Basic principles of computed tomography

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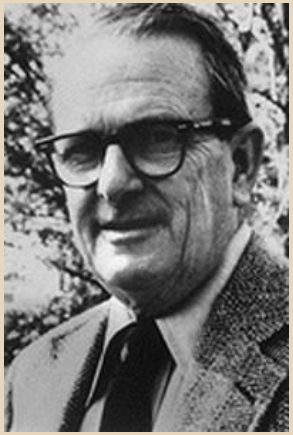
Tomography

- tomos = slice; graphein = to write
- definition - imaging of an object by analyzing its slices

Damien Hirst
Autopsy with Sliced Human Brain
2004

History

- **1924** - mathematical theory of tomographic image reconstructions (Johann Radon)
- **1930** - conventional tomography (A. Vallebona)
- **1963** - theoretical basis of CT (A. McLeod Cormack)
- **1971** - first commercial CT (Sir Godfrey Hounsfield)
- **1974** - first 3rd generation CT
- **1979** - Nobel price (Cormack & Hounsfield)
- **1989** - single-row CT
- **1994** - double-row spiral CT
- **2001** - 16-row spiral CT
- **2007** - 320-row spiral CT



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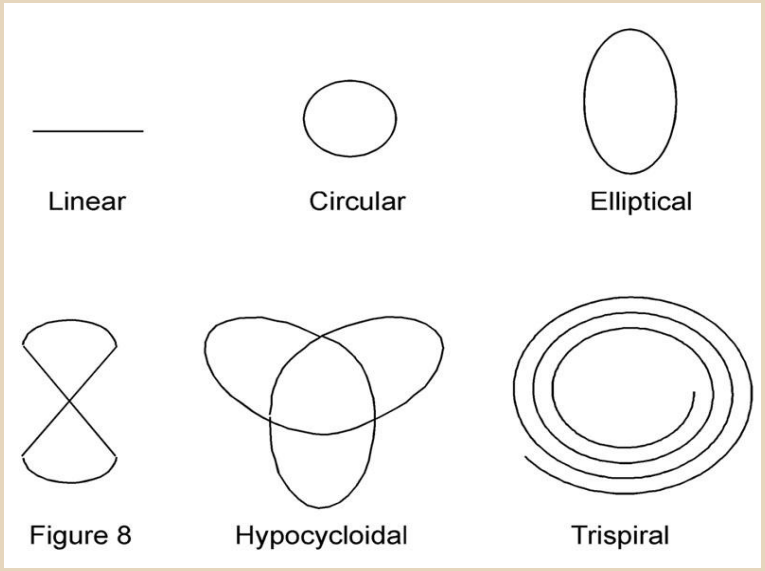
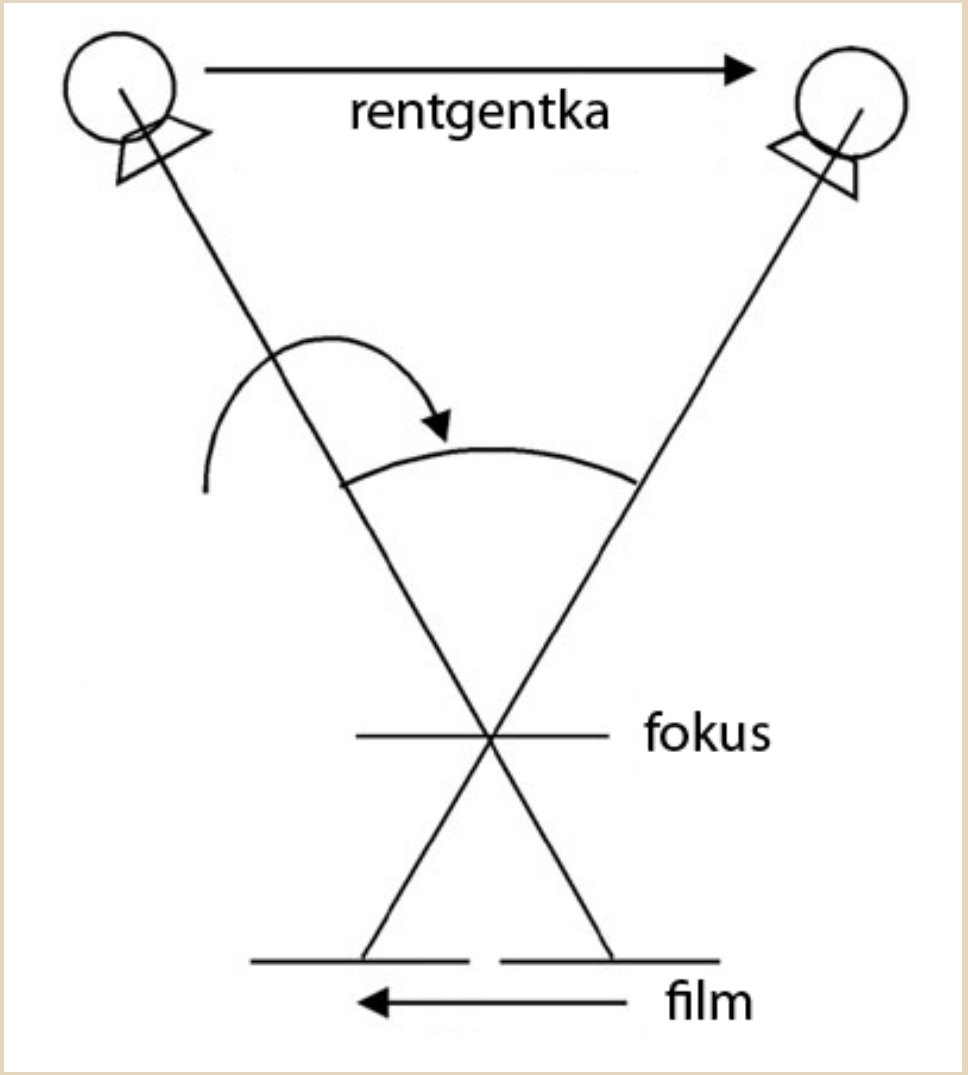
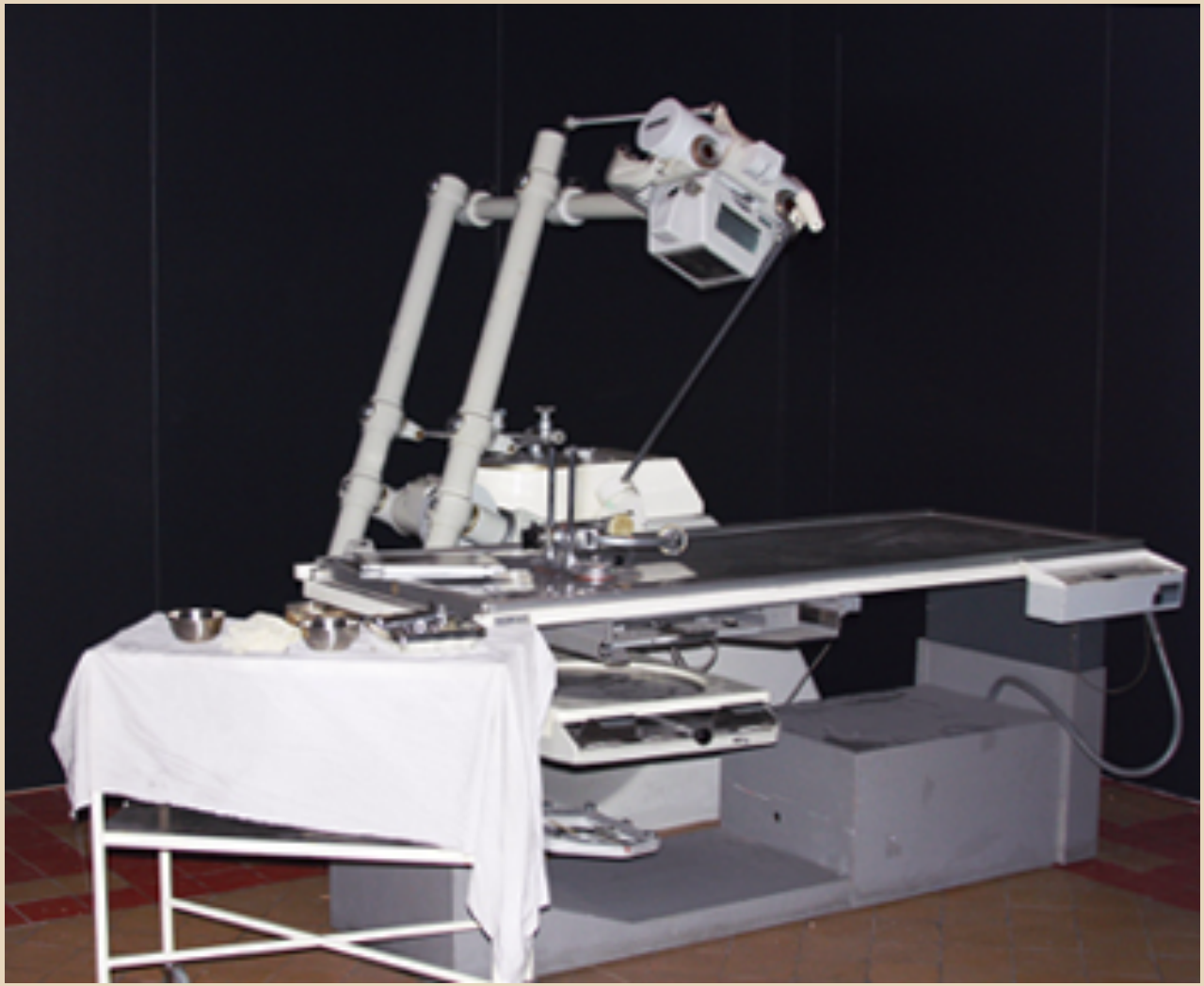
Conventional tomography

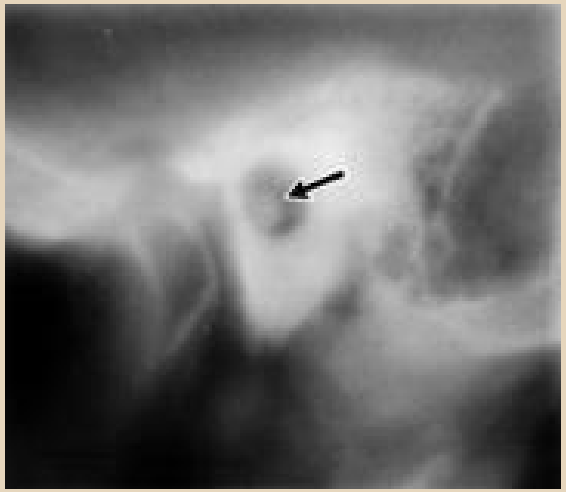
- x-ray tube moves in the oposite direction than detector
- areas outside the focus are blured, therefore not shown



