Imaging of Cancer

Imaging of Cancer:

Subtitle: What actually happens in a Radiology Department?

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Imaging of Cancer

- Imaging is a key element of:
  - Screening (e.g. lung cancer, breast cancer)
  - Staging (has it spread locally? Metastasized?)
  - Monitoring of treatment (Better or worse?)
  - Recurrence (Has it come back?)
  - Prognosis (What will happen?)

The Main Imaging Devices

- Computed Tomography (CT)
- Magnetic Resonance Imaging (MRI)
- Ultrasound (US)
- Single Photon Emission Computed Tomography (SPECT)
- Positron Emission Tomography (PET)
- Optical Imaging

The Main Imaging Devices

Quiz: Name that Scanner

CT

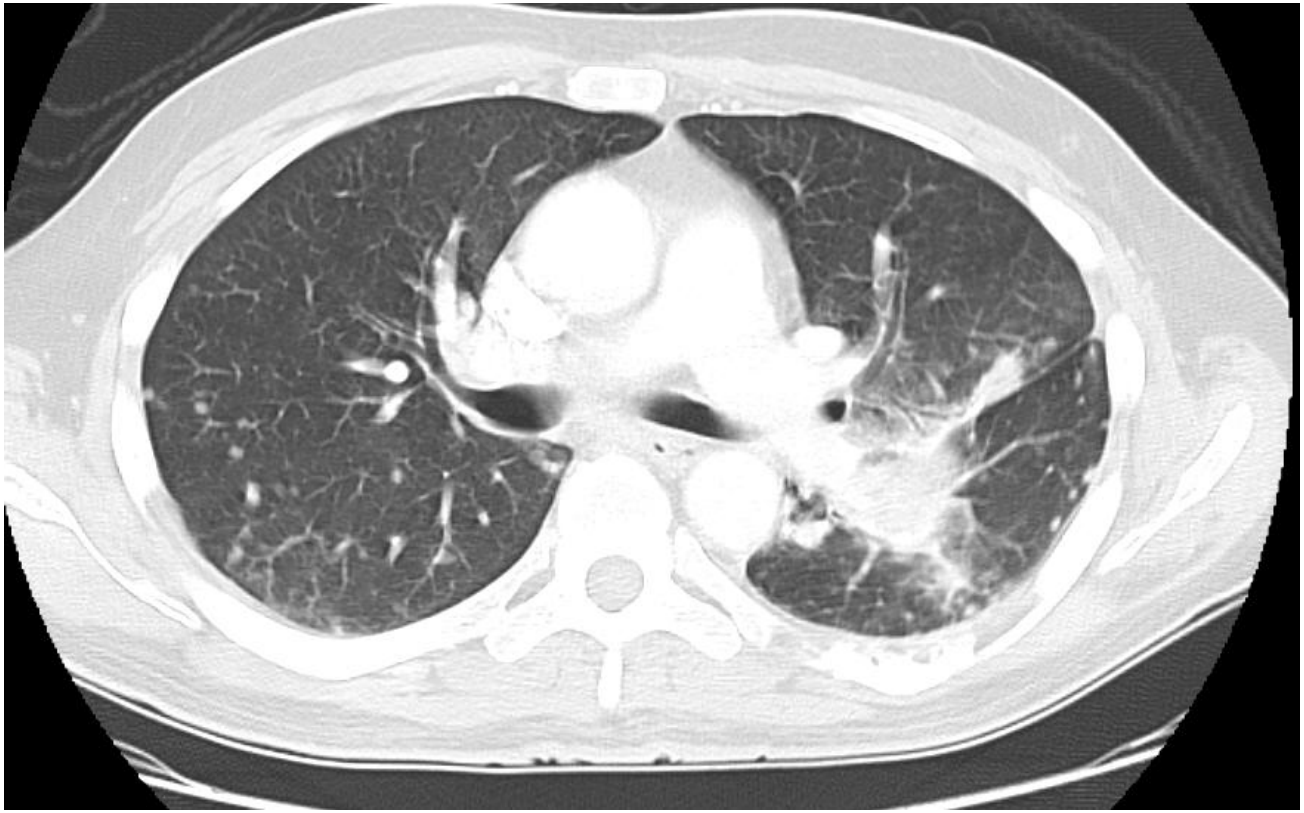
MRI

US

SPECT

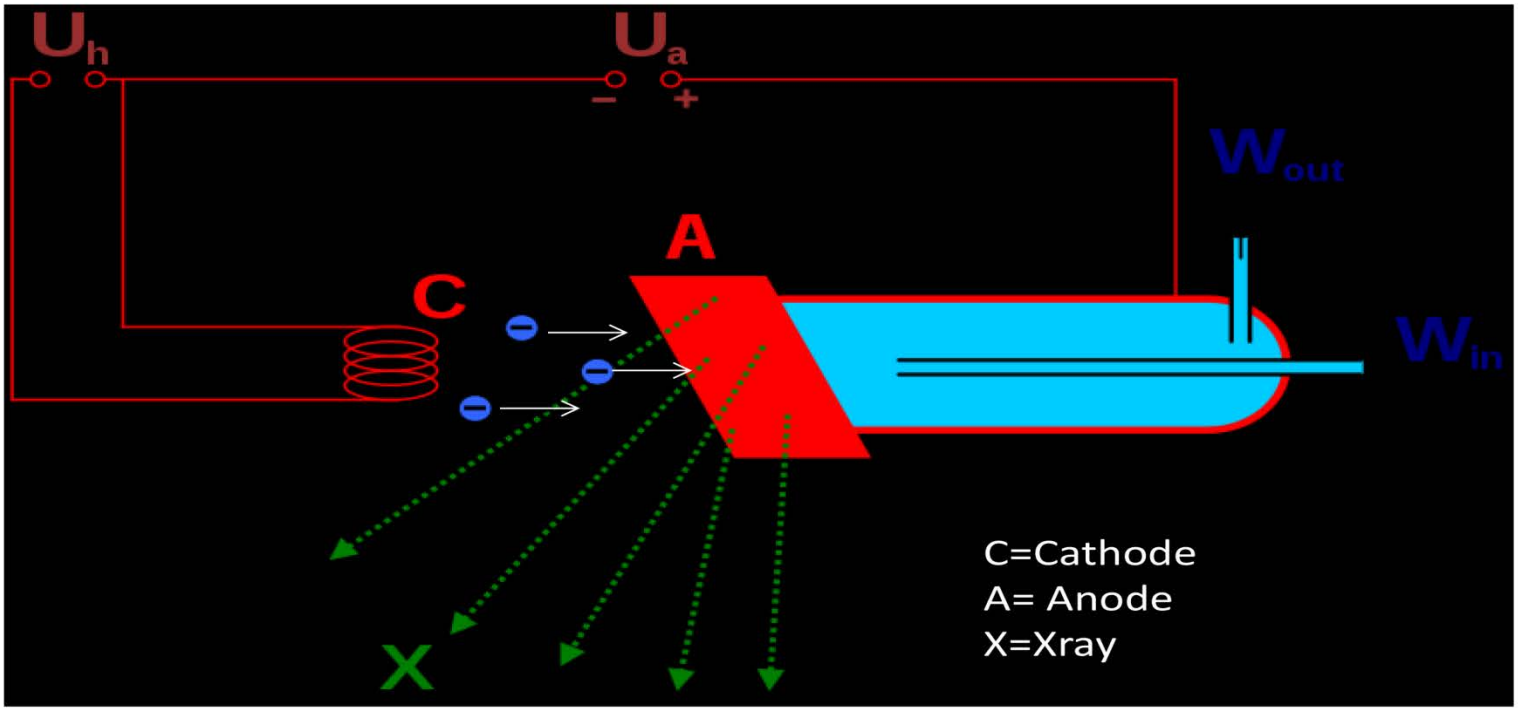
PET

Computed Tomography



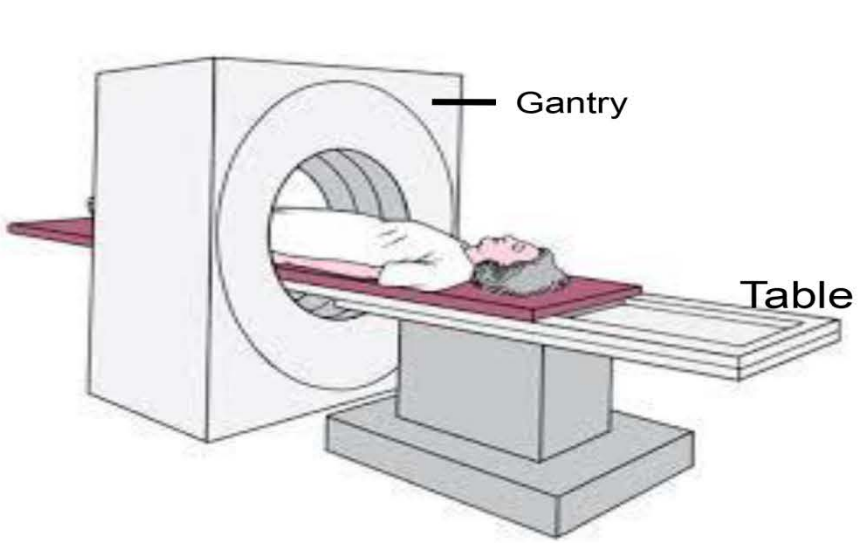
X-ray production

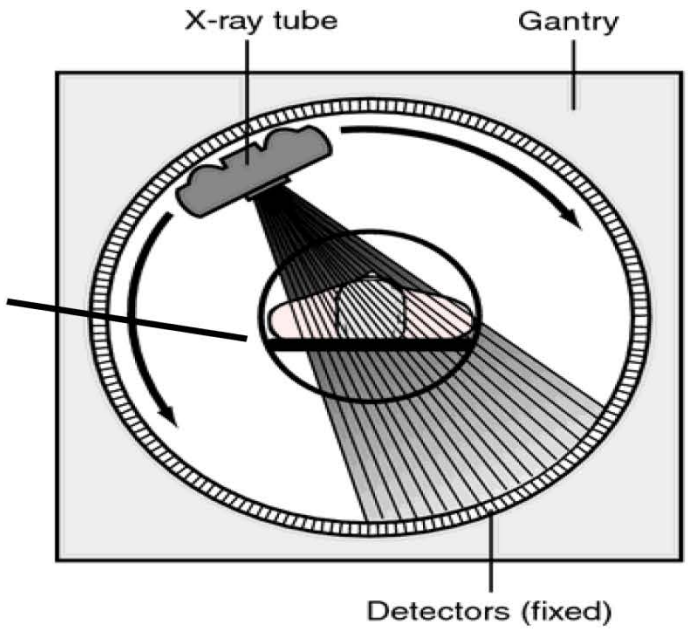
X-ray production: cathode ray tube



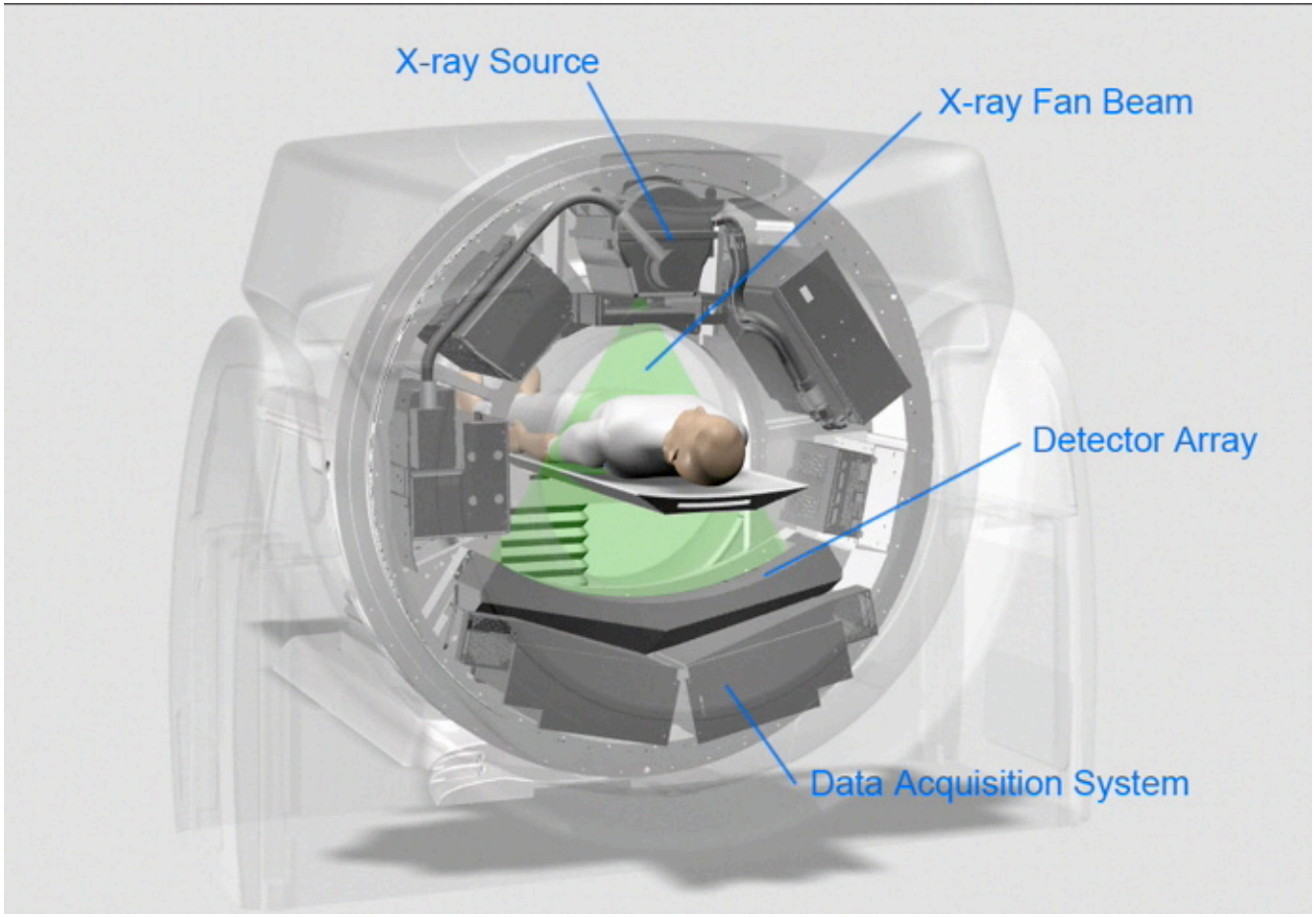
Basics of CT

Basics of CT



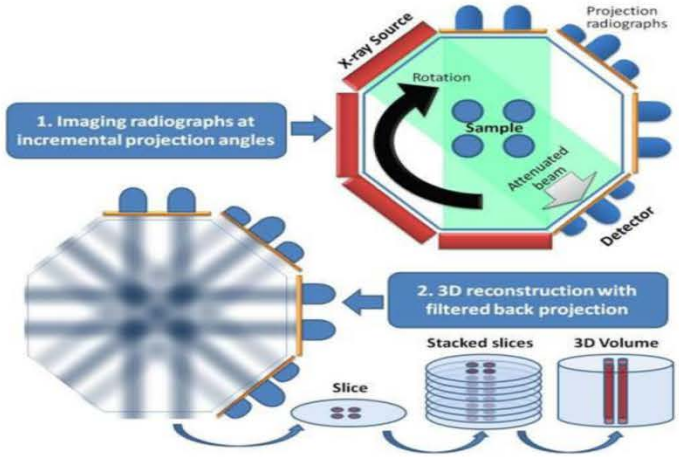


Cross section of a CT Scanner



CT projection

Filtered Back Projection



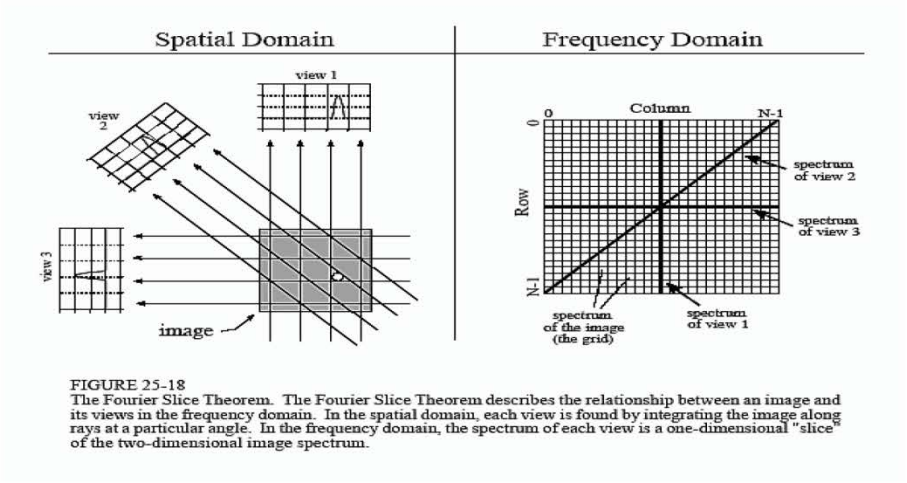


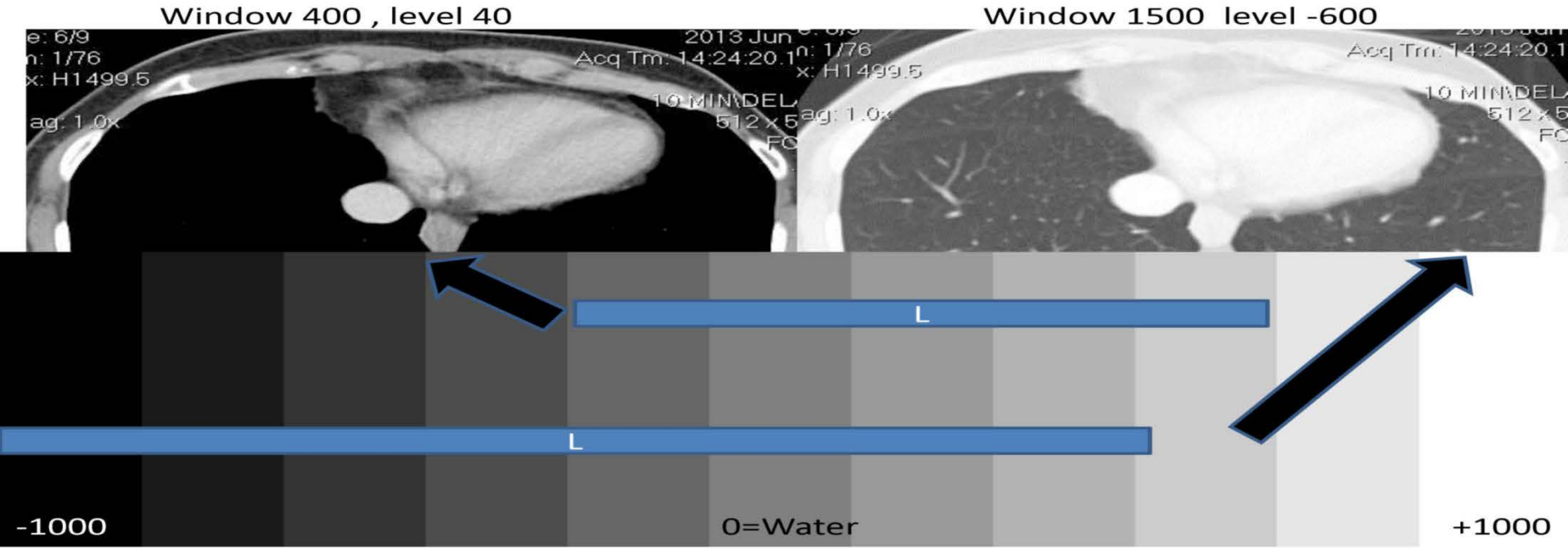
FIGURE 25-18
The Fourier Slice Theorem. The Fourier Slice Theorem describes the relationship between an image and its views in the frequency domain. In the spatial domain, each view is found by integrating the image along rays at a particular angle. In the frequency domain, the spectrum of each view is a one-dimensional "slice" of the two-dimensional image spectrum.

“Volume” CT imaging

CT

Windowing a CT

“Windowing” a CT



Advantages of CT

- Widely available
- Minimal prep (NPO, drink contrast)
- Very rapid (2-3 seconds neck to pelvis)
- High resolution
- Relatively inexpensive

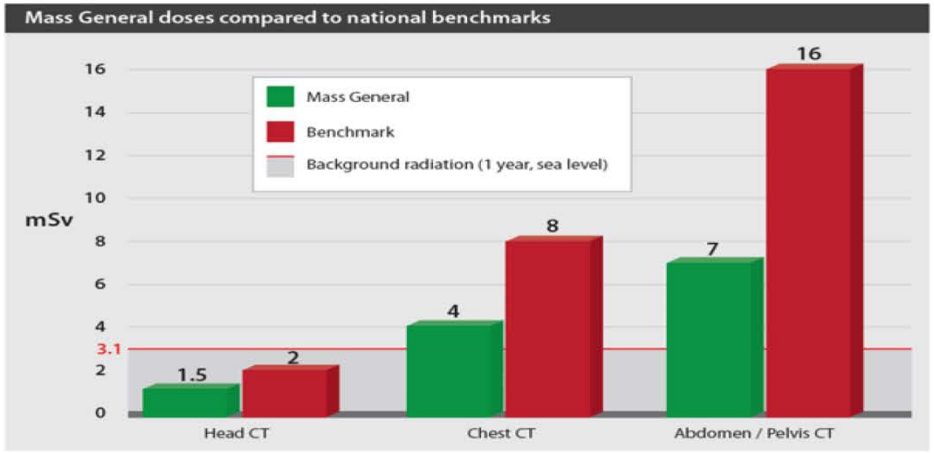
Disadvantages

- **Radiation**
- Often requires iv contrast media
  - Allergic reactions (minimal)
  - Kidney damage (only in high risk patients)
- Anatomic information only

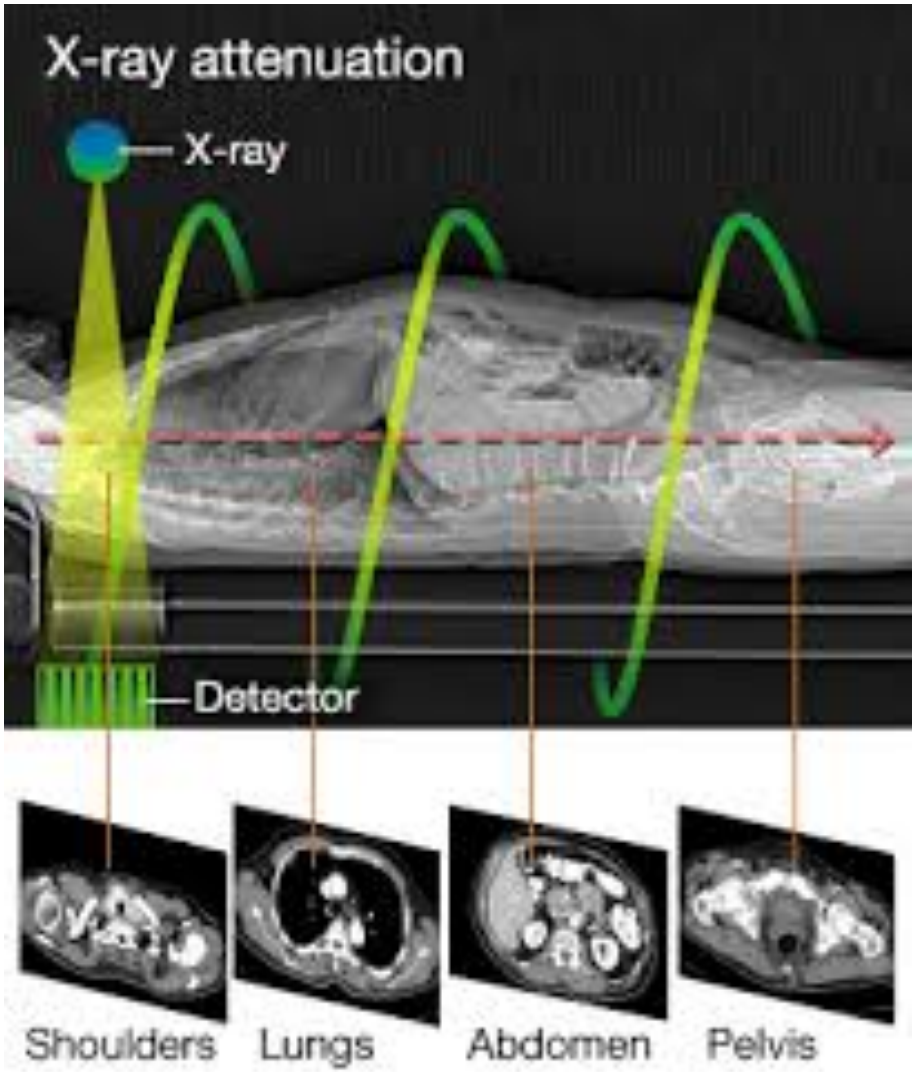
Radiation reduction on CT

Radiation

Lower kV (energy) x-rays
More sensitive detectors
Better reconstruction algorithms
"Synthetic" images

