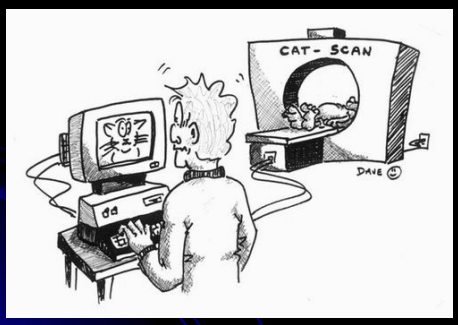
READING HOSPITAL

SCHOOL OF HEALTH SCIENCES

MEDICAL IMAGING PROGRAM

BASICS OF CT--2022



Introduction to CT

Heather Herb, R.T.(R)(M)

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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

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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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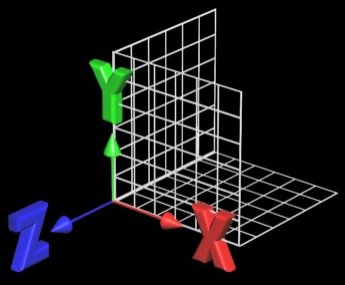
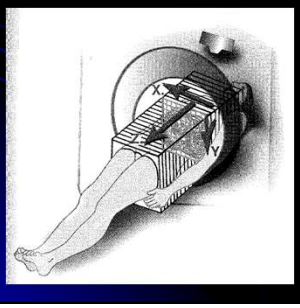
CT Coordinates





- 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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X or Sagittal

Z or Axial

Y or Coronal

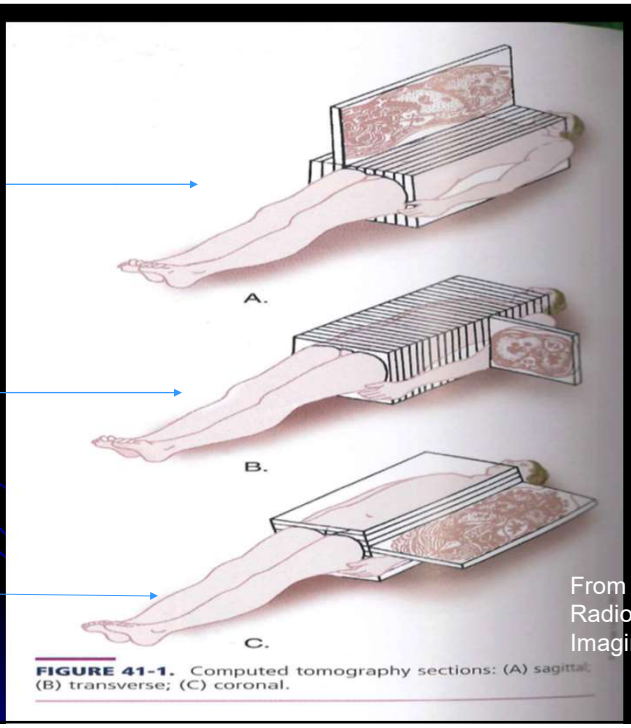

FIGURE 41-1. Computed tomography sections: (A) sagittal; (B) transverse; (C) coronal.

From Principles of Radiographic Imaging by: Carlton

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Why use CT?

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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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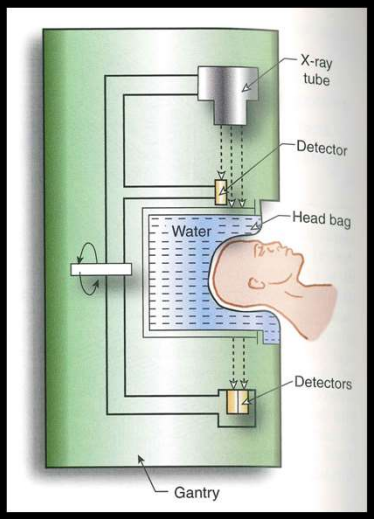
First Generation Scanner--1972