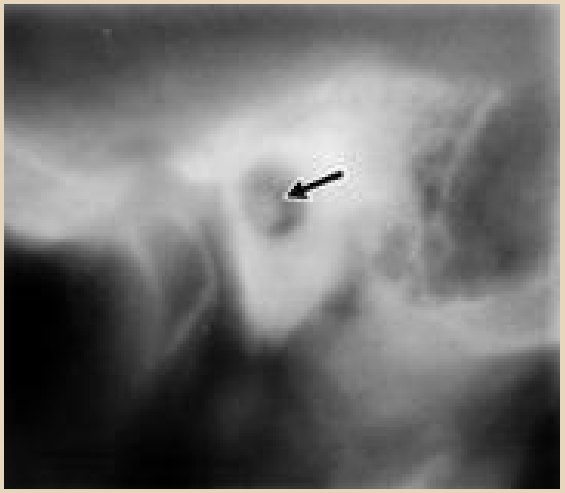


Conventional tomography

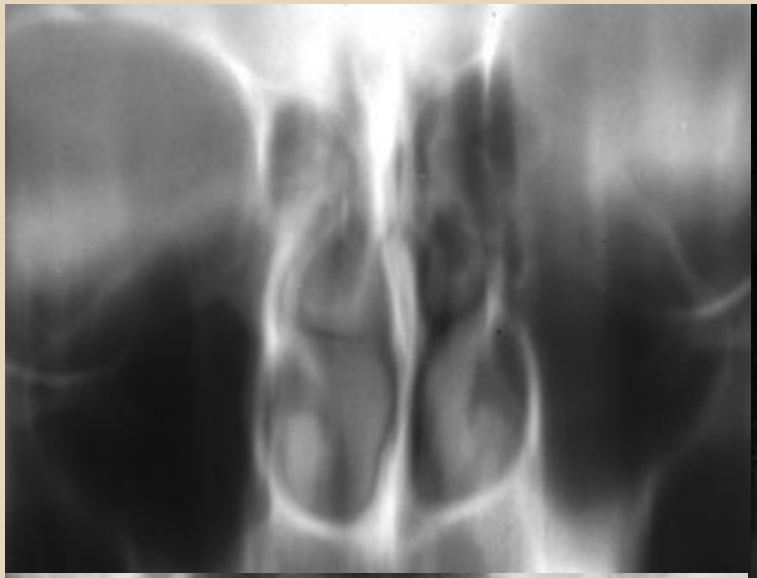


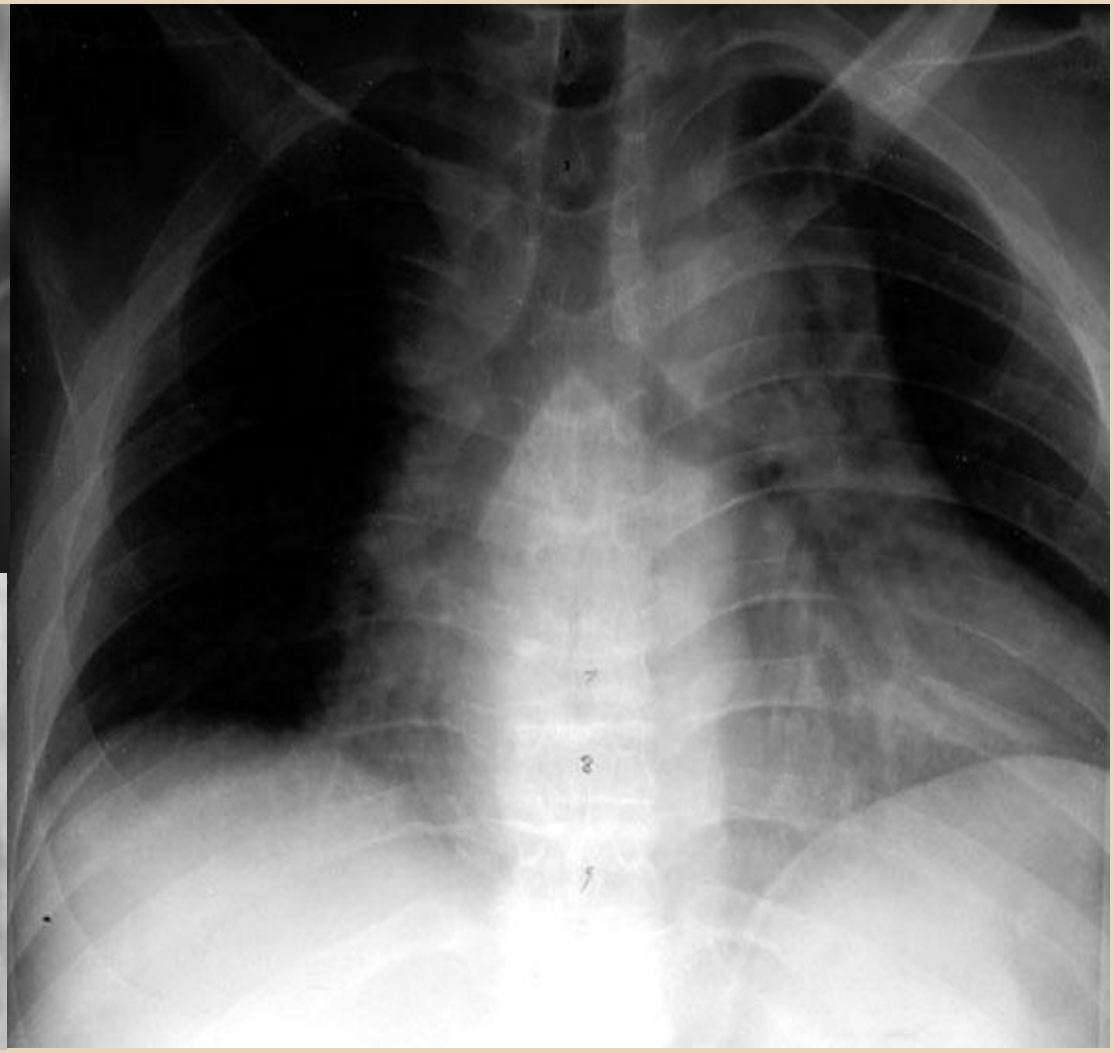


Conventional tomography



Conventional tomography

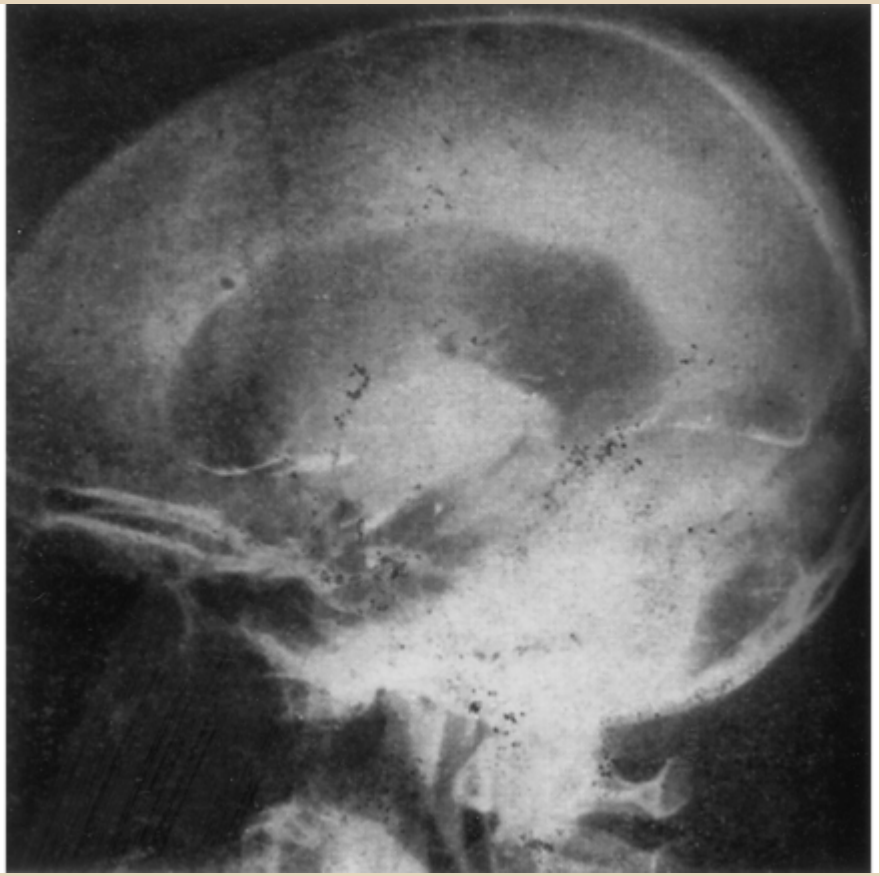




Imaging before CT

- entire body areas were inaccessible to radiography - brain, mediastinum, retroperitoneum
- diagnostic procedures showing better detail in these areas were potentially harmful and or poorly tolerated by the patient - pneumoencephalography, diagnostic pneumomediastinum, diagnostic laparotomy

Imaging before CT

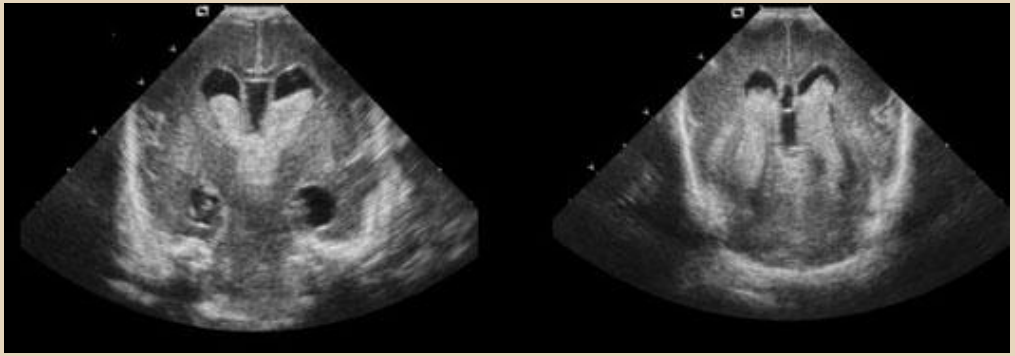


ventriculography

pneumoencephalography

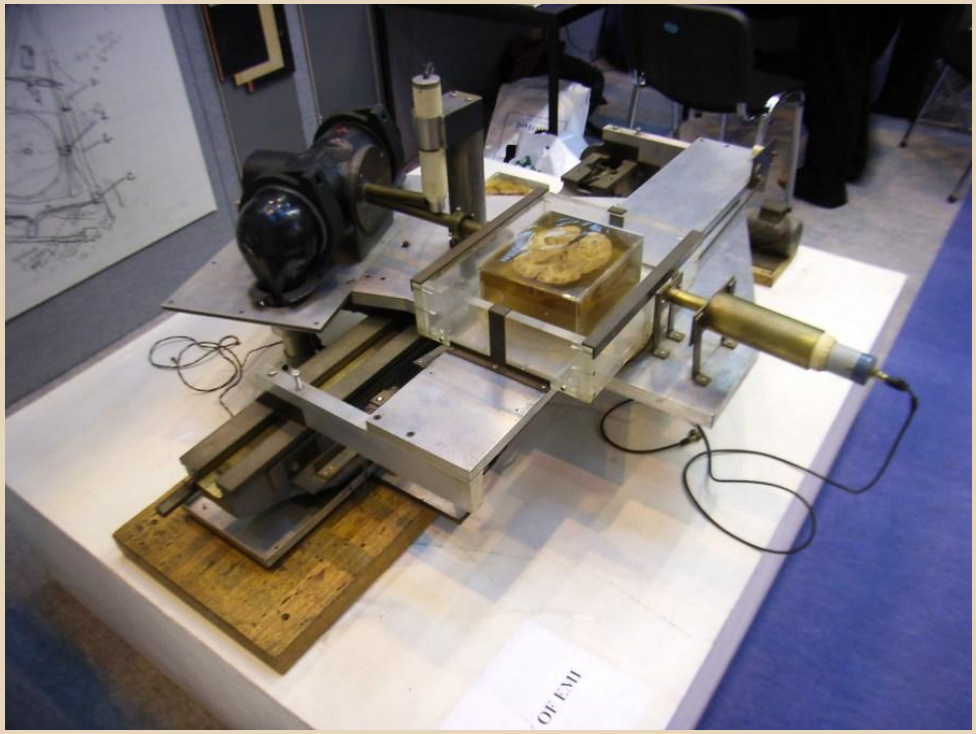
Imaging before CT

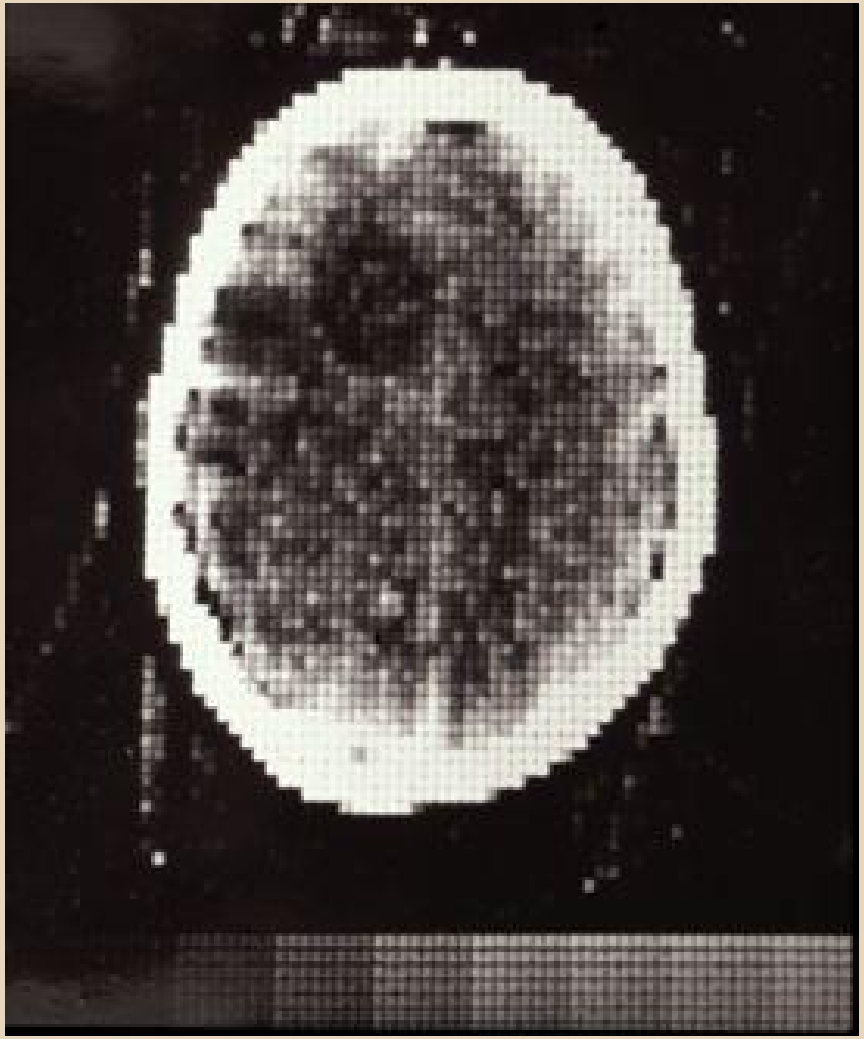
transfontanellar ultrasound



CT prototype

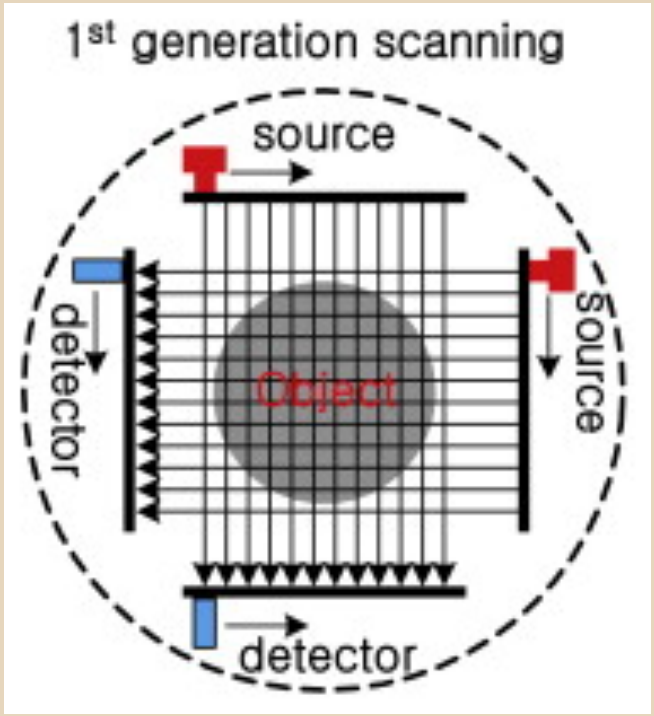
- scanning time: 9 days
- reconstruction: 2,5h
- resolution: 80x80





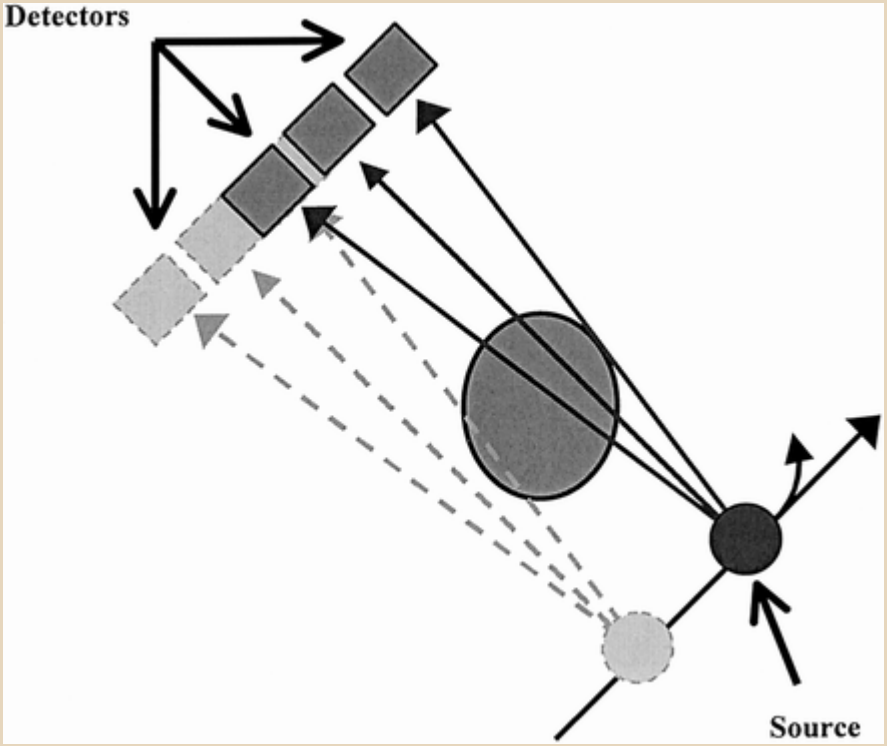
1st generation CT

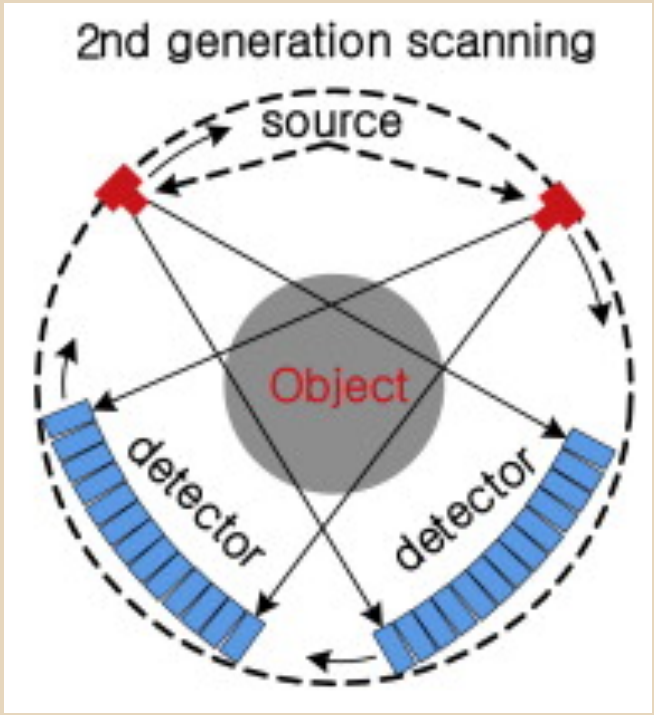
- xray tube and single detector are connected and move together by translation and then rotation
- xray beam has linear (pencil-like) shape



