

READING HOSPITAL  
SCHOOL OF HEALTH SCIENCES  
MEDICAL IMAGING PROGRAM  
BASICS OF CT--2021



*Introduction to CT*

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# Computed Tomography

- Tomo
  - Section, cut or layer
- -Graphy
  - The process of recording
- Older terms
  - EMI Scan
  - Body Section Röntgenography
  - Computerized Axial Tomography
  - Computer Assisted Tomography
  - Computed Tomography



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## Invention of Computed Tomography—1971\*

### Godfrey Newbold Hounsfield- “father of CT”

- Engineer for EMI Laboratories, England
- Developed: Pattern recognition and reconstruction techniques for the computer
- Passed x-ray beam through an object from all directions to create one image
- Used principle of mathematical reconstruction developed by **Radon** in 1917



*Godfrey Hounsfield*

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## Invention of Computed Tomography—1971\*

### Alan MacLeod Cormack

- Physicist for Tufts University in Massachusetts
- Developed: Solutions to mathematical problems in CT

\*\*Hounsfield and Cormack awarded  
Nobel Peace Prize in 1979



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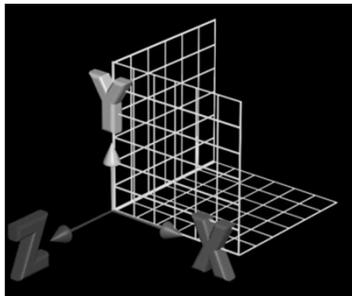
## Basic Principles of Computed Tomography



- X-ray tube used as source of x-rays
- X-rays pass through the patient into detectors at various angles throughout a circular pattern
- Detectors convert x-rays to electronic signals
- Computer processes electronic signals to mathematically create an image

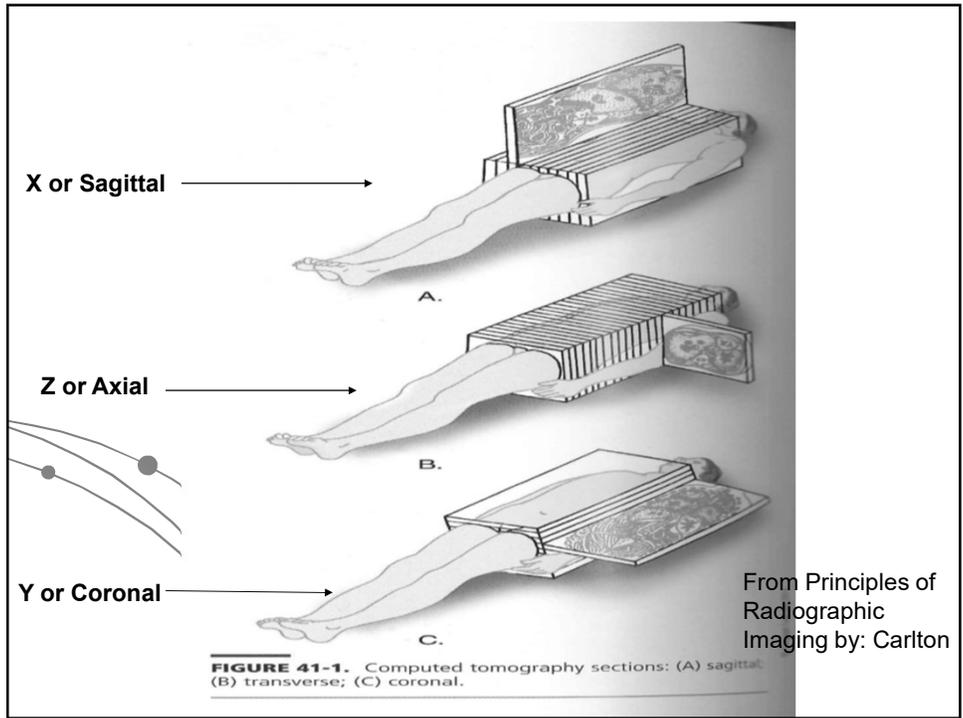
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## CT Coordinates

