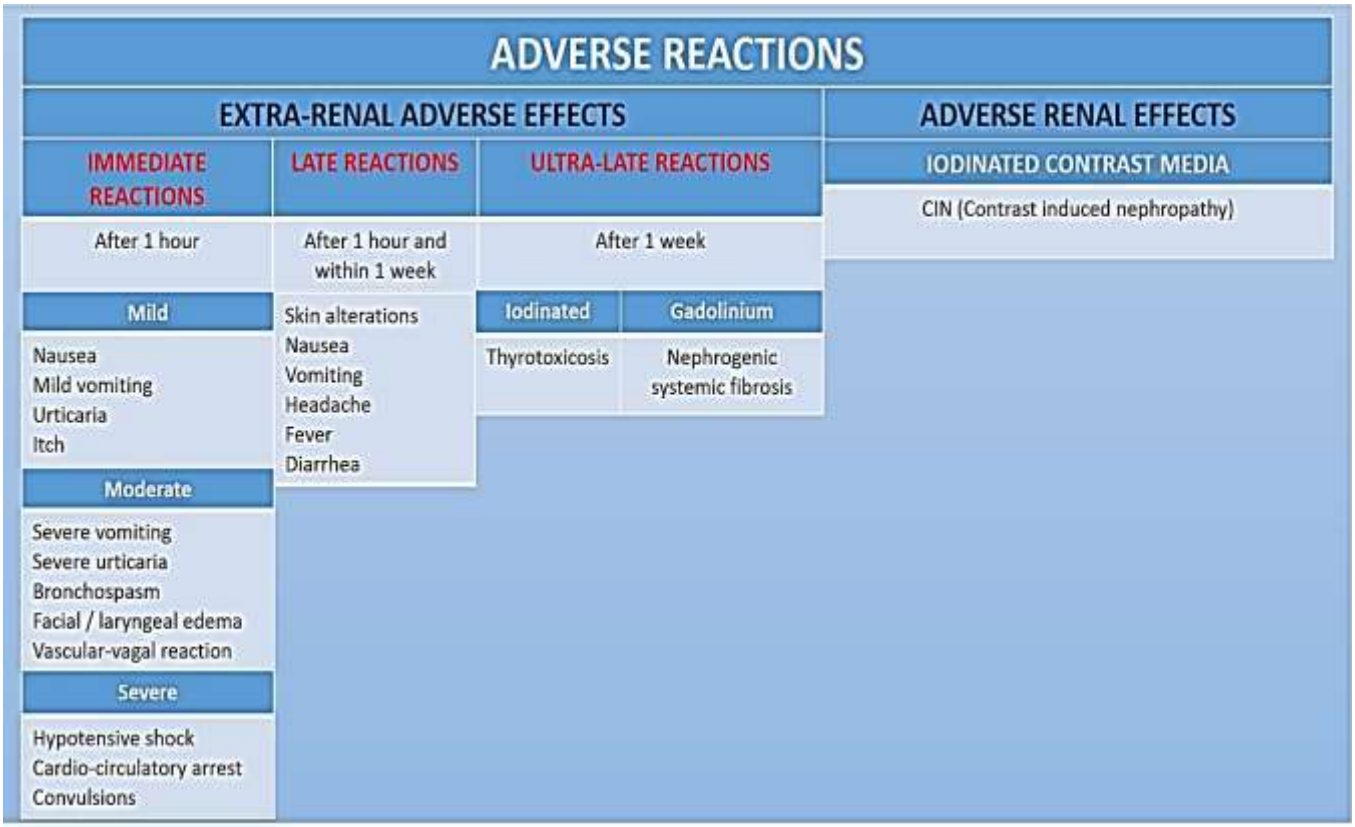
Pediatric **congenital cardiac conditions** may be at the **greatest risk** given that they often require **high doses** of contrast during invasive cardiac procedures.

An underactive thyroid during early life may be harmful for cognitive and neurological development and may require thyroid hormone replacement therapy.

After exposure to ICM, individualize thyroid function monitoring based on underlying risk factors, especially in term and preterm neonates.

6. **Hypertensive Crisis:**

- In patients with **pheochromocytoma**,
- it has occurred with iodinated contrast agents.
- Closely monitor patients when administering ICM if pheochromocytoma or catecholamine-secreting paragangliomas are suspected.
- Inject the minimum amount of ICM necessary and have measures for treatment of a hypertensive crisis readily available.



## 7 Thyroid Storm :

- in Patients with Hyperthyroidism or with an autonomously functioning thyroid nodule.

- Thyroid storm has occurred after the intravascular use of iodinated contrast agents in patients with hyperthyroidism
- Doctor should evaluate the risk in such patients before use of contrast.

## 8- Extravasation and Injection Site Reactions:

- particularly in patients with severe arterial or venous disease.

- Ex. Inflammation, blistering, skin necrosis, and compartment syndrome.
- **injection site reactions:** such as **pain** and **swelling** at the injection site can also occur.
- Ensure intravascular placement of catheters prior to injection. Monitor patients for extravasation
- Advise patients to seek medical care for progression of symptoms.

## 9- Sickle Cell Crisis :

Iodinated contrast agents may promote sickling in Patients with Sickle Cell Disease.

-**Hydrate patients** prior to administration

-use only if the necessary imaging information cannot be obtained with alternative imaging modalities.

## 10- Severe Cutaneous Adverse Reactions:

- Severe cutaneous adverse reactions (SCAR) may develop from 1 hour to several weeks after intravascular contrast agent administration.

These reactions include:

- **Stevens-Johnson syndrome** and toxic epidermal necrolysis (SJS/TEN),
- Acute generalized exanthematous pustulosis (AGEP),
- Drug reaction with eosinophilia and systemic symptoms (DRESS).

**Reaction severity** may increase and time to onset may decrease with repeat administration of contrast agent; prophylactic medications may not prevent or mitigate severe cutaneous adverse reactions.

**Avoid administering Iodinated Contrast to patients with a history of a severe cutaneous adverse reaction to It.**

**11- Interference with Laboratory Tests:** it can interfere with protein-bound iodine test.

| Table 4: Adverse Reactions Reported in >1% of Patients Receiving ULTRAVIST in Clinical Trials | | |
|---|---|---|
| System Organ Class | Adverse Reaction | ULTRAVIST N=1,142 (%) |
| Nervous system disorders | Headache | 46 (4) |
| | Dysgeusia | 15 (1.3) |
| Eye disorders | Abnormal Vision | 12 (1.1) |
| Cardiac disorders | Chest pain | 18 (1.6) |
| Vascular disorders | Vasodilatation | 30 (2.6) |
| Gastrointestinal disorders | Nausea | 42 (3.7) |
| | Vomiting | 22 (1.9) |
| Musculoskeletal and connective tissue disorders | Back pain | 22 (1.9) |
| Renal and urinary disorders | Urinary urgency | 21 (1.8) |
| General disorders and administration site conditions | Injection site and infusion site reactions (hemorrhage, hematoma, pain, edema, erythema, rash) | 41 (3.7) |
| | Pain | 13 (1.4) |



| Severity | Reaction |
|---|---|
| **Mild reactions** | Urticaria<br>Hives<br>Nausea<br>Vomiting |
| **Moderate reactions** | Facial oedema<br>Severe vomiting<br>Bronchospasm<br>Laryngeal oedema |
| **Severe reactions** | Pulmonary oedema<br>Cardiac arrythmia<br>Cardiovascular collapse<br>Respiratory collapse |

# I C M

## DRUG INTERACTIONS

### 1- Metformin :

- Iodinated contrast agents appear to increase the risk of metformin-induced lactic acidosis, possibly as a result of worsening renal function.
- Stop metformin at the time of, or prior to, administration in patients with an eGFR between 30 and 60 mL/min/1.73 m2;
- **in patients with** : hepatic impairment, alcoholism, or heart failure; or in patients who will be administered intra-arterial iodinated contrast agents. Re-evaluate eGFR 48 hours after the imaging procedure and reinstitute only after renal function is stable.

### 2- Radioactive Iodine :

ICM interfere with thyroid uptake of **radioactive iodine** (**I-131** and **I-123**) and decrease therapeutic and diagnostic efficacy.

- Avoid thyroid therapy or testing for up to 6 weeks post contrast.

3- **Drug-Laboratory Test Interactions: (**Protein-Bound Iodine Test)

- **Iodinated contrast agents**, *including ULTRAVIST*, → temporarily increase protein-bound iodine in blood.
- Do not perform protein-bound iodine test for at least ***16 days following*** administration of ULTRAVIST.

**Thyroid function tests** which **do not depend on iodine estimations**, for example, T3 resin uptake and total or free thyroxine (T4) assays are not affected.

# I C M

## SUMMARY OF USE

**IODINATE**

- Interfere with Iodine drug – Affect thyroid
- Increase Osmolarity → Need Hydration before / No Laxative
- Use with caution with any chronic patient
- Use with caution with any chronic patient
- Basic Dose 1:2 Ml/ Kg
- Take history from patient Before use of: Hypersensitivity, Chronic diseases, Drugs used
- Renal Function test is mandatory before use

Metformin
Iodine

| Before scan | Scanning | After Scan |
|---|---|---|
| ✦ Renal function test? | ✦ Type of ICM | ✦ Hydration therapy? |
| • History of renal disease or renal surgery<br>• Heart failure<br>• Diabetes<br>• Proteinuria<br>• Hypertension<br>• Gout<br>• Metformin | • Iso-osmolar ICM<br>• Low-osmolar ICM<br>• Ionic high-osmolar ICM | • Hydration to prevent PC-AKI in patients at-risk<br>• Oral hydration as the sole means of prevention for PC-AKI |
| ✦ Renal function test -> ICM administration | ✦ Dosing of ICM | ✦ Any drug for prevention? |
| • Within 7 days for patient has an acute disease<br>• Within 3 months for patient has a chronic disease with stable renal function<br>• Clinical judgment for emergency patient | • Use the minimum amount of contrast media necessary for diagnostic efficacy<br>• Use standard diagnostic dose | • Not recommend any drugs |
| ✦ eGFR cutoff for extra assessment | ✦ Scan -> Repeated scan | ✦ Blood purification therapy? |
| • Patients with eGFR < 30 ml/min/1.73m²<br>• Patients with eGFR < 45 ml/min/1.73m² in ICU or with high-risk factors | • Avoid within 72h<br>• Avoid within 48-72h<br>• Avoid within 48h<br>• Avoid within 24-48h<br>• Avoid within 24h<br>• Clinical judgment for emergency patient | • Not recommend to initiate<br>• Not recommend to change the schedule<br>• The use of ICM can be synchronized with scheduled blood purification therapy |

- Guidelines on intravenous ICM use in patients with kidney disease has suboptimal quality.
- The controversial recommendations for varying timing and protocols must be considered in future studies.

# GUIDELINES FOR USE OF ORAL CONTRAST IN ABDOMINAL IMAGING CT EXAMS

## Emergency Department:

• ED patients are typically scanned without oral contrast; however, exceptions exist and a scan can always

be protocolled with oral contrast if the radiologist feels it is indicated.

• **Oral Contrast is indicated for**:

o Leak

o Abscess

o Enterocutaneous Fistula

o Post-operative patients (regardless of the type of surgery such as GU, GI, GYN, etc.) if they are less than approximately 3-4 weeks post-operative.

• Oral contrast should be considered for pediatric patients. Particularly for bowel indications (appendicitis, colitis, diverticulitis, etc.)

• Oral contrast should be considered for those with a low BMI / weight. Particularly for bowel indications (appendicitis, colitis, diverticulitis, etc.)

**Inpatients:**

• Oral contrast is indicated for all inpatients with a 3-hour preparation time.

o If a scan is prescribed without oral contrast, the reason must be indicated in the "technologist
note" section of the protocol palette for the radiologist's reference.
o Oral contrast use should be discussed with the team, especially if the order says "no oral" or
"oral not needed." The statement "Attending doesn't want it" is not a sufficient reason for not using it.

Valid reasons include contraindications / patient-related issues (allergy, critically ill with need for emergent scan, ongoing vomiting with inability to tolerate any oral intake, etc.

•

**Exceptions include:**

o **Organ specific protocols** (liver mass, renal mass, etc.). Although it should be discussed if this workup is required as an inpatient.

o **Genitourinary (GU) indications** (CT Urography, Renal Stones, etc.).

o **CT Angiography / Venography** (oral contrast can preclude 3D reconstructions)

**Outpatients:**

• Oral contrast is indicated for all outpatients with a 2-hour preparation time.

o If a scan is prescribed without oral contrast, the reason must be indicated in the "technologist note" section of the protocol palette for the radiologist's reference.

o Oral contrast use should be discussed with the team, especially if the order says "no oral" or "oral not needed." The statement "Attending doesn't want it" is not a sufficient reason for not using it.

Valid reasons include contraindications / patient-related issues (allergy, critically ill with need for emergent scan, ongoing vomiting with inability to tolerate any oral intake, etc.

- **Exceptions include:**

o **Organ specific protocols** (liver mass, renal mass, etc.).

o **Genitourinary** (GU) indications (CT Urography, Renal Stones, etc.).

o **CT Angiography** / **Venography** (oral contrast can preclude 3D reconstructions)

Radiologists need to adhere to these guidelines to ensure the effectiveness of CT scans and the safety of patients (i.e. optimization of imaging techniques to preclude the need for repeat or unnecessary imaging).

If there are any uncertainties or specific situations, consulting with a radiologist should always be encouraged.

# CHAPTER 5

# BASICS OF ONCOLOGY

**Oncology** is the medical specialty focused on preventing, diagnosing, and treating cancer.

- It involves understanding the uncontrolled growth of cancer cells, identifying the risks and causes of cancer, and applying various treatments such as surgery, chemotherapy, and immunotherapy to combat the disease. Oncology also encompasses supportive care to manage treatment side effects and improve the patient's quality of life.

## Oncology Involves: (Diagnosis, Treatment, Prevention, Supportive care)

### Diagnosis:

Identifying cancer through accurate and timely diagnostic tests to develop personalized treatment plans ( Clinical, Imaging & Laboratory) .

### Treatment:

Using a combination of approaches, including:

**- Surgery**: To remove tumors.

**- Chemotherapy**: Using drugs to kill cancer cells.

**- Radiation therapy**: Using radiation to treat cancer.

**- Hormone therapy**: Blocking hormones that fuel some cancers, like estrogen in breast cancer or testosterone in prostate cancer.