2nd generation CT

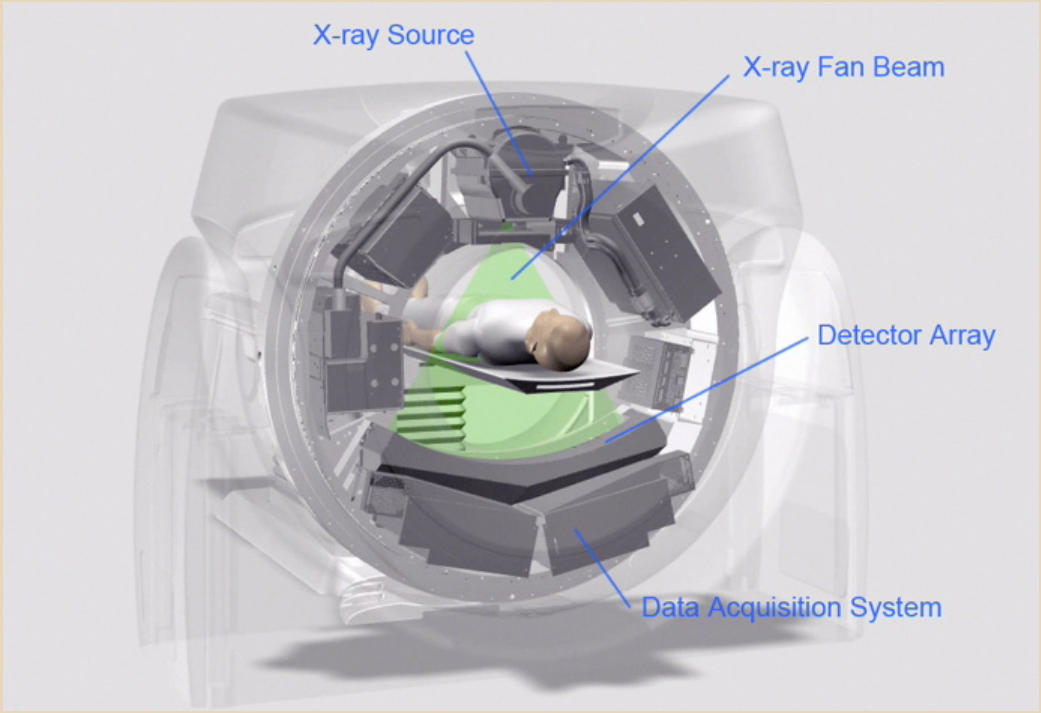
- same type of movement
- multiple detectors arranged in a row
- fan shaped xray beam instead of linear shaped

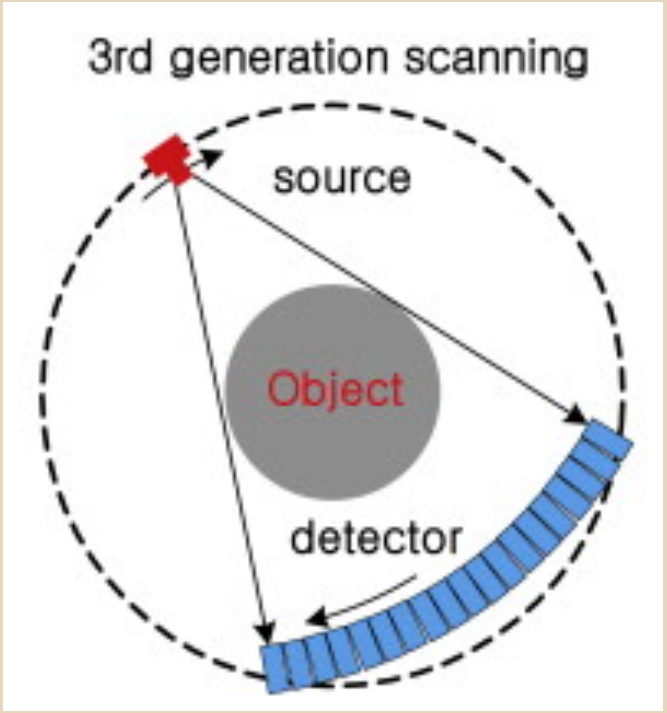




CT III. generace

- full rotation of x ray tube+detectors complex

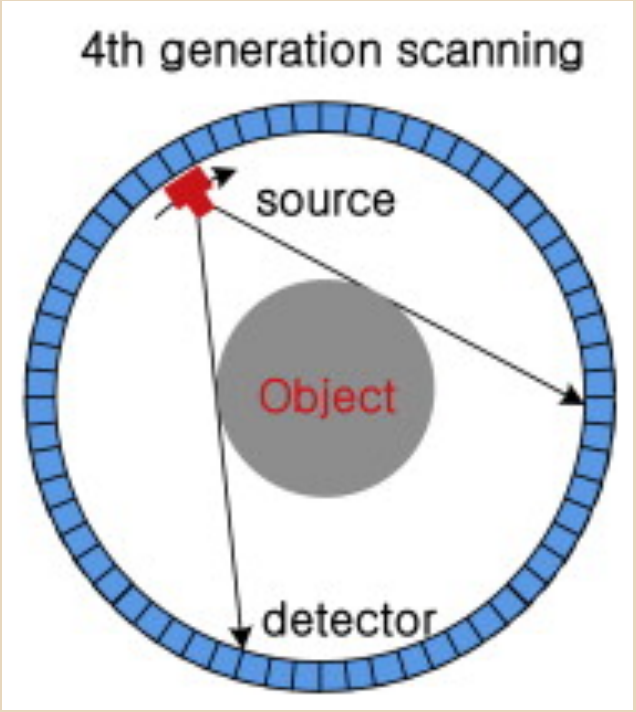




CT III. generace

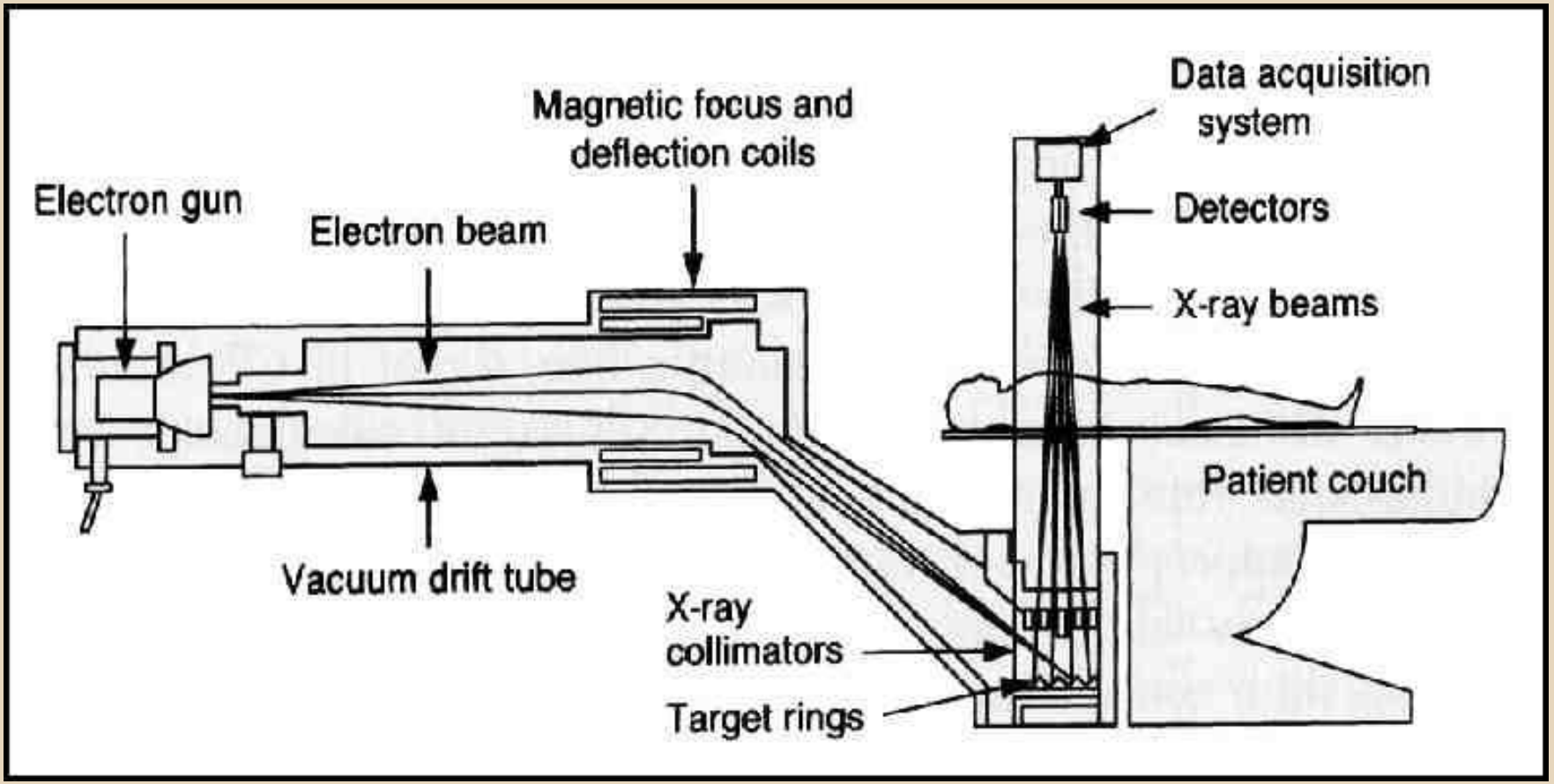
CT IV. generace

- only x ray tube rotates, detectors are stationary
- this technology was later abandoned



V. generation CT

- electron beam tomography (EBT)



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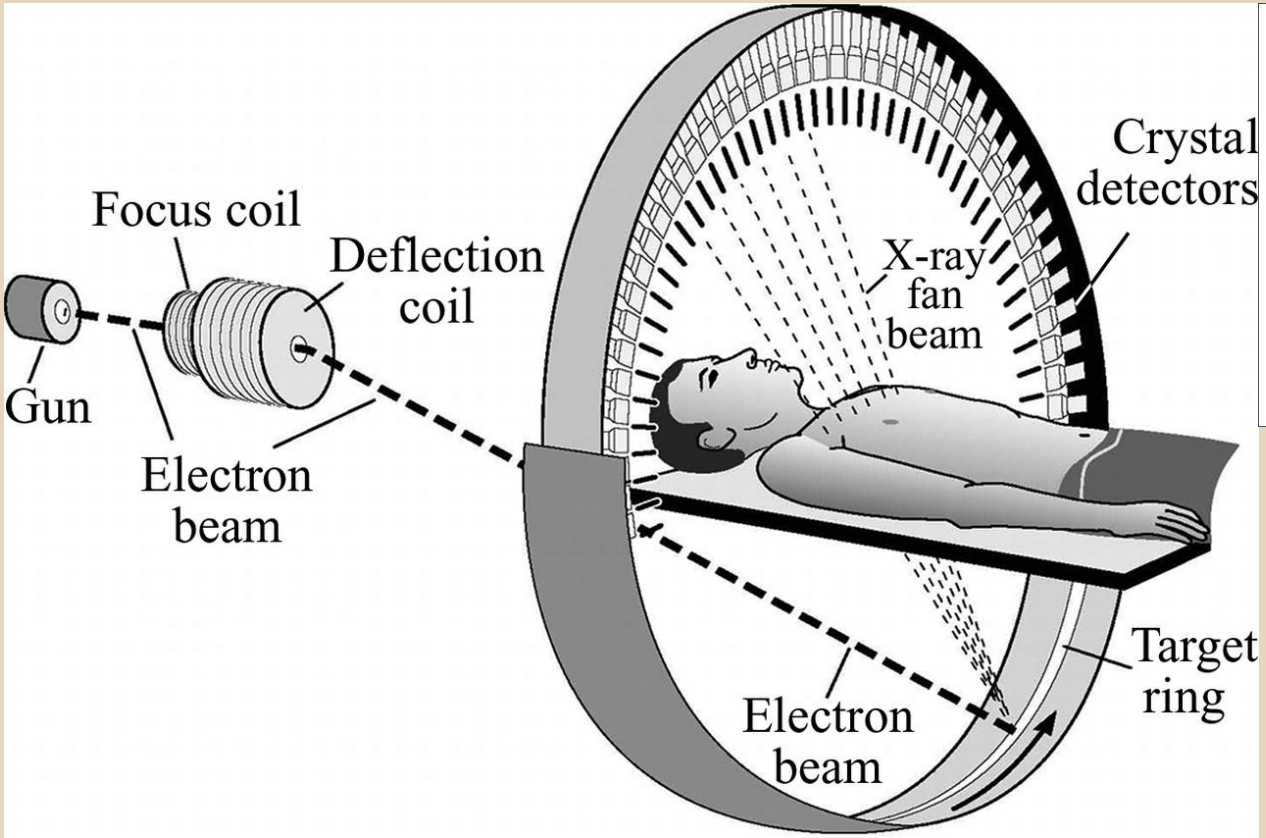
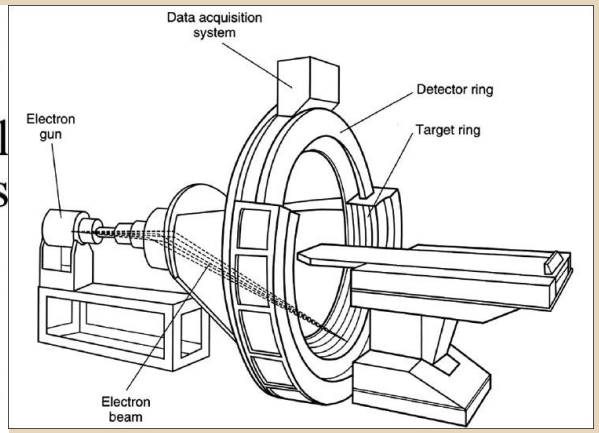
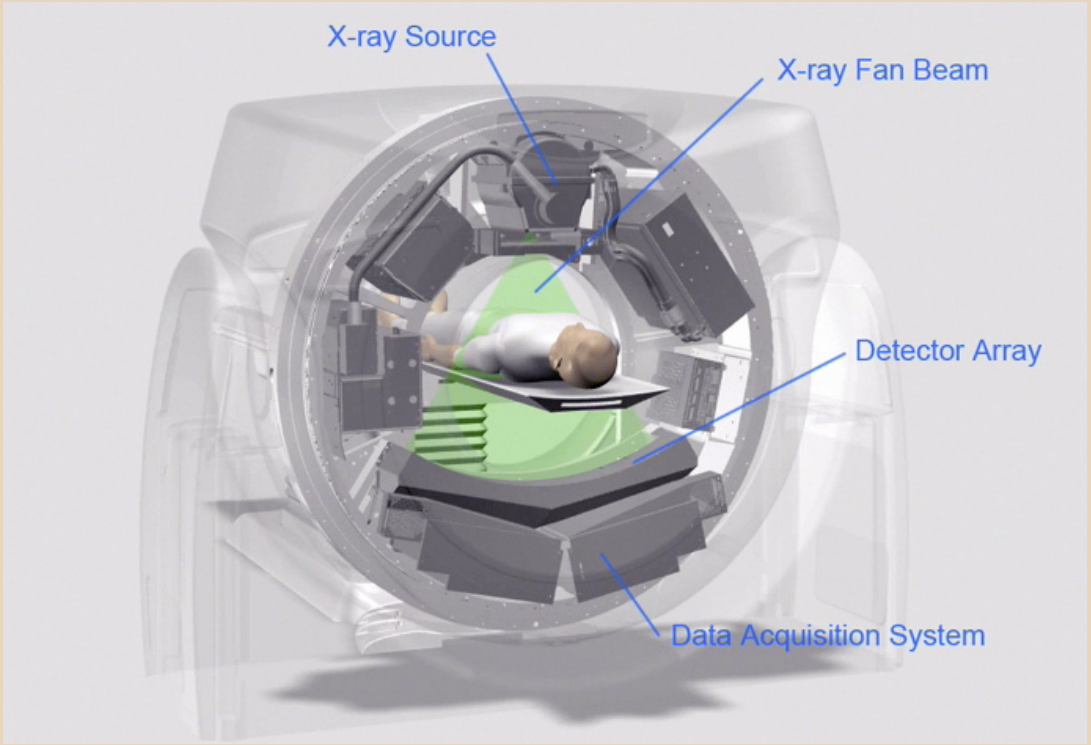