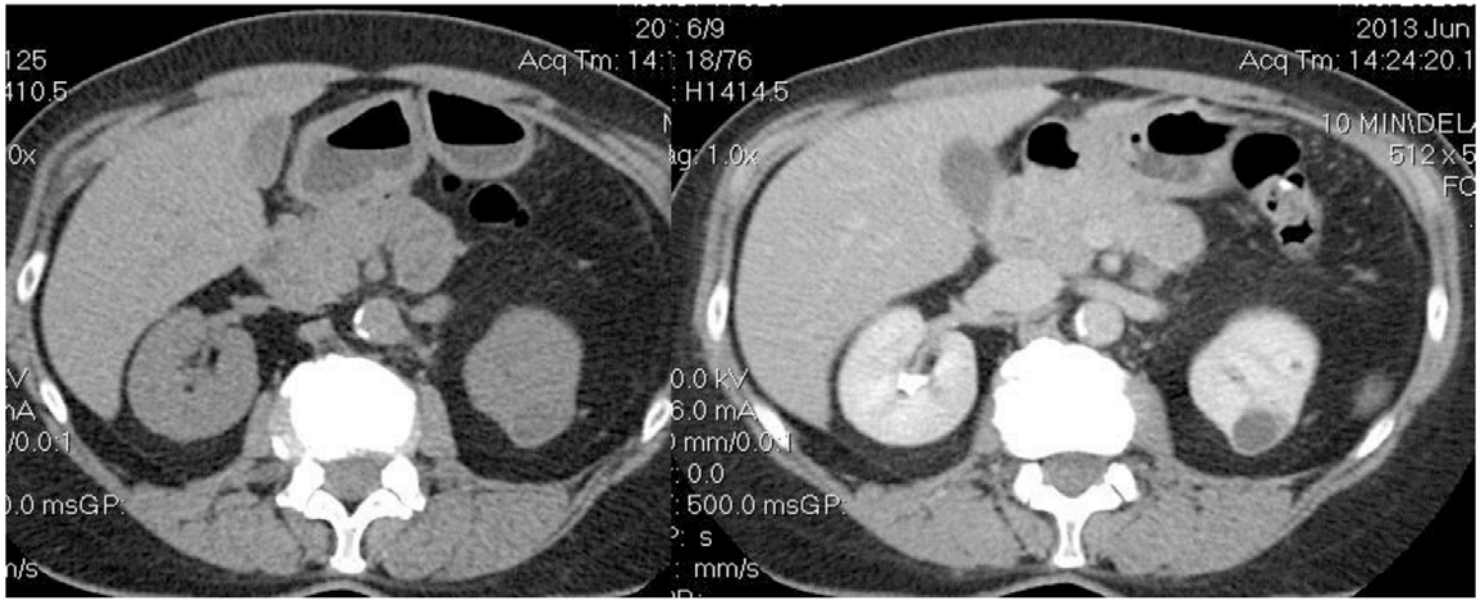


Attenuation differences thru the body



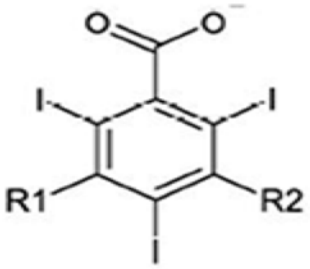
Contrast Media

Iodinated Contrast Media

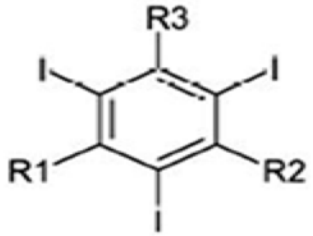


Contrast media

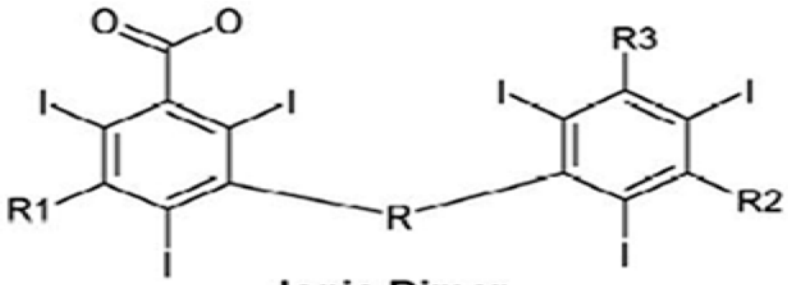
Basic Structures of Contrast Media



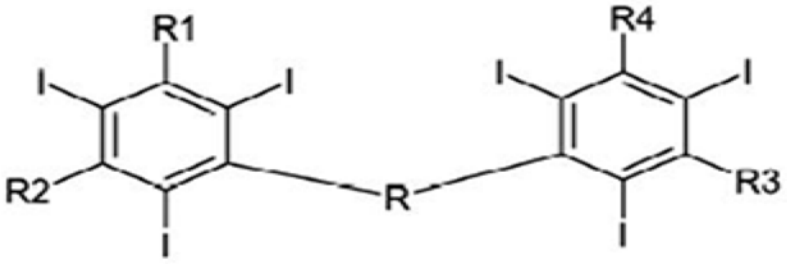
Ionic Monomer



Nonionic Monomer



Ionic Dimer

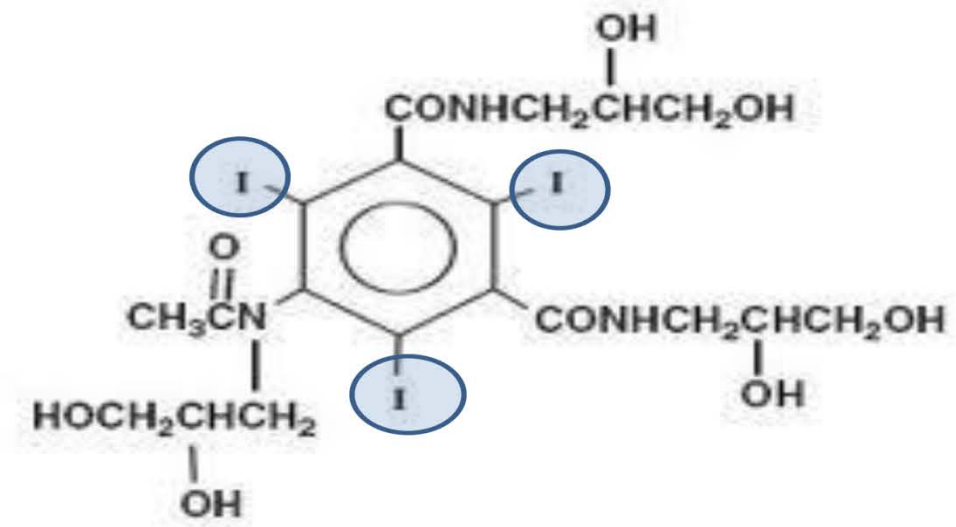


Nonionic Dimer

Voeltz MD, et al. *J Invasive Cardiol.* 2007 Mar;19(3):1A-9A. Review

Non ionic iodinated contrast

Non ionic Iodinated Contrast

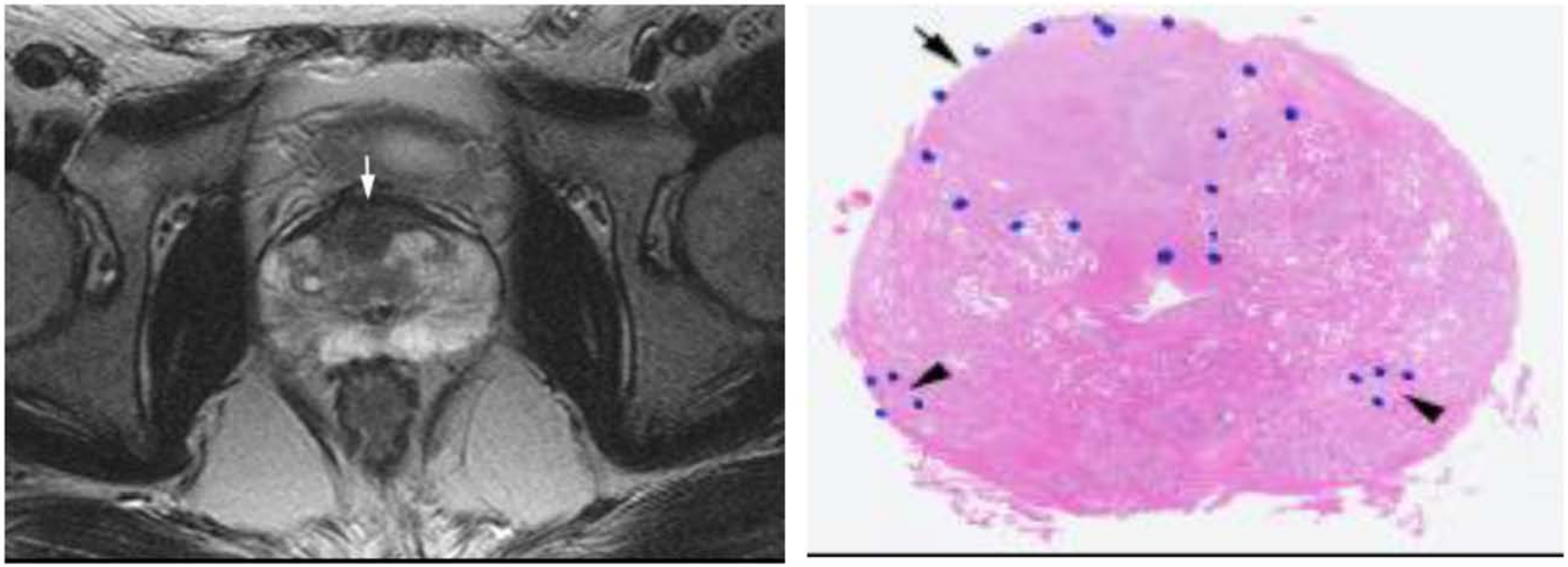


Iodinated Contrast

Iodinated Contrast

MRI

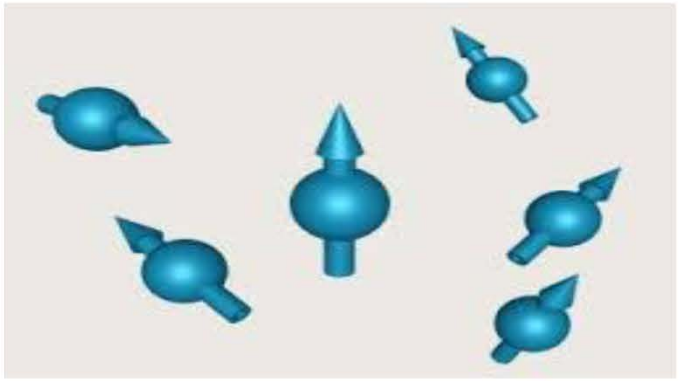
Magnetic Resonance Imaging



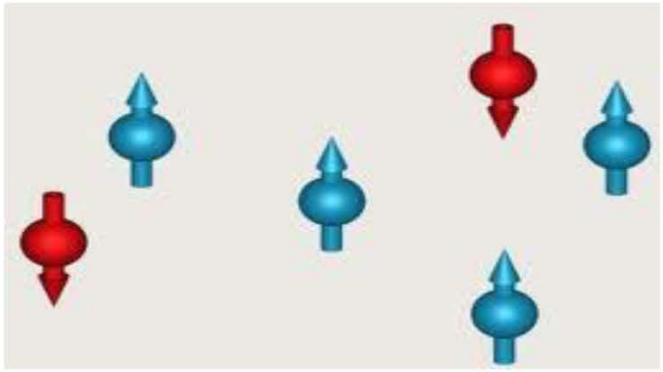
Prostate Cancer on MRI and Pathology

MRI physics

MRI Physics 101



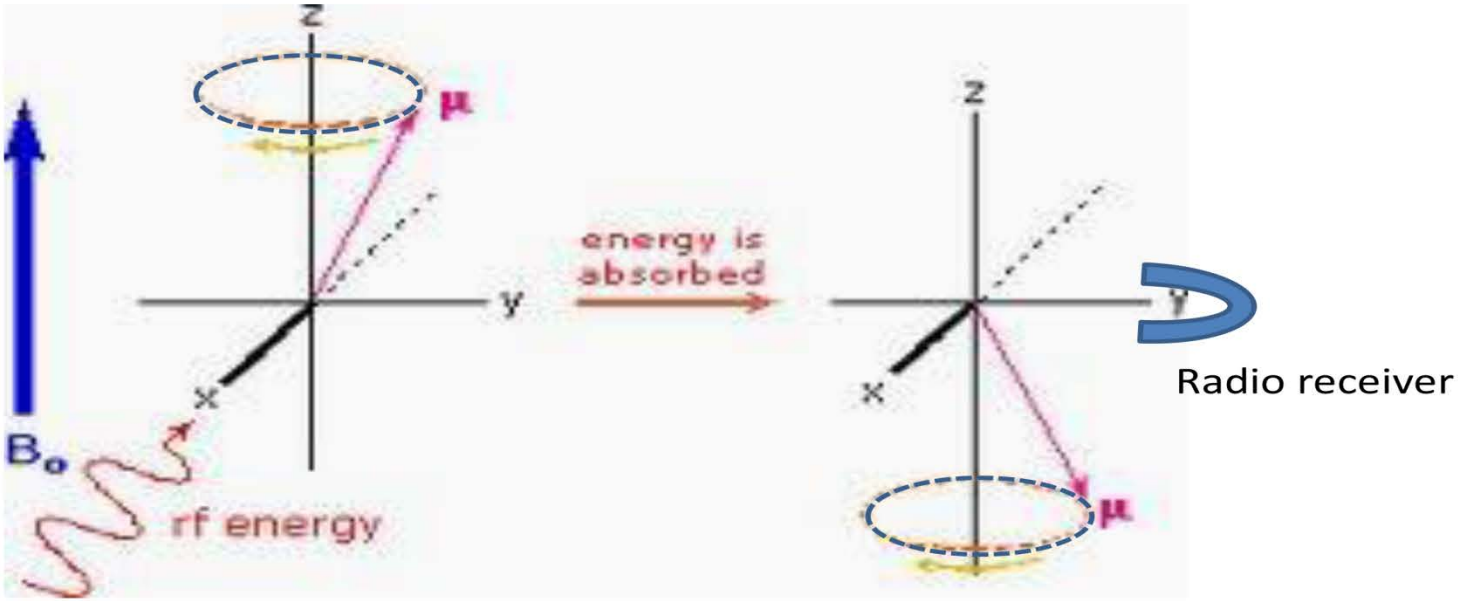
Protons in space: no field



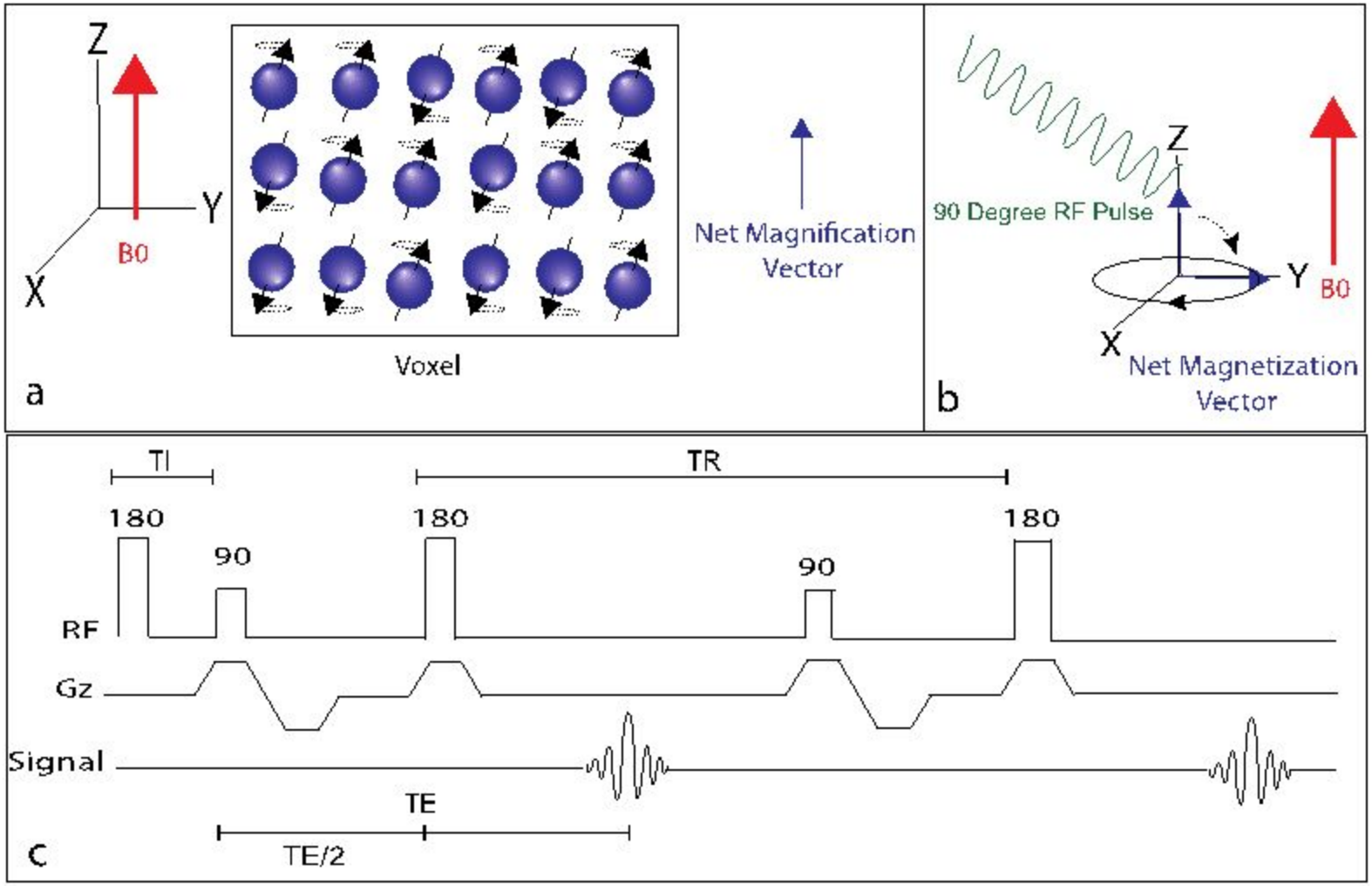
Protons in magnetic field

MR physics

MR Physics

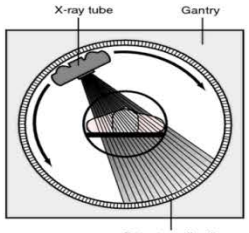


Summary

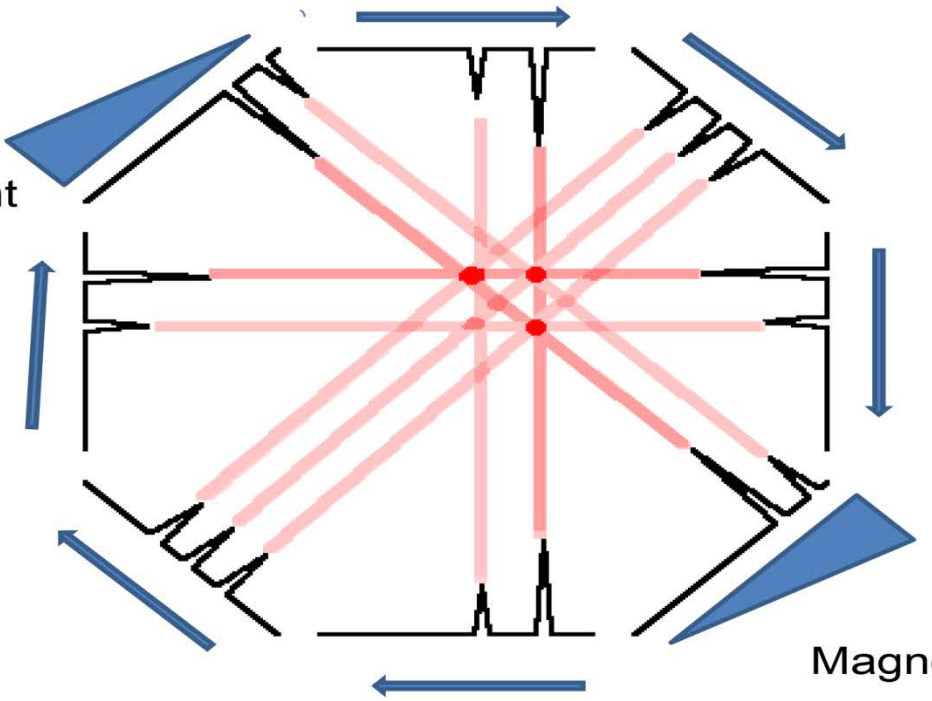

Z
Y
X
B0
Voxel
a
Net Magnification Vector
90 Degree RF Pulse
Z
Y
X
B0
Net Magnetization Vector
b
TI
TR
180
90
180
90
180
RF
Gz
Signal
TE
TE/2
c

Creating a MR Image

Creating an MR Image:
No detectors! Just antennas (coils)