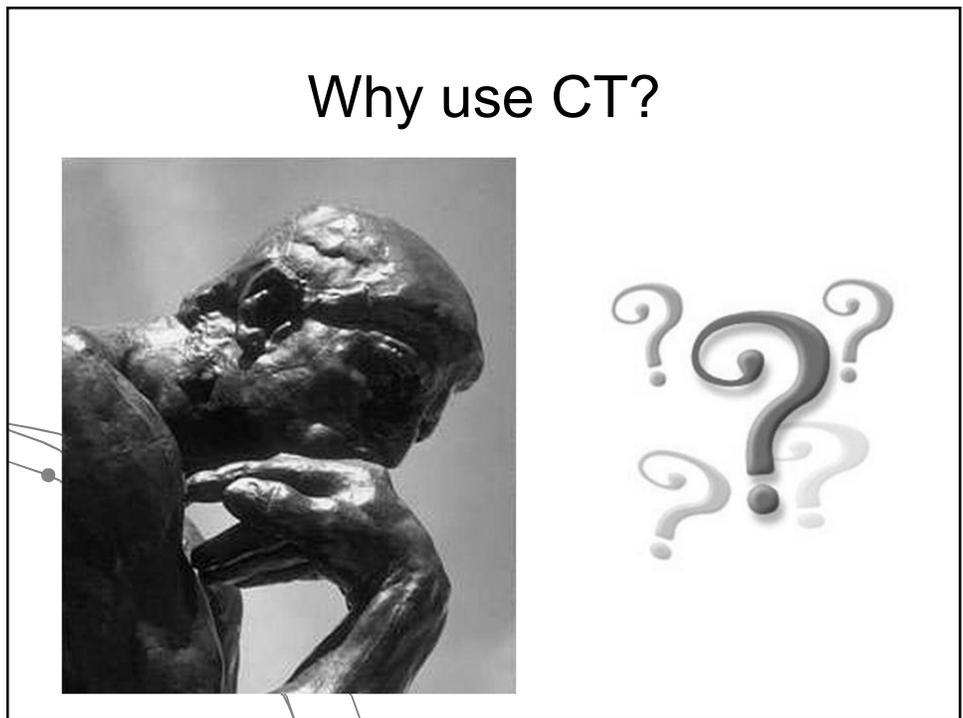


- Ability to produce an image in three planes
  - Z= Axial (transverse)
    - Cross Sectional
  - Y = Coronal (posterior to anterior)
  - X= Sagittal (left to right)

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## Benefits of CT

- **Contrast resolution** - Ability to distinguish between structures with similar densities
  - Conventional x-ray = 5-10% contrast resolution
  - CT = 0.5% contrast resolution
    - Due to tight beam collimation= less scatter
- **Spatial resolution** - ability of system to define small objects distinctly
- Eliminates superimposition of structures
- Larger volume of tissue can be imaged
  - MRI
  - US
  - NM

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## Benefits of CT

### Speed- why is it important

- Image quality
  - less motion artifact
- **Temporal resolution - The speed data is acquired**
  - Critical for contrast media exams
  - Essential for critical cases



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## Benefits of CT

- Digital imaging modality
  - Images can be modified and re-filmed
  - Film contrast setting and size can be altered
  - Lost film can be reprinted
  - Images can be post-processed with different characteristics
  - Digital files can be stored and transferred to other locations

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- First Generation
- Second Generation
- Third Generation
- Fourth Generation
- Fifth Generation
- Sixth Generation
- Seventh Generation

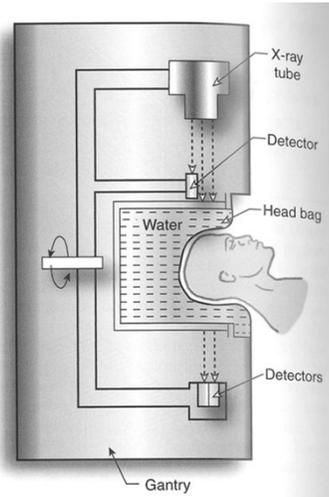
## **-Scanner Generations-**

*Characterized By: Generation & Tube/Detector Movement*

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# First Generation Scanner--1972

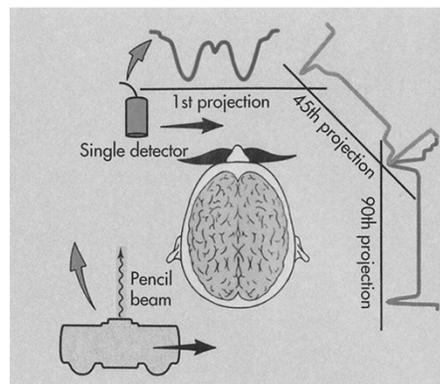
- X-ray tube – Pencil point beam
- Two detectors- capture x-rays that travel through the patient
- Tube and detector- move across the patient
- Rotation- 1 degree
- Scan Time- 5 minutes per image
  - Brain scan= 2.5 hours