CT machine anatomy

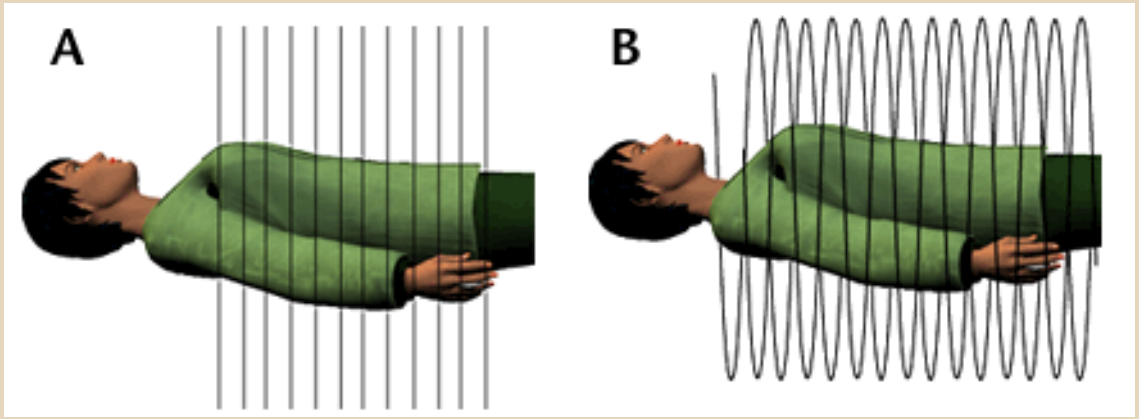
- energy source (140 kV) + slip rings
- x ray source
- detectors
- collimators
- DAS

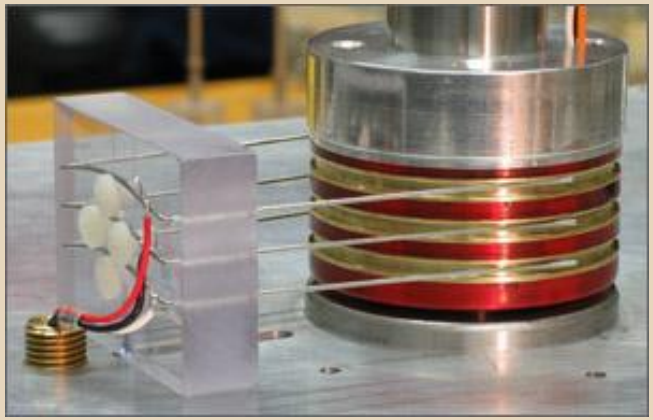
  = data acquisition system



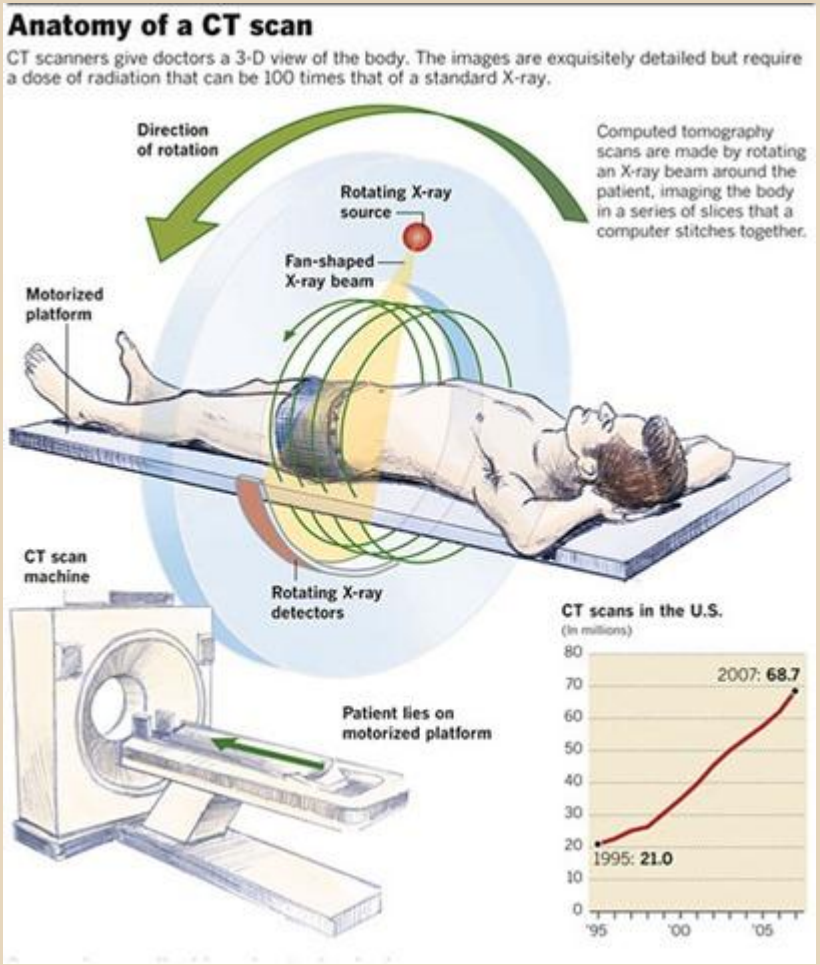
scanning

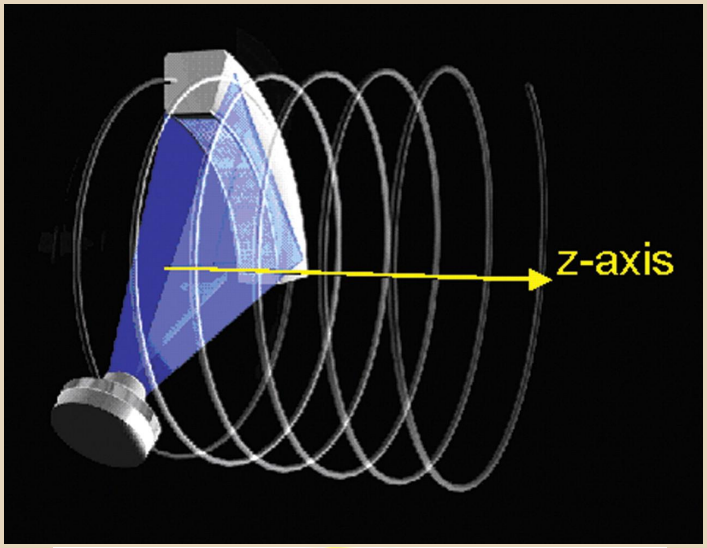
- **sequential** - sequence of complete gantry rotation followed by table movement with the patient
- **spiral** - continuous gantry rotation and table movement
  - volume of raw data is generated, from which axial images are reconstructed using interpolation
  - slip ring technology allowed transmission of energy to rotating gantry without the need of cables

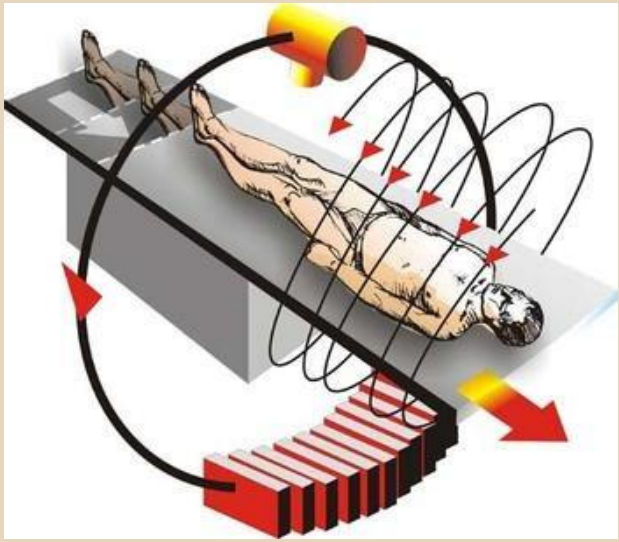




spiral scanning

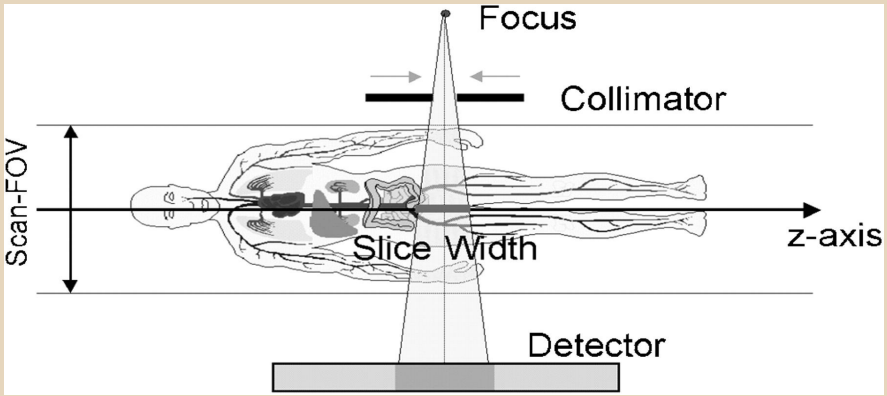


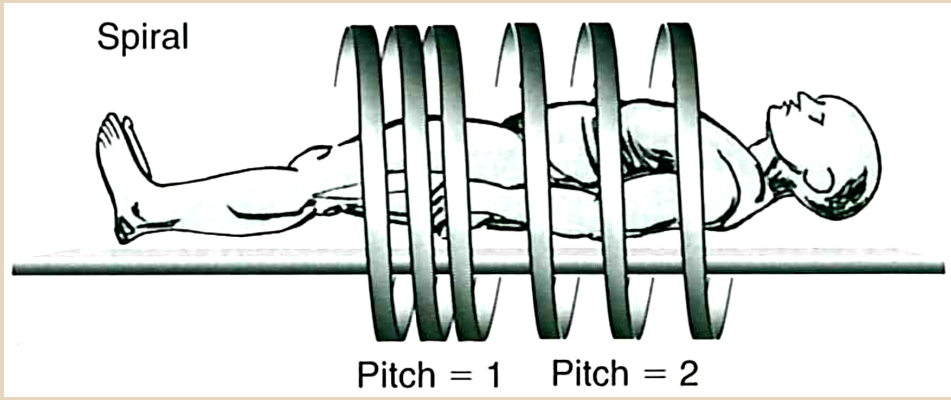




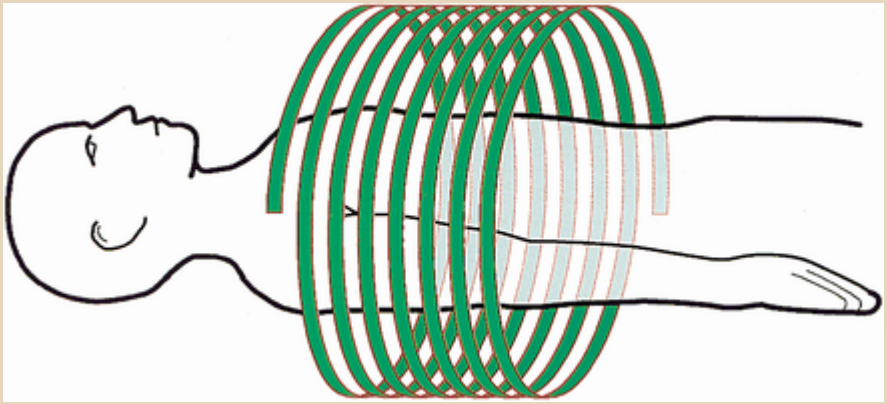
pitch

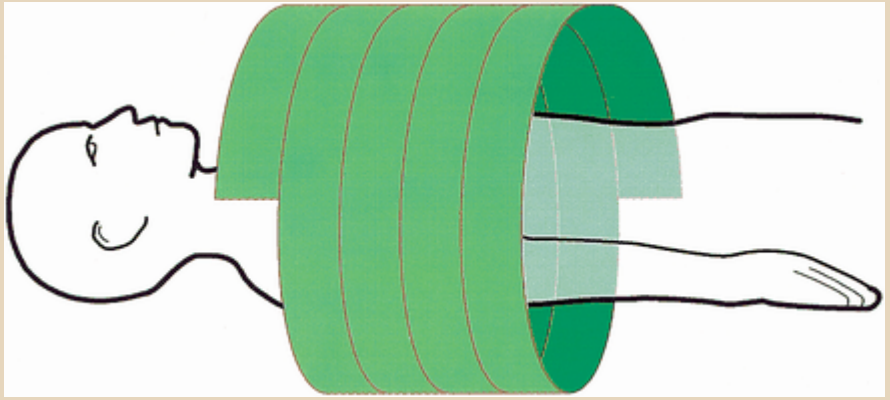
- table travel - table movement per rotation
- collimation - x ray beam width in z axis
- pitch = table travel / collimation
  - pitch = 1 - coils of the helix are in contact
  - pitch < 1 - coils of the helix overlap
  - pitch > 1 - coils of the helix are separated