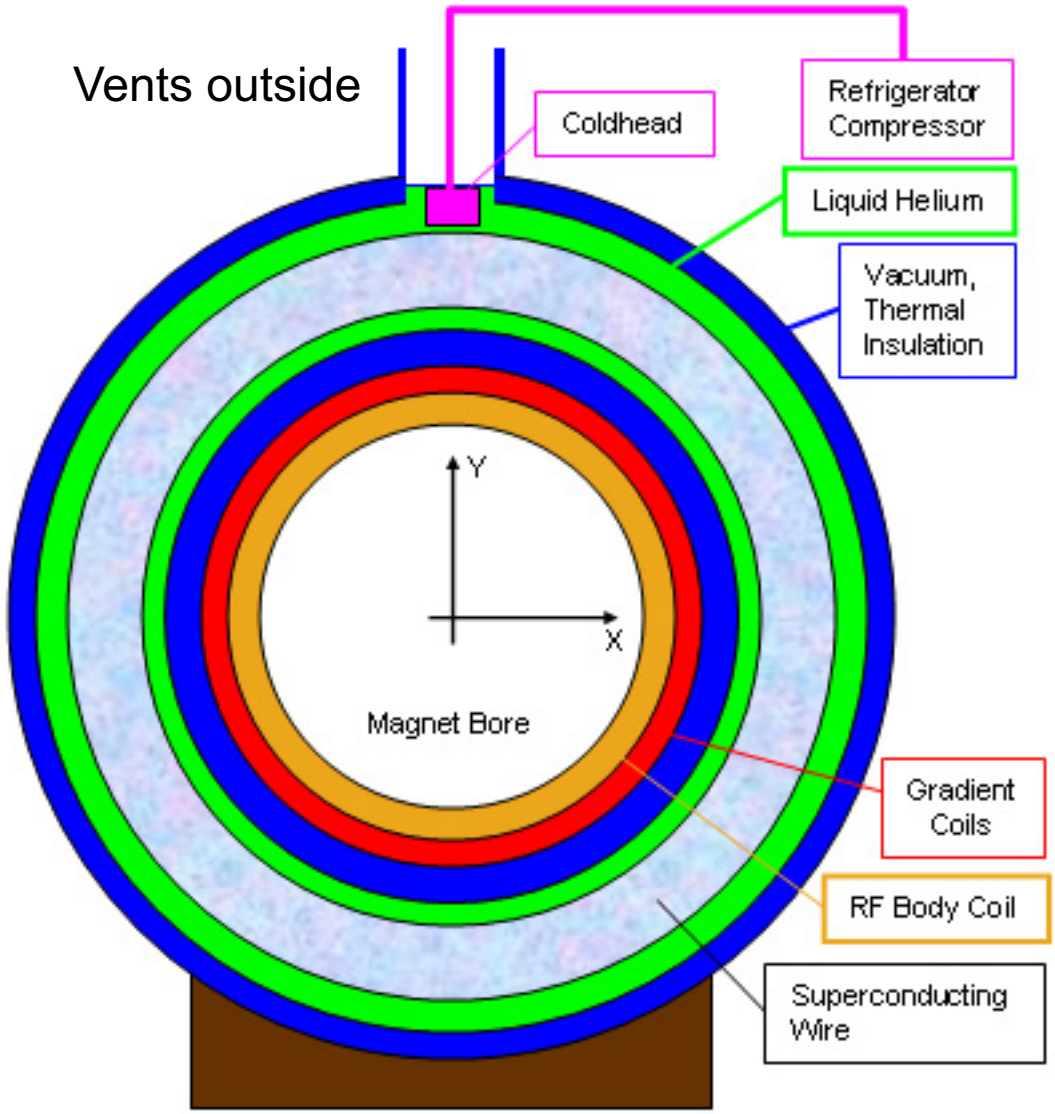


Magnetic Gradient



Magnetic Gradient

Anatomy of an MRI



MRI Advantages

- No radiation
- Multiplanar
- Multiple contrast types:
  - T1 weighting, T2 weighting
  - Diffusion weighting
  - Contrast enhanced MRI
  - Spectroscopy

MRI Disadvantages

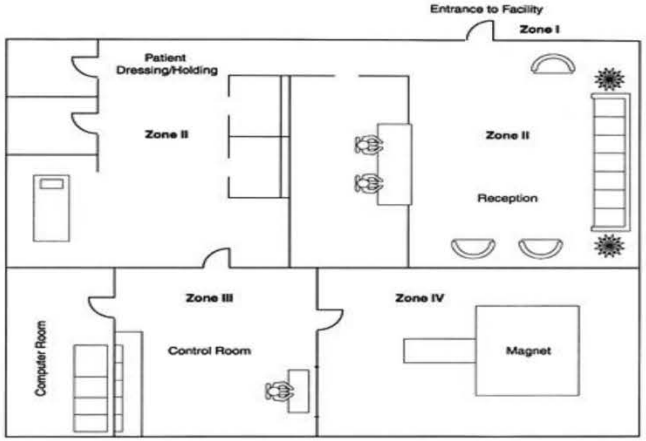
- Slower than CT
- More expensive
- Does not depict calcifications
- Safety issues
  - Metallic objects become projectiles
  - Incompatible with metallic implanted devices
    - Pacemakers
    - Cochlear implants

Safety issues in MRI

MRI Safety

MRI SAFETY

- MRI scanners are extremely powerful
- Objects that are attracted by the MRI magnetic field can reach 60 miles per hour.
- A sharp or heavy object can be deadly to anyone standing in its path.
- Metal objects used everyday (scissors, oxygen tanks, infusion pumps, etc) become projectiles
- This can causepotential injury to patients or hospital staff.
- MRI departments are divided into Zones for Safety



MRI Safety

MRI SAFETY

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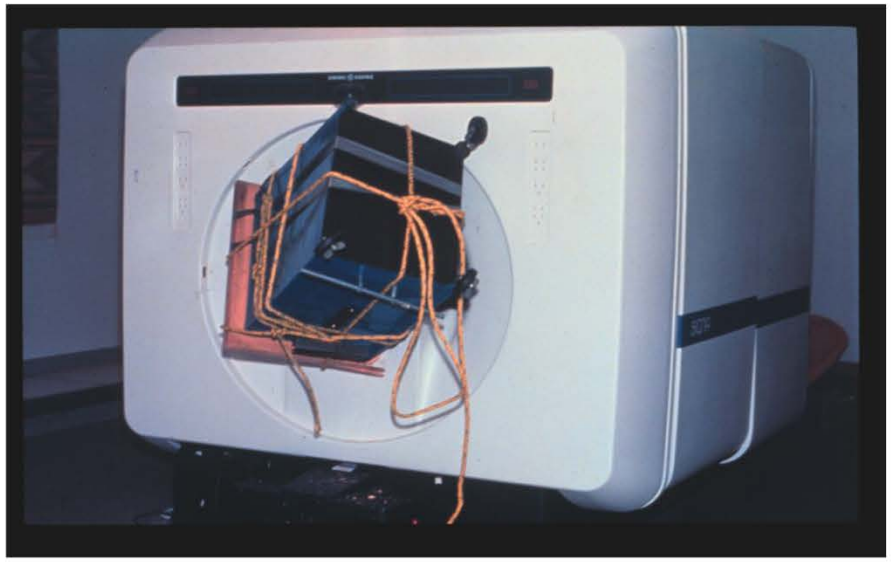


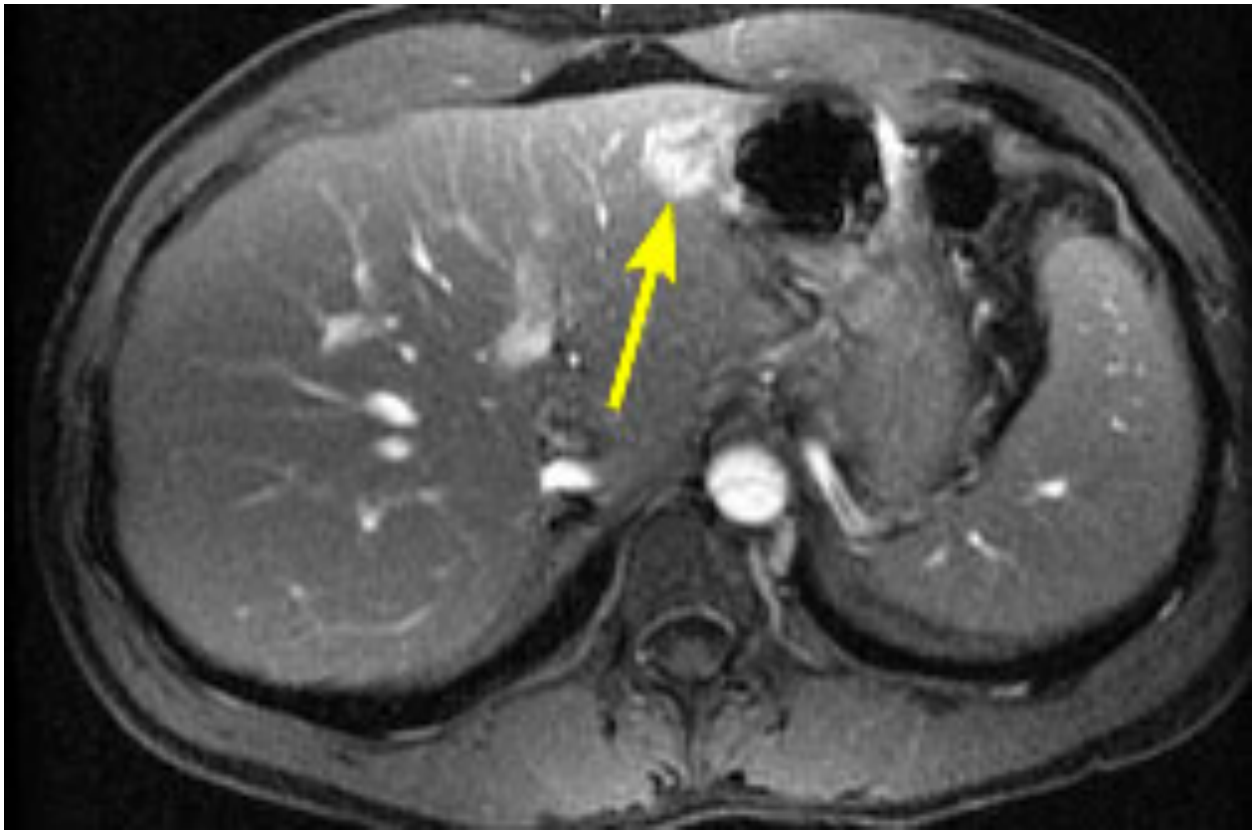
Oxygen tank

O2 Tank, “Missile”

An Oxygen tank can become an Airborne torpedo in an MRI

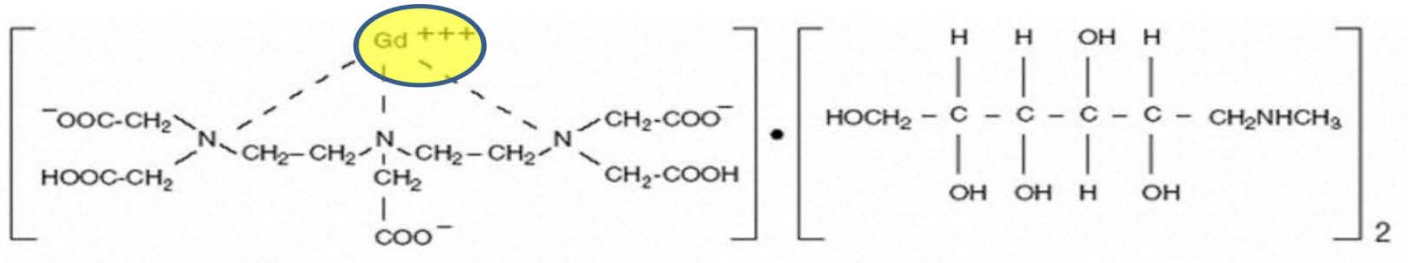
- ed
- en

Value of Contrast Media



Gd reagents

a



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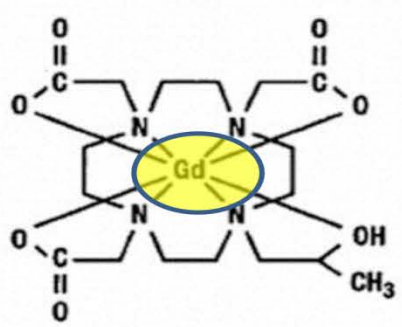

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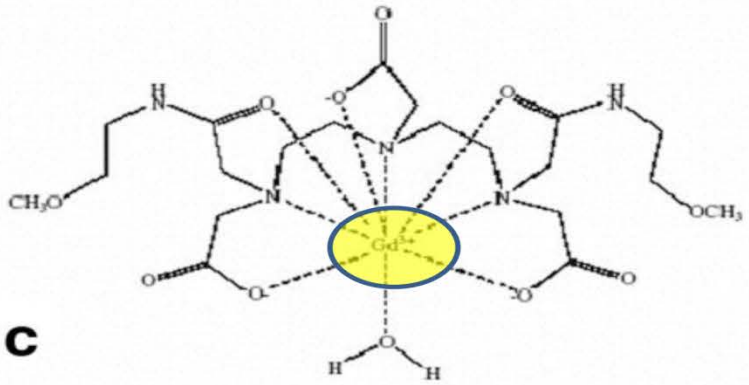

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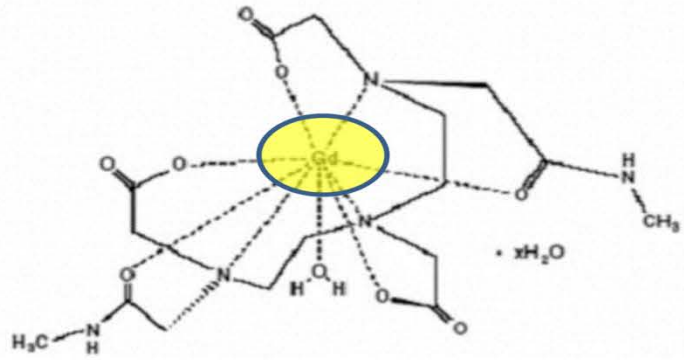

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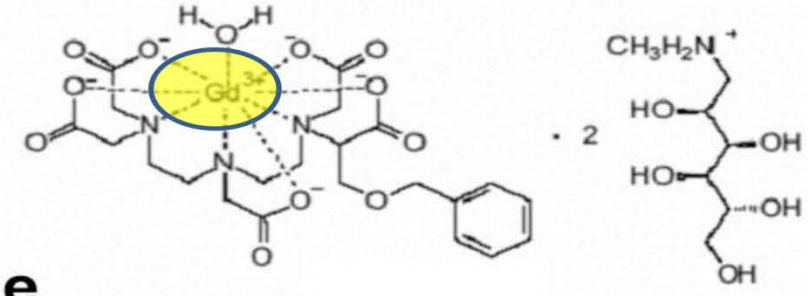


GD reagents

GD Reagents

Extracellular Gd-CM	Type	Thermodynamic stability constant	Conditional Stability	Amount of excess chelate (mg ml^{-1})	Kinetic stability (dissociation half-life at pH 1.0)
Gadoversetamide, Gd-DTPA-BMEA (OptiMark, Tyco, St. Louis, MO)	Non-ionic linear	16.6	15	28.4	Not available
Gadodiamide, Gd-DTPA-BMA (Omniscan, GE, Waukesha, WI)	Non-ionic linear	16.9	14.9	12	35 s
Gadobutrol, Gd-BT-DO3A (Gadovist, Schering, Berlin, Germany)	Non-ionic cyclic	21.8	Not available	Not available	5 min
Gadoteridol, Gd-HP-DO3A (Prohance, Bracco, Italy)	Non-ionic cyclic	23.8	17.1	0.23	3 h
Gadopentetate Gd-DTPA (Magnavist, Schering, Berlin, Germany)	Ionic linear	22.1	18.1	0.4	10 min
Gadobenate, Gd-BOPTA, (Multihance, Bracco, Italy)	Ionic linear	22.6	18.4	None	Not available
Gadoterate, Gd-DOTA (Dotarem, Guerbet, France)	Ionic cyclic	25.8	18.8	None	>1 month

Nephrogenic systemic sclerosis

Examples: nephrogenic systemic sclerosis

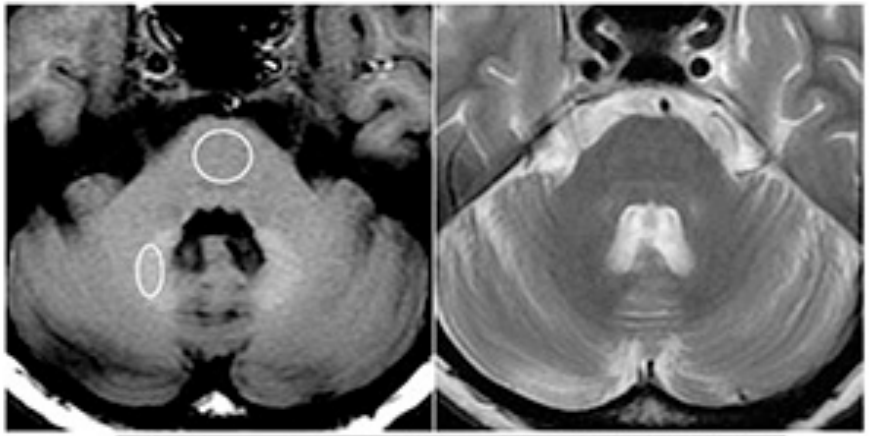
AJR 188 Feb 2007

Mechanism

- Gadolinium is highly toxic
- Patients with normal renal function excrete Gd-chelates within 24-48h
- Patients with abnormal renal function may take weeks to excrete the agent
- Dissociation of Gd from the chelate could deposit in soft tissues (documented)
  - Hugh et al. Tissue Gd conc .14-24 ng/mL
- Fibrosis is an inflammatory response to toxic Gd ion.