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# First Generation Scanner--1972

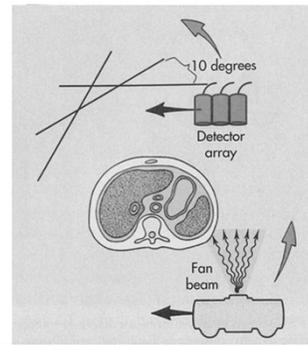
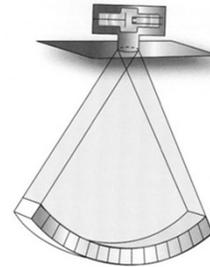
- Serial Scan
  - One image taken, table/ machine moves, then another image is taken
- **Translate, Rotate** design
  - Covers an arc of 180°
- Dedicated: Head scanners



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## Second Generation Scanner-- ~1974

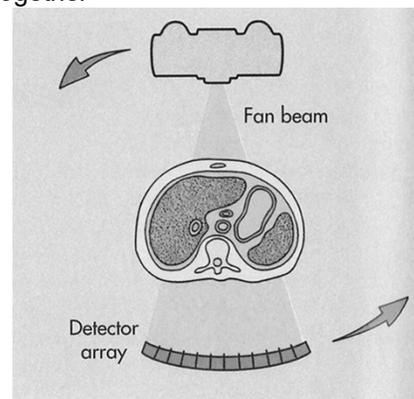
- X-ray tube- Generated fan shaped beam
- Detectors- Array of about 30
- Tube and detector assembly – Moves across the patient
- Rotation- 5 degree rotation
  - between passes
- Scan time- 20 seconds per one axial image
- Still translate, rotate design
  - Covering an arc of 180°



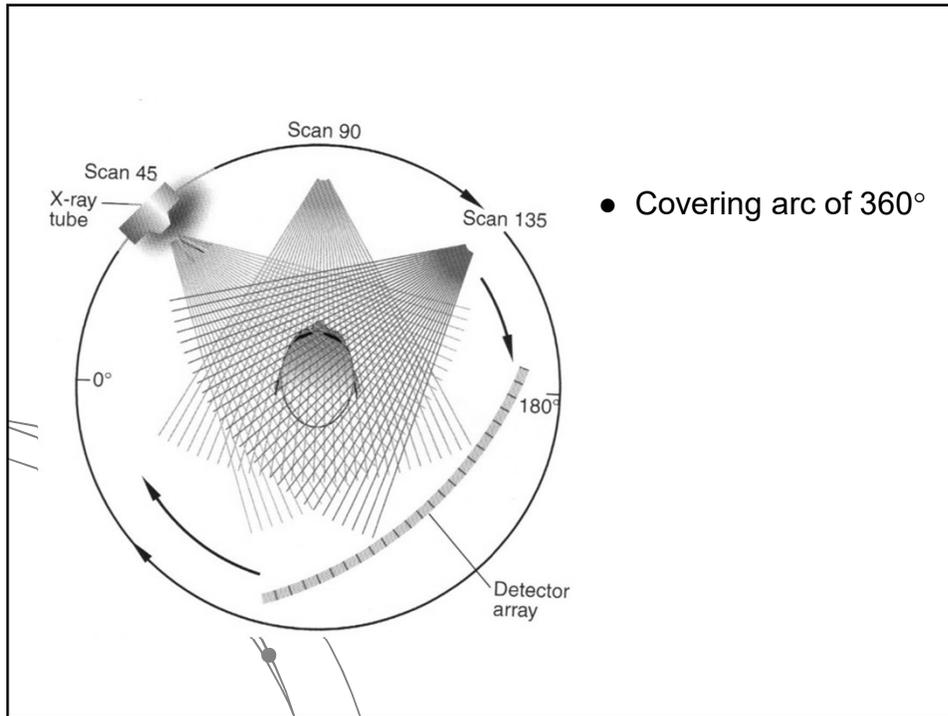
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## Third Generation Scanners--1975