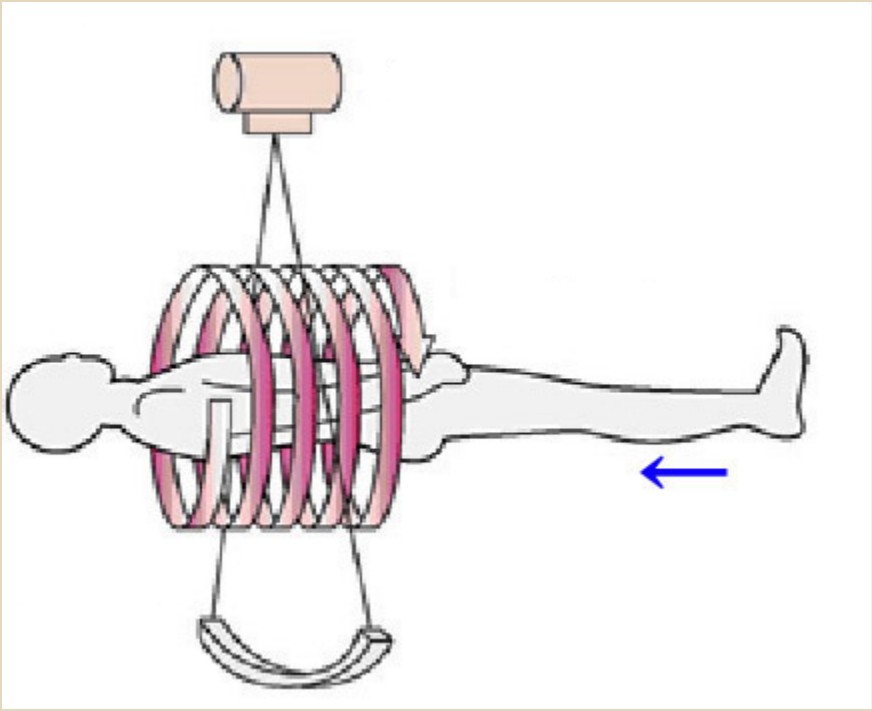
pitch

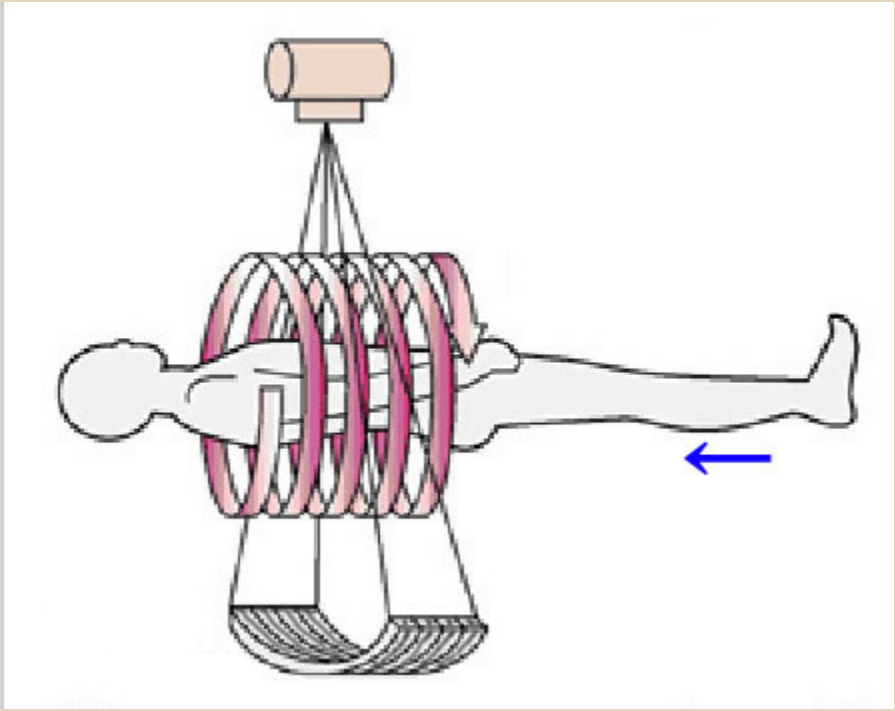




SSCT vs. MSCT

- SSCT - single slice CT
- MSCT - multiple slice CT





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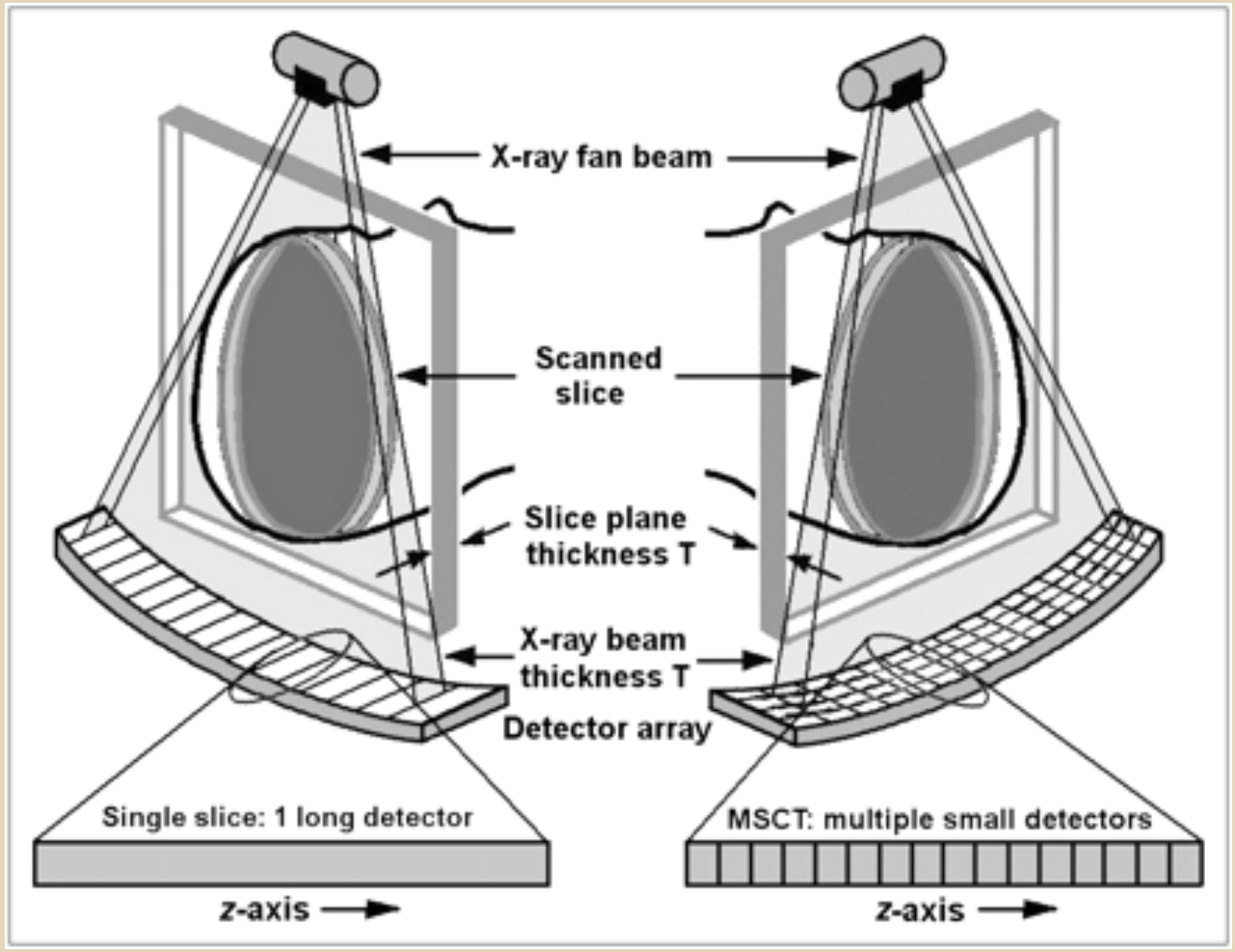
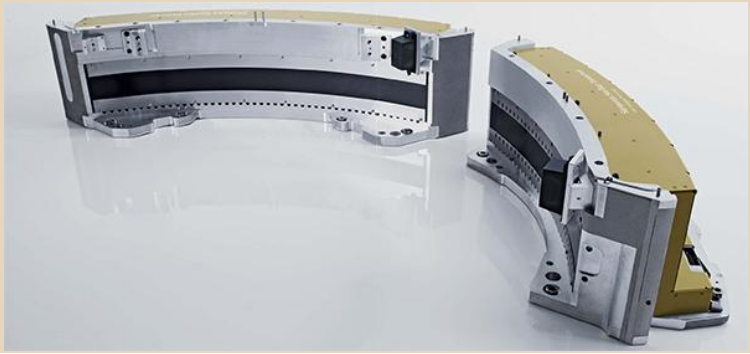
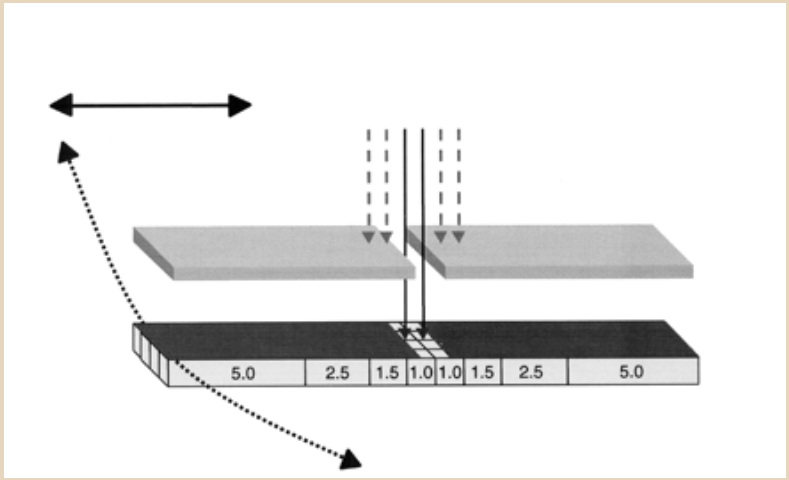
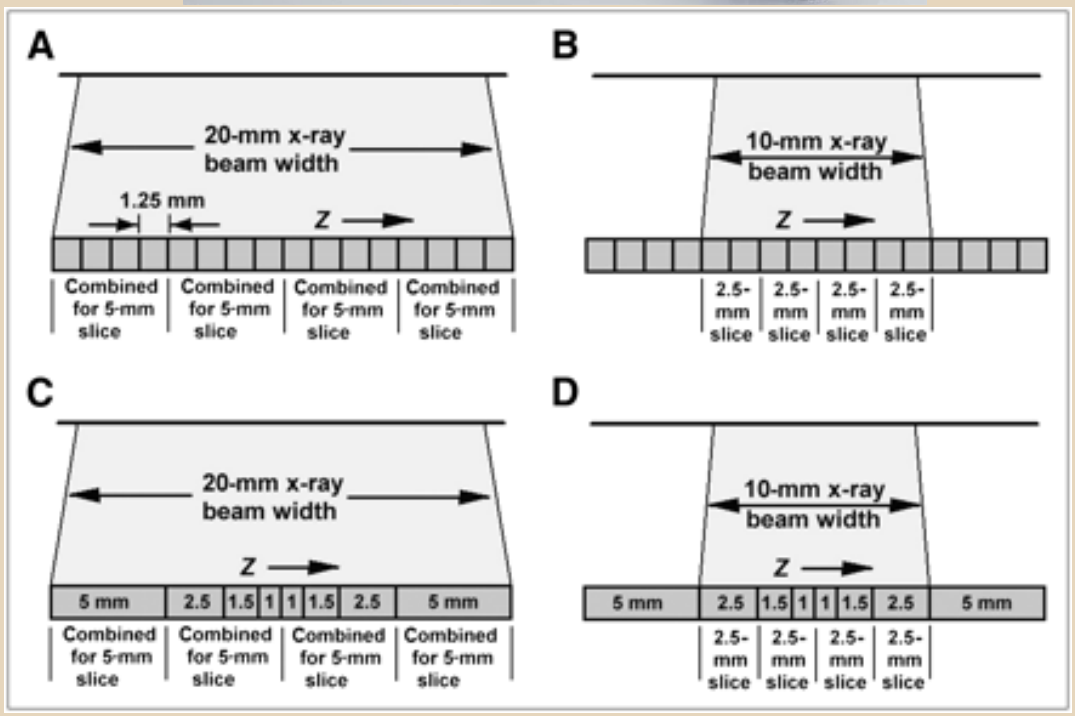

X-ray fan beam
Scanned slice
Slice plane thickness T
X-ray beam thickness T
Detector array
Single slice: 1 long detector
z-axis
MSCT: multiple small detectors
z-axis

detectors





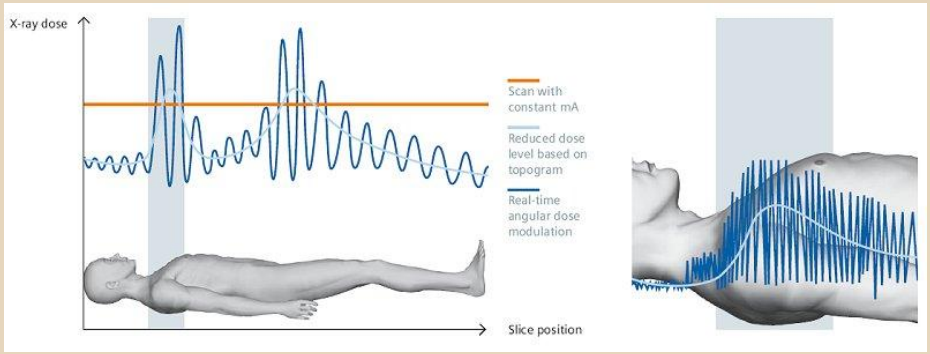


fixed array, 4 slice CT

adaptive array, 4 slice CT

voltage vs. current

- voltage (kV)
  - 80-140 kV
  - higher the voltage, better the penetration of x ray, but worse tissue contrast and larger dose
- electric current (mAs)
  - 50-500 mAs
  - higher the current, better the image quality (lower noise), but larger dose