Residual Gadolinium

Residual Gadolinium!



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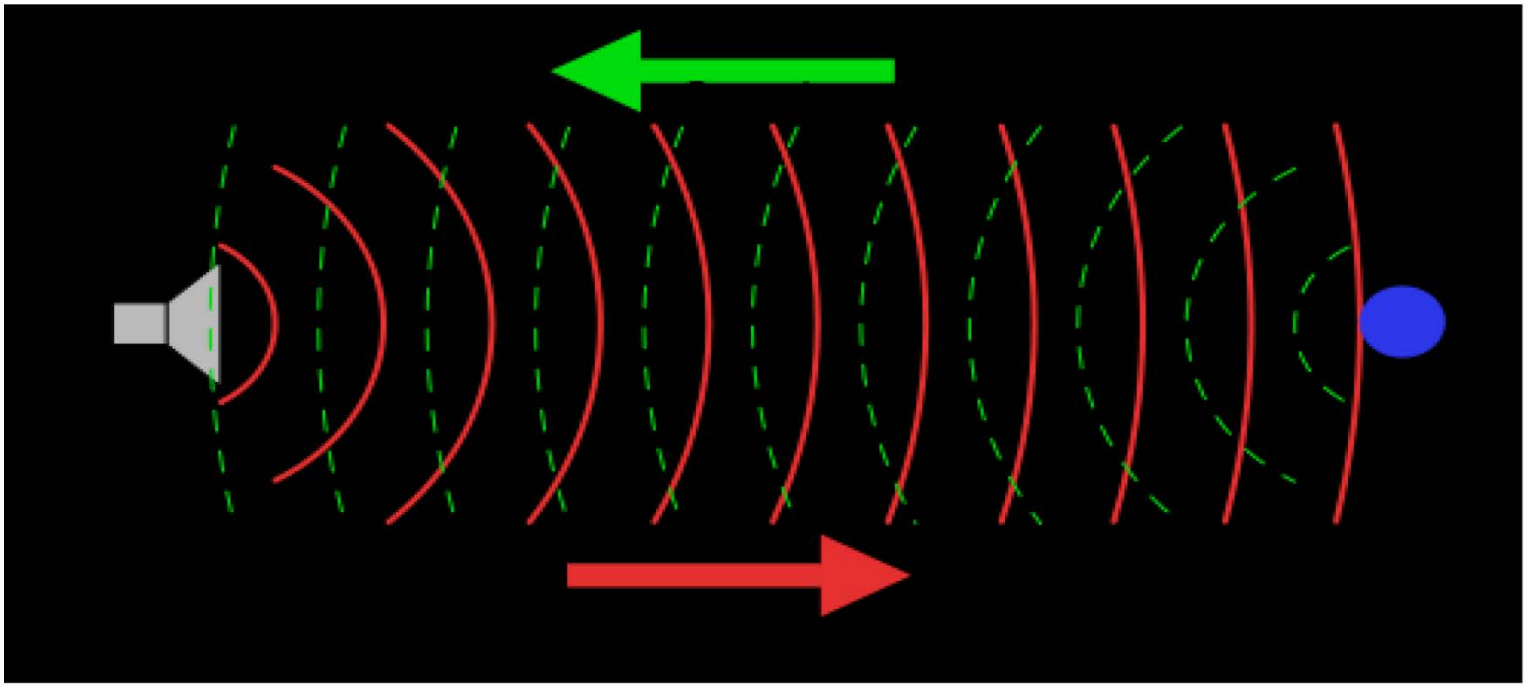
Ultrasound

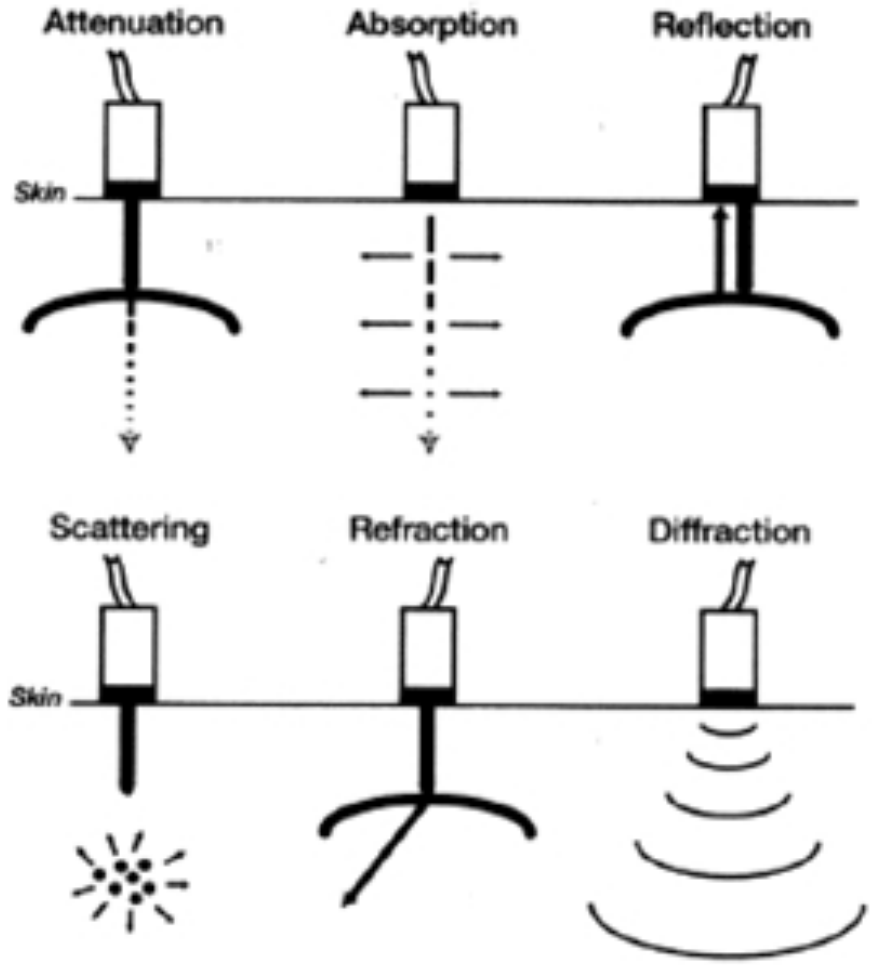
Ultrasound basics

US basics



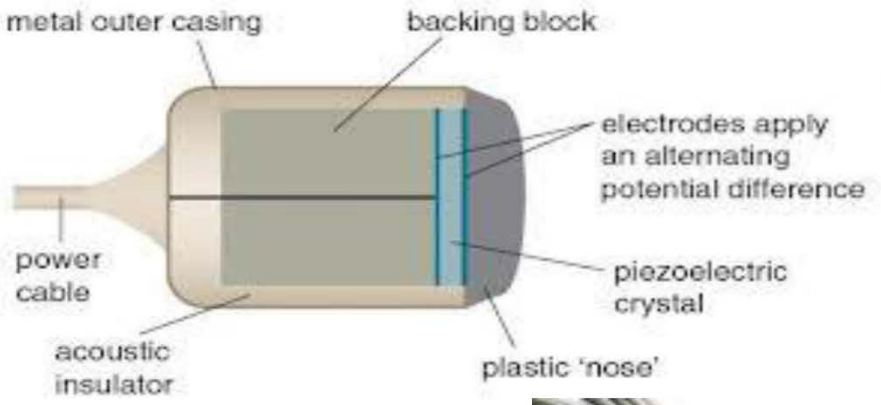
Imaging dependent on the speed of sound
In tissue

Fate of sound waves in body

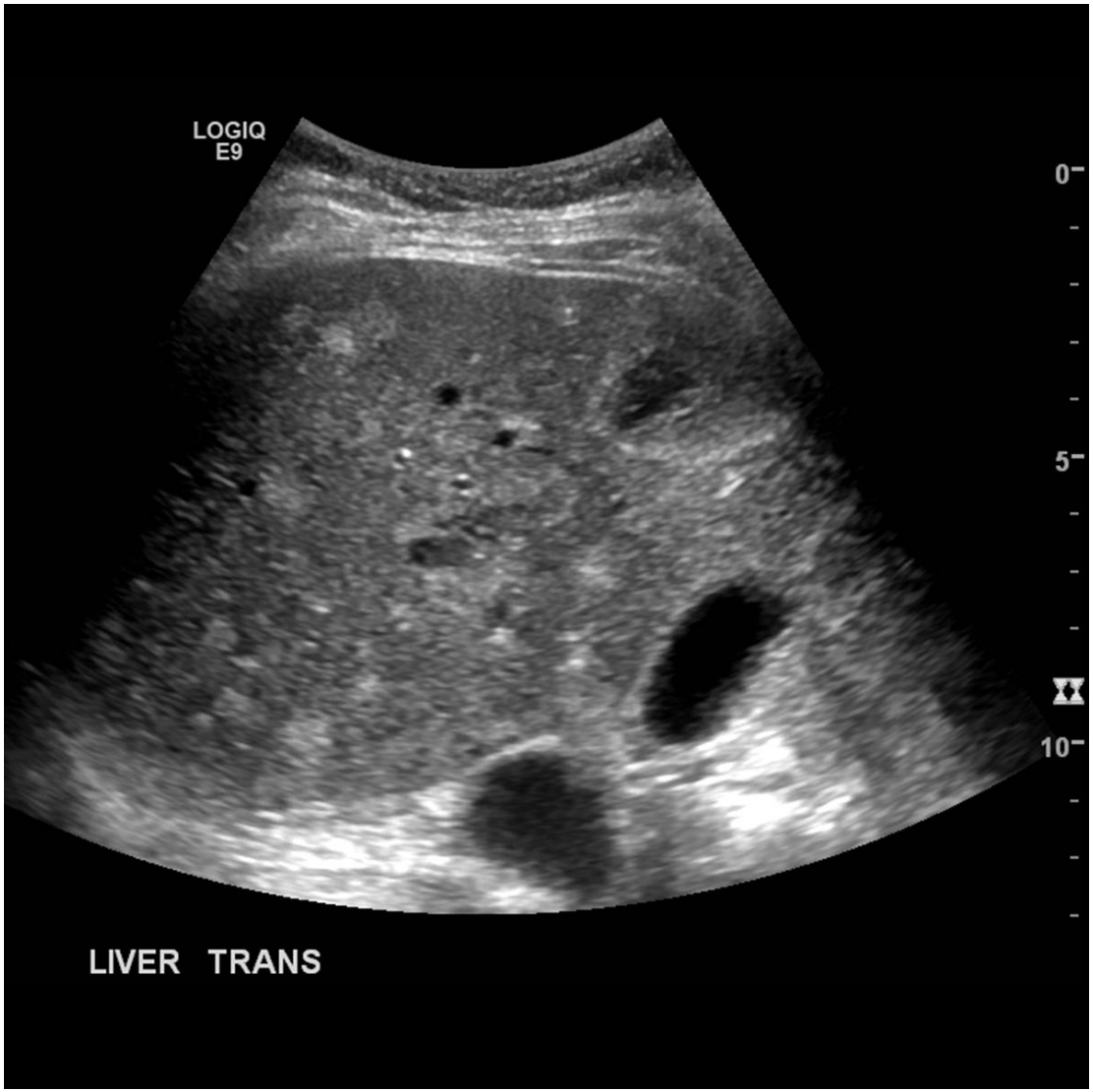


Ultrasound probes

US Probes



Liver metastases

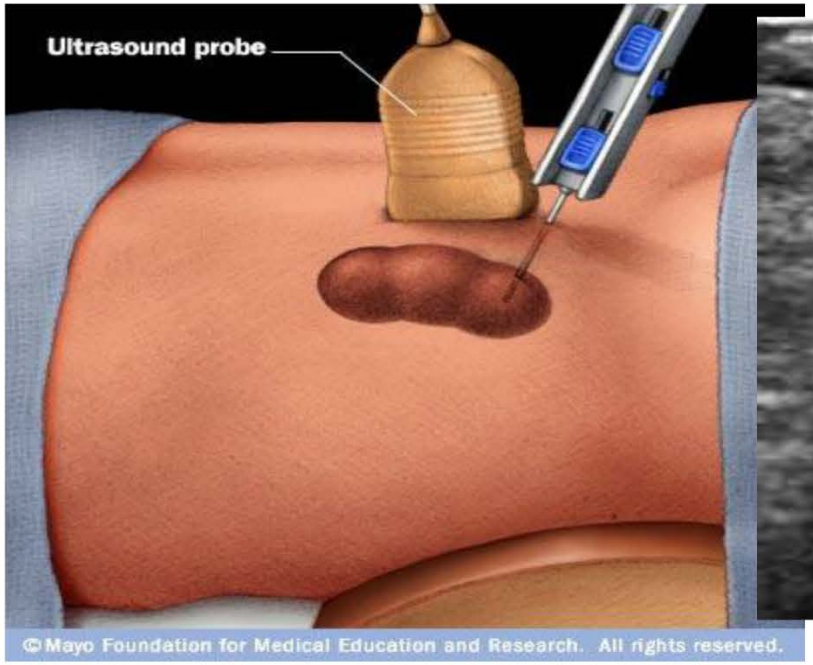


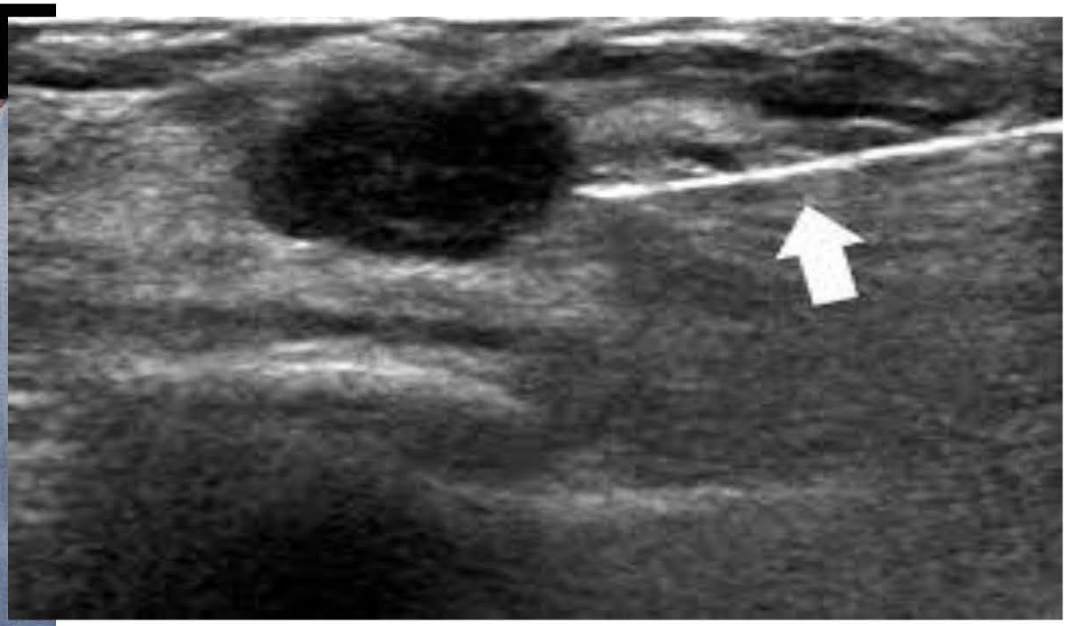
Ultrasound devices

Evolution of US devices

Ultrasound guided biopsy

US guided biopsy-real time





US advantages

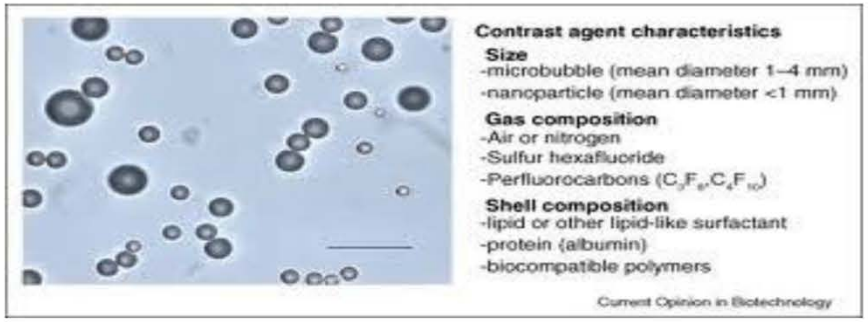
- No radiation
- Real time
- Inexpensive
- Quick, little prep
- No injection