- *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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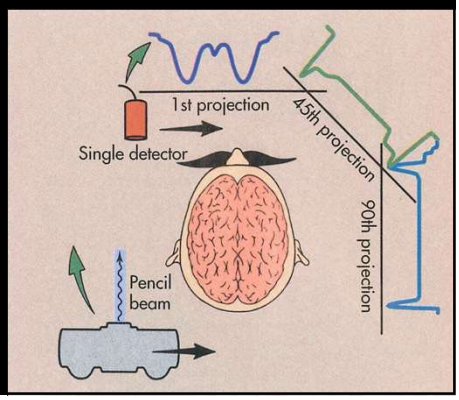
First Generation Scanner--1972

- 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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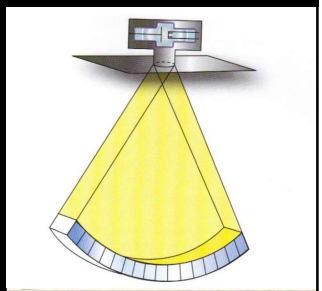
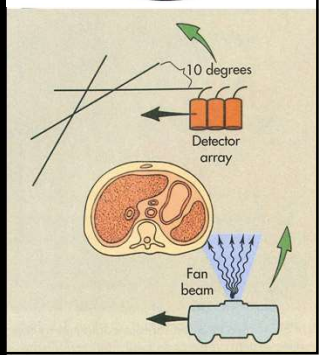
Second Generation Scanner-- ~1974

- *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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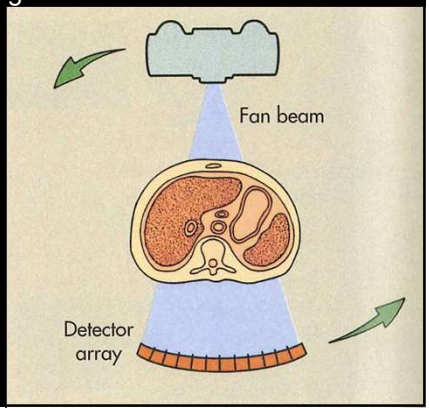
Third Generation Scanners--1975

- *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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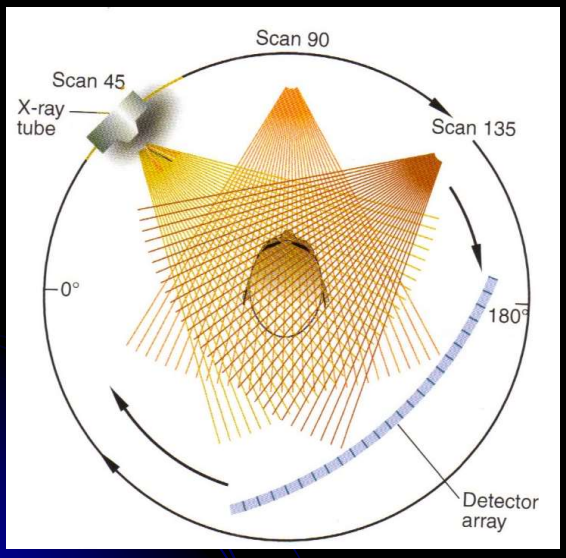

- Covering arc of 360°

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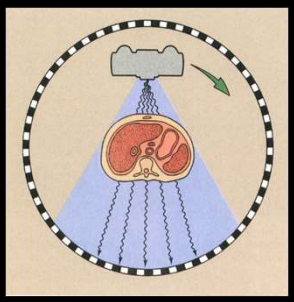
Fourth Generation Scanners

- *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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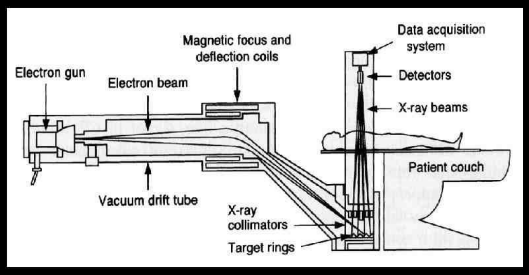
Fifth Generation Scanners--1983