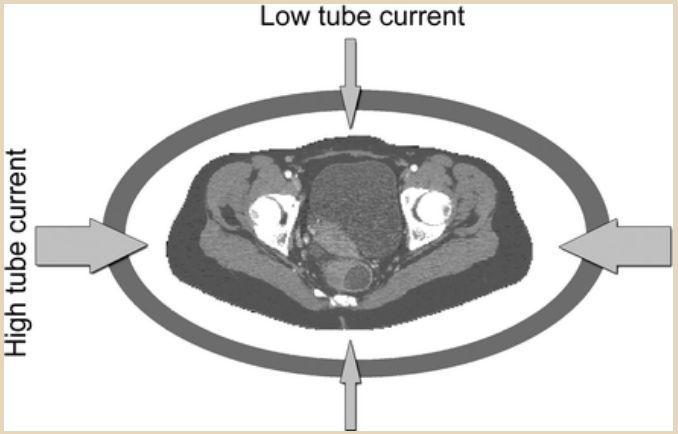
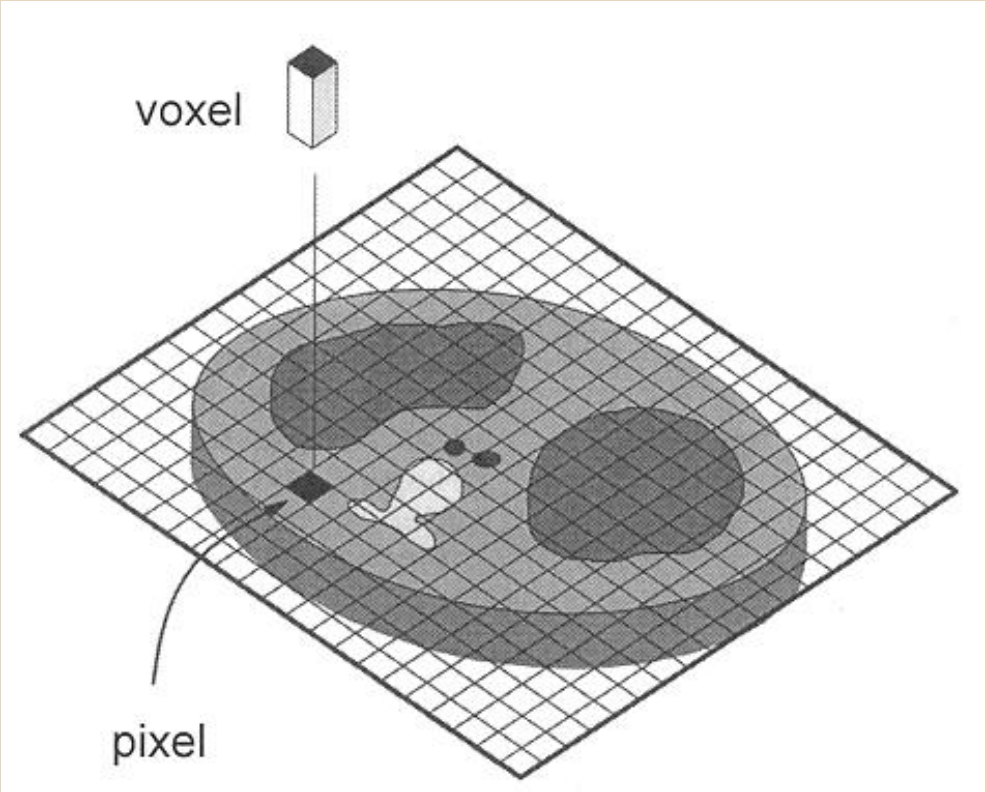
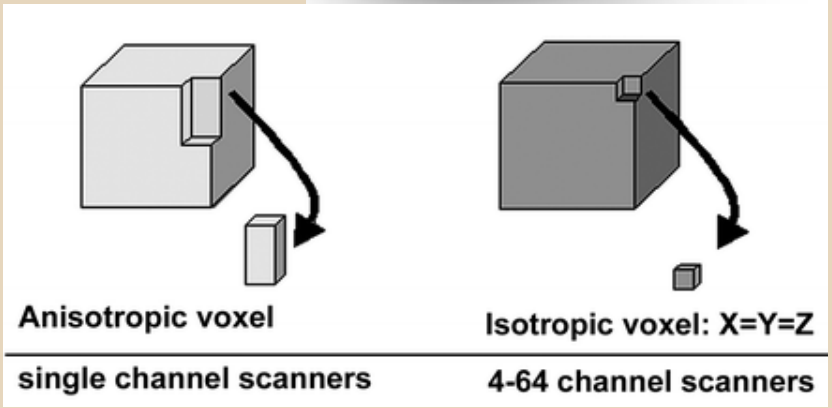


image reconstruction

- matrix - 512 x 512
- pixel - 2D object, smallest element of a raster image
- voxel - 3D object, smallest element of a 3D grid





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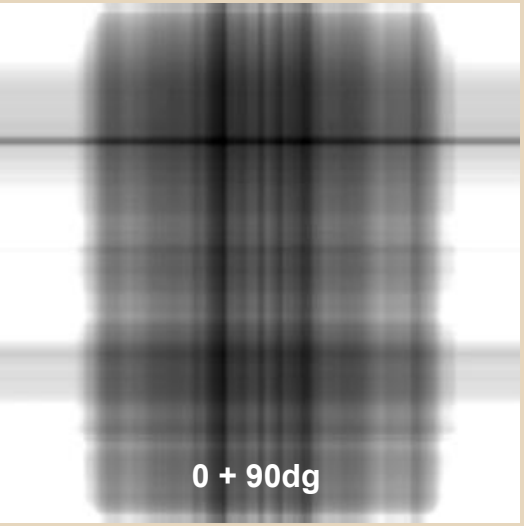
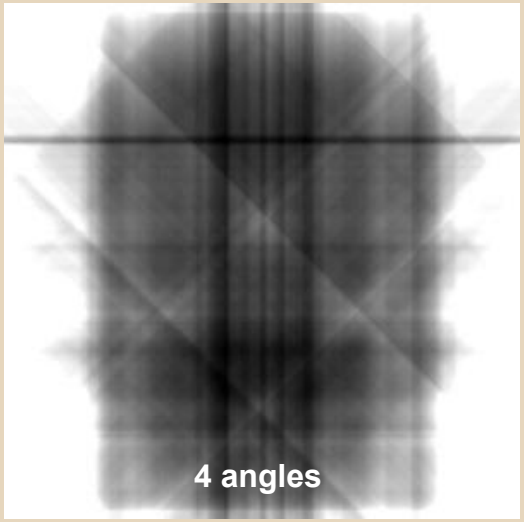
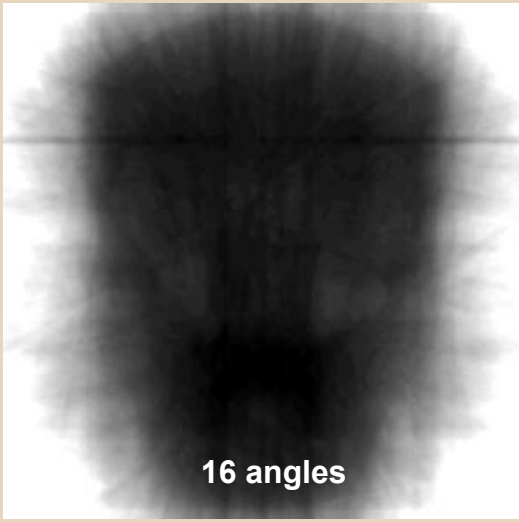
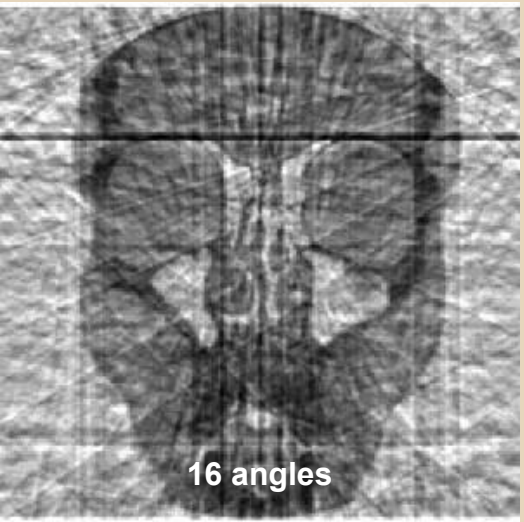
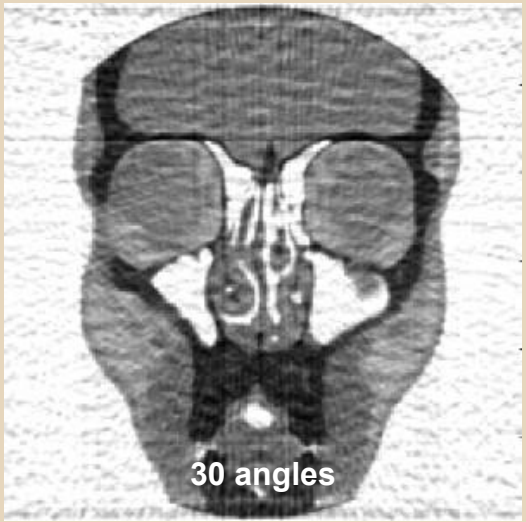










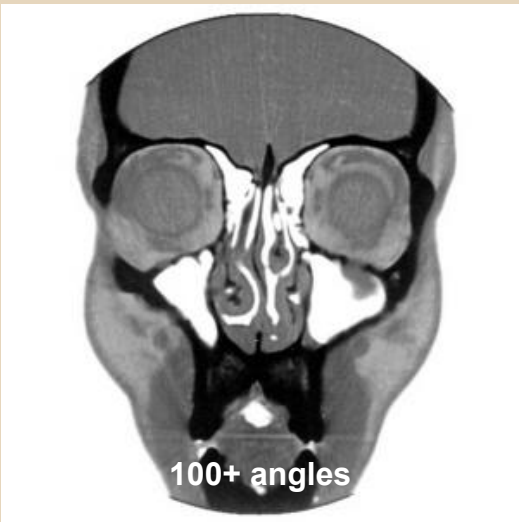
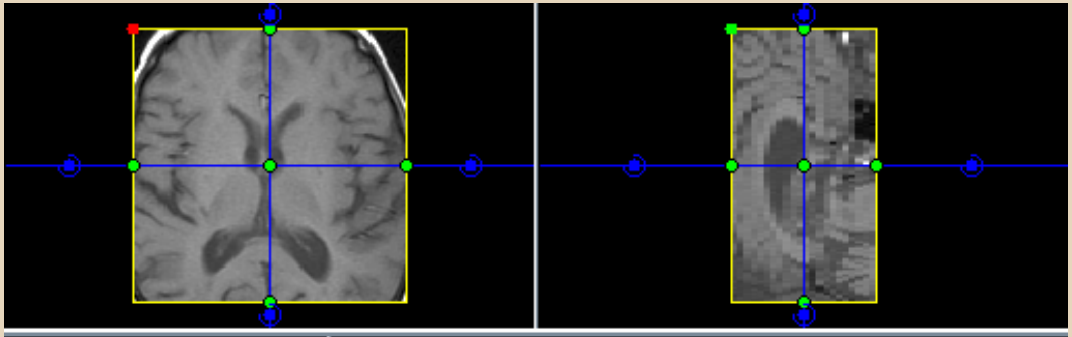
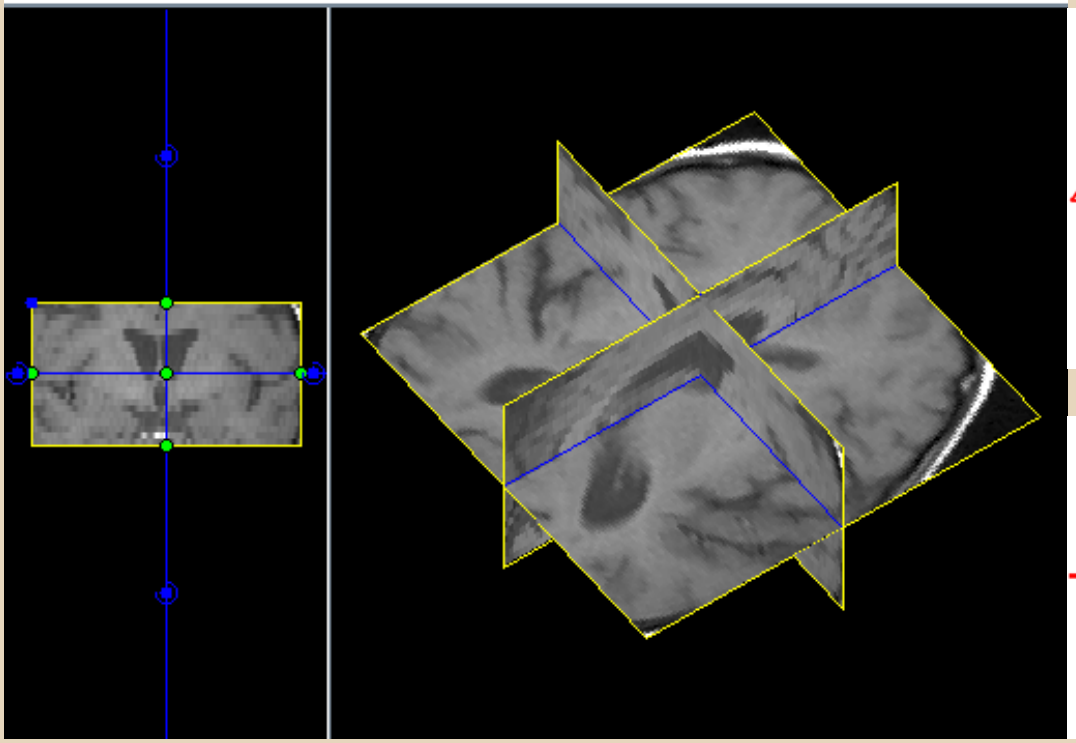
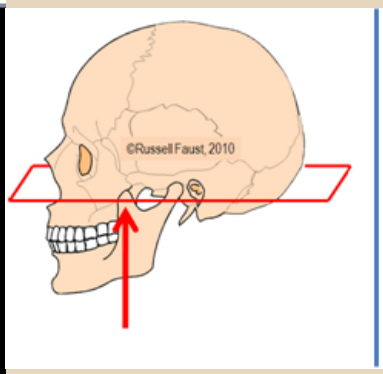