- X-ray tube- Single projection, Fan-shaped
- Detectors- 600-2,000
- Tube and Detector- assembly moves together around the patient
- Rotation- **Rotate, rotate** design
  - Covering an arc of 360°
- Scan Time- < 1 second to acquire trans-axial image



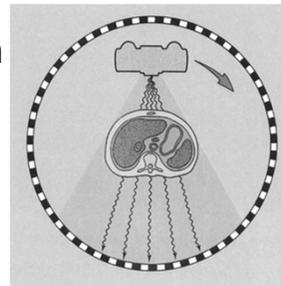
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## Fourth Generation Scanners

- X-ray tube - fan shaped beam
- Tube and Detectors – detectors form a complete circle on the gantry of the scanner that do not rotate. Tube moves around the patient
- Rotation- Rotate, stationary design
  - Covering an arc of 360°
- Scan time- <1 second to acquire axial image



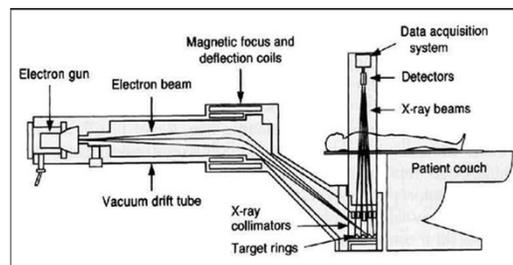
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## Fifth Generation Scanners--1983

Electron Beam Computed Tomography (EBCT) OR Cardiac Cine CT

- X-ray tube - Electrons from an electron gun strike an array of tungsten anodes under the patient
- Tube and Detectors- Radiation leaves the anodes and travels up through the patient and into the detectors

- Rotation: No moving parts



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## 5<sup>th</sup> Generation

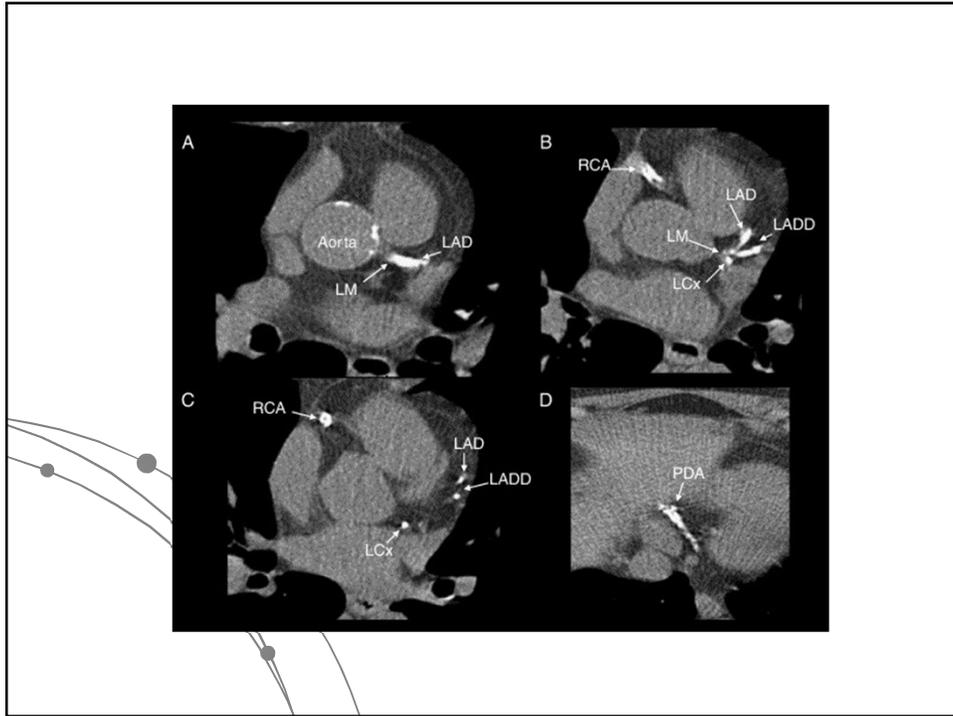
- Advantages

- Great temporal resolution
- Patient couch can swivel up to 25 degrees and be angled from 0-25 degrees