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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5th 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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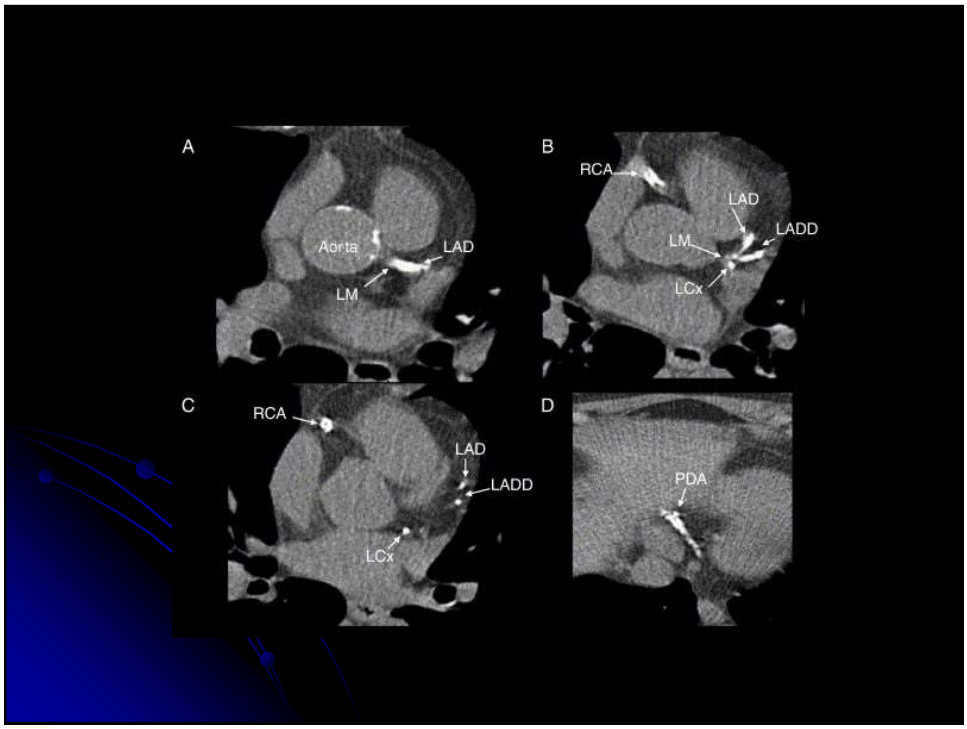

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Generation 1-5

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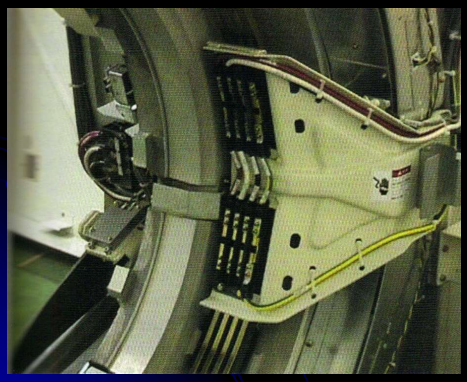
Sixth Generation Scanners--1989

Spiral/Helical Scanning

- Advances in Slip Ring connection technology



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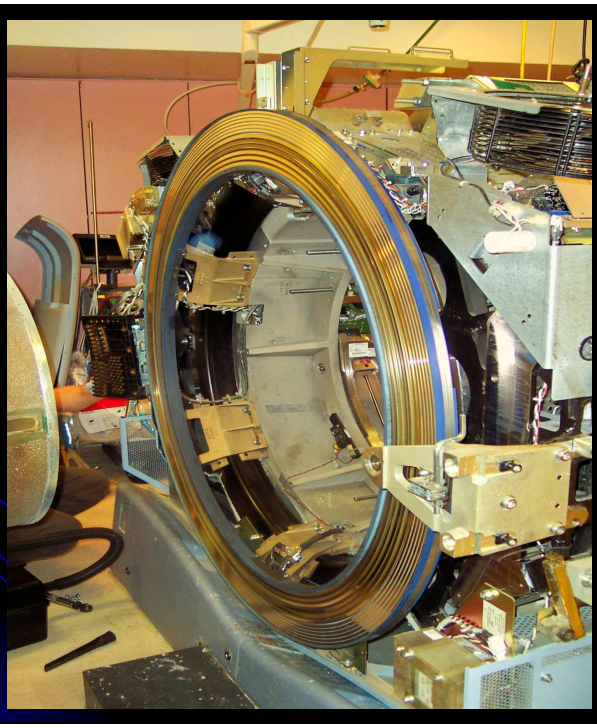