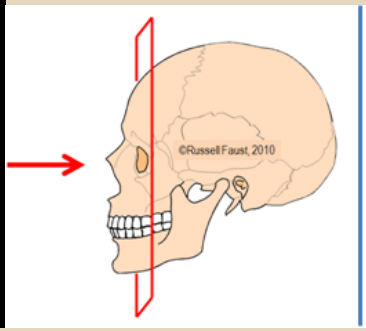
image reconstruction



isotropic imaging - all 3 sides (x, y, z) of the voxel have equal size







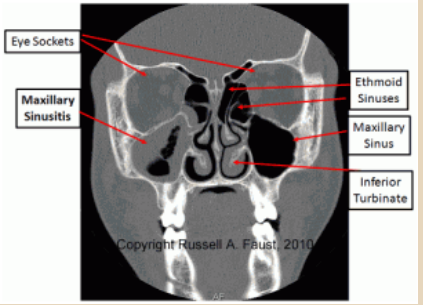


image reconstruction

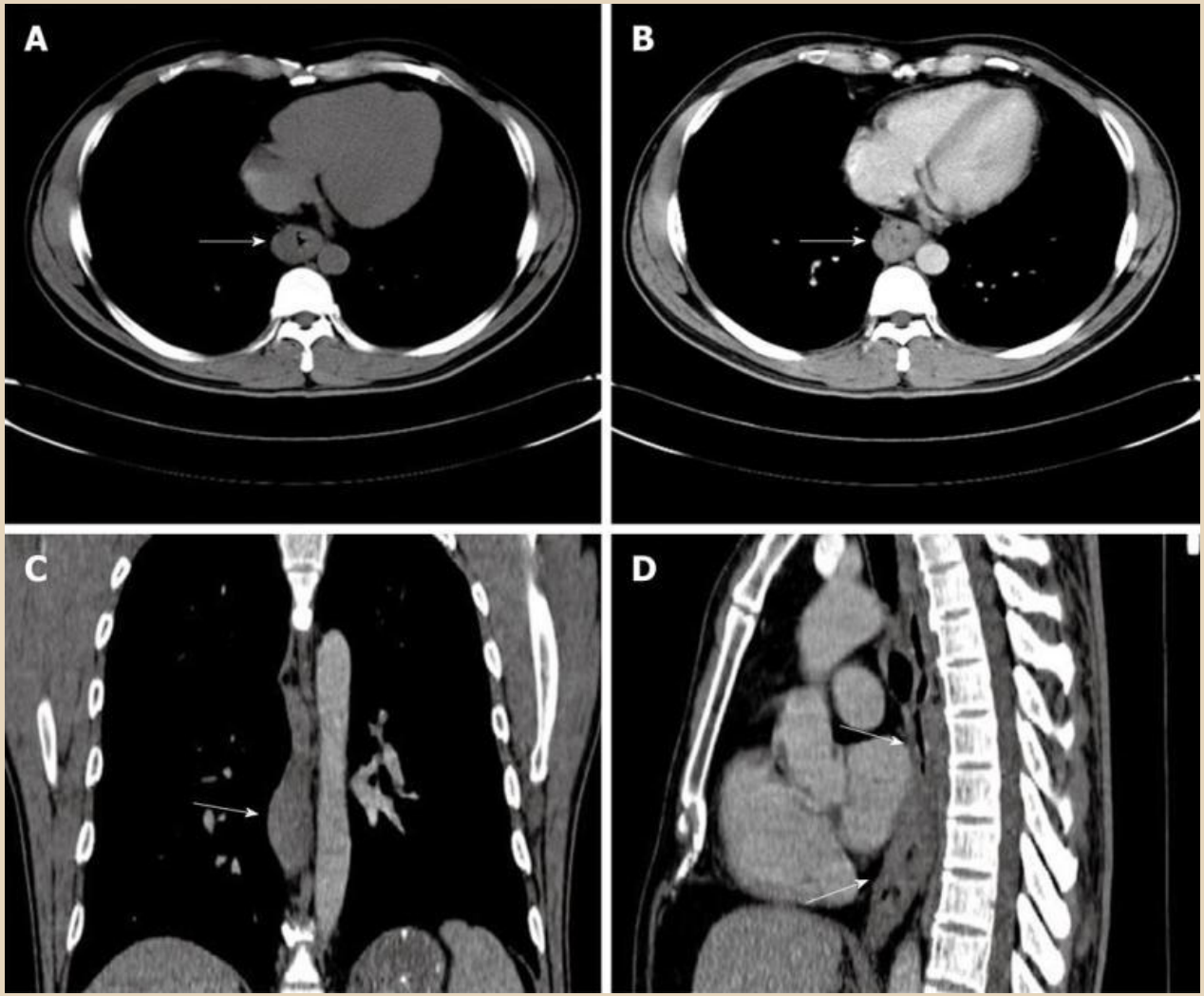
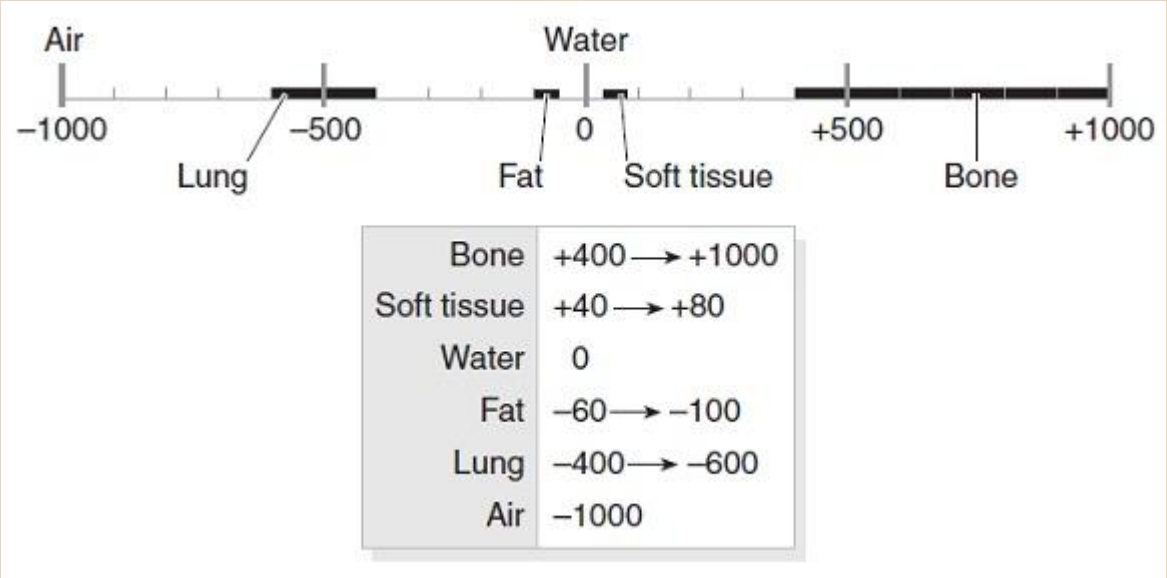


image reconstruction

- Hounsfield scale - tissue density is expressed in different shades of grey in relation to its xray absorption
  - water = 0, air = -1000
  - scale -1000 to 3095



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

image reconstruction

- CT window
  - window width
  - window level (center)
    - mediastinal window
      - W 350, L 50
      - lowest HU = -125 (50-350/2)
      - highest HU = 225 (50+350/2)
    - lung window
      - W 2000, L -200
    - bone window
      - W 1500, L 300
    - brain window
      - W 80, L 30

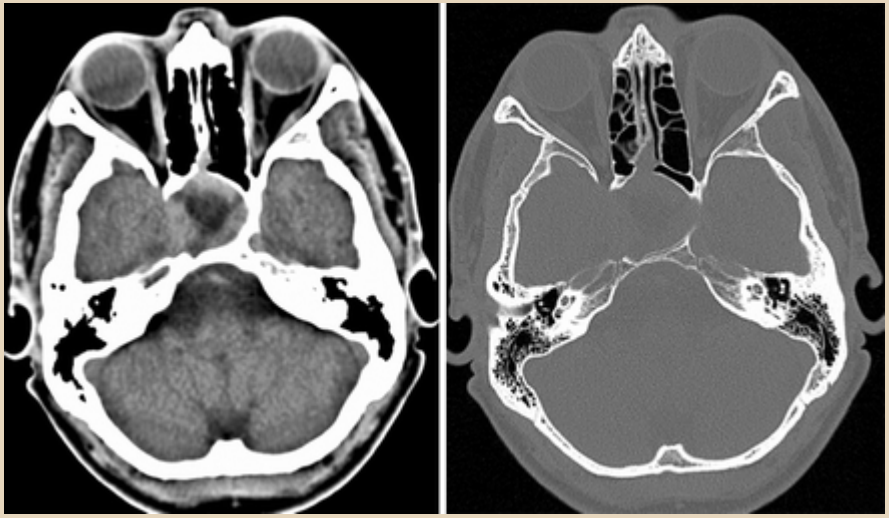
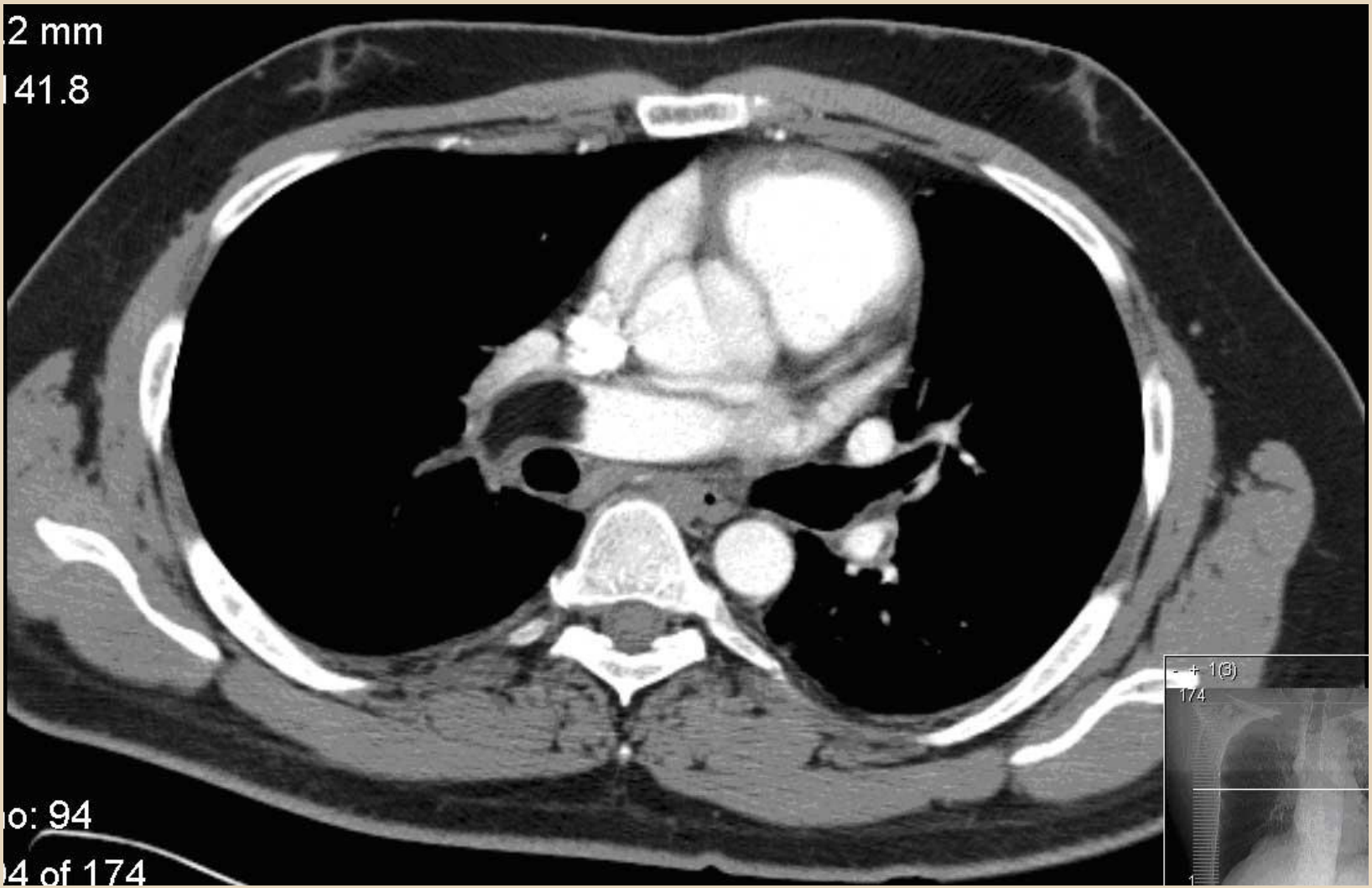
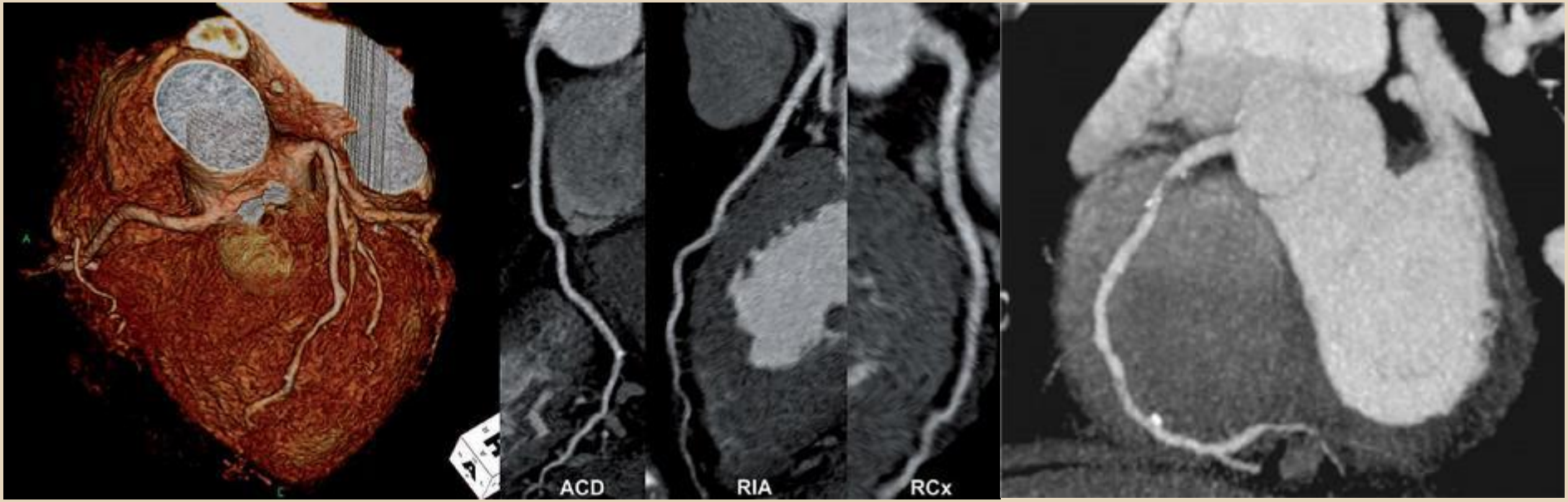


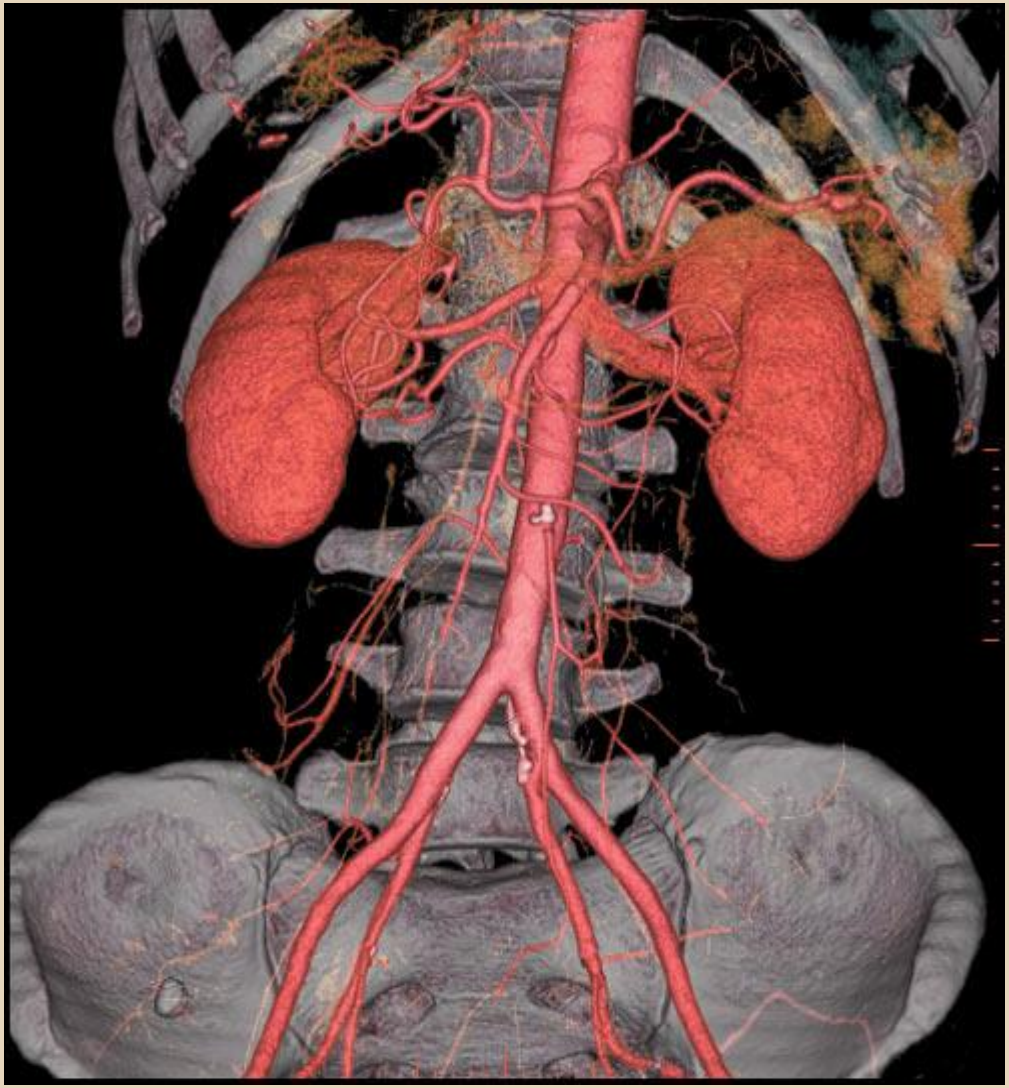
image reconstruction



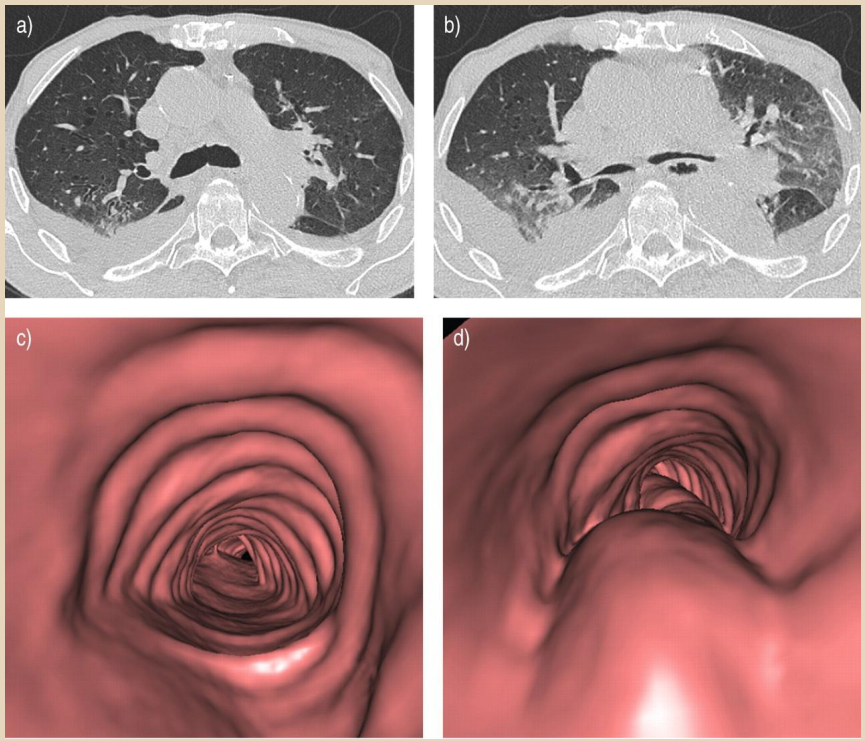
CT coronarography

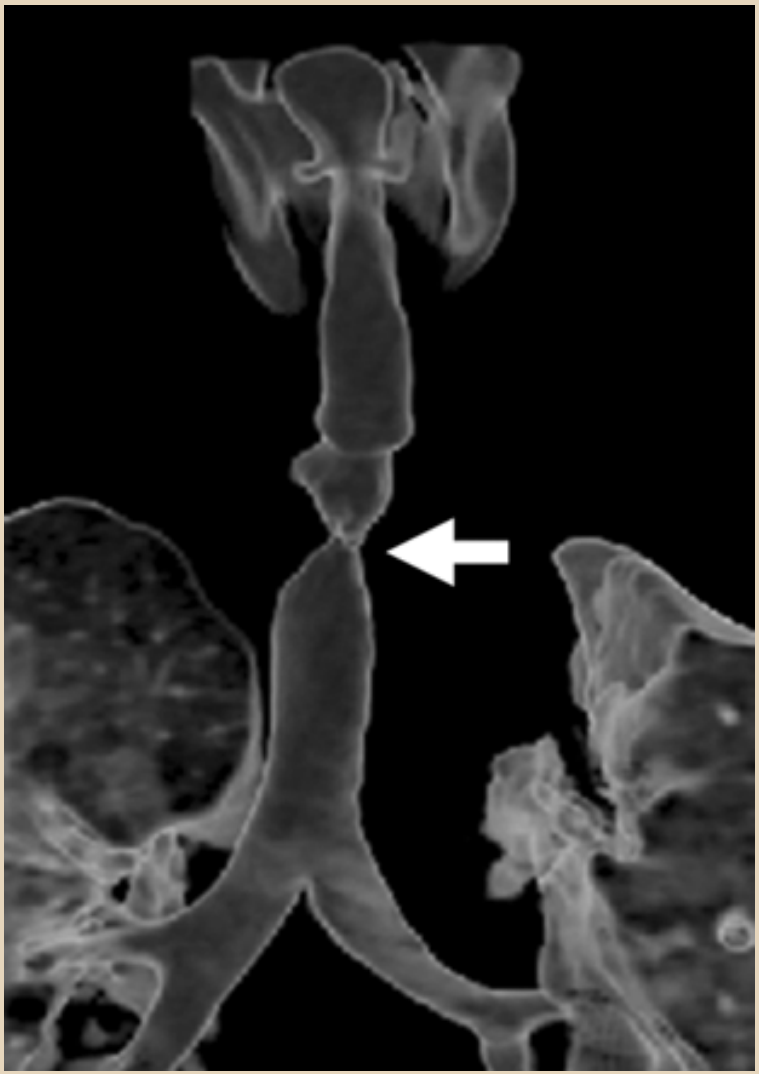


CT angiography

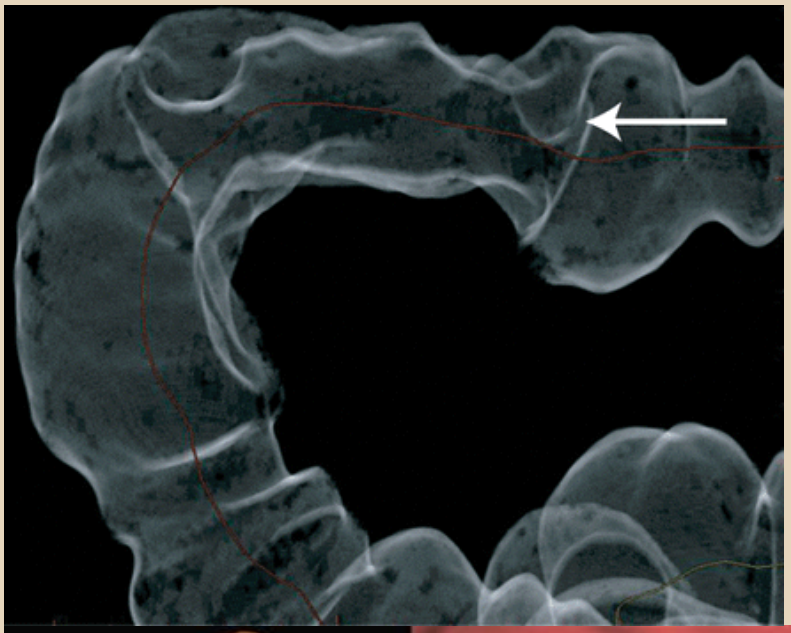


CT endoscopy

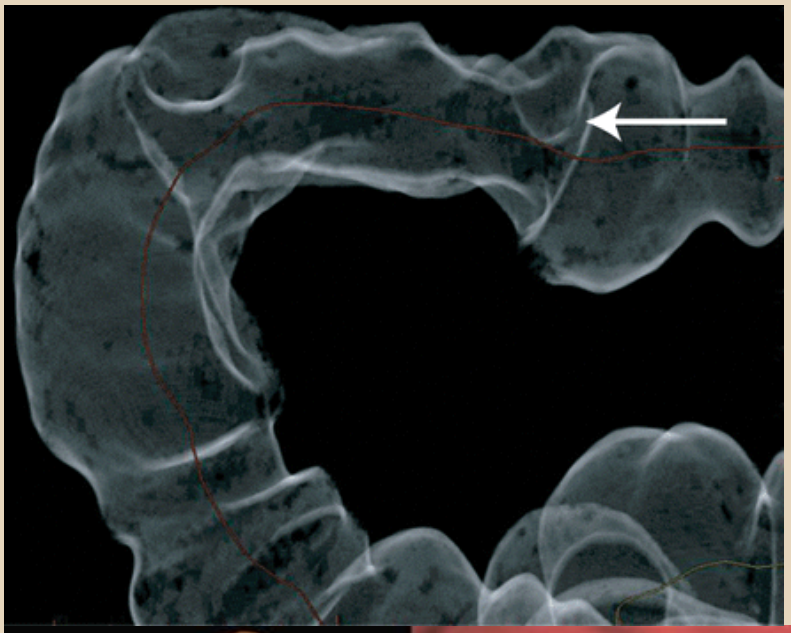




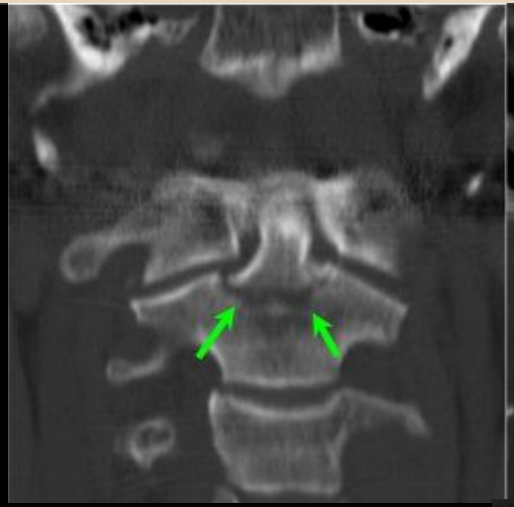
CT endoscopy

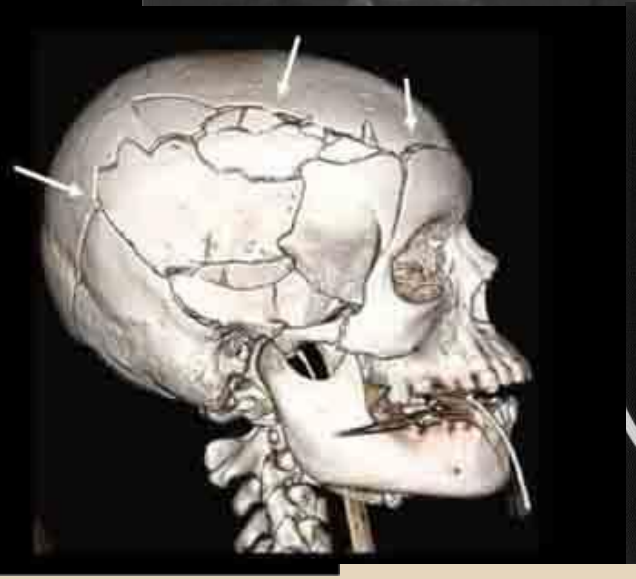


CT endoscopy

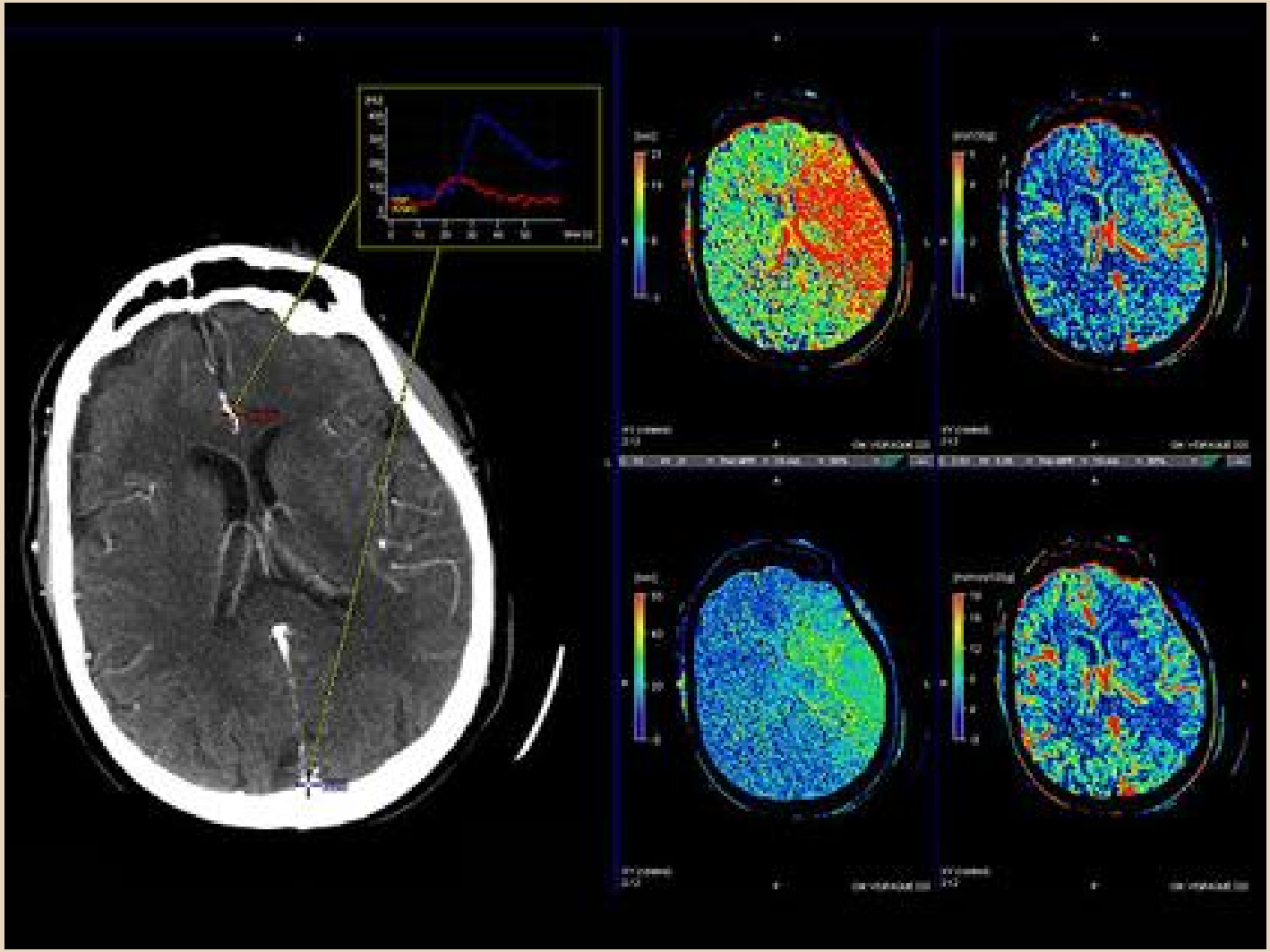


CT in polytrauma





CT in acute stroke



Thank you