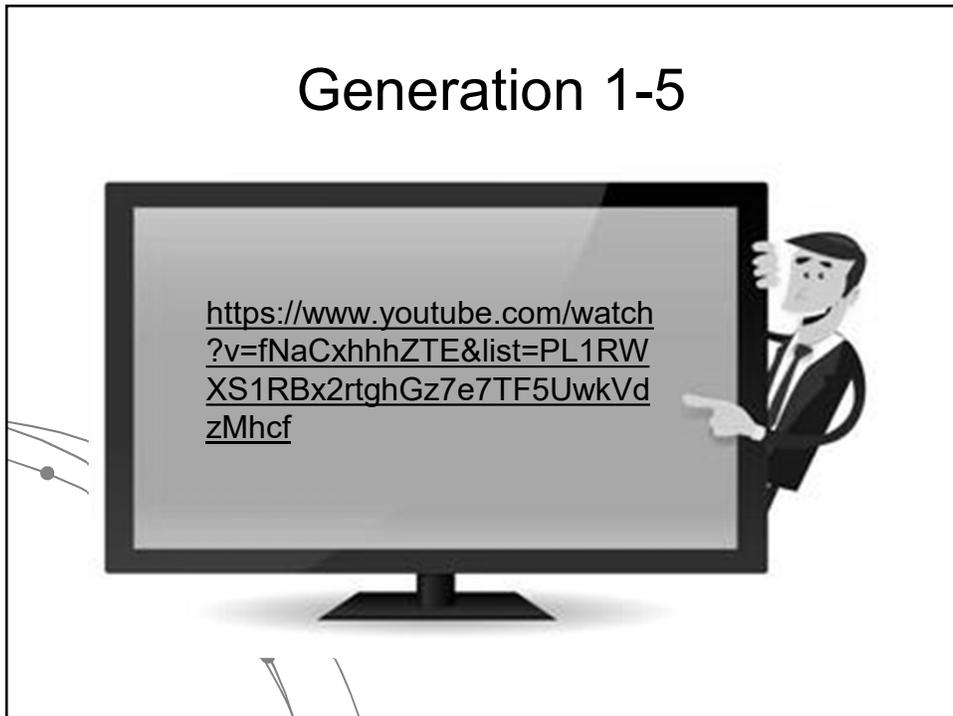
- Disadvantages

- Low spatial resolution
- Increased noise

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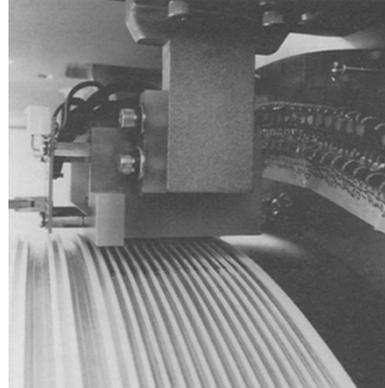
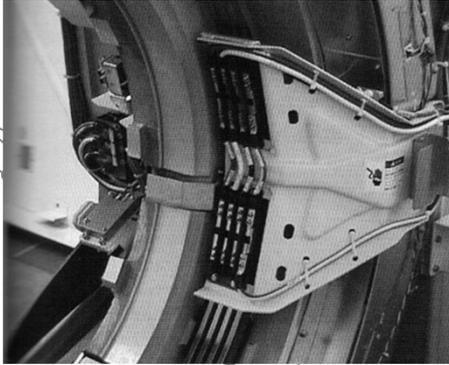