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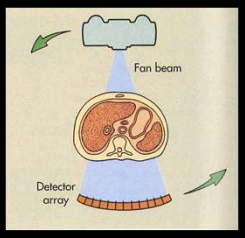
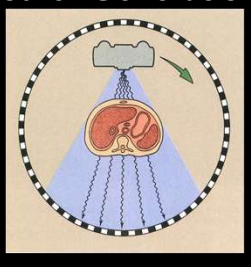
Sixth Generation Scanners--1989

Third Generation



Fourth Generation



3rd and 4th Generation Scanners with 6th Generation Slip Ring Technology

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

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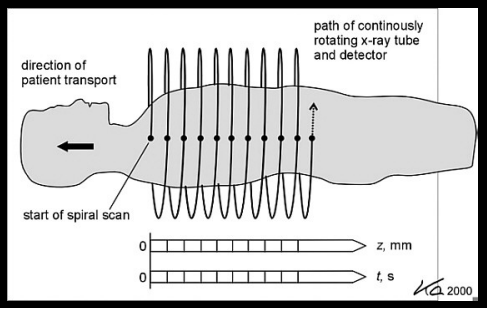
Sixth Generation Scanners--1989

- *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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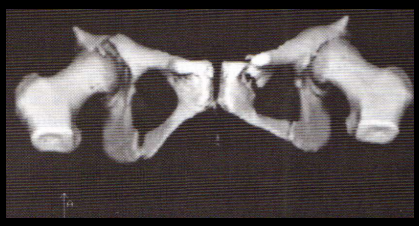
Sixth Generation Scanners

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



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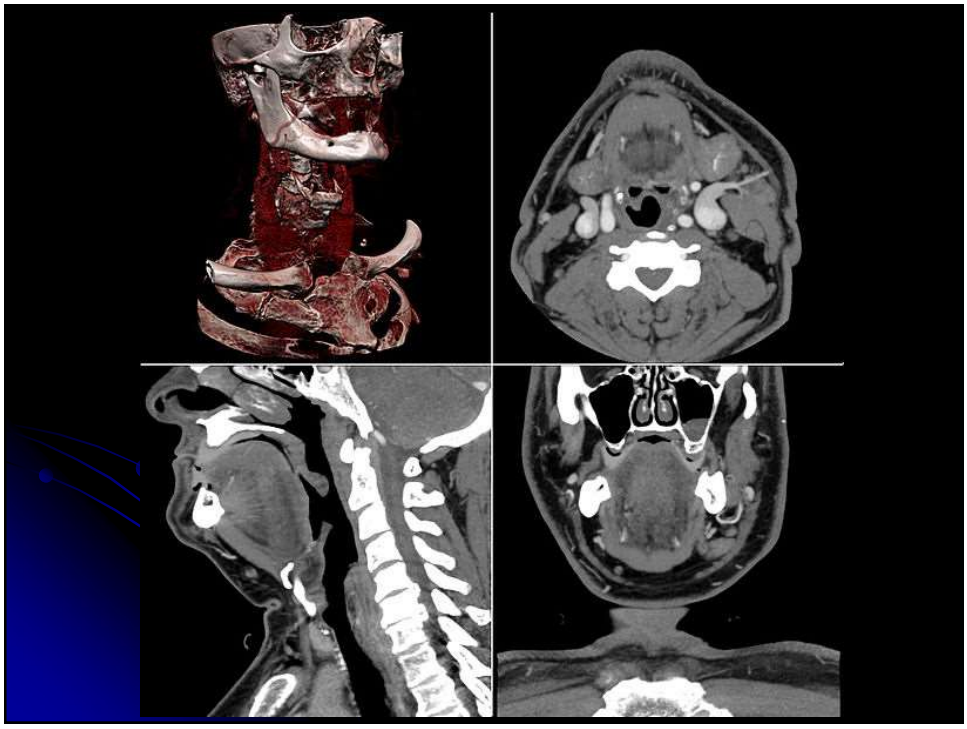