**- Immunotherapy**: Helping the body's immune system to recognize and attack cancer cells.

**Prevention**:

Identifying risk factors, such as lifestyle habits and genetic predispositions, to prevent cancer from developing.

**Supportive Care**:

Managing symptoms and side effects of cancer and its treatments, including pain, nausea, and nutritional support.

## Key Aspects of Cancer Cells

**Uncontrolled Growth**:

Unlike normal cells, cancer cells ignore signals to stop growing.

**Invasion**:

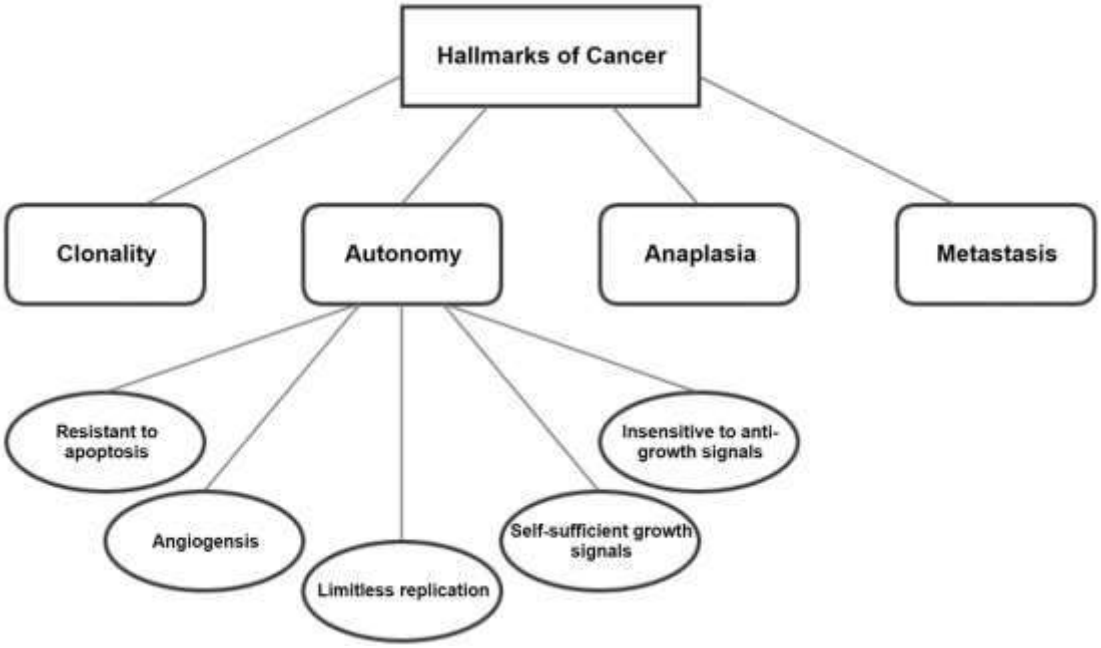
They can invade other parts of the body, spreading from their original site.

**Immune Evasion**:

Cancer cells can evade the immune system, making it harder for the body to fight them.

**Genetic Changes**:

Cancer often begins with genetic changes that turn normal growth genes into oncogenes, which cannot be turned off, and inactivate tumor suppressor genes.

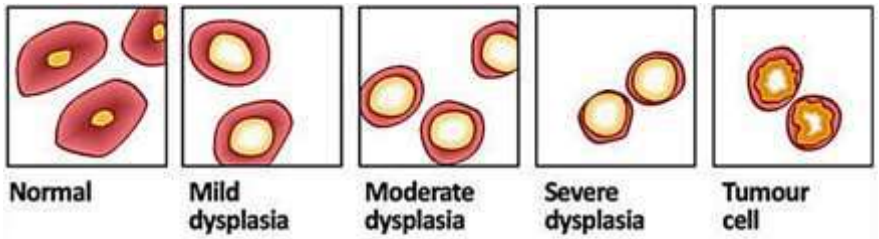


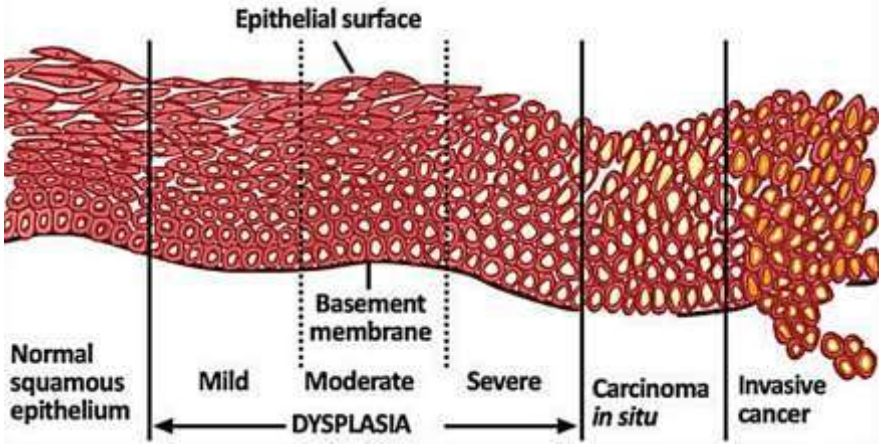

| Term | Definition |
|---|---|
| Tumor | • Abnormal mass of tissue which results from: excessive cell division and evasion of apoptosis<br>• Can be **benign** or **malignant**<br>• Equivalent to the term **neoplasm** |
| Cancer | • Disease consisting of: deregulated cell growth and the ability to **invade**<br>• Cancer is automatically **malignant** |

| Term | Definition |
|---|---|
| Benign | • Cells are **not cancerous**<br>• Local problems; does not spread<br>• Most growths do not return when removed<br>• For example: benign thymomas, acoustic neuromas |
| Malignant | • Cells are **cancerous**<br>• Cancerous cells can spread and invade other tissues |
| Metastasis | • The process and outcome of malignant or cancerous cells spreading and invading other tissues |

# Important Oncology Terms

| Term | Definition |
|---|---|
| Tumor | • Abnormal mass of tissue which results from: excessive cell division and evasion of apoptosis<br>• Can be **benign** or **malignant**<br>• Equivalent to the term **neoplasm** |
| Cancer | • Disease consisting of: deregulated cell growth and the ability to **invade**<br>• Cancer is automatically **malignant** |
| Benign | • Cells are **not cancerous**<br>• Local problems; does not spread<br>• Most growths do not return when removed<br>• For example: benign thymomas, acoustic neuromas |
| Malignant | • Cells are **cancerous**<br>• Cancerous cells can spread and invade other tissues |
| Metastasis | • The process and outcome of malignant or cancerous cells spreading and invading other tissues |
| Hyperplasia | • Increase in number of cells within an organ or tissue |
| Hypertrophy | • Increase in size of cells within an organ or tissue |
| Atrophy | • Reduction of cell size or number |



## Staging and Grading



- Staging and grading of cancers are different classification methods.

- **The grade** of a neoplasm :the *histological* and *pathological* features of the cells in a neoplasm.

- **The stage** of a neoplasm: provides a sense for how advanced a cancer is.

- Many (but not all) cancers are staged using the **TNM staging system:**

This system is divided into three components:

- the tumor (T), - nodal status (N), and - metastasis (M),

Different combinations can further be classified into general stages I, II, III, IV.

**Why We stage cancers ? for the following reasons:**

- it provides a common language of communication, guides treatment, estimates prognosis,
- allows comparison of results,
- standardizes clinical trials.

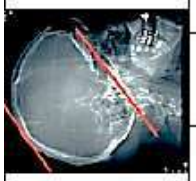
| Terms | Definition |
|---|---|
| Tumor (T) | • Extent of local, primary tumor growth<br>• TIS refers to carcinoma *in situ*<br>• T 1,2,3,4 represent the size and extent of the local, primary tumor<br>• T 0 refers to no primary tumor |
| Node (N) | • Absence or presence of malignancy in the regional lymph nodes<br>• N 0 refers to absent nodal malignancy<br>• N 1,2,3 represent the extent of nodal involvement |
| Metastasis (M) | • Absence or presence of metastasis<br>• M 0 represents no metastasis<br>• M 1 represents metastasis |

- Stage I cancers are early cancers that are often curable. Stage IV cancers are usually incurable. The TNM and staging differ for each tissue of origin and thus, specifically predict the management and prognosis of individual cancers.

# CHAPTER 7

# CT PROTOCOLS GENERAL VIEW

## BASIC HEAD



| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Skull base thru vertex of head | Axial sequential | AP, LAT | 120 | 250 auto | 22cm | 5mm | 2.5mm | Match skull base | Medium average | No | No |

Place patient in supine position with head in head holder. Assure that patient is not rotated or tilted. Elevate table to bring coronal alignment light to the center of the skull. Landmark per equipment requirements (table movement for scout images). Perform scout images. Prescribe scan locations from skull base to vertex of head. Angle gantry to match skull base (occipital bone) (foramen magnum) and frontal bone (roof of orbit).

## CORONAL SINUSES

| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Entire sphenoid sinus thru entire frontal sinus | Axial sequential | AP, LAT | 120 | 200 auto | 16cm | 5mm 3mm | 2.5mm 1.5mm | 90° to max. sinus | Sharp bone | No | No |

OPTION 1: Direct coronals - Place patient in prone position with extended chin resting in head holder (see diagram).
OPTION 2: Place patient in supine position with head in head holder (basic head positioning). Assure that patient is not rotated or tilted. Elevated table to bring coronal alignment light to the center of the skull. Landmark per equipment requirements (table movement for scout images). Perform scout images. Prescribe scan locations to include entire sphenoid sinus thru entire frontal sinus Angle gantry to 90° orientation to floor of maxillary sinus. Volume scans can be performed with either positioning option with MPR's in opposite planes. Direct coronal positioning provides better information about maxillary meatus.

## SOFT TISSUE NECK

| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Above floor of frontal fossa to mid aortic arch | Helical | AP, LAT | 120 | 150 auto | 20cm | 5mm | 2.5mm | Usually none | Medium average | Yes 15s delay | No |

Place patient supine on table with head resting on radiolucent sponge. Assure that patient's head and neck is within table scan range. Assure that patient's head and shoulders are not rotated or tilted. Elevate table to bring coronal alignment light to the center of the neck. Landmark per equipment requirements (table movement for scout images). Tip chin up to bring plane of teeth perpendicular to tabletop. Perform scout images. Prescribe scan locations from above floor of frontal fossa to mid aortic arch. Usually no gantry tilt needed - however, scans should be perpendicular to midcoronal plane. Scans typically performed with IV contrast and a scan delay of 15 seconds.

## CERVICAL SPINE

| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Occipital condyles to below T2 | Helical | AP, LAT | 120 | 250 auto | 16cm | 3mm | 1.5mm | Usually none | Sharp bone | No | No |

Place patient supine on table with head resting on radiolucent sponge. Assure that patient's head and neck is within table scan range. Assure that patient's head and shoulders are not rotated or tilted. Elevate table to bring coronal alignment light to the center of the neck. Landmark per equipment requirements (table movement for scout images). Perform scout images. Prescribe scan locations from skull base/occipital condyles to below T1. Usually no gantry angle when scanning the entire C-Spine. If individual vertebral bodies are of interest - gantry can be angled to match vertebral bodies/disc spaces. Volume scans performed with MPR's in sagittal and coronal planes.

## PEDIATRIC IMAGING

The following five points should be considered for pediatric imaging: (1) "Child size" the radiation dose, (2) scan only when necessary, (3) scan only indicated areas, (4) multiphase scanning usually not indicated, (5) utilize shielding whenever possible. Most protocols are adjusted based on patient weight as opposed to patient age, with 55kg being the top of the scale for pediatric adjustments. Note: kVp and mAs values listed are typical low/high ranges for imaging based on patient weight.

## PEDIATRIC PROTOCOLS

| Anatomical region | Pediatric considerations | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Head | Avoid eyes with scan plane | Helical | AP, LAT | 80<br>120 | 100<br>200<br>auto | 16-20 cm | 5mm<br>3mm | 2.5mm<br>1.5mm | Match skull base | Medium average | No | No |
| Soft tissue neck | Typically same coverage as adults | Helical | AP, LAT | 80<br>120 | 20<br>80<br>auto | 10-14 cm | 5mm<br>3mm | 2.5mm<br>1.5mm | Usually none | Medium average | Typically yes | No |
| C-spine | Typically entire C-spine, avoid eyes | Helical | AP, LAT | 80<br>120 | 40<br>100<br>auto | 10-14 cm | 3mm | 1.5mm | Usually none | Sharp bone | No | No |
| Chest | Restrict to area of interest, typically single phase for peds | Helical | AP, LAT | 80<br>120 | 20<br>70<br>auto | Edge of anatomy | 5mm<br>3mm | 2.5mm<br>1.5mm | Usually none | Medium average | Yes | No |
| Abdomen | Restrict to area of interest, typically single phase for peds | Helical | AP, LAT | 80<br>120 | 40<br>100<br>auto | Edge of anatomy | 5mm<br>3mm | 2.5mm<br>1.5mm | Usually none | Sharp bone | Yes | Yes |
| Pelvis | Restrict to area of interest, typically single phase for peds | Helical | AP, LAT | 80<br>120 | 40<br>100<br>auto | Edge of anatomy | 5mm<br>3mm | 2.5mm<br>1.5mm | Usually none | Sharp bone | Yes | Yes |
| Extremities | Typically same coverage as adults | Helical | AP, LAT | 80<br>120 | 50<br>150<br>auto | Edge of anatomy | 3mm | 1.5mm | Usually none | Sharp bone | Depends on pathology | No |

## ROUTINE CHEST

| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Above lung apices to below adrenal glands | Helical | AP, LAT | 120 | 100 auto | Thorax margin | 5mm | 2.5mm | None | Medium average | Yes 25s delay | No |

Place 22g needle in antecubital space - assure patency. Place patient in supine position with head on pillow, cushion under patient's knees for comfort. Assure that patient is not rotated or tilted. Elevate table to bring coronal alignment light to the center of the chest. Landmark per equipment requirements (table movement for scout images). Bring patient's arms above their head and support with sponges/pillows for comfort and to protect IV site. Perform scout images. Prescribe scan locations from above lung apices to below adrenal glands. Define FOV to include lateral margins of chest and use lateral scout to center FOV to include anterior and posterior margins of the chest. Scans typically performed with IV contrast and a scan delay of 25 seconds.