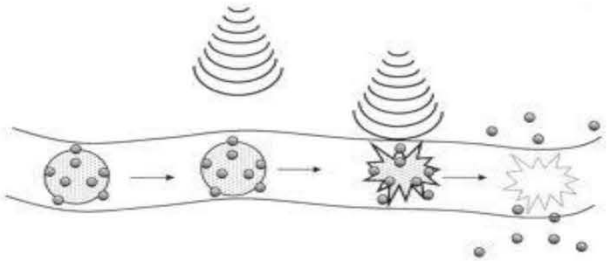
US disadvantages

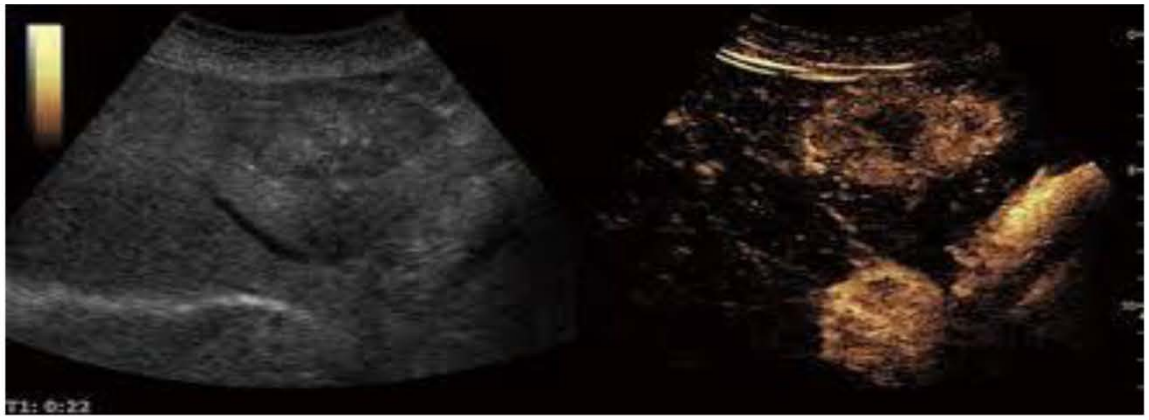
- Operator dependent
- What you see is all there is
- Difficult to quantify
- Limited access (lungs, brain, bone etc.)

Ultrasound

US Microbubble contrast



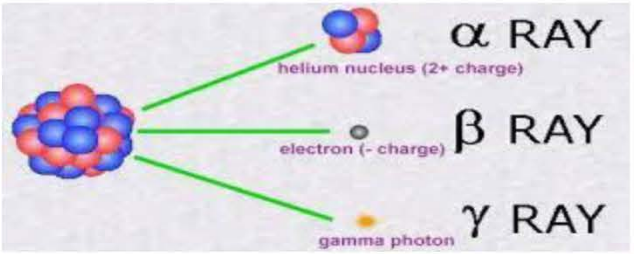




SPECT

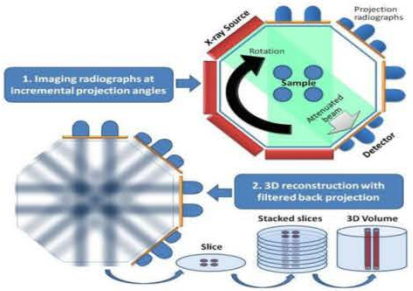
Single Photon Emission Computed Tomography-SPECT

- Single Photon Emission



+

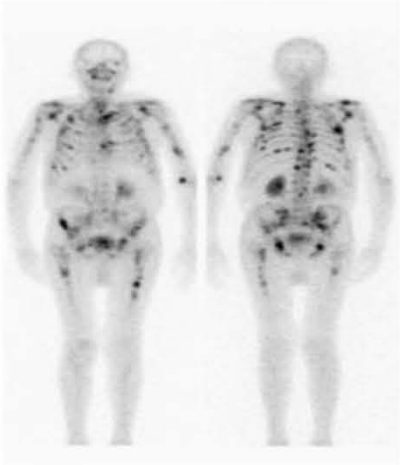
- Computed Tomography



SPECT imaging

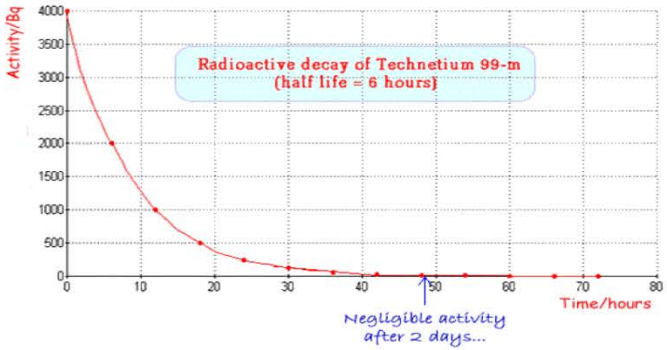
SPECT Imaging

- Requires conjugation of a radioactive isotope to a compound of interest which is injected into the patient:



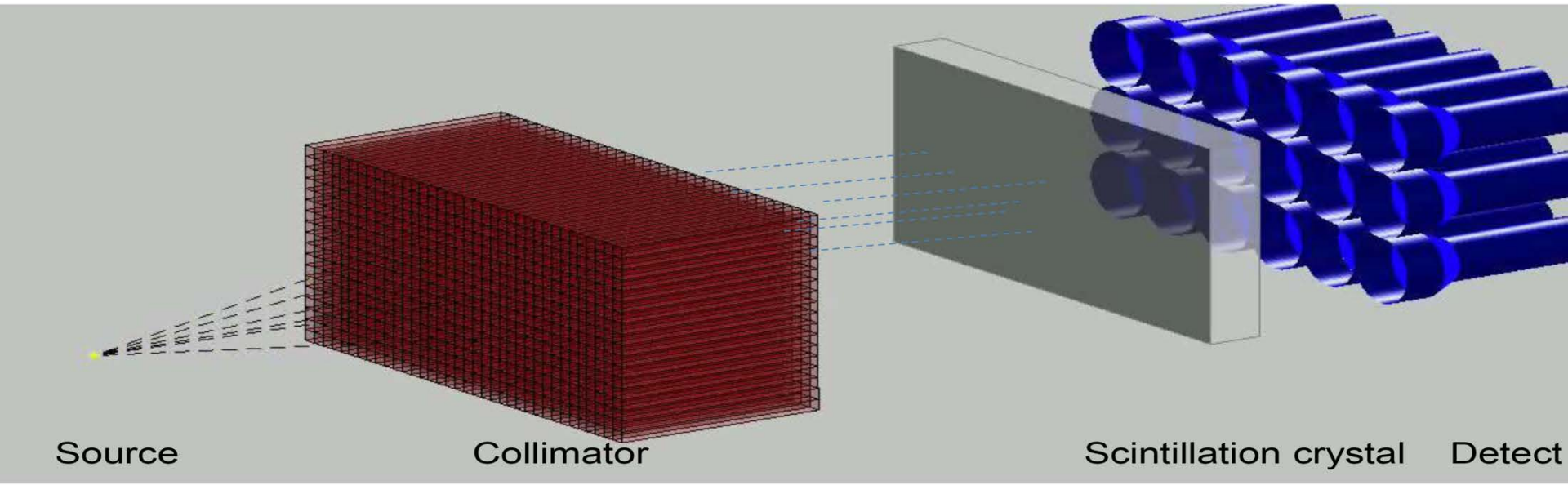
The bone scan:

^{99m}Technetium-methyl diphosphonate



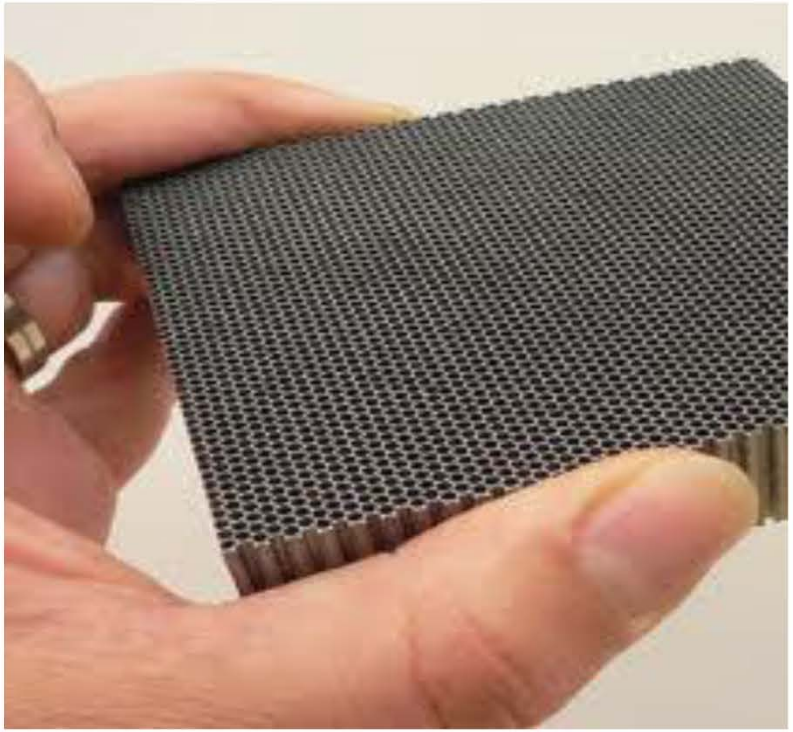
SPECT detectors

SPECT detectors



Collimation

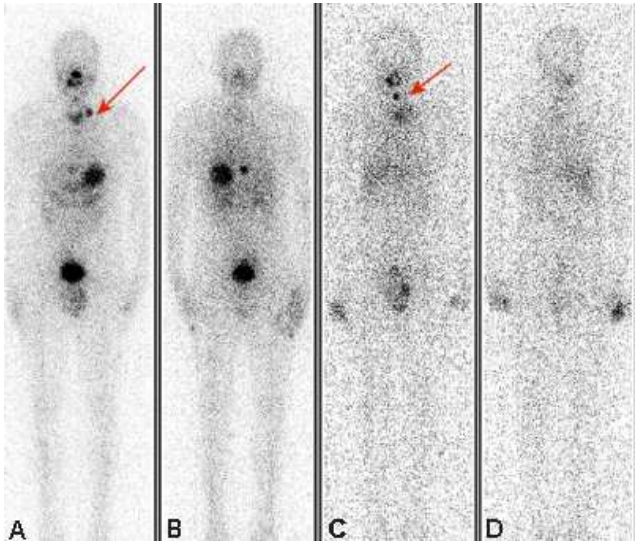
Collimation cont’d



Collimation reduces the sensitivity and resolution of SPECT by rejecting the majority of events

SPECT agents for cancer

- ^{99m}Tc MDP Bone Scan
- ^{99m}Tc Pertechnetate (thyroid, salivary gland)
- ^{201}Thallium Chloride (parathyroid)
- ^{111}Indium oxine (WBC labelling)
- ^{131}Iodine (thyroid)