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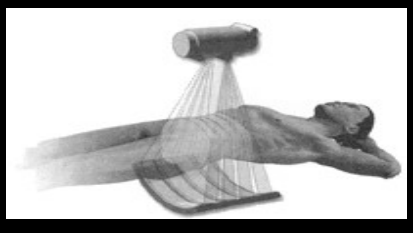
Seventh Generation Scanners--1999

- *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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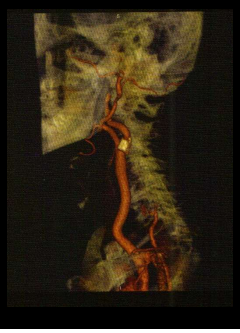
Applications of CT

- 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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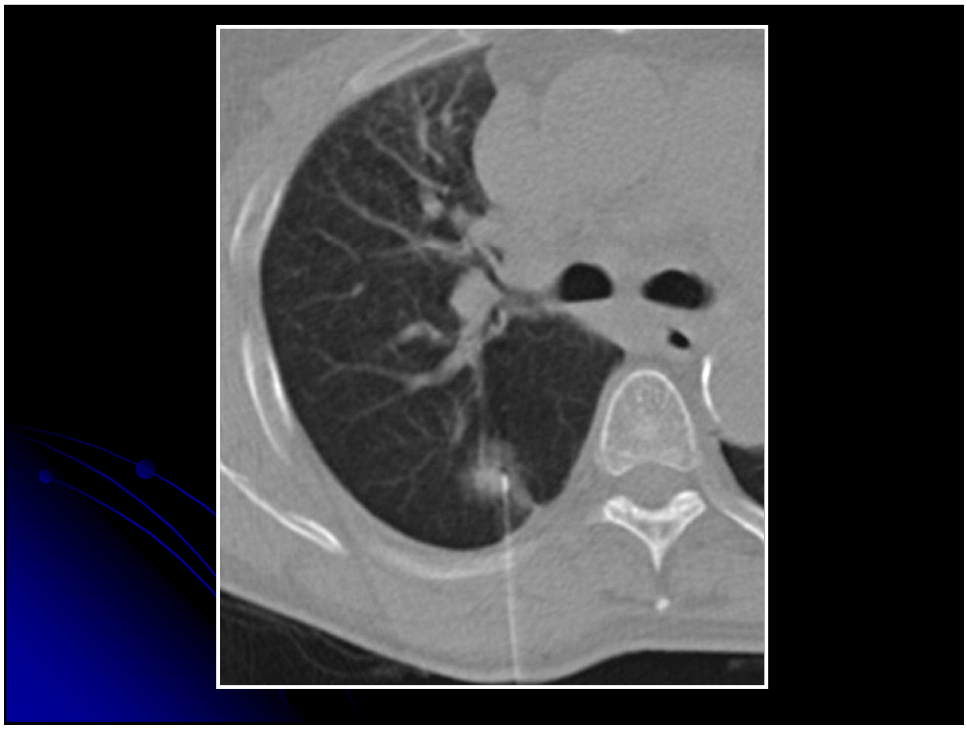

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Applications of CT

- 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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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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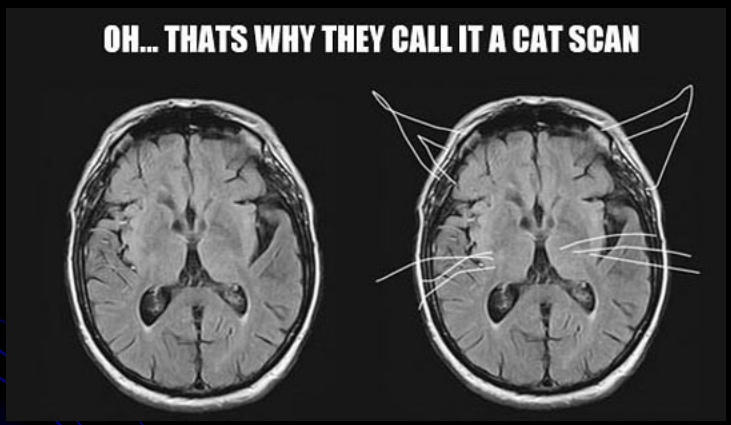

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