## ROUTINE ABDOMEN

| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Above hemidiaphragms to iliac crest | Helical | AP, LAT | 120 | 200 auto | Body margin | 5mm | 2.5mm | None | Medium average | Yes 60s delay | Yes 24 hr/ 1 hr |

Exams typically performed with oral contrast - give contrast 24 hours and 1 hour before exam or timing as requested by Radiologist. Place 22g needle in antecubital space - assure patency. Place patient in supine position with head on pillow, cushion under patient's knees for comfort. Assure that patient is not rotated or tilted. Elevate table to bring coronal alignment light to the center of the abdomen. Landmark per equipment requirements (table movement for scout images). Bring patient's arms above their head and support with sponges/pillows for comfort and to protect IV site. Perform scout images. Prescribe scan locations from above hemidiaphragms to iliac crest (scan area must include all of liver). Define FOV to include lateral margins of abdomen and use lateral scout to center FOV to include anterior and posterior margins of the abdomen. Scans typically performed with IV contrast and a scan delay of 60 seconds.

## ROUTINE PELVIS

| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Above iliac crest to mid symphysis pubis | Helical | AP, LAT | 120 | 200 auto | Body margin | 5mm | 2.5mm | Usually none | Medium average | Yes 120s delay | Yes 24 hr/ 1 hr |

Exams typically performed with oral contrast - give contrast 24 hours and 1 hour before exam or timing as requested by Radiologist. Place 22g needle in antecubital space - assure patency. Place patient in supine position with head on pillow, cushion under patient's knees for comfort. Assure that patient is not rotated or tilted. Elevate table to bring coronal alignment light to the center of the pelvis. Landmark per equipment requirements (table movement for scout images). Bring patient's arms above their head and support with sponges/pillows for comfort and to protect IV site. Perform scout images. Prescribe scan locations from above iliac crest to mid symphysis or below symphysis. Define FOV to include lateral margins of pelvis and use lateral scout to center FOV to include anterior and posterior margins of the pelvis. Scans typically performed with IV contrast and a scan delay of 120-180 seconds.

## Typical window settings

| CT examination | Width | Center (level) |
|---|---|---|
| Brain | 190 | 50 |
| Skull | 3500 | 500 |
| Orbits | 1200 | 50 |
| Abdomen | 400 | 35 |
| Liver | 175 | 45 |
| Mediastinum | 325 | 50 |
| Lung | 2000 | −500 |
| Spinal cord | 400 | 50 |
| Spine | 2200 | 400 |

# Average Hounsfield units (HU) for selected substances

| Substance | HU |
|---|---|
| Air | −1000 |
| Lungs | −250 to −850 |
| Fat | −100 |
| Orbit | −25 |
| Water | 0 |
| Cyst | −5 to +10 |
| Fluid | 0 to +25 |
| Tumor | +25 to +100 |
| Blood (fluid) | +20 to +50 |
| Blood (clotted) | +50 to +75 |
| Blood (old) | +10 to +15 |
| Brain | +20 to +40 |
| Muscle | +35 to +50 |
| Gallbladder | +5 to +30 |
| Liver | +40 to +70 |
| Aorta | +35 to +50 |
| Bone | +150 to +1000 |
| Metal | +2000 to +4000 |

# ROLE OF CT IN NEOPLASMS IMAGING

- Detection of tumors
- Staging
- Follow Up After treatment

CHAPTER 6

# CT IMAGING IN ONCOLOGY

# DO NOT FORGET
# THESE ARE THE BASICS
# BUT
# THE PRACTICE
# IS MANDATORY

## SO, WE WILL EXPLORE IMPORTANT HINTS

2025

THESE FILES ARE A GOOD GUIDE FOR CT & MRI PROTOCOLS …… YOU CAN DOWNLOAD

## RADIOLOGY PROTOCOLS

HTTPS://GEISELMED.DARTMOUTH.EDU/RADIOLOGY/POLICIES-PROTOCOLS/PROTOCOLS/


**DO NOT FORGET**

**PRACTICING WORK ONE TIME ON SCIENTIFIC STEPS**

**IS MUCH BETTER THAN**

**READING IT ONLY EVEN 1000 TIMES**

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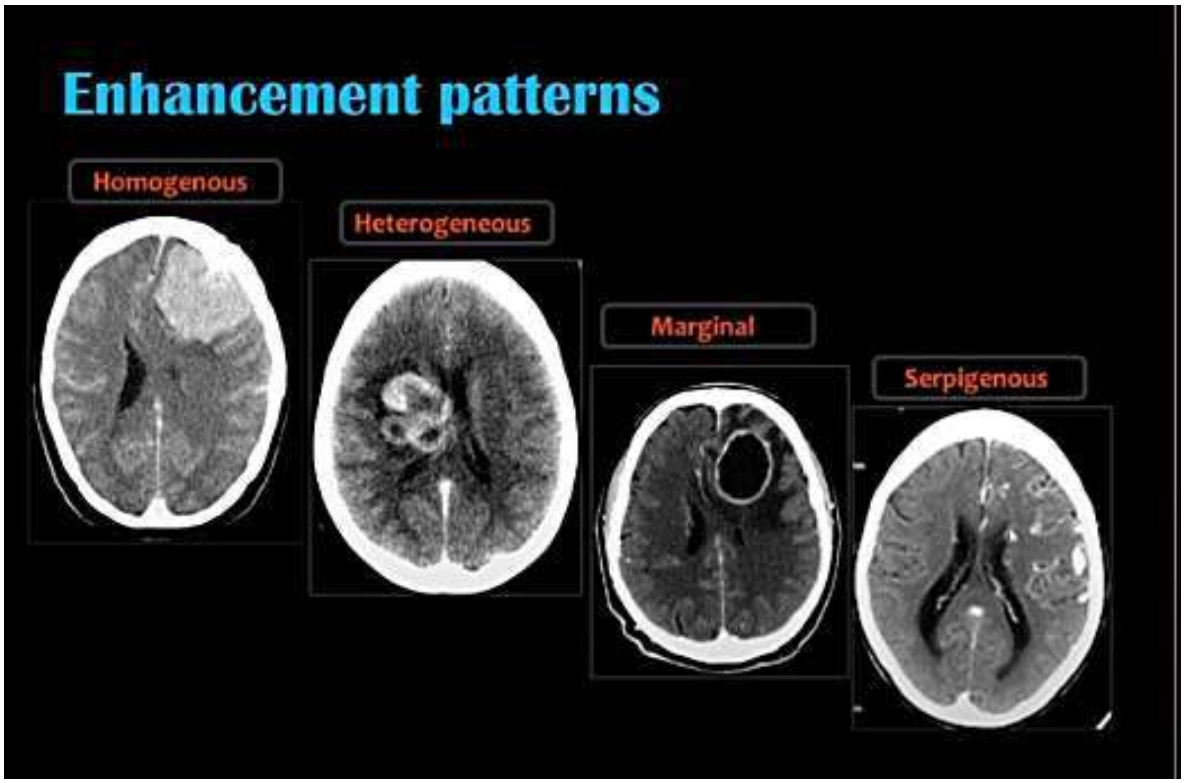
# BRAIN TUMORS

- **I.V. Contrast Is mandatory for assessment of any suspected brain Tumors**
- **The scan Must be done Pre & Post Contrast**

**Scan:** CT Head

**Patient Preparation:** No advanced preparation required.
**Scan Instructions:** Patient positioned supine, head-first, skull base parallel to axial plane of scanner, scan skull base to vertex.
**Injection Parameters:**
Routine C- Head: No injection.
C+ Head: 1.5mL/kg upto max 50mL injected by hand or pump at 2mL/s, 1 minute prior to scanning.
C+ Brain Venogram: For cerebral venousthrombosis, may be done in conjuction with C- scan first. 1.5mL/kG upto 90mL injected by pump at 4mL/s, 30 seconds prior to scanning.

**Scanogram:**

| Category: | Mode: | AP kV: | Lat kV: | AP mA: | Lat mA: |
|---|---|---|---|---|---|
| BABY 0-2 YRS | DualScano (AP/Lat) | 100 | 100 | 10 | 10 |
| ALL OTHER CAT. | DualScano (AP/Lat) | 120 | 120 | 10 | 10 |

**Scan Parameters:**

| Category: | Mode: | kV: | mA: | Rot. (s): | Detector Config.: | Pitch: |
|---|---|---|---|---|---|---|
| BABY 0-2 YRS | Helical | 100 | 200 | 0.5 | 0.5mm x 40 | Detail, 0.625 |
| CHILD 3-5 YRS | Helical | 120 | 170 | 0.5 | 0.5mm x 40 | Detail, 0.625 |
| CHILD 6-12 YRS | Helical | 120 | 180 | 0.5 | 0.5mm x 40 | Detail, 0.625 |
| TEEN 13-16 YRS | Helical | 120 | 180 | 0.75 | 0.5mm X 40 | Detail, 0.625 |
| ADULT | Helical | 120 | 220 | 0.75 | 0.5mm x 40 | Detail, 0.625 |

mple CT Head Protocol >

**BASIC HEAD**

| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Skull base thru vertex of head | Axial sequential | AP, LAT | 120 | 250 auto | 22cm | 5mm | 2.5mm | Match skull base | Medium average | No | No |

Place patient in supine position with head in head holder. Assure that patient is not rotated or tilted. Elevate table to bring coronal alignment light to the center of the skull. Landmark per equipment requirements (table movement for scout images). Perform scout images. Prescribe scan locations from skull base to vertex of head. Angle gantry to match skull base (occipital bone) (foramen magnum) and frontal bone (roof of orbit).

**CORONAL SINUSES**

| Anatomical scan range | Scan type | Localizer scans | kVp | mAs | FOV | Scan slice thickness | Recon slice thickness | Gantry tilt | Recon kernel | IV contrast | Oral contrast |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Entire sphenoid sinus thru entire frontal sinus | Axial sequential | AP, LAT | 120 | 200 auto | 16cm | 5mm 3mm | 2.5mm 1.5mm | 90° to max. sinus | Sharp bone | No | No |

OPTION 1: Direct coronals - Place patient in prone position with extended chin resting in head holder (see diagram).
OPTION 2: Place patient in supine position with head in head holder (basic head positioning). Assure that patient is not rotated or tilted. Elevated table to bring coronal alignment light to the center of the skull. Landmark per equipment requirements (table movement for scout images). Perform scout images. Prescribe scan locations to include entire sphenoid sinus thru entire frontal sinus Angle gantry to 90° orientation to floor of maxillary sinus. Volume scans can be performed with either positioning option with MPR's in opposite planes. Direct coronal positioning provides better information about maxillary meatus.

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# LIVER TUMORS

## Detection of liver masses

- Detection depends on the attenuation difference between the lesion and the normal liver.
- **On a non enhanced CT-scan (NECT) :** liver tumors usually are not visible, because the inherent contrast between tumor tissue and the surrounding liver parenchyma is too low.
- Only a minority of tumors contain **c**alcifications, **c**ystic components, fat or **h**emorrage and will be detected on a NECT.

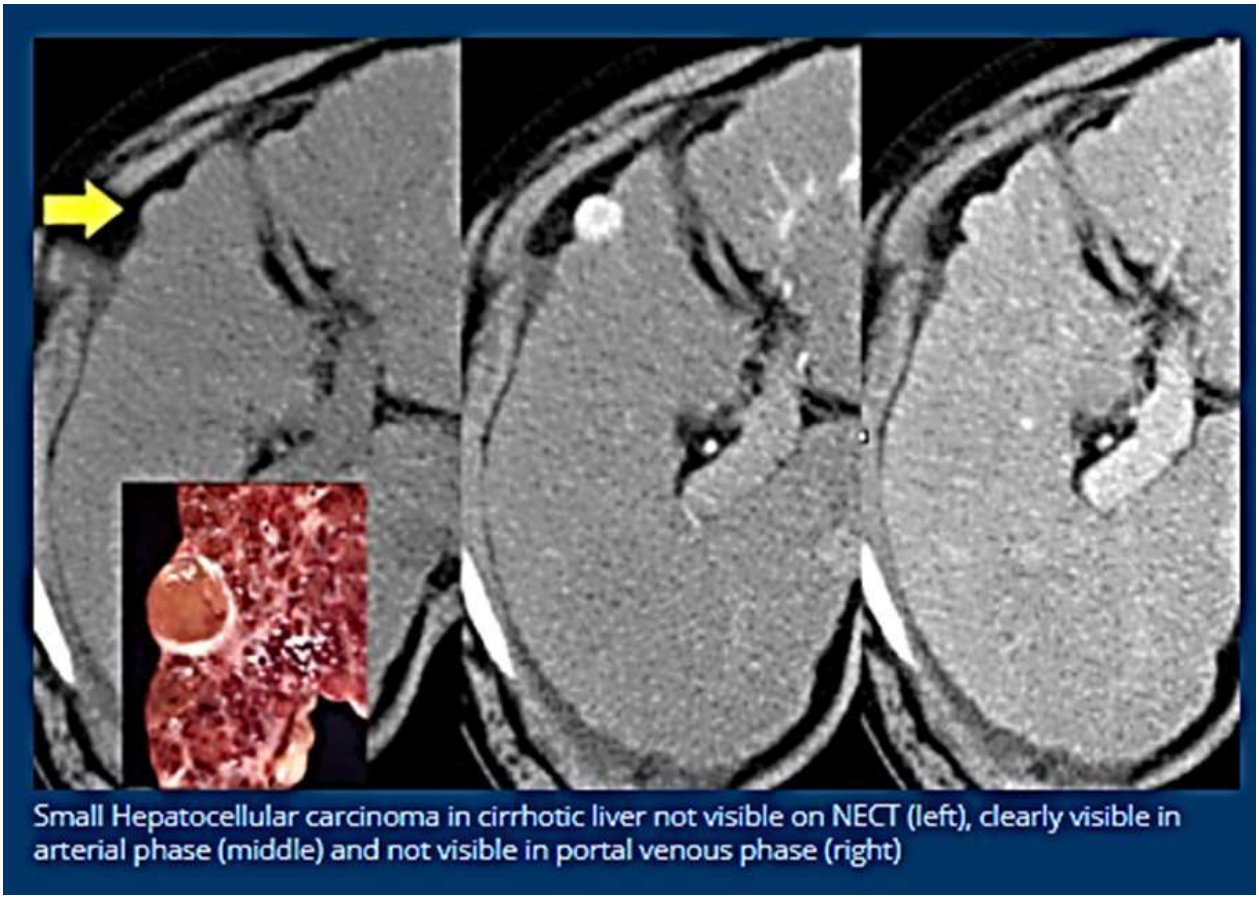
  → **So i.v. contrast is needed to increase the conspicuity of lesions.**
- When we give i.v. contrast, it is important to understand, that there is a Dual blood supply to the liver.