SPECT advantages/disadvantages

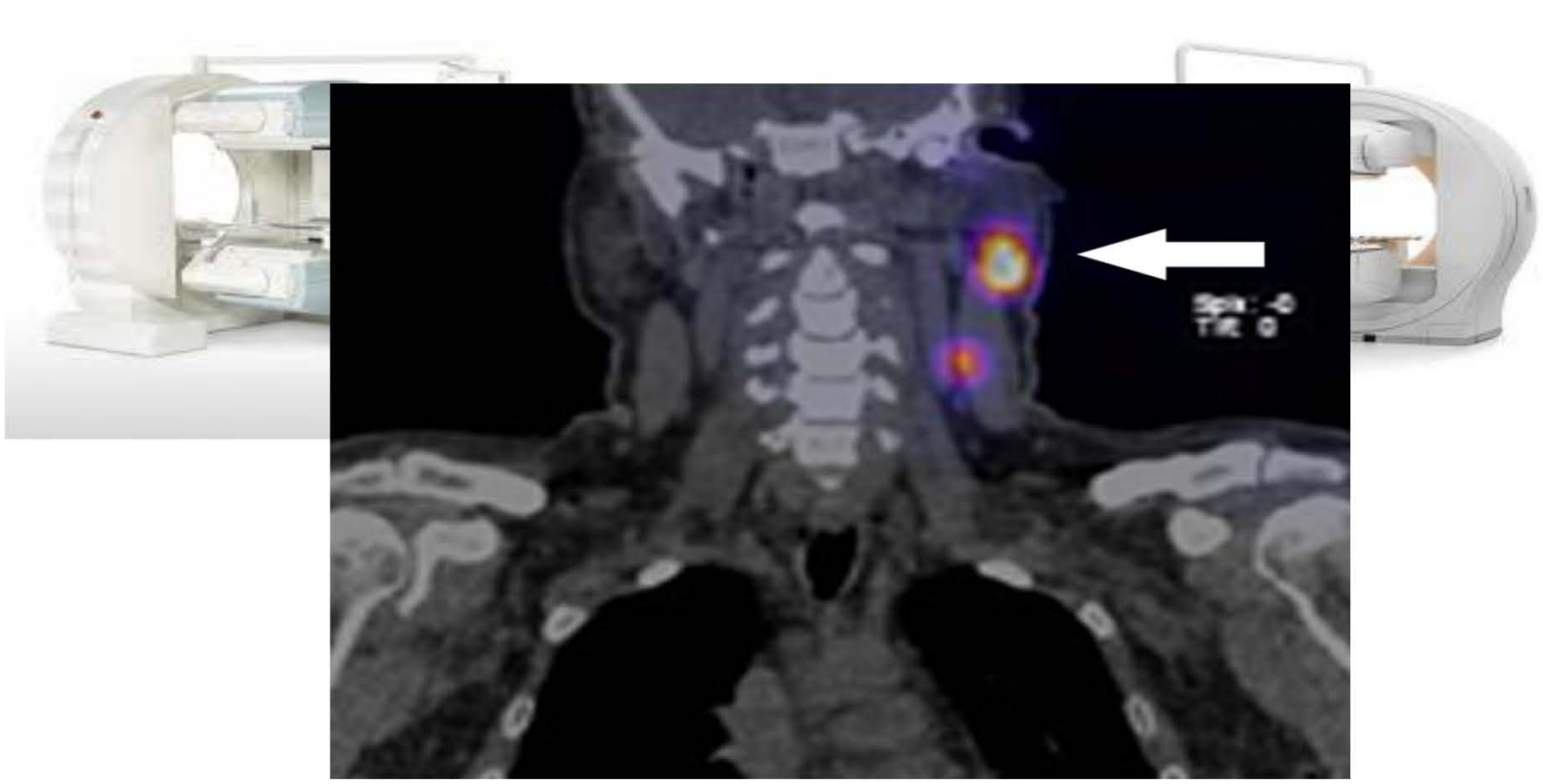
SPECT Advantages/Disadvantages

- Relatively inexpensive
- Broad experience

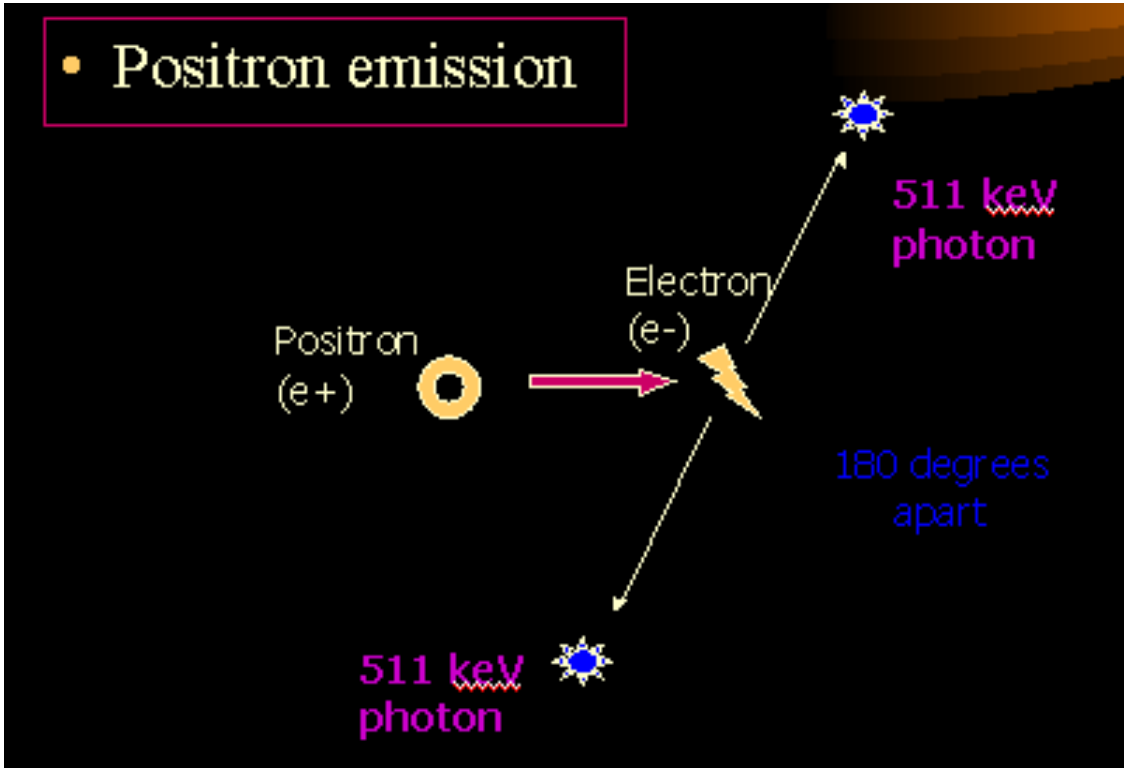
- Disadvantages
  - Radiation exposure
  - Preparation of imaging agent
  - Nuclear Regulatory
  - Scanning is slow, low resolution