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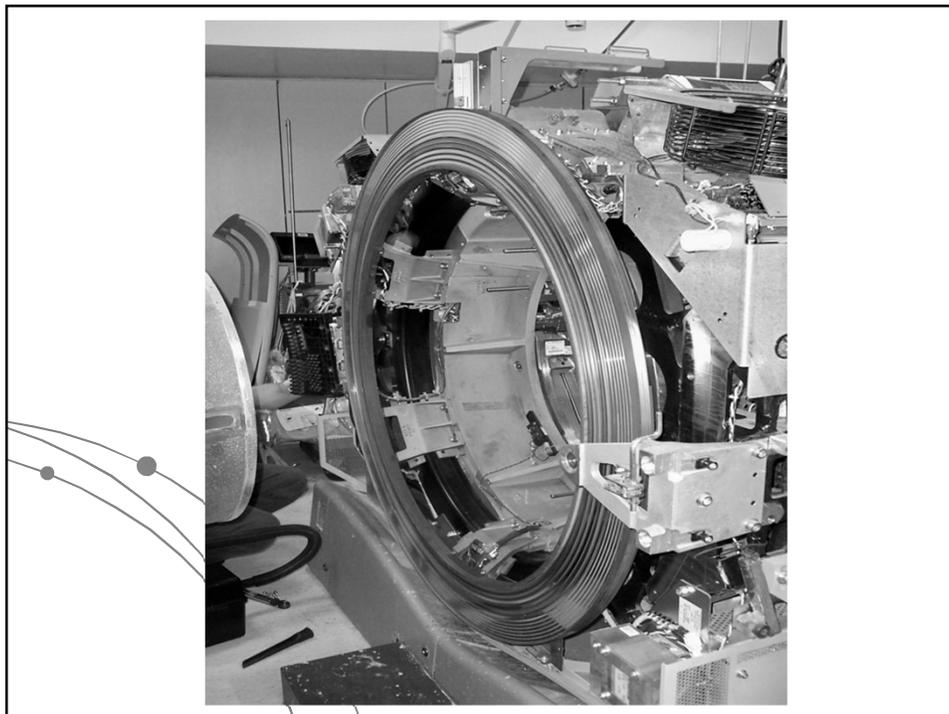
## Sixth Generation Scanners--1989

### Spiral/Helical Scanning

- Advances in Slip Ring connection technology



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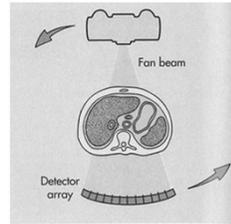
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# Sixth Generation Scanners--1989

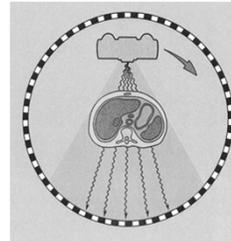
## 3<sup>rd</sup> and 4<sup>th</sup> Generation Scanners with 6<sup>th</sup> Generation Slip Ring Technology

- Remained the same in how images are obtained with detector motion
  - New addition with 6<sup>th</sup> Generation is slip ring technology to continuously rotate versus having to stop and recoil.
    - 3<sup>rd</sup> Generation – Tube and detector array rotate together to obtain images
    - 4<sup>th</sup> Generation – Tube rotates and detector array remains stationary around the gantry

### **Third Generation**



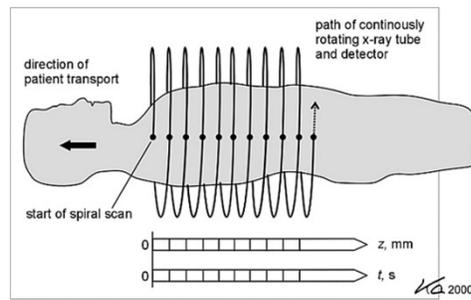
### **Fourth Generation**



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# Sixth Generation Scanners--1989

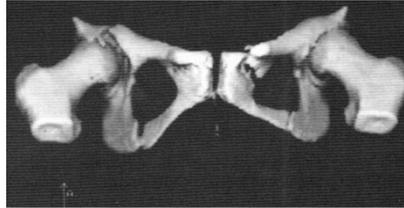
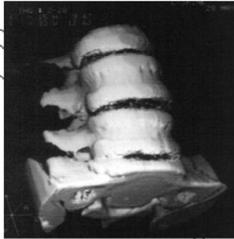
- Helical Scanning Patterns
  - Table movement
  - Continuous scan
- Scan Time- Allows imaging of entire anatomic regions (e.g. lungs)
  - 20-30 second breath hold
  - 3D image reformation
- *Entire exam completed in one breath hold*
- Disadvantage- Full 360° set of data not acquired