* Normal parenchyma is supplied for 80% by the portal vein and

* only for 20% by the hepatic artery, → so it will enhance in the portal venous phase.

**All liver tumors get 100% of their blood supply from the hepatic artery, so when they enhance it will be in the arterial phase.**

- This difference in blood supply results in different enhancement patterns between liver tumors and normal liver parenchyma in the various phases of contrast enhancement.



Small Hepatocellular carcinoma in cirrhotic liver not visible on NECT (left), clearly visible in arterial phase (middle) and not visible in portal venous phase (right)

In the **arterial phase**

hypervascular tumors will enhance via the hepatic artery, when normal liver parenchyma does not yet enhances, because contrast is not yet in the portal venous system.

These hypervascular tumors will be visible as hyperdense lesions in a relatively hypodense liver.

However when the surrounding liver parenchyma starts to enhance in the portal venous phase, these hypervascular lesion may become obscured.

In the **portal venous phase**

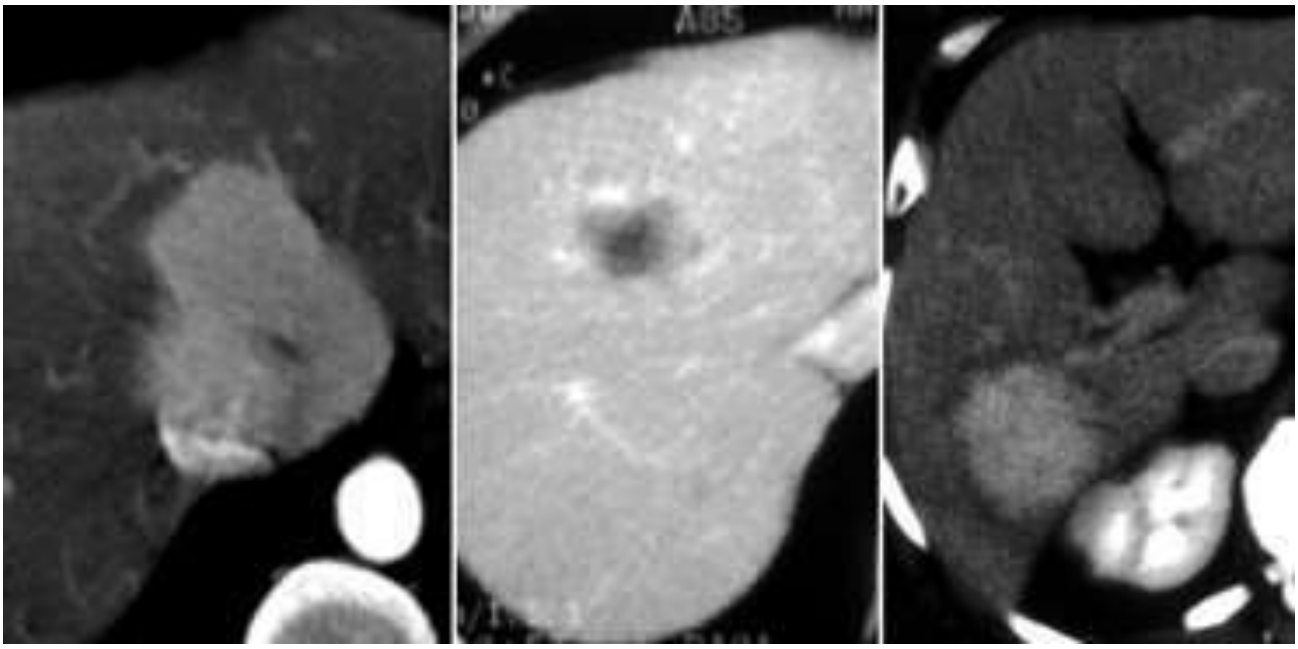
hypovascular tumors are detected, when the normal liver parenchyma enhances maximally.

These hypovascular tumors will be visible as hypodense lesions in a relatively hyperdense liver.

In the **equilibrium phase**

at about 10 minutes after contrast injection, tumors become visible, that either loose their contrast slower than normal liver, or wash out their contrast faster than normal liver parenchyma.

These lesions will become either relatively hyperdense or hypodense to the normal liver.



Detection of a lesion depends on the difference in attenuation between the liver and the lesion.

LEFT: Arterial phase showing hypervascular lesion

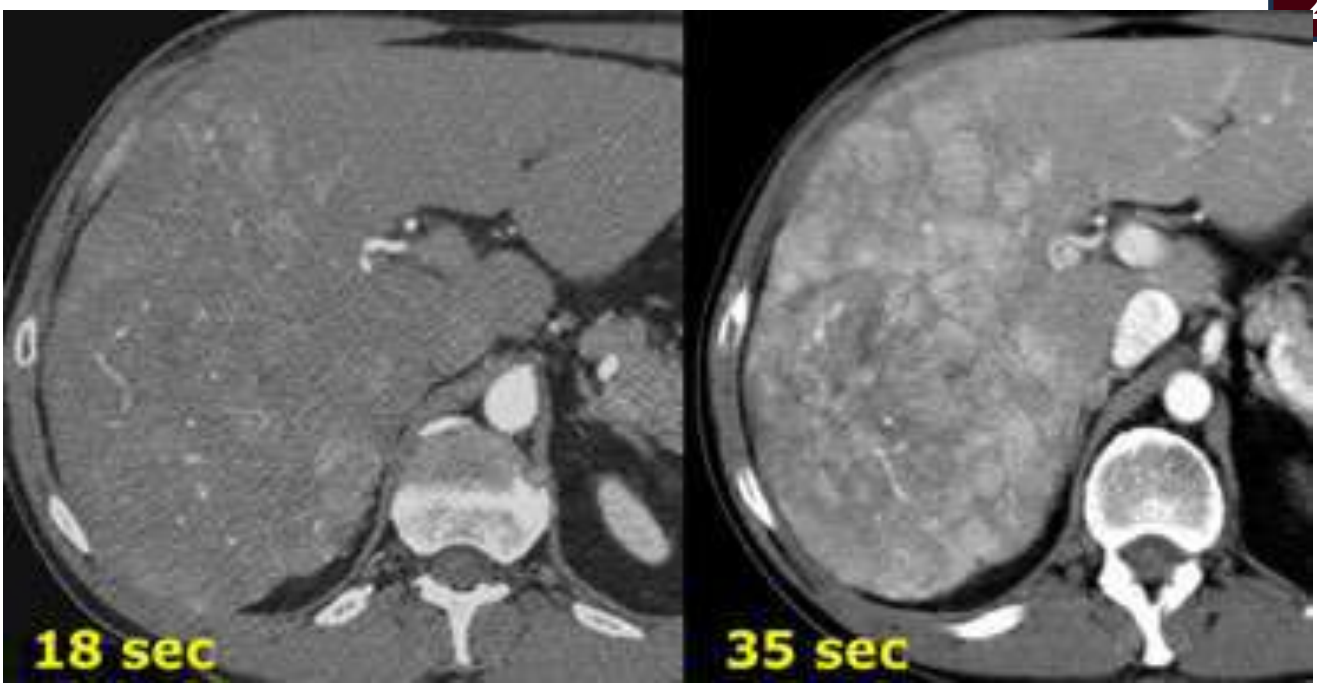
MIDDLE: Portal venous phase showing hypovascular lesion

RIGHT: equilibrium phase showing relatively dense Lesion.

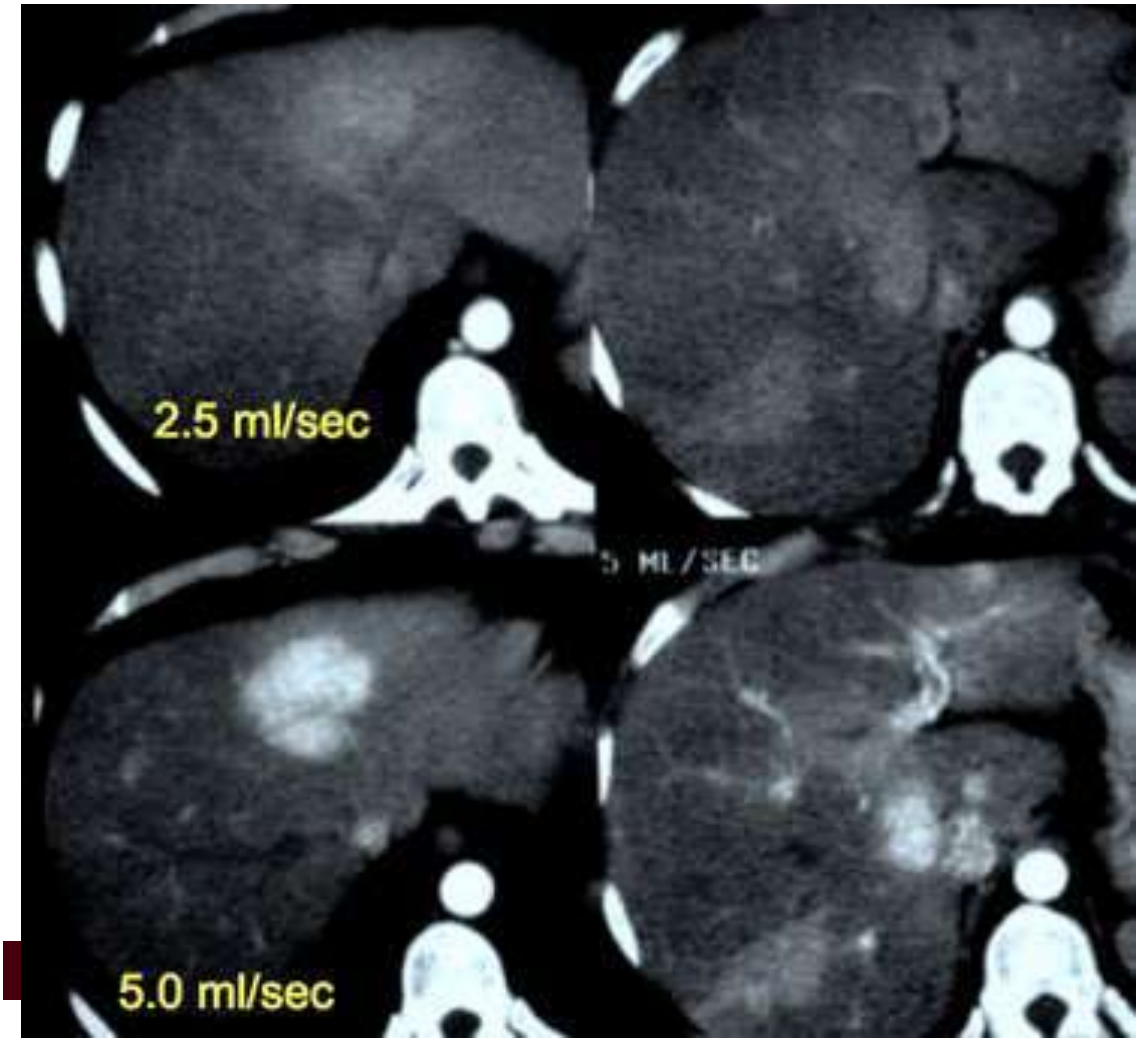
| | |
|---|---|
| **INDICATION** | EVAL HEMANGIOMA / HCC / CIRRHOSIS |
| **ORAL PREP** | |
| **SCAN** | 1. I+ LATE ARTERIAL PHASE LIVER ONLY – 40 SEC AFTER START OF INJECTION<br>2. I+ PV PHASE – ENTIRE ABDOMEN 60-70 SEC AFTER START OF INJECTION<br>3. I+ DELAY – LIVER ONLY ~ 5 MINUTES AFTER START OF INJECTION |
| **RECON** | • 3.75mm AXIAL RECONS – STANDARD ALGORITHM (ALL PHASES)<br>• 0.625mm / 1.25mm AXIAL RECONS – STANDARD ALGORITHM (ALL PHASES) |
| **REFORMAT** | ○ 3mm CORONAL AND SAGITTAL (ALL PHASES) |
| **3D POST PROCESSING** | NONE |

| | | |
|---|---|---|
| **IV SIZE** | | 20g |
| **IV CONTRAST** | | WEIGHT BASED |
| **INJECTION RATE** | | 4cc/SEC |
| **PT POSITION** | | SUPINE / FEET FIRST |
| **LANDMARK** | **GE** | XYPHOID |
| | **SIEMENS** | |
| **BREATHING** | | EXPIRATION |
| **SCOUTS** | | AP AND LATERAL |

