PRINCIPLES OF NEUROTECHNOLOGY:

BRAIN IMAGING

IONIZING NEUROIMAGING TECHNIQUES

The Nobel Prize in Physics 1901

Photo from the Nobel Foundation archive.

Wilhelm Conrad Röntgen

Prize share: 1/1

The Nobel Prize in Physics 1901 was awarded to Wilhelm Conrad Röntgen "in recognition of the extraordinary services he has rendered by the discovery of the remarkable rays subsequently named after him."

Radiological Systems

Three Ionizing Imaging Modalities used in Clinical Radiobiology

(Tomography = Section imaging. From "Ana-tomy": Sectioning apart. "Tomo = sectioning)

- ► **DXR: Digital X-ray Radiography** **(Anatomical Imaging).**

- ✓ **CAT: Computed Axial Tomography** **(Anatomical Imaging).**
- ✓ **PET: Positron Emission Tomography** **(Physiological Imaging).**
- ✓ **SPECT: Single Photon Emission Computed Tomography** **(Physio. Imaging: Cheaper. Less tests possible).**

IMAGING MODALITIES

X-Ray (Rontgen, 1895)

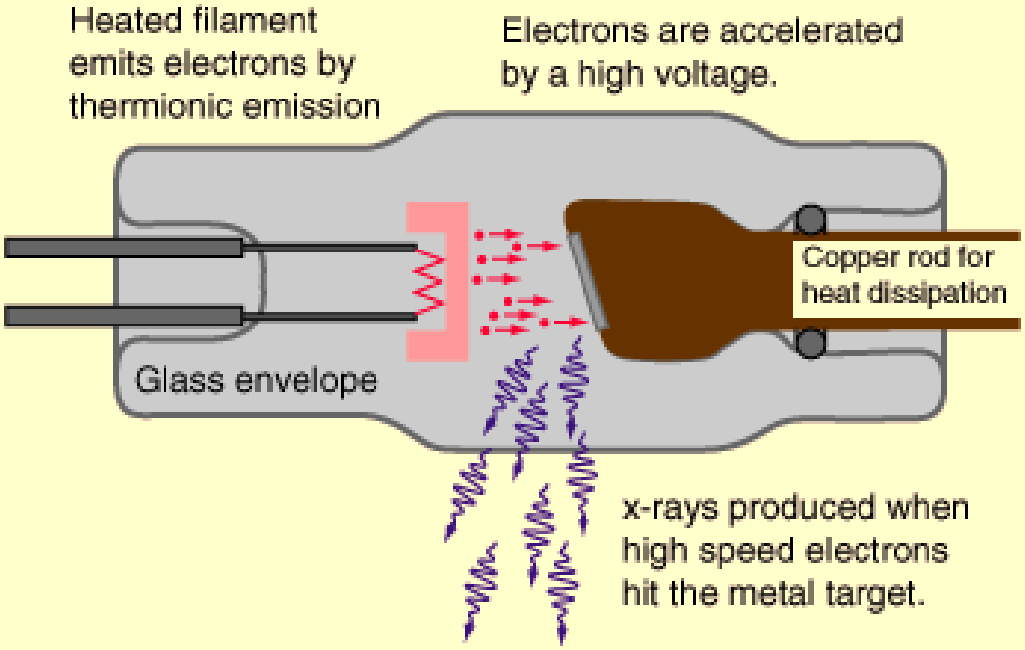
CAT Scan – 3-D X-Ray (Radon, 1917, Hounsfield 1969):
Computed Tomography

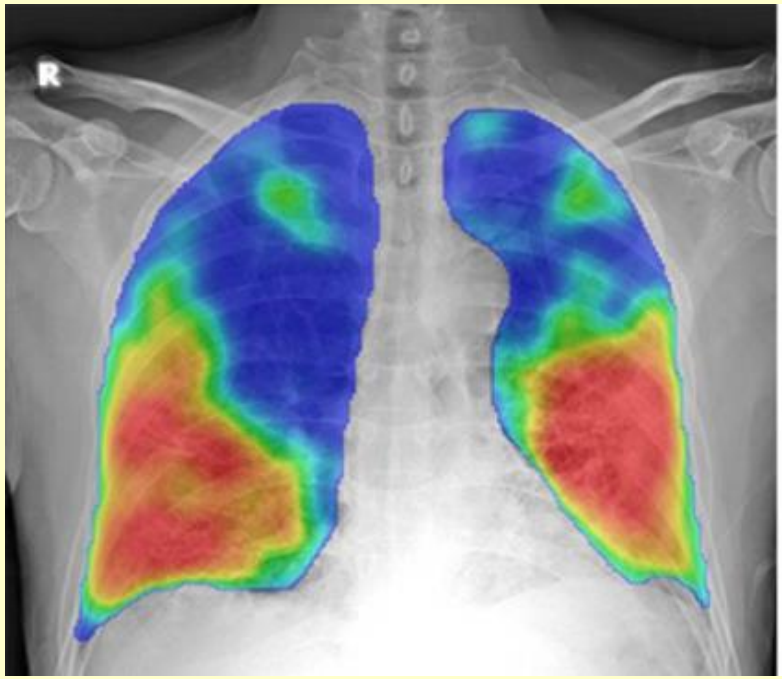
NMR/MRI (Stern, 1919, Bloch, 1944, Ernst, 1965, Mansfield, 1973):
Nuclear Magnetic Resonance

PET (Lawrence, 1938, Poggosian, 1955):
Positron Emission Tomography

Digital X-Ray

X-RAY


Heated filament
emits electrons by
thermionic emission
Electrons are accelerated
by a high voltage.
Copper rod for
heat dissipation
Glass envelope
x-rays produced when
high speed electrons
hit the metal target.


R

CAT Scanning

Proc. Nat. Acad. Sci. USA
Vol. 68, No. 9, pp. 2236–2240, September 1971

Three-dimensional Reconstruction from Radiographs and Electron Micrographs: Application of Convolutions instead of Fourier Transforms

(computer time/accuracy/x-ray/shadowgraphs)

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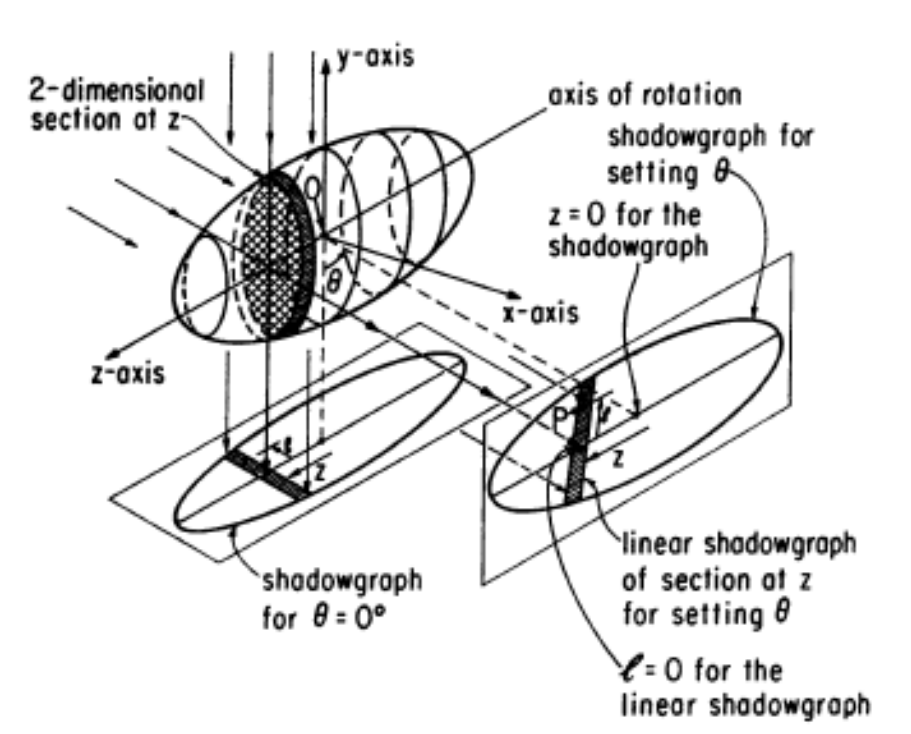
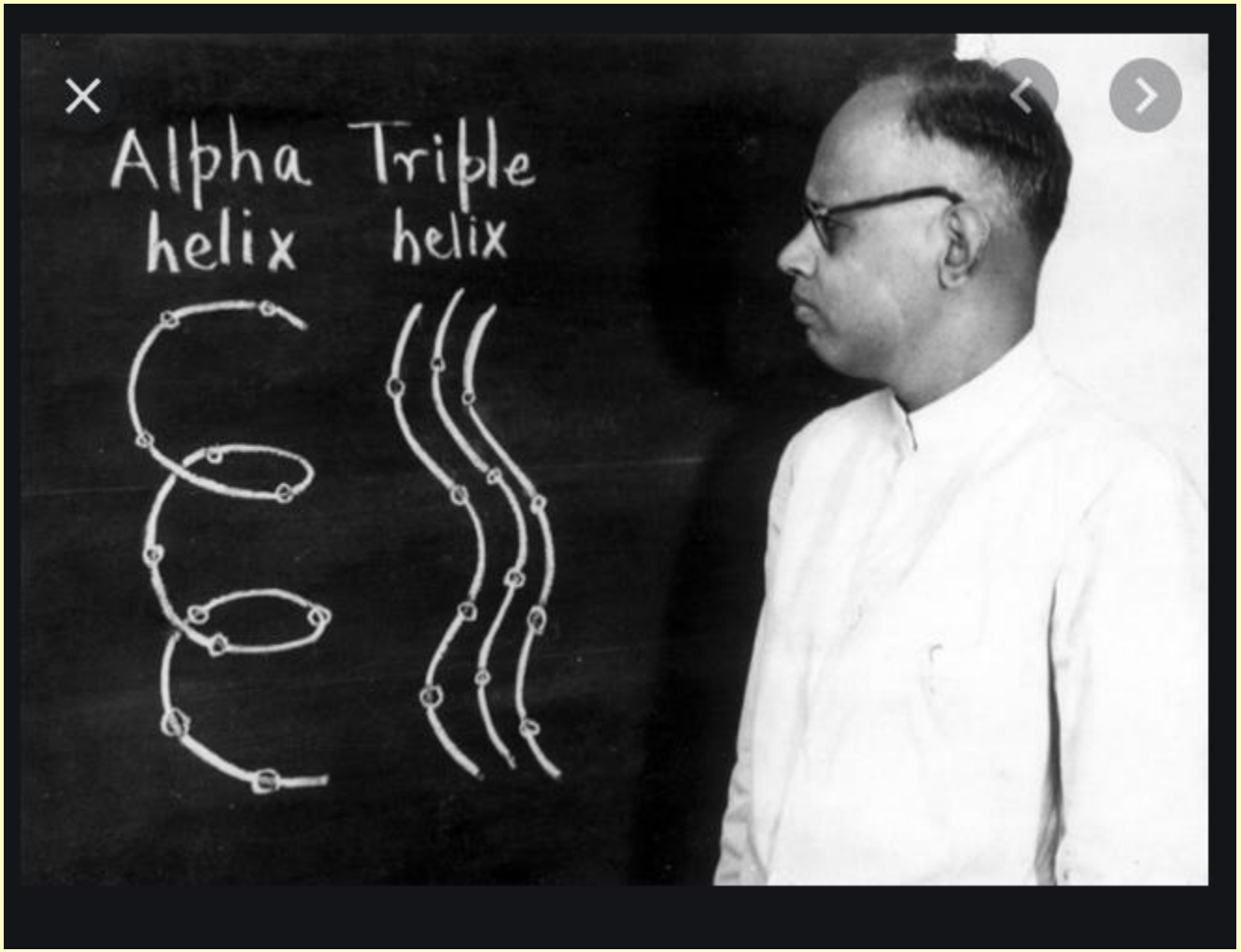
Communicated by S. Chandrasekhar, June 14, 1971

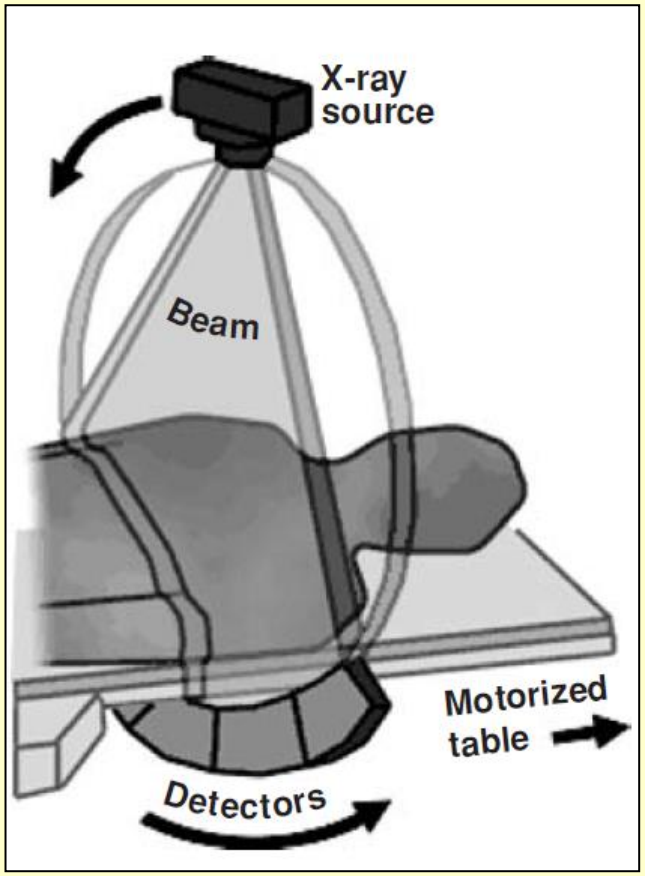


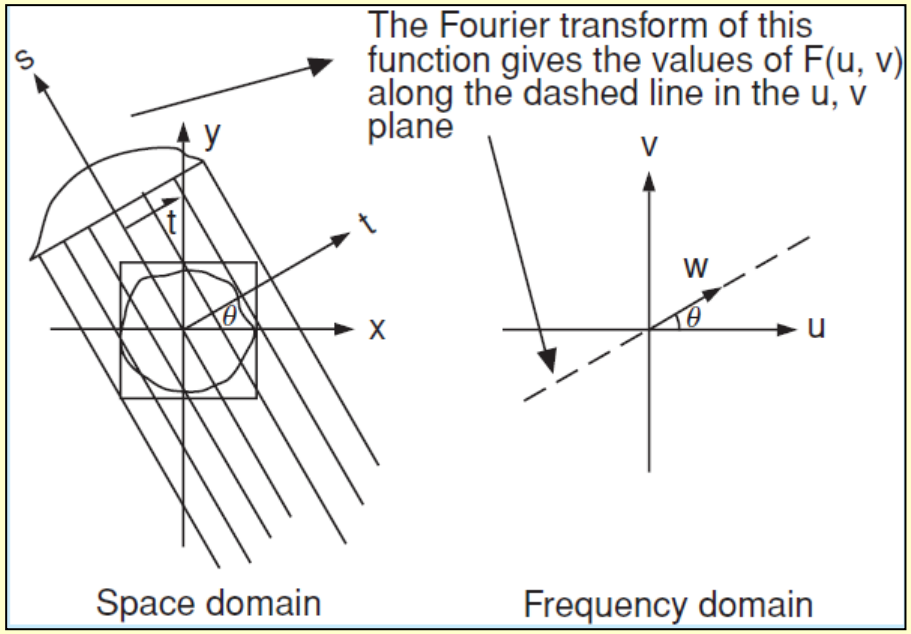
G. N. Ramachandran (Madras University)



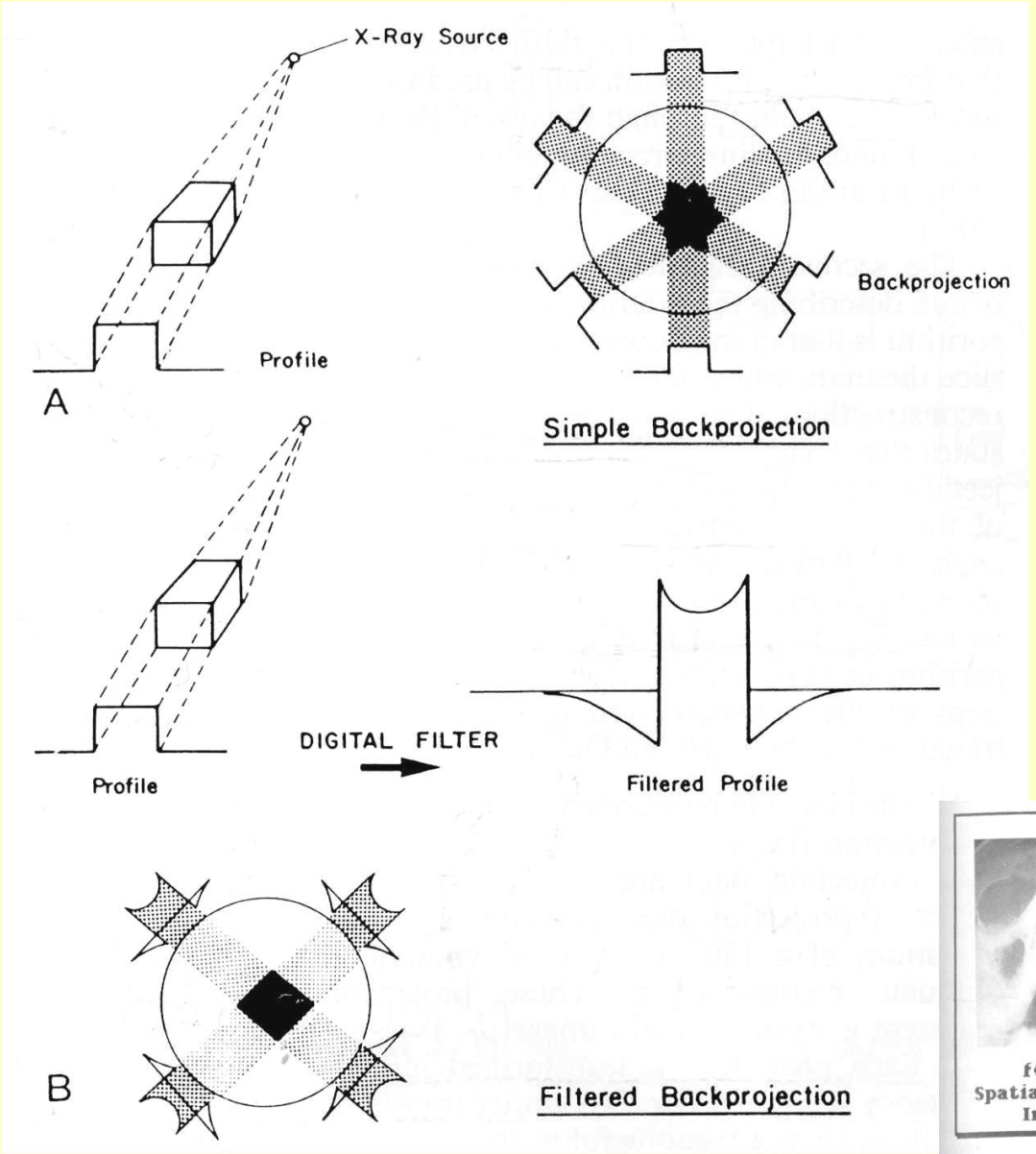
Computed Axial Tomography:

CAT scan (X-Ray)

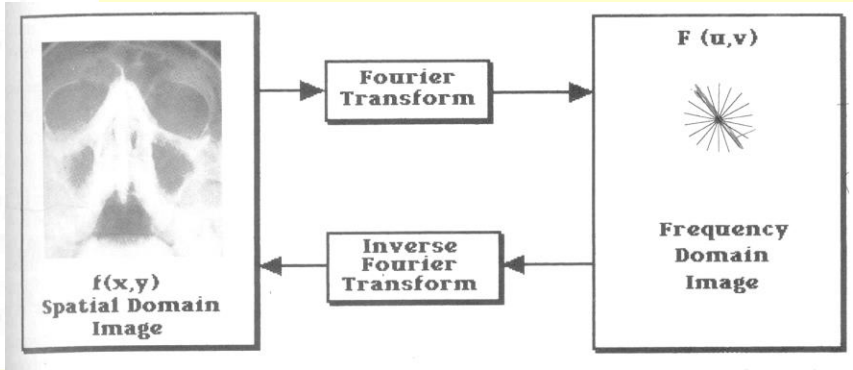




Backprojection Tomography: Basis of computation in CT, MRI, PET



$$F(k) = \int_{-\infty}^{\infty} f(x)\, e^{-2\pi i k x}\, dx.$$



The Nobel Prize in Physiology or Medicine 1979

Photo from the Nobel Foundation archive.

Allan M. Cormack

Prize share: 1/2

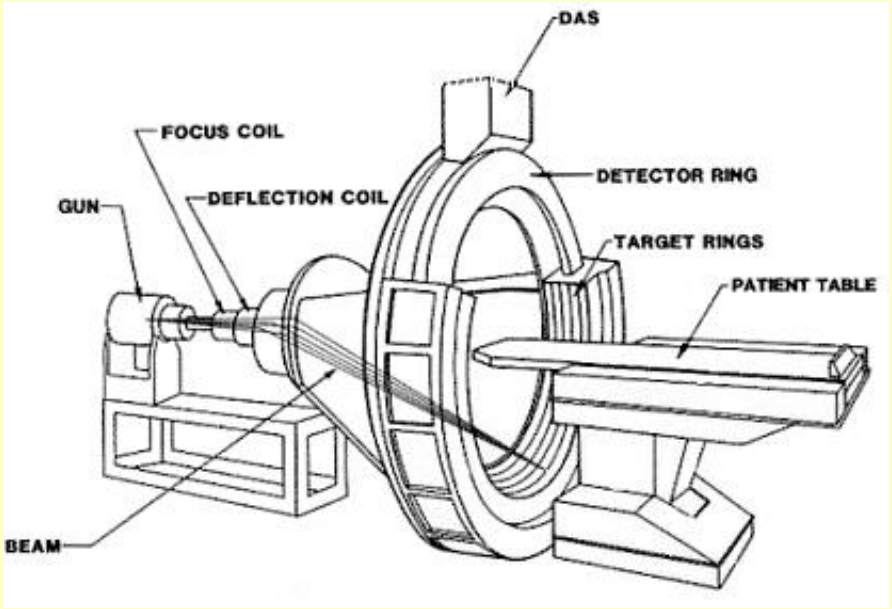
Photo from the Nobel Foundation archive.

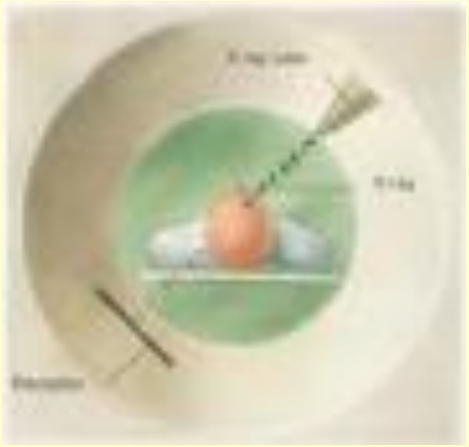
Godfrey N. Hounsfield

Prize share: 1/2

The Nobel Prize in Physiology or Medicine 1979 was awarded jointly to Allan M. Cormack and Godfrey N. Hounsfield "for the development of computer assisted tomography."

CAT: Computed Axial Tomography





Hounsfield Equation

Hounsfield Units

$$HU = 1{,}000 \times (\mu - \mu_{\text{water}}) / \mu_{\text{water}}$$

H.U. Ranges

- HU of water is 0
- HU of air = – 1,000.
- Water and water-based soft tissues: HU = 0 – 100

  - Fatty tissues: HU = – 100 to 0.
  - Bones: HU > 500.
  - Modern CT scanners are capable to detect Δ H = 5 to 10 HU

Contrast Agents

(Atomic No. Z > 50)

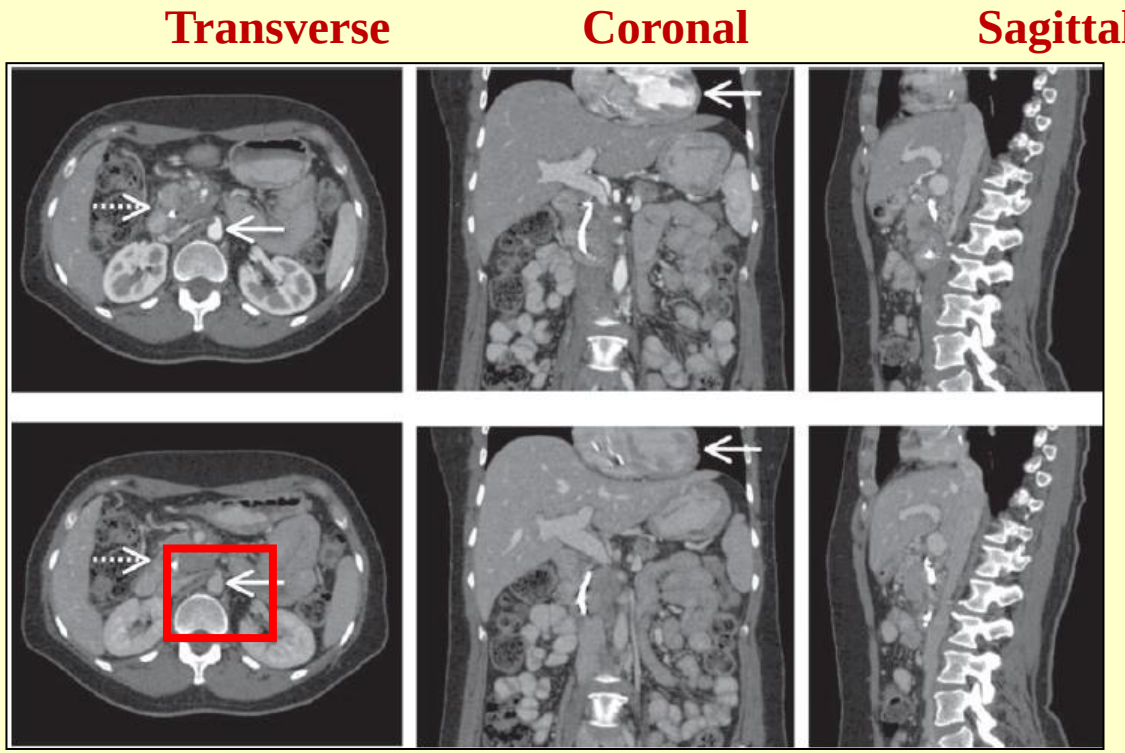
- **Barium (Z = 56)**
- **Gadolinium (Z = 64)**
- **Gold (Z = 79)**
- **Bismuth (Z = 83)**
- **Tungsten (Z=_ 74)**

Iodine (Z = 53) : Inorganic (Na Iodide: Z high), Organic (Iodinated-Hexol) = 10 mM reqd.

- **Krypton (Z = 36)**
- **Xenon (Z = 54)**

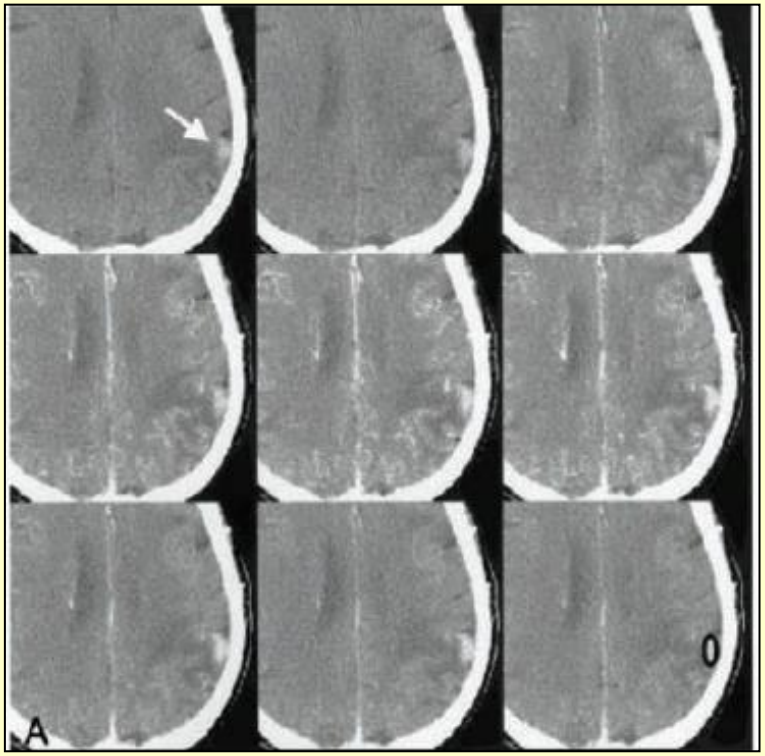
Neural Spine Spread: CT "Angiography" for Diagnosing Cancer

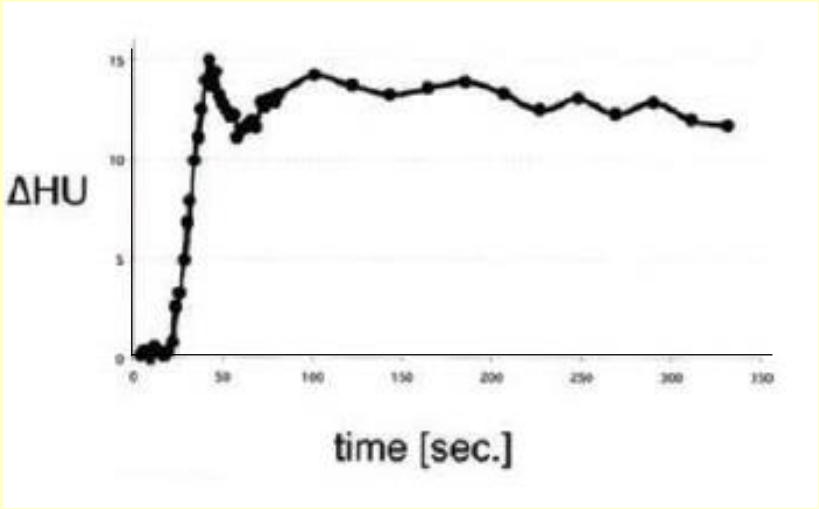
(Angiography = Blood Flow via Vessels; Angio = Blood Vessels)



CT Dynamic Imaging of lesion:

Using Enhancement by Contrast Agent

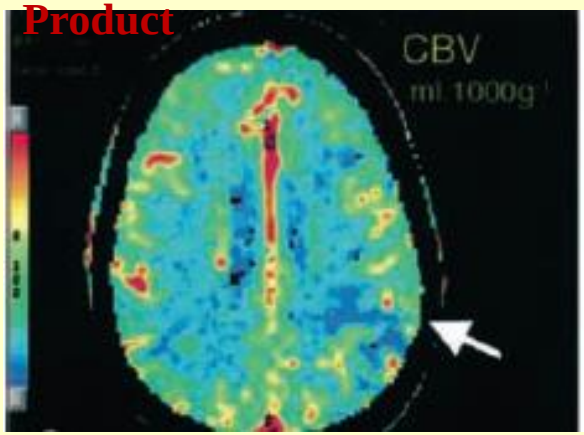




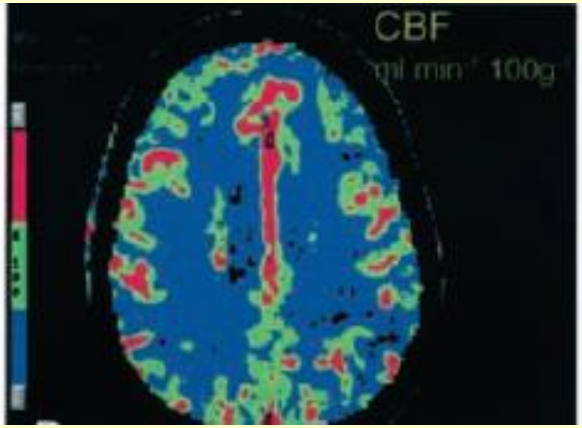
CT Perfusion Study

**(Perfusion = Blood Flow through tissue capillaries:
[Not via Blood Vessels of Artery/Vein]**

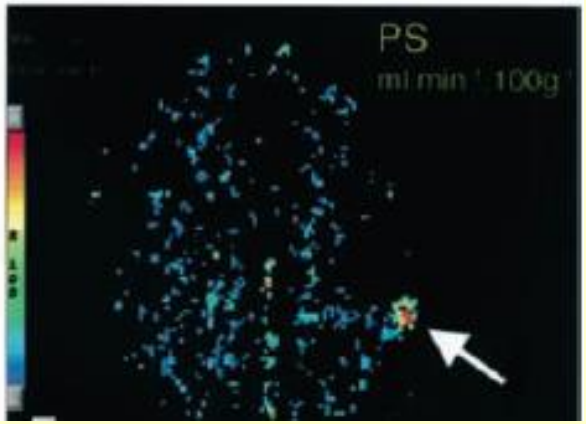
Cerebral Blood Volume Product



Cerebral Blood Flow



Vascular Permeation Area



Compartment Model of Contrast Agent's Pharmacokinetics

CAT: Volume Rendering