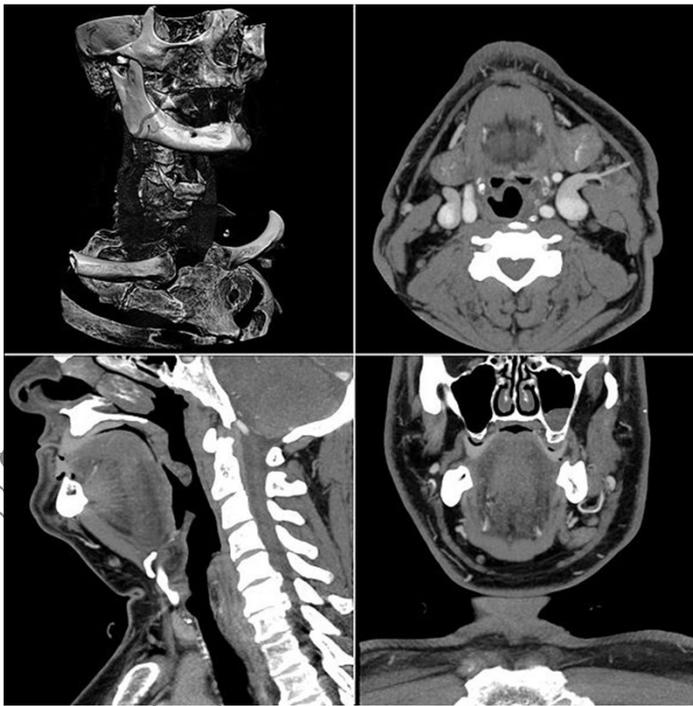
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# Sixth Generation Scanners

- Advantages:
  - Data can be reconstructed in 3-D
    - Complex blood vessels visualized
    - Complex fractures needing reconstructive surgery



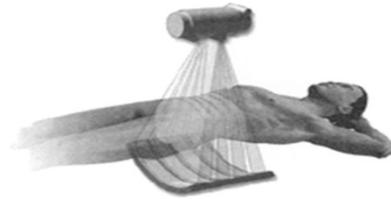
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## Seventh Generation Scanners--1999

- X-ray Tube - Single beam exposure to produce multiple sets of image receptor data
- Tube and detectors – Multiple rows of detectors exposed simultaneously
- Rotation- 360° rotation
- Scan Time- 4 slices of data in 250-350ms
  - Entire chest scan in 5-10 seconds
- Resolution- increased due to decreased section thickness
- Cutting edge
  - Speed, patient comfort, reduction in exposure to the patient



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## Seventh Generation Scanners--1999

### Names:

- **Multi-Slice Scanners**
- **Multisection Scanner**
- **Multislice Computed Tomography**
- **Multidetector Computed Tomography**
- **Multiple Detector Array Scanners**

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## Progress in CT--2002

- AEC system added to CT scanner
  - Controls radiation exposure to patient
- Volume scanning
  - Ability to cover entire organ with a single rotation
- CT screening exam
  - Colon, cardiac, lung “general health check”

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## Progress in CT--2003

- Scanners with extra wide gantry bores for radiotherapy planning and large patients (80-90 cm aperture)
- Scanners that can acquire 32, 40, 64, 128 or 256 slices per rotation
  - Decrease patient dose

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## Progress in CT—PET/CT

- Dual headed gamma camera which allows fusion of two sets of data
- 2-D and 3-D modes
- 70 cm bore

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## Applications of CT

- Tissue Biopsy
- CT Angiography – look at arteries and veins
- CT Colonography (Virtual Colonoscopy)- 3D image of colon
- CT Radio Frequency Ablation (RFA)- radiofrequencies used to ablate tissue