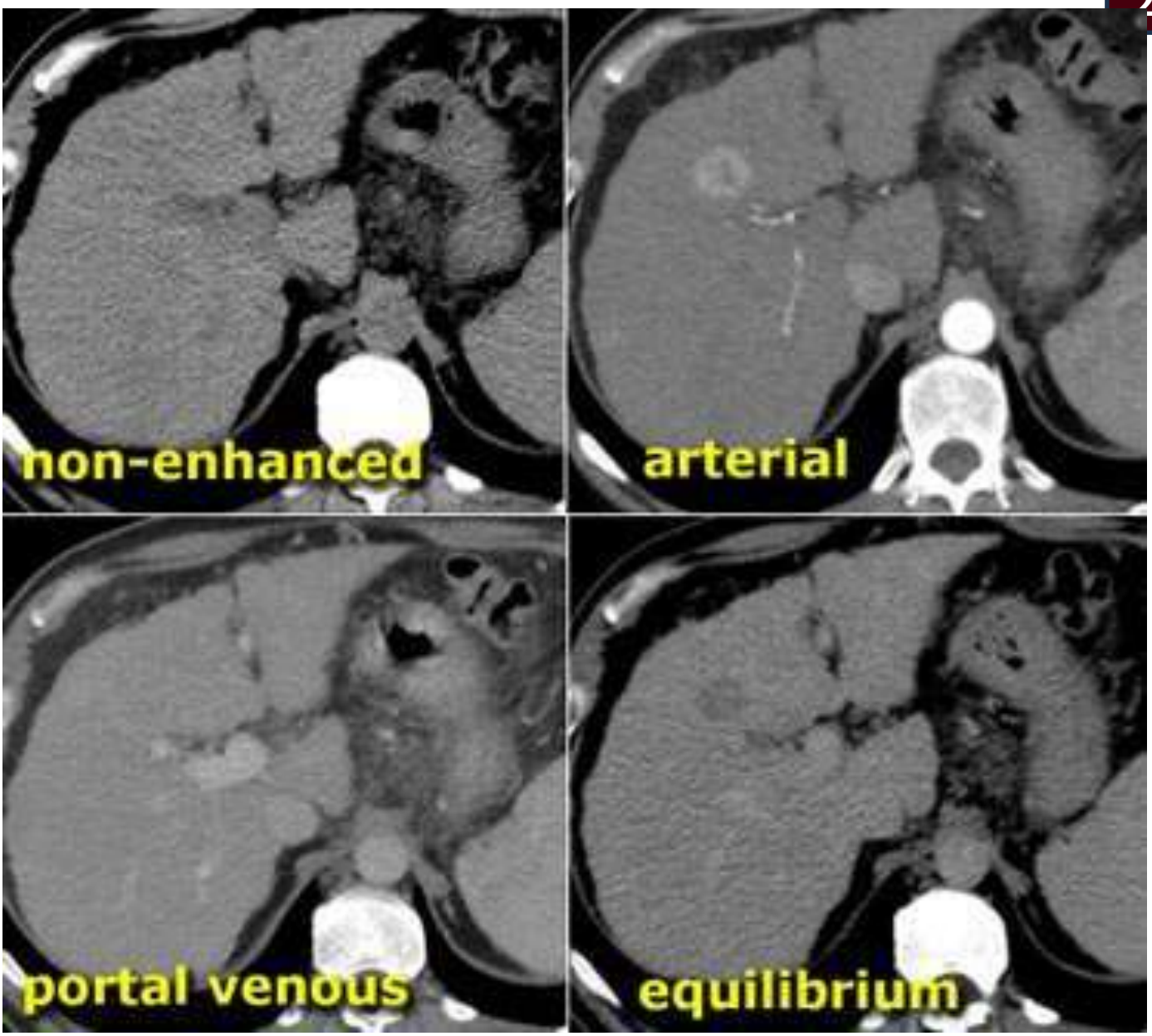
| **PARAMETER** | | **ART** | **PV** | **DELAY** |
|---|---|---|---|---|
| **START** | | ABOVE DIAPHRAGM | ABOVE DIAPHRAGM | ABOVE DIAPHRAGM |
| **END** | | ILIAC CREST | ILIAC CREST | ILIAC CREST |
| **DFOV** | | <TO PATIENT> | <TO PATIENT> | <TO PATIENT> |
| **PREP GROUP** | **GE** | 40 SEC | 70 SEC | 5 MINS |
| | **SIEMENS** | | | |




CT of the liver in the early arterial phase (left) and the late arterial phase (right).




Patient with liver cirrhosis and multifocal HCC injected at **2.5ml/sec** (left) and at **5ml/sec** (right).




HCC in a cirrhotic liver. Notice fast wash out in equilibrium phase compared to surrounding liver parenchyma.

2025

# RENAL MASSES

| | |
|---|---|
| **INDICATION** | ? MASS / ? STAGING / F/U KNOWN MASS / RFA |
| **ORAL PREP** | NONE |
| **SCAN** | 1. NON-CONTRAST - KIDNEYS ONLY<br>2. I+ NEPRHOGRAPHIC PHASE ~90 SEC AFTER INJECTION – ABDOMEN/PELVIS<br>3. 5 MINUTE DELAY - KIDNEYS ONLY |
| **RECON** | • 3.0mm / 3.75mm AXIAL RECONS – STANDARD ALGORITHM (ALL PHASES)<br>• 0.6mm / 0.625mm / 1.25mm AXIAL RECONS – STANDARD ALGORITHM (ALL PHASES) |
| **REFORMAT** | o 3mm CORONAL AND SAGITTAL |
| **3D POST PROCESSING** | NONE |

| | | |
|---|---|---|
| **IV SIZE** | | 18g OR 20g |
| **IV CONTRAST** | | WEIGHT BASED |
| **INJECTION RATE** | | 4cc/SEC |
| **PT POSITION** | | SUPINE / FEET FIRST |
| **LANDMARK** | **GE** | XYPHOID |
| | **SIEMENS** | ABOVE DIAPHGRAM |
| **BREATHING** | | EXPIRATION |
| **SCOUTS** | | AP AND LATERAL |

| **PARAMETER** | | **NON CONTRAST** | **PV PHASE** | **DELAYED** |
|---|---|---|---|---|
| **START** | | ABOVE KIDNEYS | ABOVE DIAPHRAGM | ABOVE KIDNEYS |
| **END** | | BELOW KIDNEYS | BELOW SYMPHYSIS PUBIS | BELOW KIDNEYS |
| **DFOV** | | <TO PATIENT> | <TO PATIENT> | <TO PATIENT> |
| **PREP GROUP** | **GE** | NONE | 90 SEC | 5 MINUTE |
| | **SIEMENS** | NONE | 90 SEC | 5 MINUTE |

# BREAST TUMORS

- CT breast imaging is a specialized 3D imaging technique that captures detailed views of the breast in multiple planes, offering potential advantages over traditional methods like mammography.

- **Role**: visualizing masses and soft tissue,

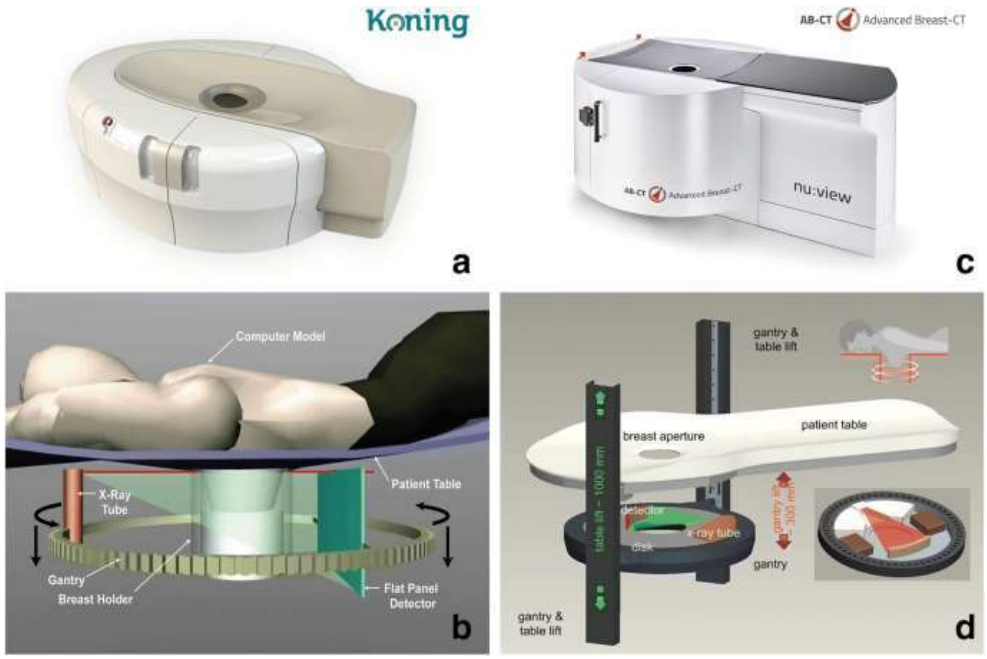
## Technique:

**•3D Imaging:**

•Unlike 2D mammograms, breast CT produces a complete **3D volume** of the breast, →allowing radiologists to view the tissue from multiple perspectives.

**•Patient Positioning:** a prone (face-down) position, → allowing the breast to hang freely in a dedicated opening.

**•Image Reconstruction:** Computer processing converts these projections into a 3D image.



## Advantages

•**True 3D View:** Provides comprehensive anatomical detail and improved visualization of soft tissue.

•**Non-Compression:** Eliminates the discomfort associated with breast compression in mammography.

•**Versatility:** Can be used for evaluating the extent of disease, monitoring treatment response to chemotherapy, and as a screening tool for high-risk women.

## Limitations

•**Microcalcification Visibility:** May have difficulty visualizing microcalcifications, which is a significant challenge for breast cancer screening.

•**Coverage:** The prone positioning can limit coverage of the chest wall and axilla (armpit region).

•**Ionizing Radiation:** Uses ionizing radiation, though at doses comparable to mammography.

## Applications

•**Diagnostic Workup:** Can help in assessing indeterminate breast lesions that require further investigation.

•**High-Risk Screening:** May serve as a supplemental screening tool for women at high risk of breast cancer.

•**Treatment Monitoring:** Useful for tracking tumor response to treatments.

CHAPTER 7

# ADVANCED CT TECHNIQUES OF TUMORS IMAGING

# PET CT

**Positron emission tomography–computed tomography** (known as **PET–CT** or **PET/CT**)

## History

- **1991**: was first suggested by R. Raylman in his Ph.D. thesis.
- **2001**: The first commercial system reached the market,
- **2004:** over 400 systems had been installed worldwide.

## Basics

- is a nuclear medicine technique
- combines, in a single gantry, a positron emission tomography (PET) scanner and (CT) scanner, → to acquire sequential images from both devices in the same session,
- It combines into a single superposed image.
- Thus, functional imaging obtained by PET,
- Two- and three-dimensional image reconstruction can be rendered.

PET–CT adds precision of **anatomic localization** to **functional imaging**, which was previously lacking in pure PET imaging.

## Materials

- Fluorine-18 ($^{18}$F) : (using fluorodeoxyglucose, **FDG**)
- The half-life is only two hours.
- Its production requires a very expensive cyclotron.

## Benefits of PET–CT

•The advantages of combining two methods.

•The result exceeds images obtained by the two devices taken separately.

•The method allows identification of all cancerous formations in the body, regardless of their size or degree of development.

•**Short diagnosis time** → saves precious time in the fight against the disease

• **Very low risk**, of the substance used, although it is radioactive, is naturally eliminated by the body within a maximum of 24 hours after administration

PET–MRI, like PET–CT, combines modalities to produce co-registered images.

## Obstacle of Use

- Difficulty and cost of producing and transporting the radiopharmaceuticals used for PET imaging, which are usually extremely short-lived.
- Expensive cost of machine.

## Procedure for FDG imaging

•**Fasting:** Before the exam, at least 6 hours.

•**On the day of the exam**, the patient **rests** lying for a minimum of **15 min,** → quiet down muscular activity, which might be interpreted as abnormal metabolism.

•**An intravenous bolus :** injection of a dose of recently produced 2-FDG or 3-FDG is made, → usually by arm vein.

•**Dosage:** 3.7 : 7.4 megabecquerels (0.1 to 0.2 mCi) per kilogram of body weight.

•**After one or two hours:** , the patient is placed into the PET–CT in a supine position - arms resting at the sides, or brought above the head, depending on the main region of interest (**ROI**).

•**Tomogram: An automatic bed moves head first** into the gantry, first obtaining a tomogram, (also called a scout view or surview), which is a kind of whole body flat sagittal section, obtained with the X-ray tube fixed into the upper position.

•The operator uses the PET–CT computer console to identify the patient and examination.

•The patient is automatically moved head first into the CT gantry, and the X-ray tomogram is acquired.

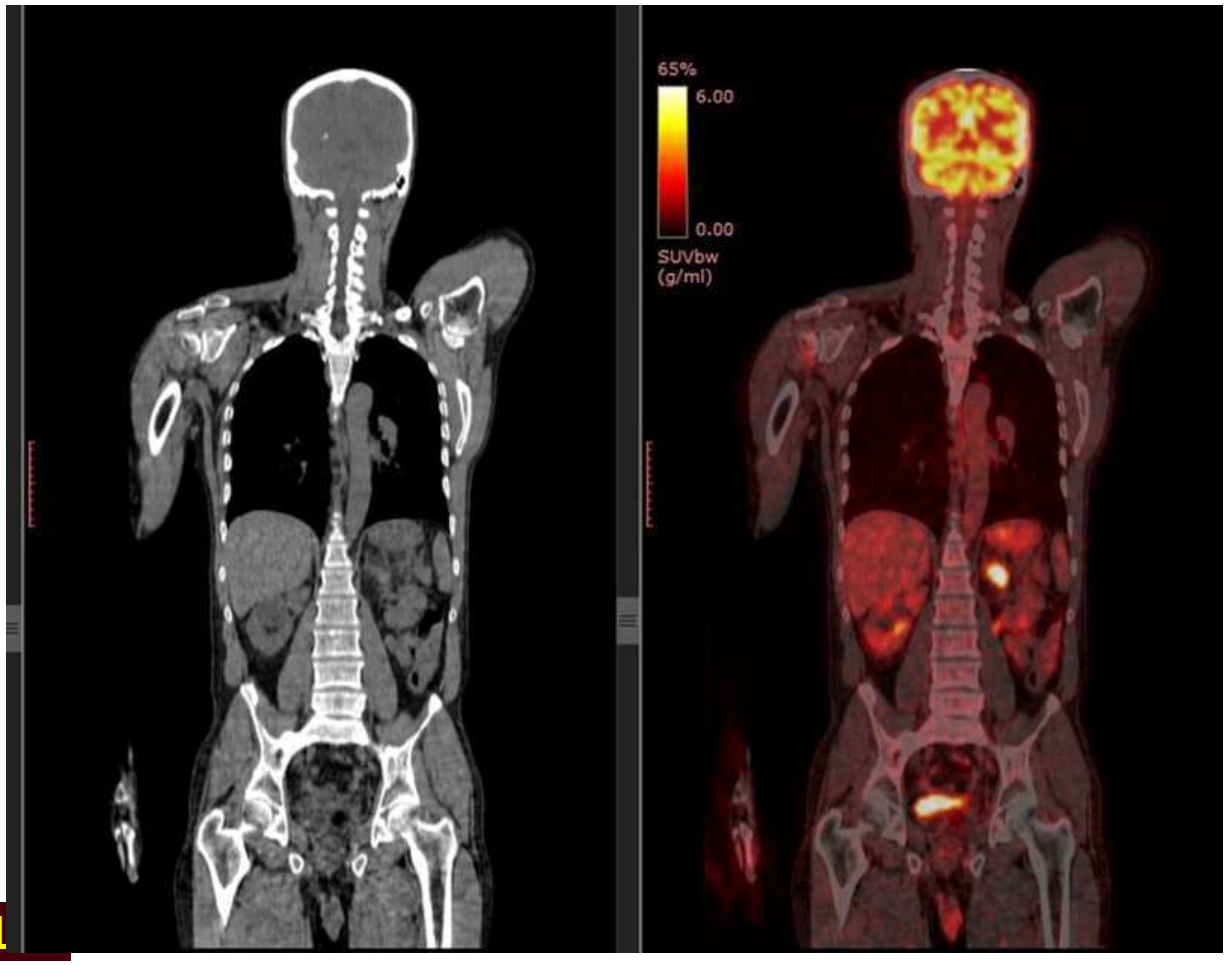
•Now the patient is automatically moved through the PET gantry, which is mounted in parallel with the CT gantry, and the PET slices are acquired.

•The patient leaves the device, and the PET–CT software starts reconstructing and aligning the **PET** and CT images.

A complete body PET–CT fusion image

Siemens Biograph PET–CT scanner

- A **whole body scan**, which usually is made
- from mid-thighs to the top of the head,
- **Time of scan**: 5 minutes to 40 minutes ← depending on the acquisition protocol and technology of the equipment used.
- **Slice Thickness**: FDG imaging protocols acquires slices with a thickness of 2 to 3 mm.
- It provides a quantification of the **size of the lesion**, since functional imaging does not provide a precise anatomical estimate of its extent.
- The CT → Explore  anatomical images
- PET → Functional images by radioactive uptake.

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# SPECT/CT



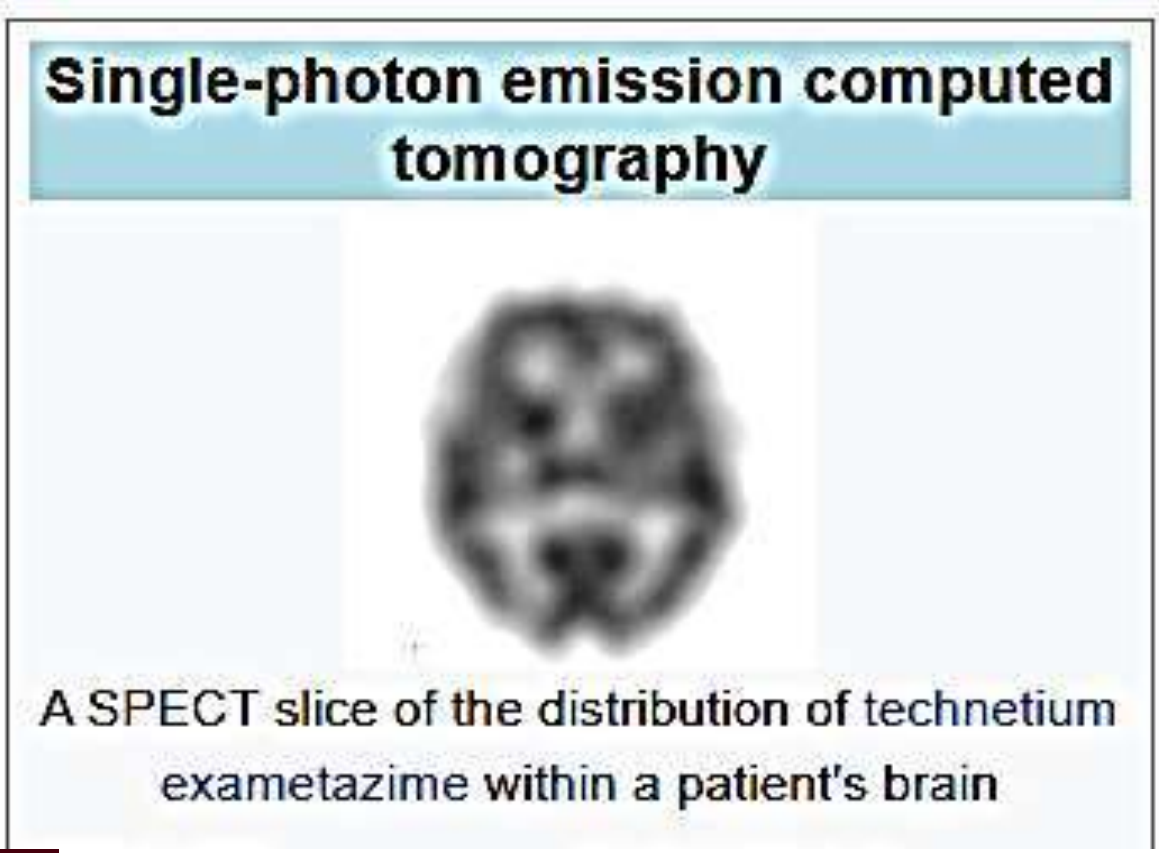
**Single-photon emission computed tomography**

## Basics

- is a nuclear medicine imaging technique using gamma rays.
- It is very similar to conventional nuclear medicine planar imaging using a gamma camera (scintigraphy), but is able to provide true 3D information.
- This information is typically presented as **cross-sectional slices** through the patient, but can be freely reformatted or manipulated as required.
- The technique → a gamma-emitting radioisotope (a radionuclide) injected into the patient.
- Instead of just "taking a picture of anatomical structures", a SPECT scan monitors the level of biological activity at each place in the **3-D region** analyzed.
- Emissions from the radionuclide → indicate amounts of blood flow in the capillaries of the imaged regions.
- In the same way that a plain X-ray is a 2-dimensional (2-D) view of a 3-dimensional structure, the image obtained by a gamma camera is a 2-D view of 3-D distribution of a radionuclide.

In some cases, a SPECT gamma scanner may be built to operate with a conventional CT scanner as in PET/CT,


SIEMENS


Single-photon emission computed tomography
A SPECT slice of the distribution of technetium exametazime within a patient's brain

## Application

SPECT can be used to complement any gamma imaging study, where a true 3D representation can be helpful, such as

- Tumor imaging,
- infection (leukocyte) imaging,
- thyroid imaging
- Bone scintigraphy..
- Myocardial perfusion imaging
- Functional brain imaging

| Study | Radioisotope | Emission energy (keV) | Half-life |
|---|---|---|---|
| Bone scan | technetium-99m | 140 | 6 hours |
| Myocardial perfusion scan | technetium-99m | 140 | 6 hours |
| Sestamibi parathyroid scan | technetium-99m | 140 | 6 hours |
| Brain scan | technetium-99m | 140 | 6 hours |
| Neuroendocrine or neurological tumor scan | iodine-123 or iodine-131 | 159 | 13 hours or 8 days |
| White cell scan | indium-111 & technetium-99m | 171 & 245 | 67 hours |

# CHAPTER 8

# SUMMARY & IMPORTANT POINTS

## Imaging Modalities

- ✓ X ray
- ✓ Ultrasonography & Doppler
- ✓ Computed Tomography (CT)
- ✓ Magnetic Resonance Imaging (MRI)
- ✓ Radio-isotope scan
- ✓ ..... & Others (PET – SPECT )

**In Every modality you should know:**

- ➲ Basics of work
- ➲ Energy used
- ➲ Main Indications
- ➲ Contraindications
- ➲ Finding of main Pathologies

**Please, don't suggest any imaging modality for any patient unless you know the value of it for diagnosis of the case.**

### ✍ X-ray / CT

**Contraindications :**

- × **Pregnancy**

  (Especially, early) , it can lead to **teratogenicity**.

- × **Non indicated diagnosis ,**

  As you will expose patient to radiation without any benefit .

- × **Contrast Hypersensitivity:** for X ray techniques using IV contrast as IVU.

| Types of MRI | |
|---|---|
| • **According to shape:** | • **According to Magnet Type :** |
| ▪ Open<br>▪ Closed<br>▪ Dynamic<br>▪ Extremity | ▪ Permanent<br>▪ Electeric<br>▪ Super magnet |

**Don't Forget**

**MRI is large powerful Magnet**

## - Contraindications of MRI:

☒ **Pacemaker (Fatal)**

☒ **Any Iron FB**

☒ **Contrast Hypersensitivity**

☒ **Fire arm / Vascular metallic clips**

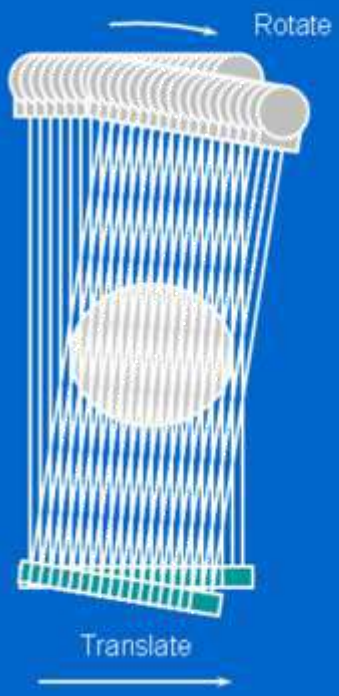
## CT HISTORY:

| Year | Development |
|---|---|
| 1924 | Johann Radon formulated the mathematical theory of tomographic image reconstruction. |
| 1930 | A. Vallebona constructed equipment and published 1st clinical body section imaging material. |
| 1963 | A. McLeod Cormack developed the theoretical underpinnings of CT scanning. |
| 1971 | 1st generation CT: commercial CT introduced by Sir Godfrey Hounsfield. |
| 1972 | EMI scanner was introduced as clinical system of cranial examination. |
| 1974 | 2nd generation CT. |
| 1975 | 3rd generation CT. |
| 1976 | 4th generation CT. |
| 1979 | Cormack & Hounsfield shared the noble prize in physiology or medicine. |
| 1980 | 5th generation cardiac CT. |
| 1989 | Single-row CT. |
| 1991 | Spiral CT was introduced. |
| 1994 | Double row spiral CT. |
| 1998 | Multidetector CT. |
| 2004 | 16 row spiral CT. |
| 2006 | Dual source CT introduced. |
| 2007 | 320 row spiral CT. |

## CT GENERATIONS:

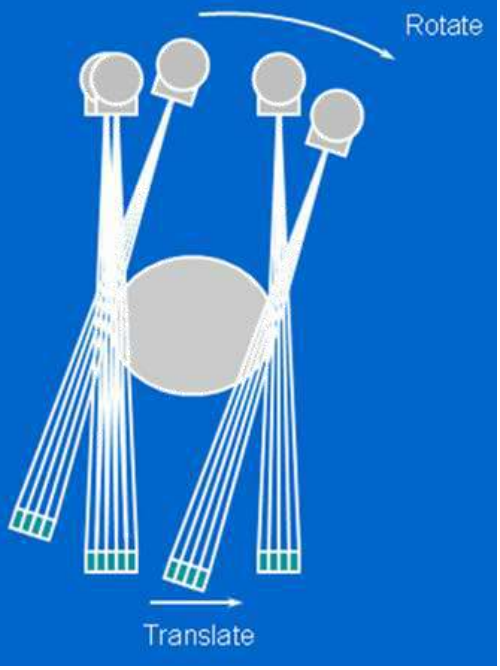
### First generation CT scanner

- Single detector
- Translate - rotate acquisition
  - Translates across patient
  - Rotates around patient
- Very slow
  - minutes per slice



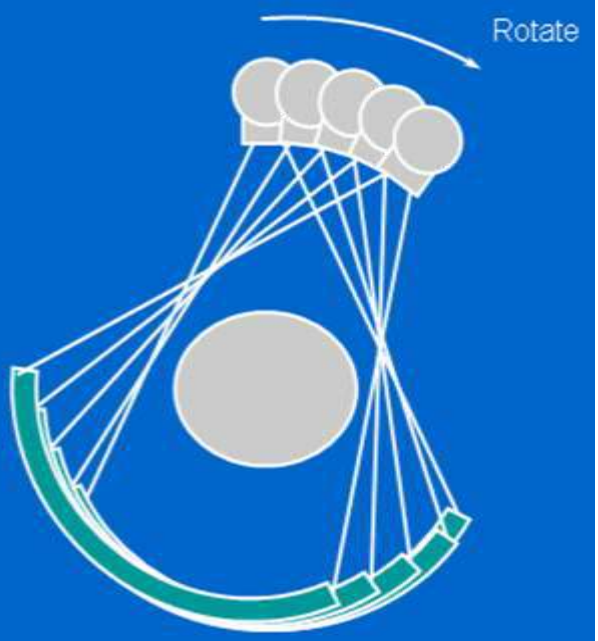

### Second generation CT scanner

- Narrow fan beam (10°)
- Multiple detectors
- Multiple angle acquisition at each position
  - Larger angle rotate
  - Translate still required
- Slow
  - 20s per slice



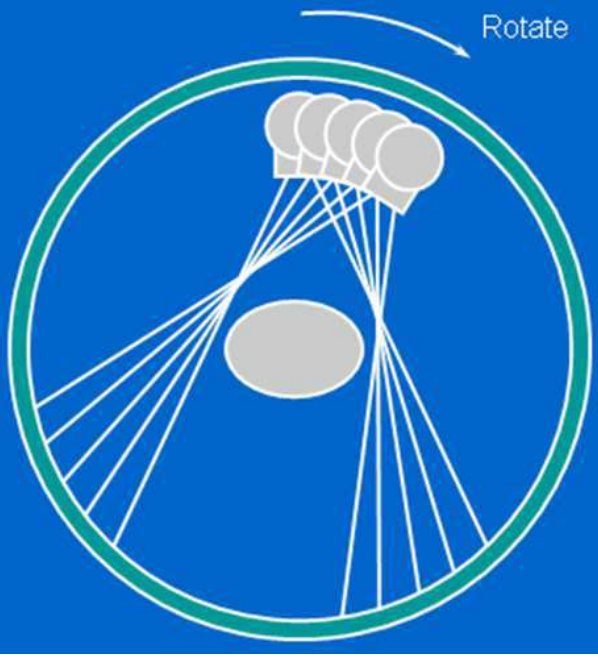
## Third generation CT scanner

- Fan beam
- Multiple (500 - 1000) rotating detectors
- Rotation only
  - no translation required
- Much faster
  - as fast as 0.5 s per rotation
- Most common modern scanner design




## Fourth generation CT scanners

- Fan beam
- Static detectors all round gantry
- Only tube rotates
- Avoids ring artefact problems of 3rd generation scanners



- The British electrical engineer

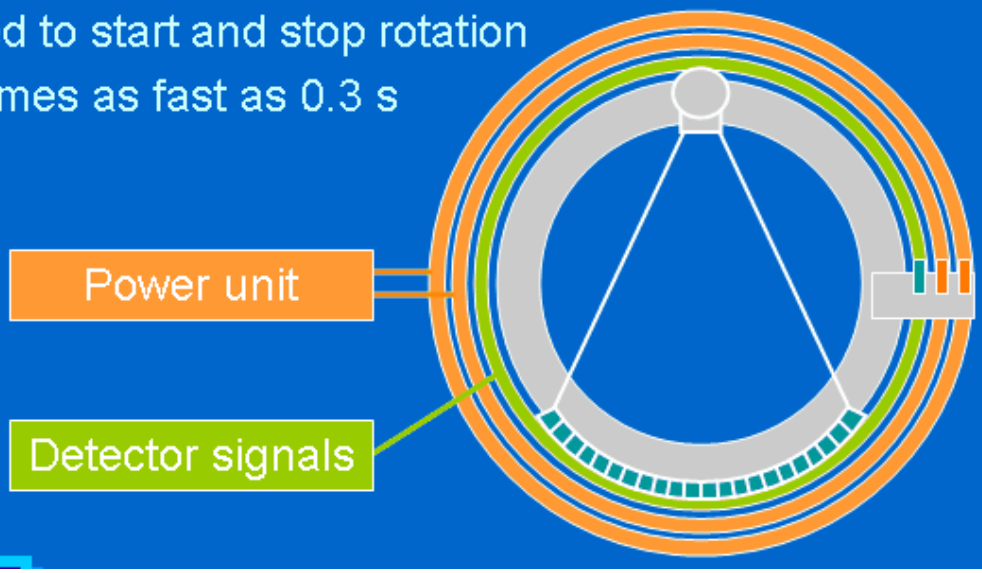
Godfrey N. ***Hounsfield***

CT INVENTOR

## Slip rings

**Helical CT depends mainly on Slip Ring Technology**

- Slip rings introduced in 1990 allowed continuous rotation
  - Power and signals transmitted to rotating gantry using 'brushes' on static rings
  - no need to start and stop rotation
  - scan times as fast as 0.3 s



The combination of Helical scanning and Multi-slice technology → acquisition of very thin slices, → anatomical data can now be viewed from any angle without distortion (multiplanar reconstruction), → allowing the extraction, analysis, and visualization of accurate 3D models of the scanned structures.

## Dual-Source and Dual-Energy CT

In **2005**, Siemens introduced, a scanner equipped with **two X-ray tubes** and **two detectors** mounted 90° apart on the gantry, each operating at **different energies**.

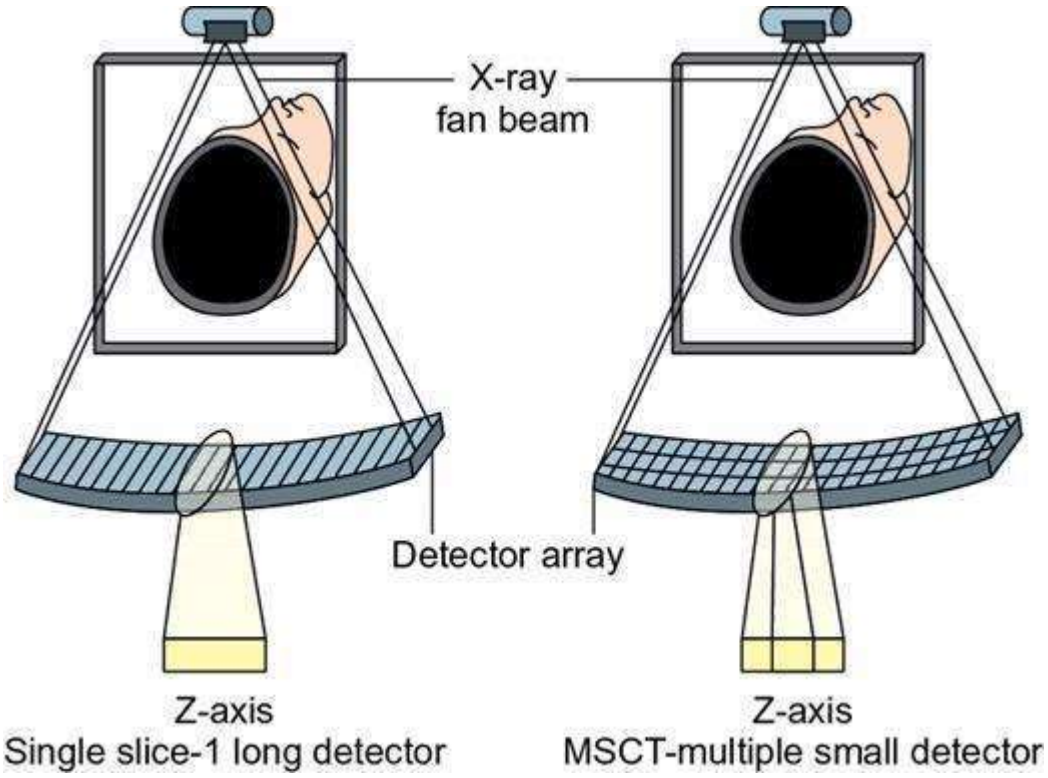
### Components of a CT scanner:

*1,* computer and operator's console;

*2,* gantry;

*3,* patient table.

| PIXELs | VOXELs |
|---|---|
| picture elements | volume elements |
| tiny squares (2D) | tiny cubes (3D) |
| building blocks making up a slice | building blocks making up a chunk (many slices stacked together) |




## Advantages of MDCT

١.Faster and simultaneous acquisition

٢.Reduced scanning time

٣.Reduced gantry rotation time (0.5–0.8 s)

٤.Rapid table translation

٥.Larger anatomical coverage

٦.Better tube loading capacity

### Two essential features of MDCT technology

١.Improved scan speed

٢.Isotropic imaging

**Cardiac Gating : CT Technique used In pediatric patients and coronary angiography, for reduction of patient motion artefact .**

# Average Hounsfield units (HU) for selected substances

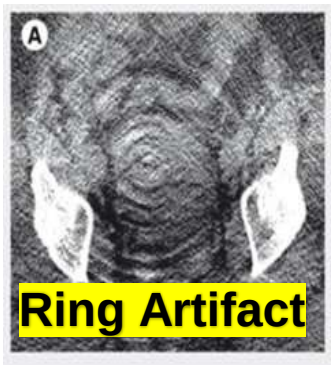
| Tissue | CT Number (HU) |
|---|---|
| Bone | +1000 |
| Liver | 40-60 |
| White mater | -20 to -30 |
| Grey mater | -37 to -45 |
| Blood | 40 |
| Muscle | 10-40 |
| Kidney | 30 |
| CSF | 15 |
| Water | 0 |
| Fat | -50 to -100 |
| Air | -1000 |

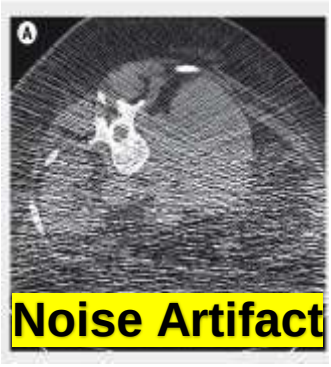
## WINDOW WIDTH AND WINDOW LEVEL

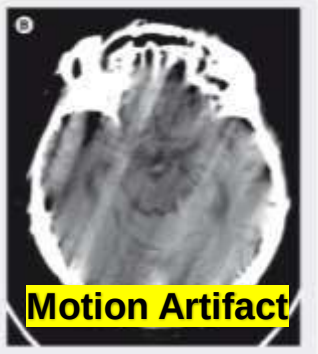
| CT Examination | Width | Level |
|---|---|---|
| Brain | 190 | 50 |
| Skull | 3500 | 500 |
| Orbits | 1200 | 50 |
| Abdomen | 400 | 35 |
| Liver | 175 | 45 |
| Mediastinum | 325 | 50 |
| Lung | 2000 | -500 |
| Spinal Cord | 400 | 50 |
| Spine | 2200 | 400 |

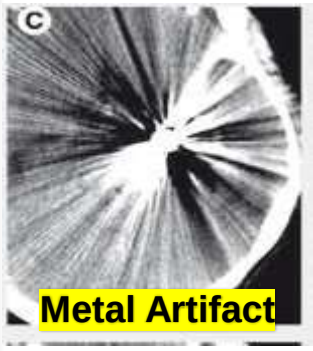
- **Artifacts : Unreal image abnormality or distortion** are commonly encountered in clinical CT and may obscure or simulate pathology.
- T**ypes of CT artifacts** :

| | |
|---|---|
| - Noise,<br>- Beam hardening,<br>- Scatter,<br>- Pseudo-enhancement | - Motion,<br>- Cone-beam,<br>- Helical,<br>- Ring<br>- Metal artifacts. |



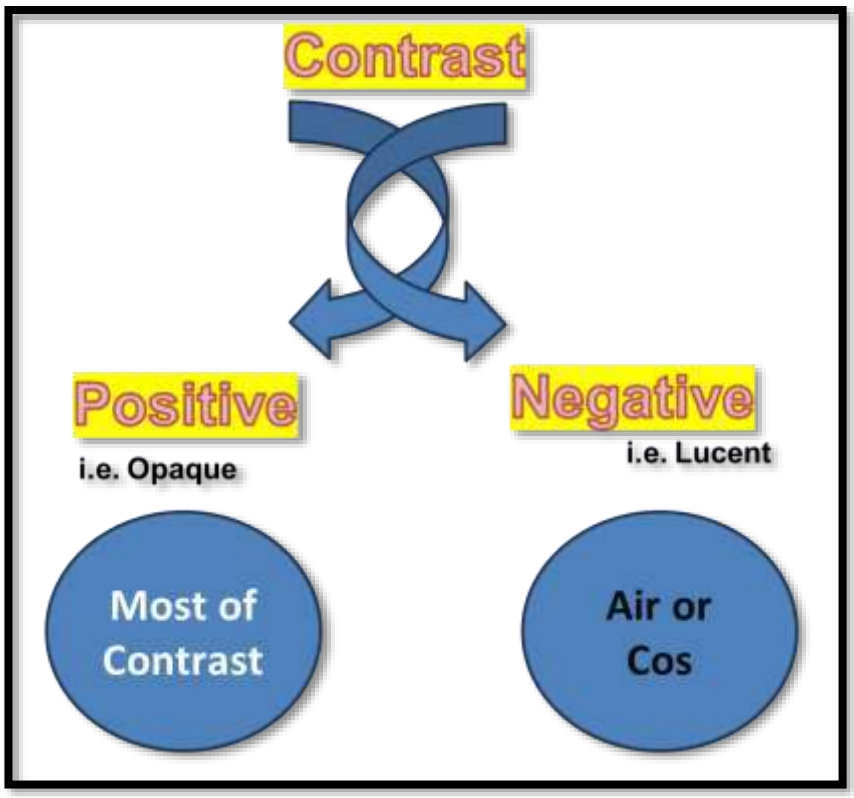

**For Ideal CT Image:**

- High radiation dose, → high photon counts,
- monochromatic x-rays,
- infinite detector resolution,
- perfect detectors,
- No motion and
- No scatter,

→ CT images would be a **perfect**.

If any of those conditions are not met, → **artifacts will occur**.

**Contrast :** A material given to enhance visualization of a lesion or structure




## Contrast Routes :

- **Oral**
- **IV**
- **Rectal**

# CT Contrast Composition

## Iodinated Contrast Material

* Do not administer ICM if particulate matter (including crystals) and/or discoloration is observed or if containers are defective

* Do not mix or inject ICM in intravenous administration lines containing other drugs or total nutritional admixtures.

The safety & effectiveness of ULTRAVIST in younger than 2 years of age have not been established.

ULTRAVIST is not approved for use in patients younger than 2 years of age

**3 DOSAGE FORMS AND STRENGTHS**

ULTRAVIST injection is a clear, colorless to slightly yellow, odorless solution available in two concentrations:

300 mg Iodine per mL available as

- 50 mL, 100 mL, 125 mL, and 150 mL in single-dose vials
- 200 mL and 500 mL in pharmacy bulk packages
- 200 mL and 500 mL in imaging bulk packages

370 mg Iodine per mL available as

- 50 mL, 100 mL, 125 mL, and 150 mL in single-dose vials
- 200 mL and 500 mL in pharmacy bulk packages
- 200 mL and 500 mL in imaging bulk packages

## I C M Adverse Reactions:

- Hypersensitivity Reactions
- Renal Impairment
- Cardiovascular adverse
- Thromboembolic Events
- Thyroid Dysfunction
- Hypertensive Crisis (in Pheochromocytoma)
- Sickle Cell Crisis

**So…….**
= Use the **lowest necessary dose** of contrast in patients with renal impairment.
= **Hydrate patients** prior to administration.
= **Do not use** laxatives, diuretics, or preparatory dehydration prior to administration.

**Deaths from the administration of iodinated contrast agents range from 6.6 per 1 million (0.00066 %) to 1 in 10,000 patients (0.01 %).**

**To decrease thromboembolic events**, :

- Use meticulous (accurate) angiographic techniques and
- Minimize the length of the procedure.
- Avoid **blood remaining** in contact with syringes containing iodinated contrast agents, which increases the risk of clotting.
- Avoid angiography in patients with homocystinuria because of the risk of inducing thrombosis and embolism.

Pediatric **congenital cardiac conditions** may be at the **greatest risk** given that they often require **high doses** of contrast during invasive cardiac procedures.

## I C M Drug Interaction

### 1- Metformin:

Stop metformin at the time of, or before, administration in patients with an eGFR between 30 and 60 mL/min/1.73 m2;

### 2- Radioactive Iodine:

- ICM interferes with thyroid uptake of **radioactive iodine** (**I-131** and **I-123**) and decreases therapeutic & diagnostic efficacy.
- Avoid thyroid therapy or testing for up to 6 weeks post-contrast.

### 3- Drug-Laboratory Test Interactions

**Thyroid function tests** which **do not depend on iodine estimations**, for example, T3 resin uptake and total or free thyroxine (T4) assays are not affected.

## I C M SUMMARY OF USE

**IODINATE**

- **Interfere with Iodine drug – Affect thyroid**
- **Use with caution with any chronic patient**
- **Take history from patient Before use of: Hypersensitivity, Chronic diseases, Drugs used**
- **Renal Function test is mandatory before use**

**Metformin**
**Iodine**

| Before scan | Scanning | After Scan |
|---|---|---|
| ✦ Renal function test? | ✦ Type of ICM | ✦ Hydration therapy? |
| • History of renal disease or renal surgery<br>• Heart failure<br>• Diabetes<br>• Proteinuria<br>• Hypertension<br>• Gout<br>• Metformin | • Iso-osmolar ICM<br>• Low-osmolar ICM<br>• Ionic high-osmolar ICM | • Hydration to prevent PC-AKI in patients at-risk<br>• Oral hydration as the sole means of prevention for PC-AKI |
| ✦ Renal function test -> ICM administration | ✦ Dosing of ICM | ✦ Any drug for prevention? |
| • Within 7 days for patient has an acute disease<br>• Within 3 months for patient has a chronic disease with stable renal function<br>• Clinical judgment for emergency patient | • Use the minimum amount of contrast media necessary for diagnostic efficacy<br>• Use standard diagnostic dose | • Not recommend any drugs |
| ✦ eGFR cutoff for extra assessment | ✦ Scan -> Repeated scan | ✦ Blood purification therapy? |
| • Patients with eGFR < 30 ml/min/1.73m²<br>• Patients with eGFR < 45 ml/min/1.73m² in ICU or with high-risk factors | • Avoid within 72h<br>• Avoid within 48-72h<br>• Avoid within 48h<br>• Avoid within 24-48h<br>• Avoid within 24h<br>• Clinical judgment for emergency patient | • Not recommend to initiate<br>• Not recommend to change the schedule<br>• The use of ICM can be synchronized with scheduled blood purification therapy |

- Guidelines on intravenous ICM use in patients with kidney disease has suboptimal quality.
- The controversial recommendations for varying timing and protocols must be considered in future studies.

| Severity | Reaction |
|---|---|
| Mild reactions | Urticaria<br>Hives<br>Nausea<br>Vomiting |
| Moderate reactions | Facial oedema<br>Severe vomiting<br>Bronchospasm<br>Laryngeal oedema |
| Severe reactions | Pulmonary oedema<br>Cardiac arrythmia<br>Cardiovascular collapse<br>Respiratory collapse |

**Oncology** is the medical specialty focused on preventing, diagnosing, and treating cancer.

## Oncology: (Diagnosis, Treatment, Prevention, Supportive care)

| Term | Definition |
|---|---|
| Tumor | • Abnormal mass of tissue which results from: excessive cell division and evasion of apoptosis<br>• Can be **benign** or **malignant**<br>• Equivalent to the term **neoplasm** |
| Cancer | • Disease consisting of: deregulated cell growth and the ability to **invade**<br>• Cancer is automatically **malignant** |
| Benign | • Cells are **not cancerous**<br>• Local problems; does not spread<br>• Most growths do not return when removed<br>• For example: benign thymomas, acoustic neuromas |
| Malignant | • Cells are **cancerous**<br>• Cancerous cells can spread and invade other tissues |
| Metastasis | • The process and outcome of malignant or cancerous cells spreading and invading other tissues |
| Hyperplasia | • Increase in number of cells within an organ or tissue |
| Hypertrophy | • Increase in size of cells within an organ or tissue |

**Why do we stage cancers? for the following reasons:**

- it provides a common language of communication, guides treatment, estimates prognosis,
- allows comparison of results,
- standardizes clinical trials.

- **Staging & grading** of cancers are different classification methods.

- **The grade** of a neoplasm :the *histological* and *pathological* features of the cells in a neoplasm.

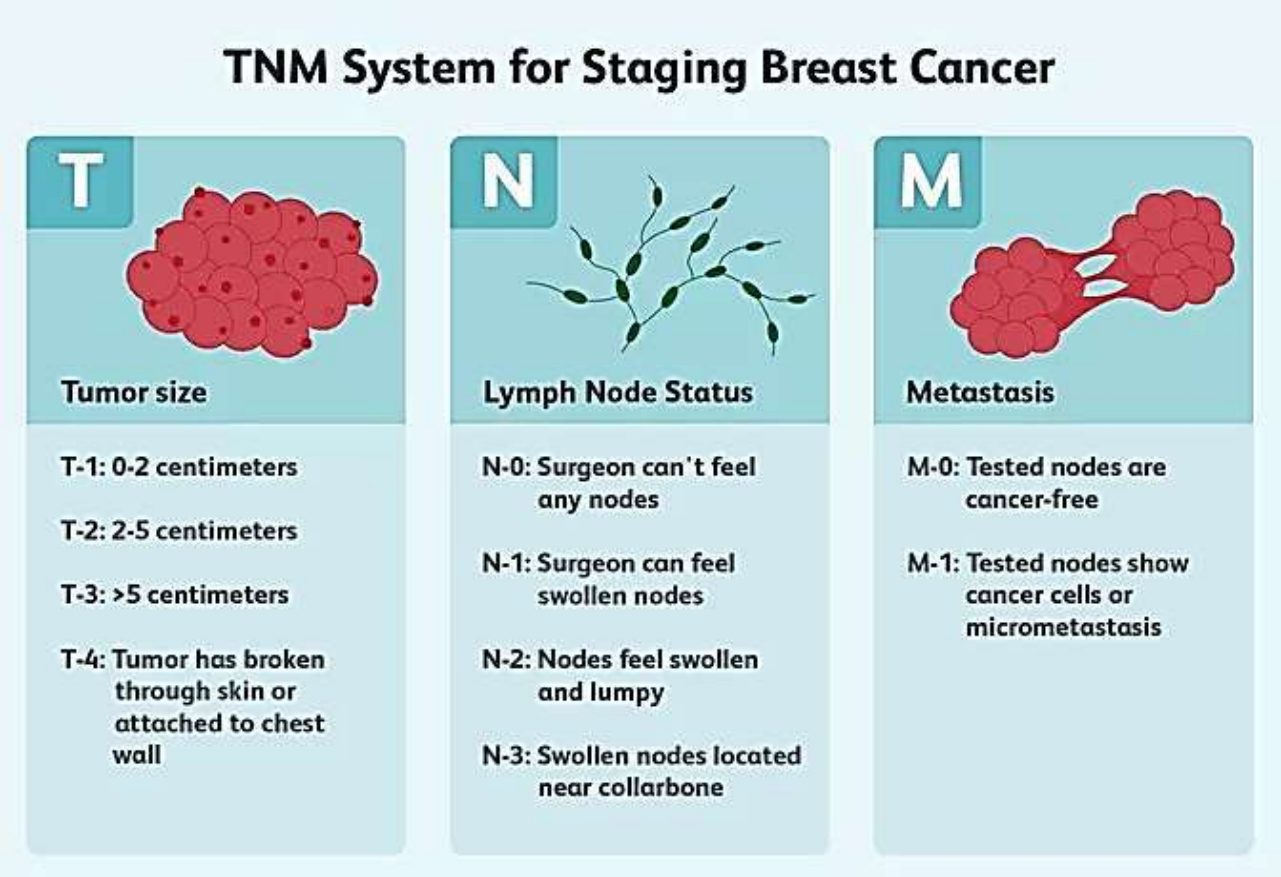
- **The stage** of a neoplasm: provides a sense for how advanced a cancer is.

- Many (but not all) cancers are staged using the **TNM staging system:**

This system is divided into <u>three components</u>:

- Tumor (**T**), - Nodal status (**N**), and - Metastasis (**M**),

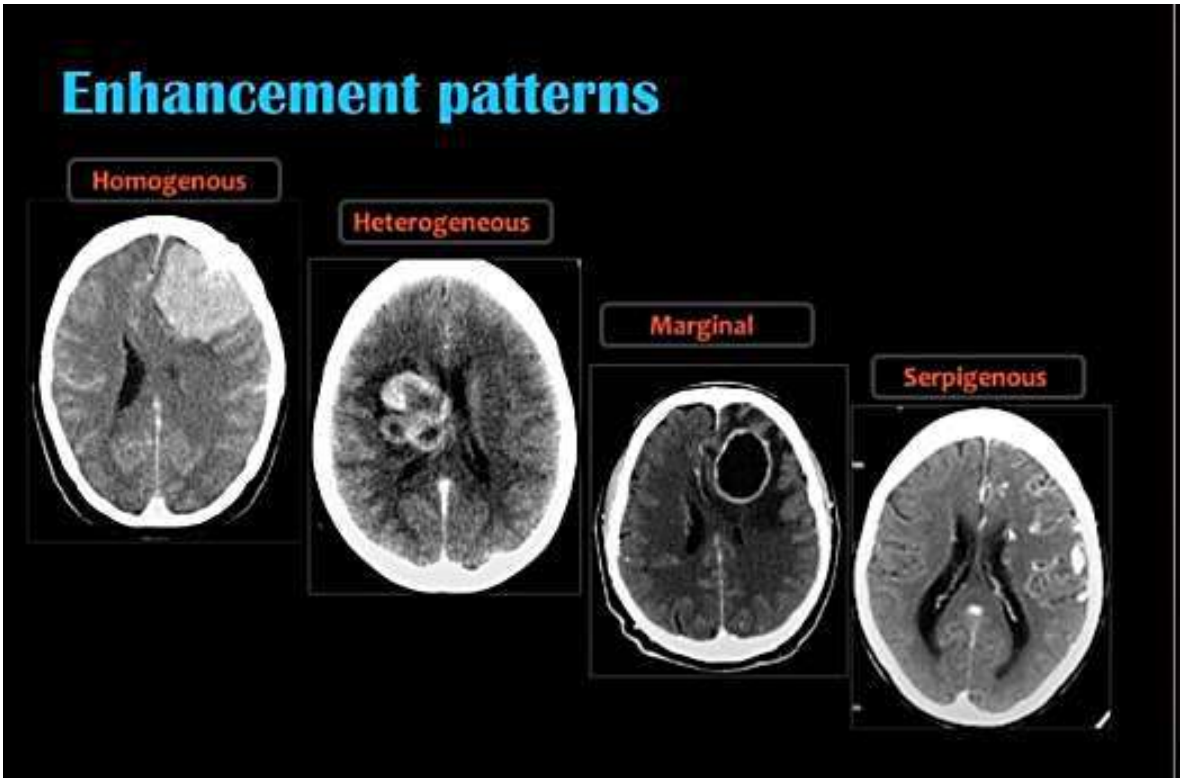
Different combinations can further be classified into general stages I, II, III, IV.



# ROLE OF CT IN NEOPLASMS IMAGING

- Detection of tumors
- Staging
- Follow Up After treatment

- I.V. Contrast Is mandatory for assessment of any suspected Brain Tumors
  - The scan Must be done Pre & Post Contrast



**All liver tumors get 100% of their blood supply from the hepatic artery, so when they enhance it will be in the arterial phase.**

| | | |
|---|---|---|
| IV SIZE | | 20g |
| IV CONTRAST | | WEIGHT BASED |
| INJECTION RATE | | 4cc/SEC |
| PT POSITION | | SUPINE / FEET FIRST |
| LANDMARK | GE | XYPHOID |
| | SIEMENS | |
| BREATHING | | EXPIRATION |
| SCOUTS | | AP AND LATERAL |

| PARAMETER | | ART | PV | DELAY |
|---|---|---|---|---|
| START | | ABOVE DIAPHRAGM | ABOVE DIAPHRAGM | ABOVE DIAPHRAGM |
| END | | ILIAC CREST | ILIAC CREST | ILIAC CREST |
| DFOV | | <TO PATIENT> | <TO PATIENT> | <TO PATIENT> |
| PREP GROUP | GE | 40 SEC | 70 SEC | 5 MINS |
| | SIEMENS | | | |

## Benefits of PET–CT

•The advantages of combining two methods.

•The result exceeds images obtained by the two devices taken separately.

•The method allows identification of all cancerous formations in the body, regardless of their size or degree of development.

•**Short diagnosis time**

• **Very low risk**, of the substance used, ← eliminated by the body within a maximum of 24 hours after administration

## PET-CT Obstacle of Use

- Difficulty and cost of producing and transporting the radiopharmaceuticals used for PET imaging, which are usually extremely short-lived.
- Expensive cost of machine.

**IV Contrast is mandatory for any CT brain for diagnosis or follow up of any BRAIN TUMORS.**

# Add Your Points

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# REFERENCES

# *About The Author*

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- **"MBBCH" Faculty of Medicine, Sohag University, Egypt (2004).**
- **Master's "MSc" in Diagnostic Radiology - Sohag Faculty of Medicine (2011).**
- **Doctorate "MD, PhD" in Diagnostic Radiology - Sohag Faculty of Medicine (2021).**
- **Diploma of Total Quality Management – Sadat Academy of Management Sciences (2021).**
- **Diploma of Hospitals Management – Sadat Academy of Management Sciences (2024).**
- **Lecturer & Consultant of Diagnostic Radiology, Faculty of Medicine, Sohag University.**
- **Vice Manager of the New Sohag University Hospital (Emergency) for Information Systems (formerly).**
- **Certified trainer at the Supreme Council of Egyptian Universities.**
- **Trainer at Sohag University (for digital transformation and TOT).**
- **Supervisor of the University Clinics (Urban Center) (formerly).**
- **Lecturer at the Saudi Virtual Medical Academy, KSA (VMA).**
- **Worked in several Medical Centers and Hospitals inside and outside Egypt (as a Radiologist, Consultant, and Medical Director).**
- **Trainer and Administrator of PACS & Teleradiology systems.**
- **Volunteer for several years with civil society organizations (73 Historians') & (QELADA "Necklace").**
- **More than 40 articles and stories about Egyptian and historical heroism.**
- **more than 150 lectures at teaching, conferences, seminars, and scientific meetings, and YouTube.** *Dr. AHMAD MOKHTAR ABODAHAB – YouTube*
  - **More than 33 published research papers in different scientific journals in the fields of *diagnostic radiology, teaching techniques, medical education, and management.***