Hybrid Imaging

Hybrid Imaging

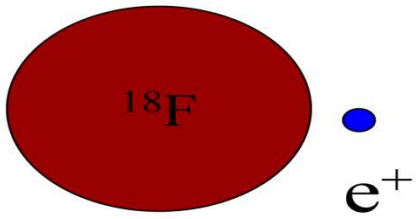


Positron Emission Tomography

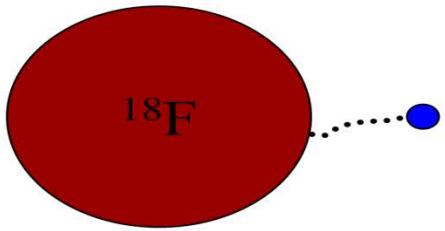


PET

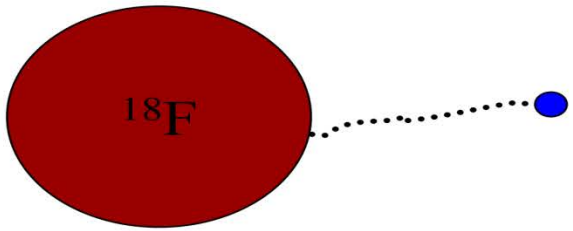
Positron Emission Tomography



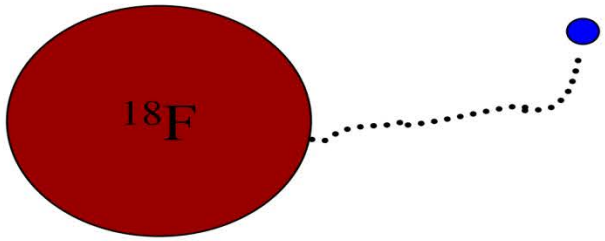
Positron travel



Positron travel



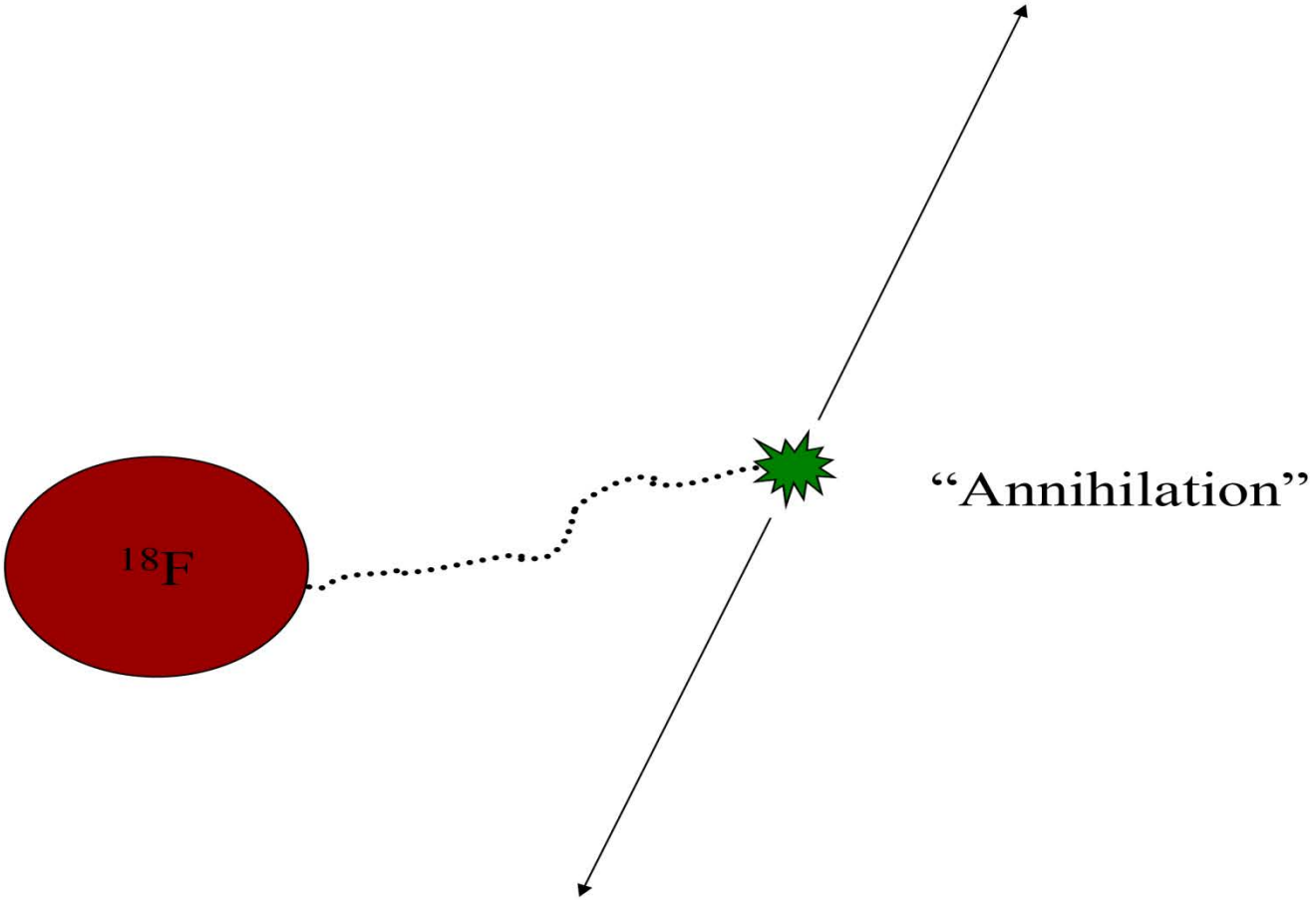
Positron travel



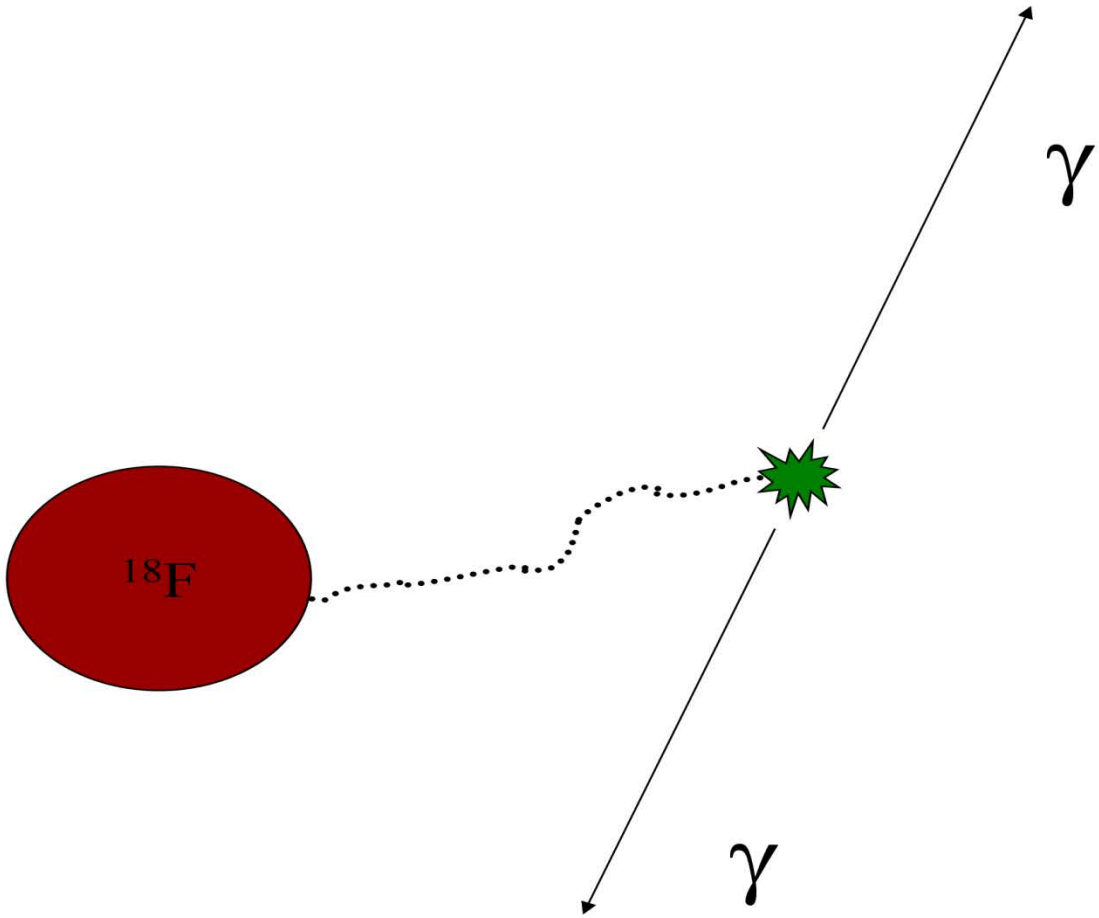
Positron travel

Positron and Electron

Annihilation

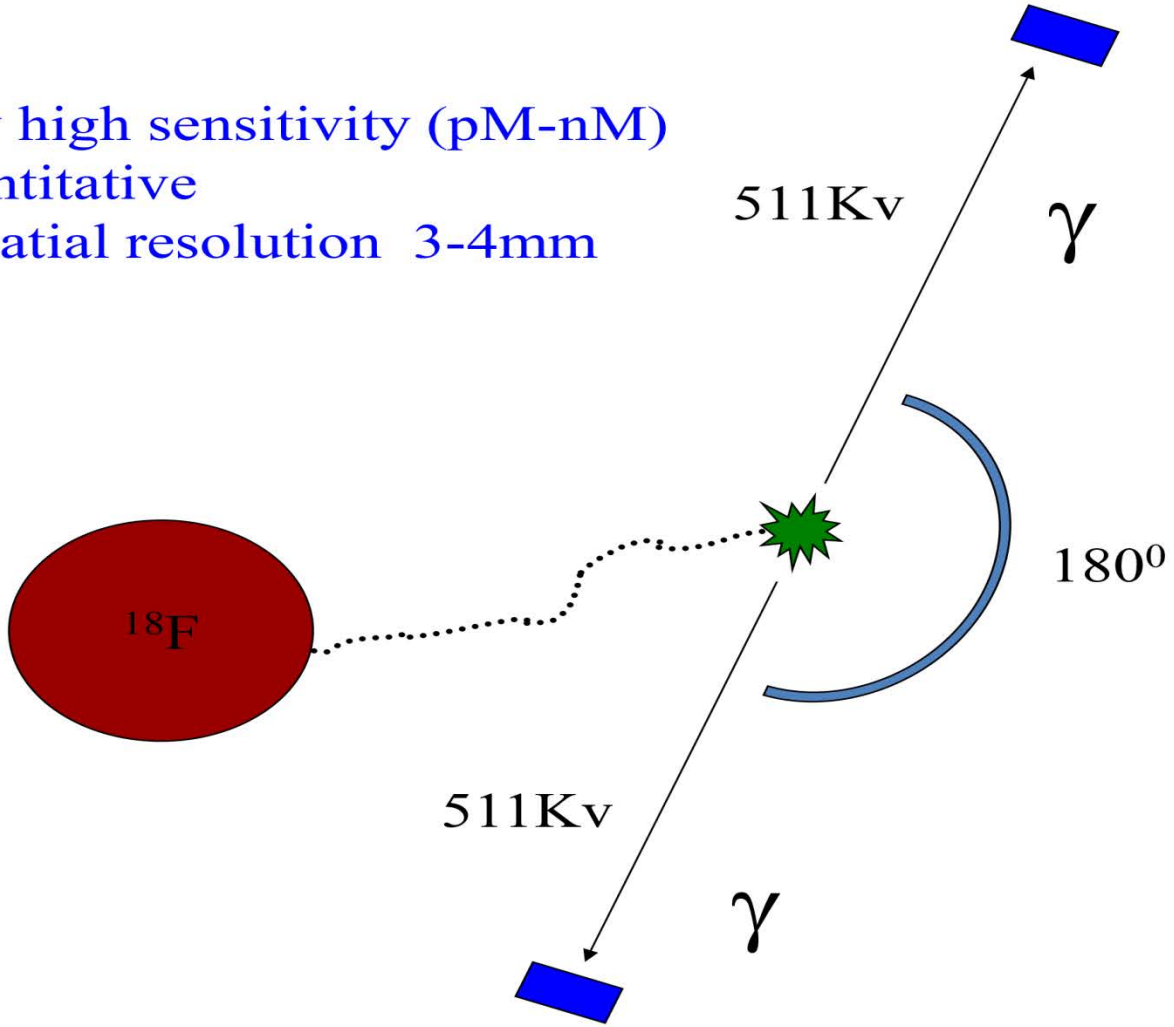


Gamma rays



Gamma ray orientation

Very high sensitivity (pM-nM)
Quantitative
± Spatial resolution 3-4mm

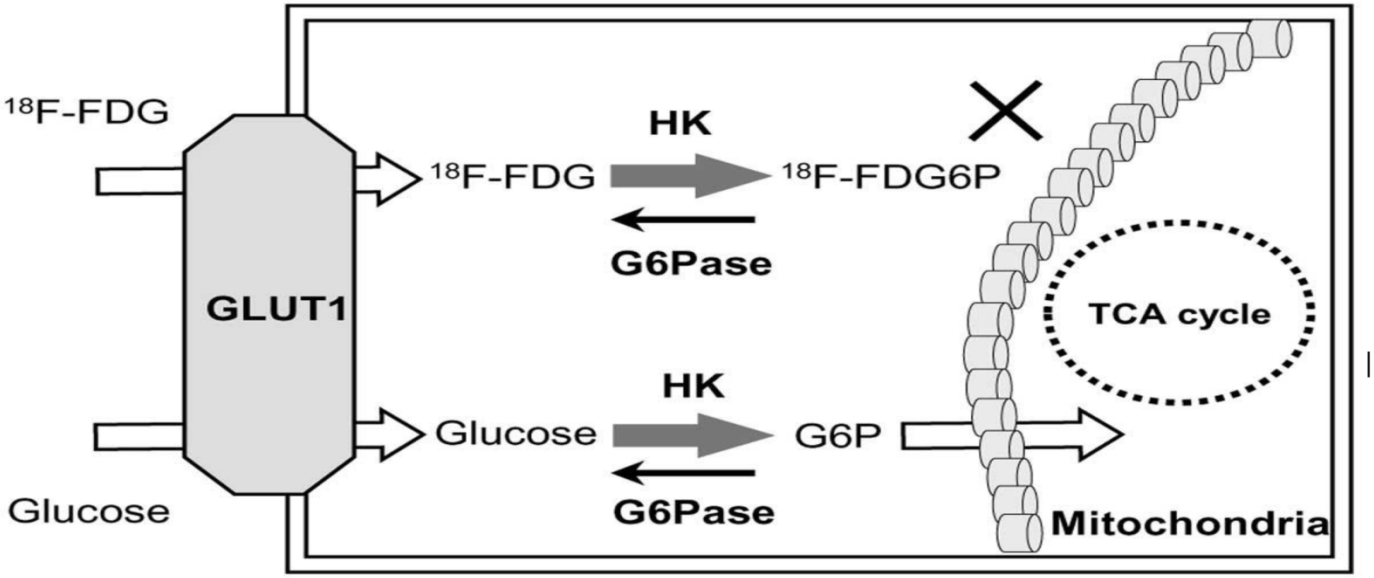


F-18 Deoxyglucose

Otto Warburg

Lou Sokoloff

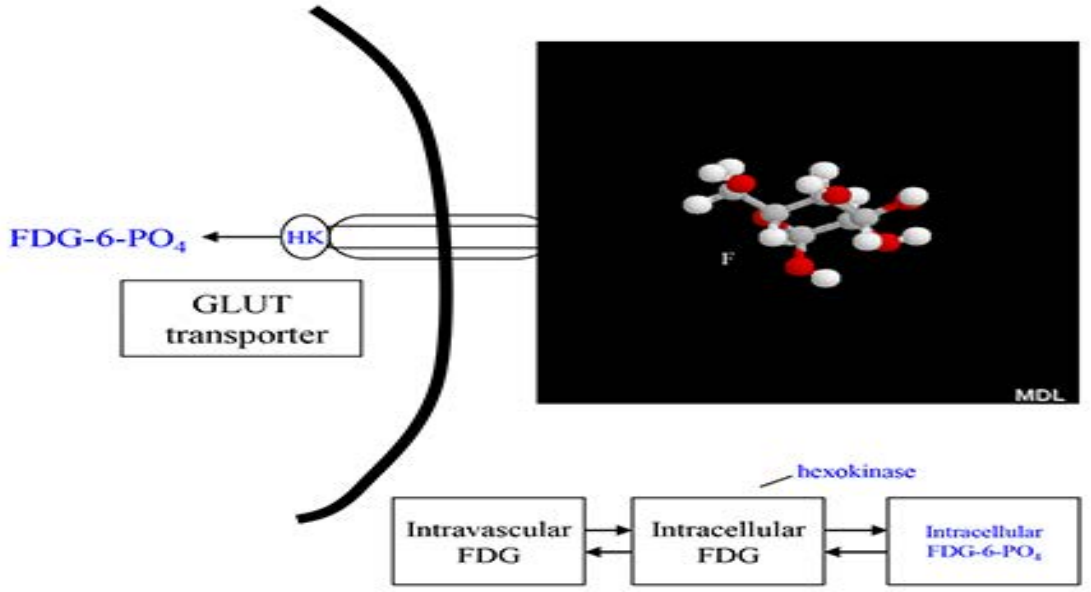
F-18 Deoxyglucose



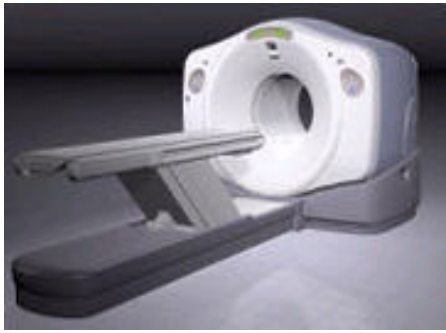
18FDG PET Imaging

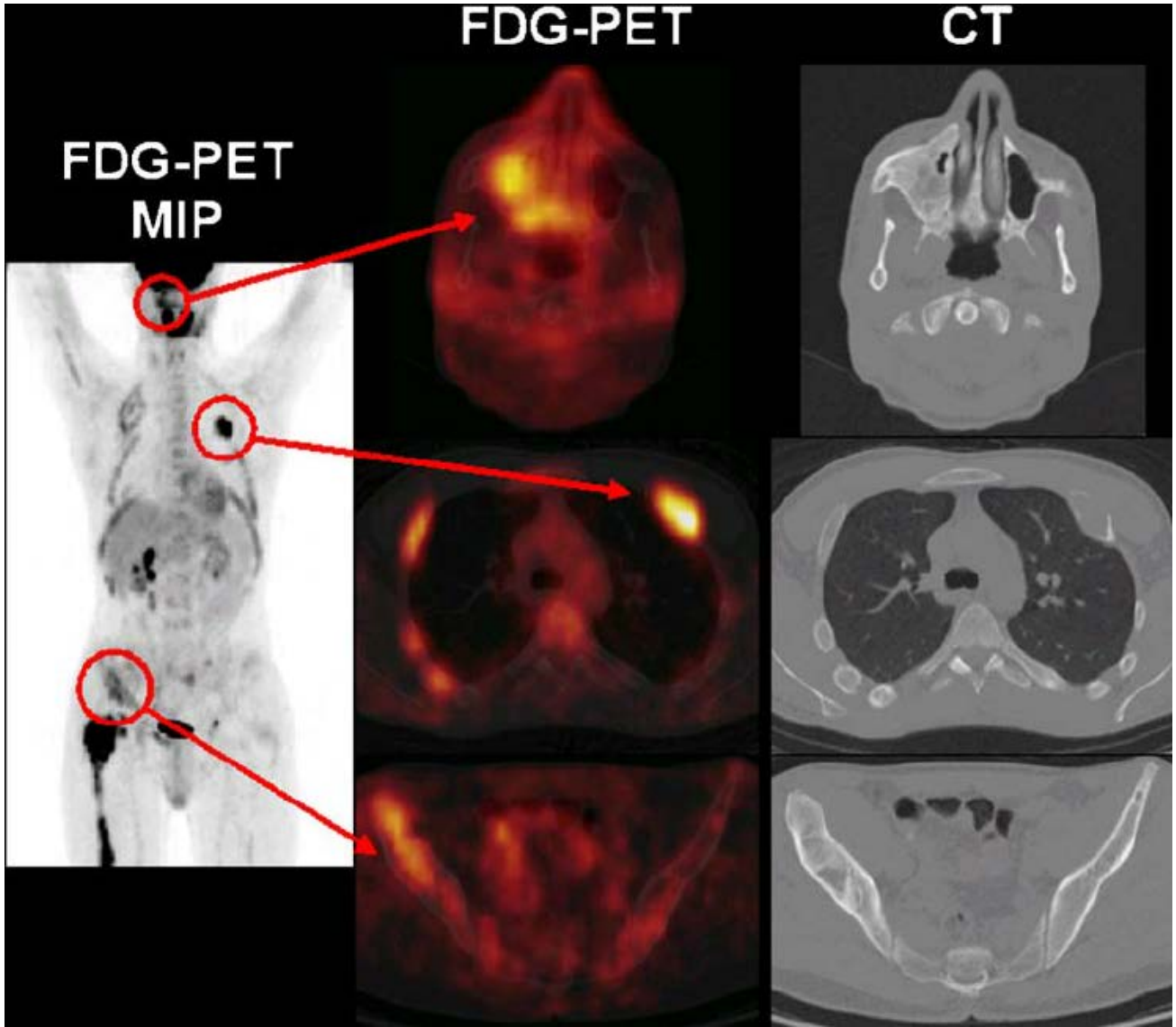
^{18}FDG PET Imaging

E PET MIP



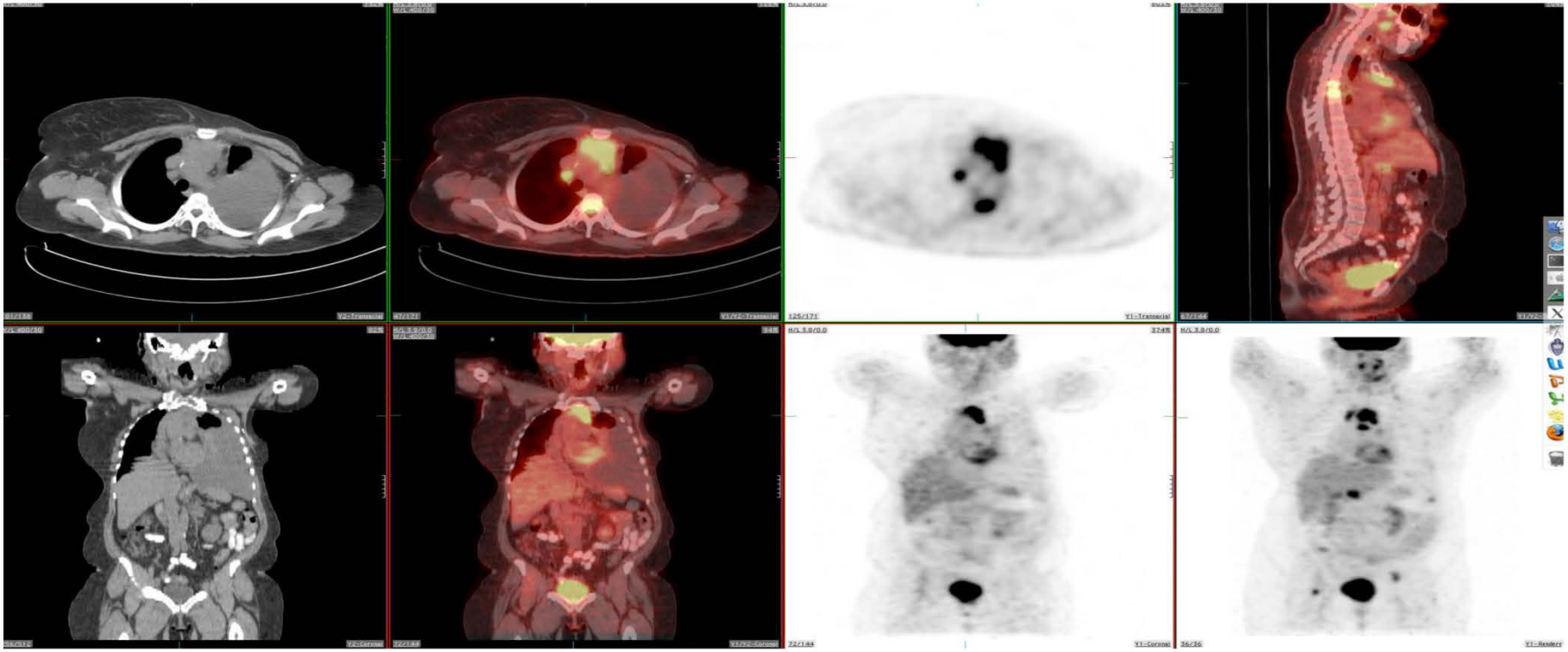
PET-CT scanners





Metastatic Breast Cancer

Mediastinal and spine metastases (breast)



Metastatic Breast Cancer

PET:Advantages and Disadvantages

- Highly sensitive
- Metabolic information
- Better spatial resolution than SPECT
- Combined with CT
- _____
- Expense
- Regulatory
- Short half life

Notable PET Agents

- Sodium Fluoride: Bone target
- Fluorothymidine: Cellular Proliferation