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# Applications of CT

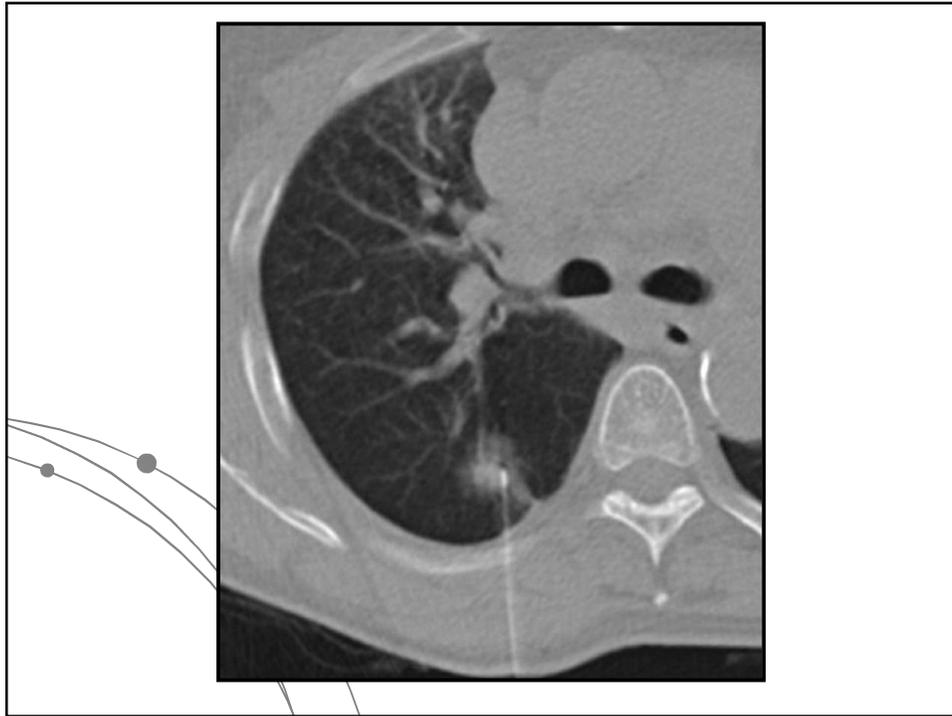
## ● CT Fluoroscopy

- Drainage of fluid collections (cysts, abscesses or tumors)
- Remove fluid from an infection or wound
- Diagnostic biopsy
  - Remove a tissue sample for pathologic or cytological testing
- Pain therapy – i.e. placing therapeutic agent into spinal disk

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## Applications of CT

- Minimally invasive operations
- Dynamic studies- shows motion or function
- CT Arthrogram
- Guidance of embolization to stop bleeding (e.g. liver or spleen)
- Treatment planning- radiation therapy

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## Patient Dose

Standard radiation protection procedures should be followed:

- Lead aprons – appropriate for anyone in the scanning room during exams.
- CT dose > single radiograph exposure

**\*\*1981---(Center for Devices and Radiological Health)**

- Computed Tomography Dose Index (CTDI)- average dose to a single CT slice (mGy)
- Dose Length Product (DLP)- CTDI x scan length. Uses slice thickness and number of slices to calculate (mGy-cm)
- Multiple Scan Average Dose (MSAD) – average dose a patient receives during a multiple slice scan.

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## Factors Affecting Dose

- **Radiation Beam Geometry** - Possibility of over scanning 360° arc
- **Filtration** – Removes low energy x-rays
- **Detector Efficiency** – Less efficient detectors require higher radiation exposure to produce adequate images
- **Radiographic Technique** – The higher the mAs and kVp settings the higher the dose
  - kVp has less effect on patient dose

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## Factors Affecting Dose

- **Patient Size and Body Part Thickness** – Large patients or thick body parts = increase in radiation dose to decrease noise on images
- **Collimation** – Control the size of the beam
- **Repeat Scans** – Areas of patients rescanned for IV contrast enhancement or for other technical reasons.

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One Size **Does Not** Fit All ...

There's no question – CT helps us save kids' lives! But... radiation matters! So, when we image, let's image gently.

More is often not better.  
When CT is the right thing to do:

- Child size the kVp and mA
- One scan (single phase) is often enough
- Scan only the indicated area

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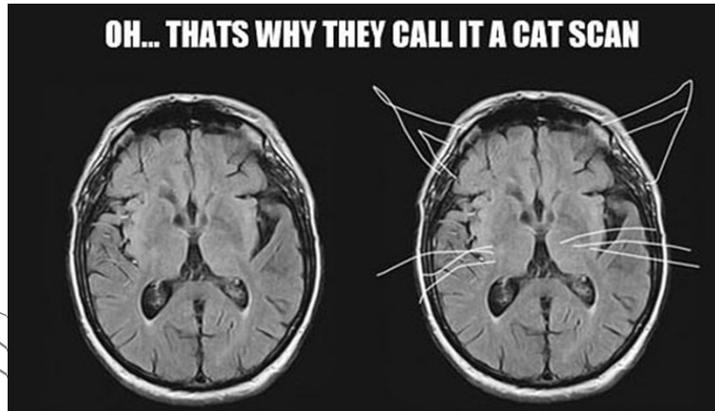
# Strategies for Reducing Dose

- **Confirm Necessity of CT**
  - Other options?
- **Adjusting mAs**
  - To patient size
- **Avoid increasing kVp**
  - Avoid 120 kVp and higher except for larger patients
- **Automatic Tube Current Modulation**
  - Can change mA depending on the attenuation of the patient
- **Limit Repeat Scans**
- **Immobilization**
- **Patient Shielding**



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OH... THATS WHY THEY CALL IT A CAT SCAN



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