- Fluoroestadiol: Estrogen receptor
- Fluorocholine: Membrane Turnover
- Fluoromiso: Hypoxia
- Florbetaben: Amyloid (Alzheimers)
- Zirconium Herceptin: labeled antibody
- Zirconium Oxine: Cell labeling

PET Imaging

- Positron emission tomography (PET) has the advantages of :
  - **High energy photon imaging**
  - **High Sensitivity, Moderate Specificity**
  - **The ability to correct for attenuation**
  - **No need for collimation**
  - **Resolution is still limited**

Summary

Summary of Cancer Imaging

Presentation	Resolution	Sensitivity	Cost (low-hi)
CT	CT	PET	US
MRI	MRI	SPECT	CT
US	US	US (microbubble)	SPECT
SPECT	PET	MRI	MRI
PET	SPECT	CT	PET

Cancer Imaging

Summary of Cancer Imaging

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Cancer Imaging

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PET	SPECT	CT	PET

Cancer Imaging

Summary of Cancer Imaging

Presentation	Resolution	Sensitivity	Cost (low-hi)
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MRI	MRI	SPECT	CT
US	US	US (microbubble)	SPECT
SPECT	PET	MRI	MRI
PET	SPECT	CT	PET

General Guidelines

- Overall “workhorse” for oncology: CT
- Specialty cancers: brain, liver, prostate: MRI
- Problem solving (e.g cyst vs. solid): US
- Bone mets: SPECT
- Metabolic activity: PET

Imaging of cancer

Imaging of cancer




Imaging of Cancer: