



## ***What You Need to Know about CT, MRI, and PET Imaging***

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1

## Imaging of Cancer

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

2

## 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

3

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4

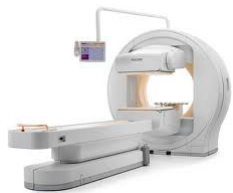
## They all look the same!



CT



MRI



SPECT



PET



US

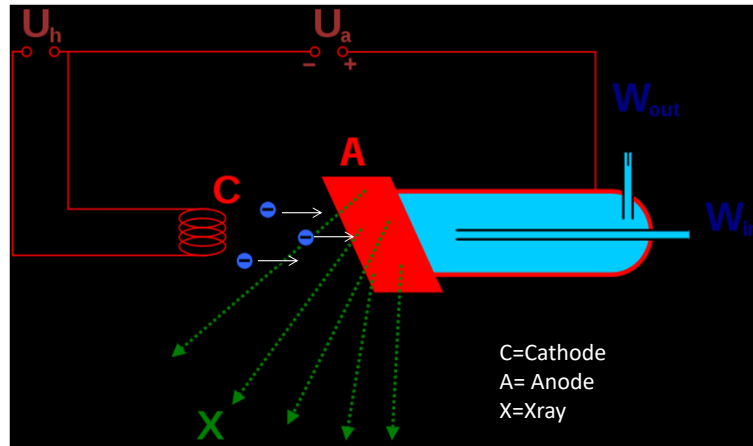
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## Computed Tomography

- Hint: Radiologists never say “CAT” scan
- The cool name is “CT”

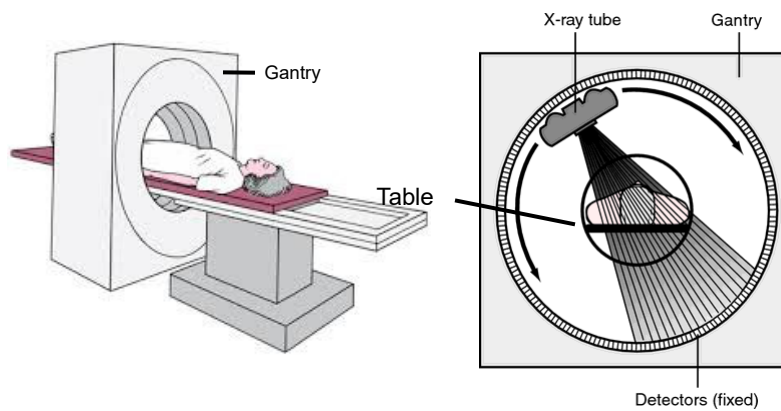
6

## X-ray production: cathode ray tube



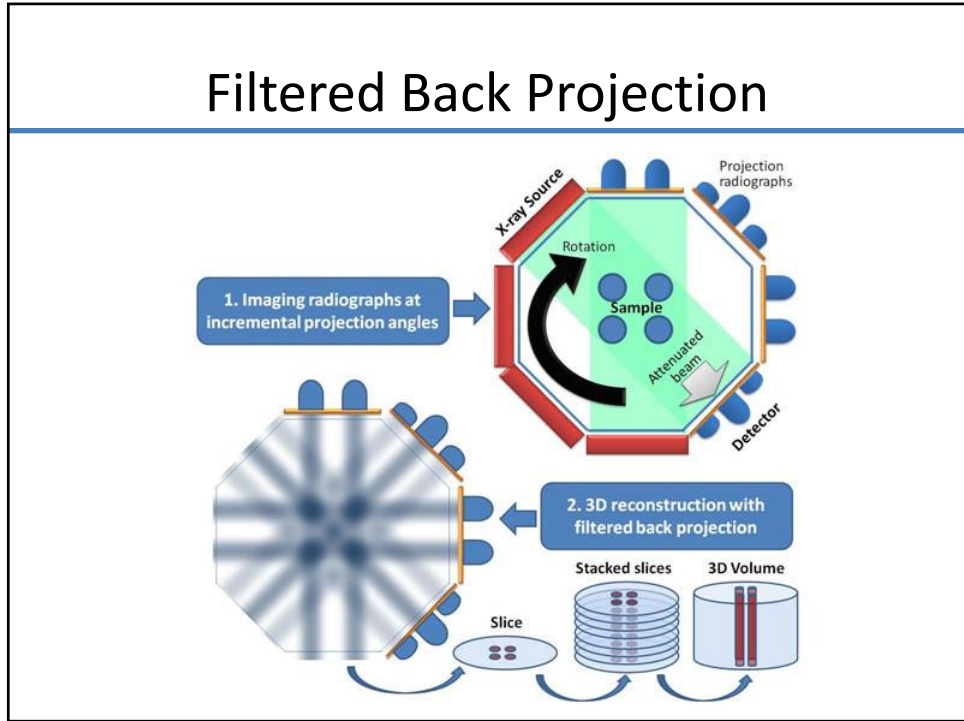
7

## Basics of CT



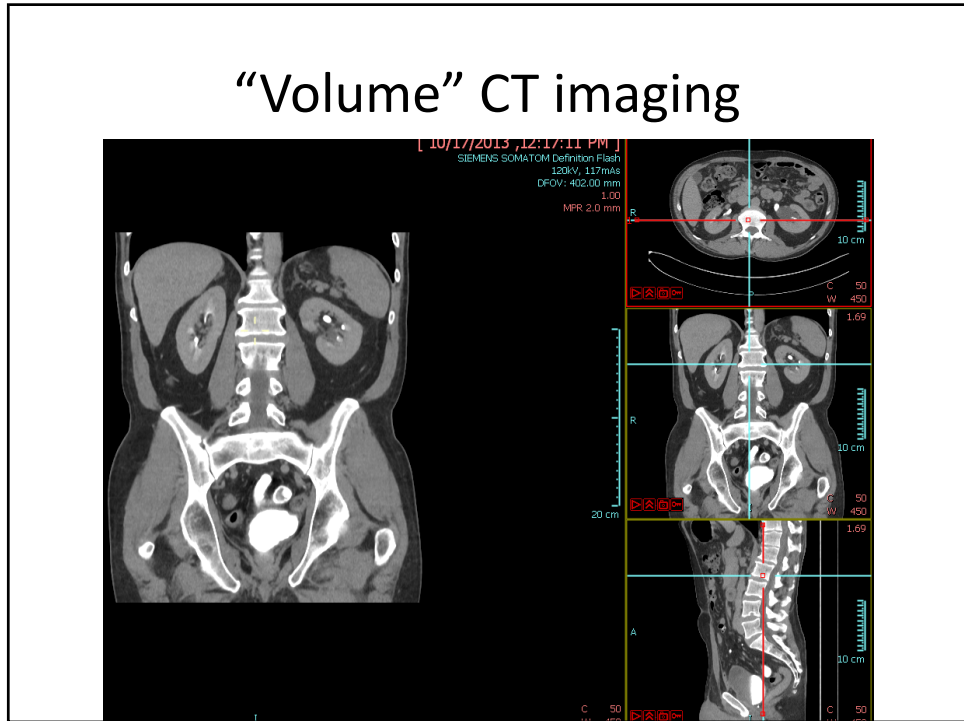
8

# Filtered Back Projection



9

# “Volume” CT imaging



10

## Advantages of CT

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

11

## Disadvantages

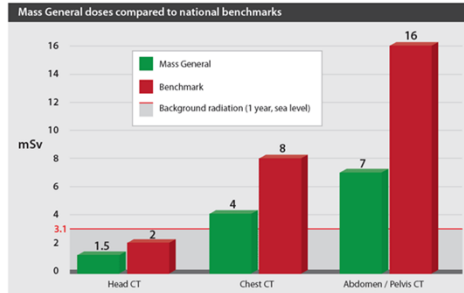
- **Radiation**
- Often requires IV contrast media
  - Allergic reactions (minimal)
  - Kidney damage (only in high risk patients)
- Anatomic information only

12

## Radiation Reduction on CT

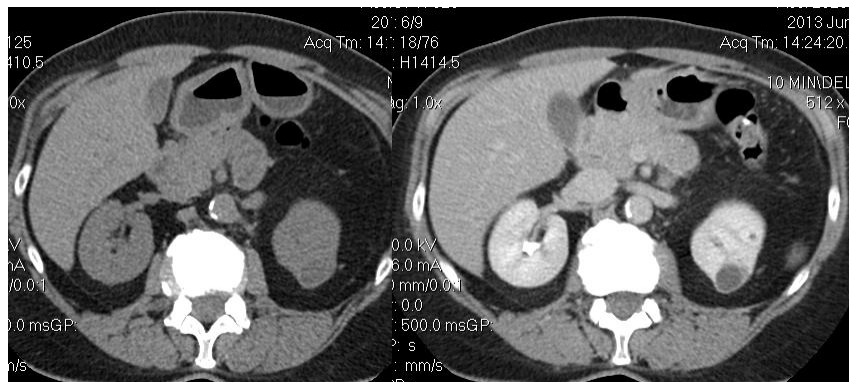


Lower kV (energy) x-rays  
 More sensitive detectors  
 Better reconstruction algorithms  
 "Synthetic" images



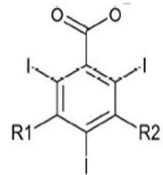
13

## Iodinated Contrast Media

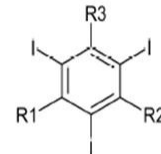


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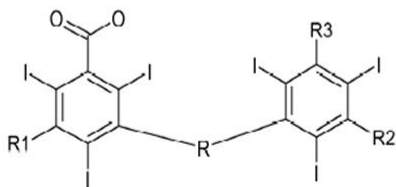
## Basic Structures of Contrast Media



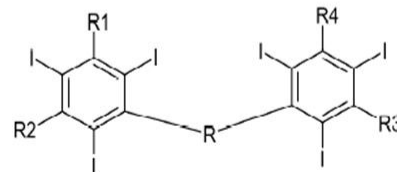
Ionic Monomer



Nonionic Monomer



Ionic Dimer



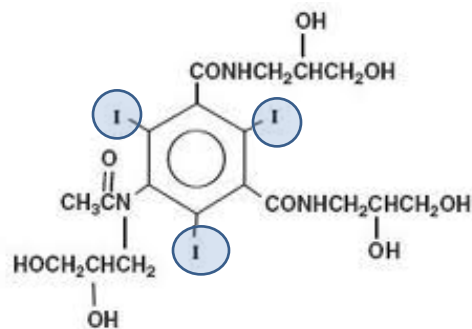
Nonionic Dimer

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



15

## Non ionic Iodinated Contrast



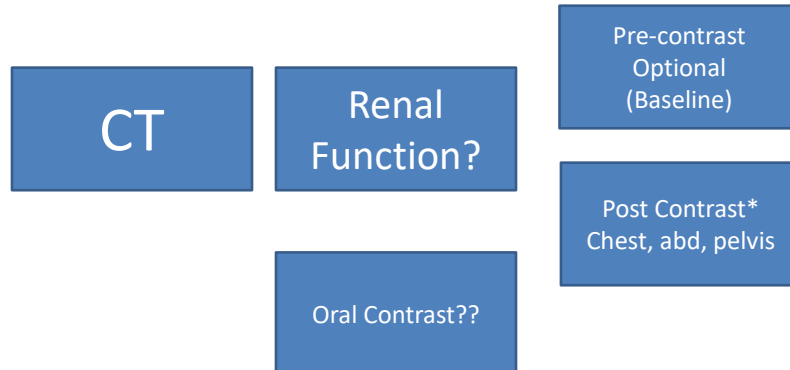
Typical dose 30-45 Grams of Iodine!!!

16



## Using contrast with CT: Yes or No?

62 year old male with history of renal cancer for new NCI protocol



17

## Iodinated Contrast Media and Renal Function

- Not as dangerous as previously thought
  - Minor changes in Creatinine can be observed
  - Overt renal failure is rare.
- Avoid contrast in presence of renal dysfunction.
  - eGFR <30 cc/min seek an alternative
  - eGFR 30-60 cc/min review indication, if needed it can be given.

18

## General comments

- Hydration (advisable)
- Fasting: (ACR not required)
- Extravasation (elevation, compresses, compartment syndrome)
- Metformin (renal dysfunction)

19

## Allergies to CM

- Feeling hot, flushed: normal
- Hives: mild allergy (antihistamine)
- Laryngeal edema/bronchospasm: breathing (epi, antihistamine, oxygen, fluids)
- Anaphylactoid reaction: Code team (epi, vascular support, ICU admission)
- Record type of reaction and brand of contrast if possible

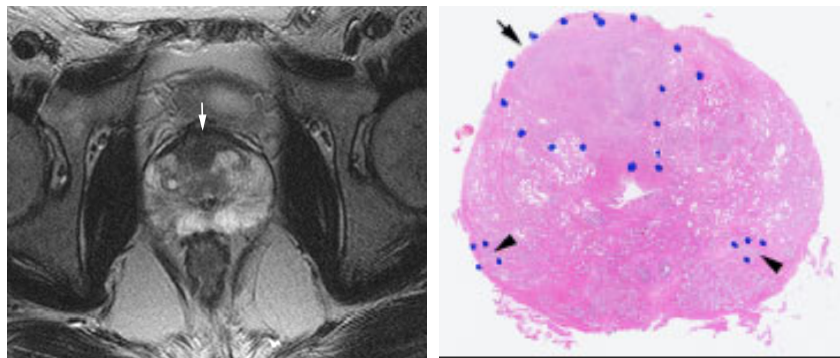
20

## Prophylaxis

- Prednisone 13h, 1h, and just before CM dose
- Benadryl or Allegra
- Change contrast brand (this change alone can reduce reactions by 60%)

21

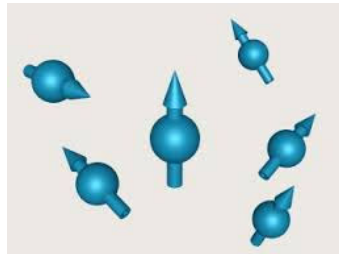
## Magnetic Resonance Imaging



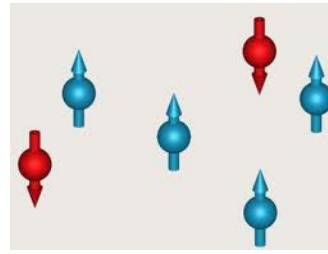
Prostate Cancer on MRI and Pathology

22

## MRI Physics 101



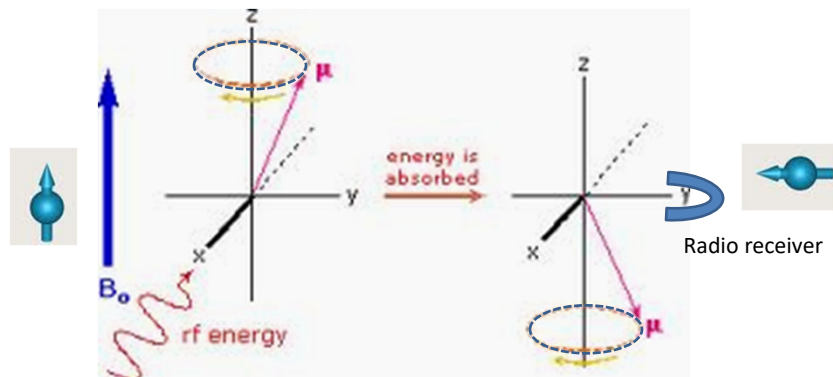
Protons in space: no field



Protons in magnetic field

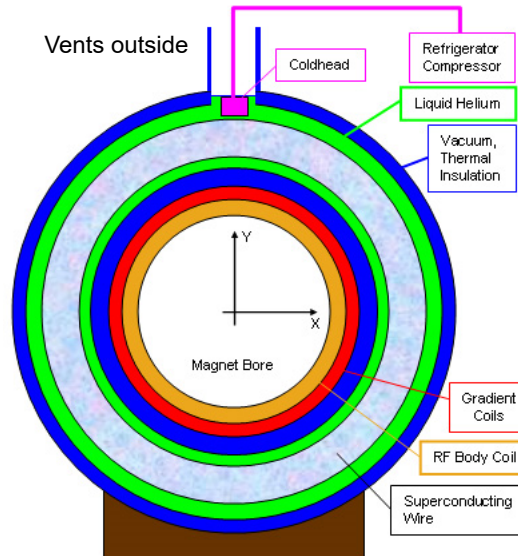
23

## MR Physics



24

## Anatomy of an MRI



25

## MRI Advantages

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

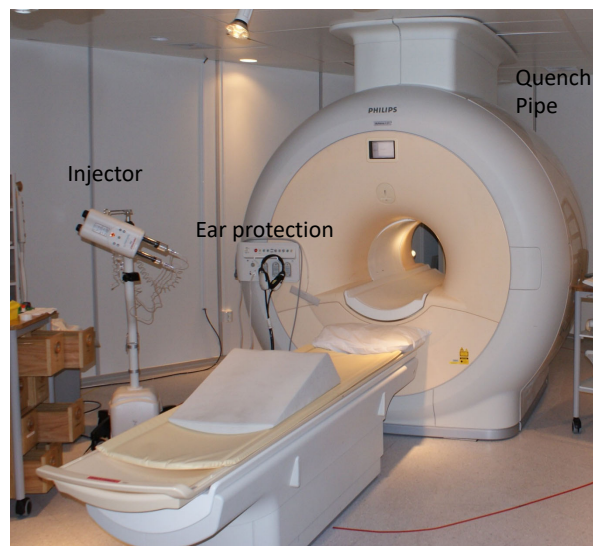
26

## MR Disadvantages

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

27

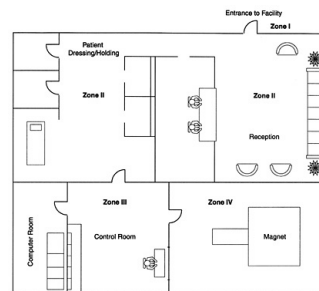
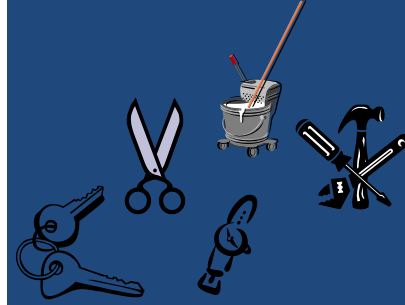
## Safety issues in MRI



28

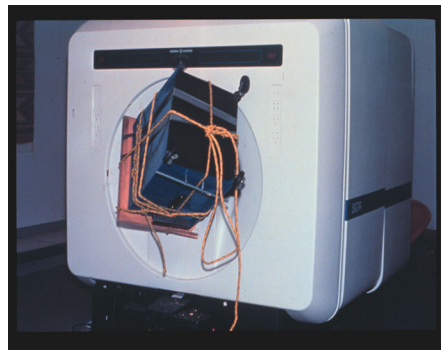
## MRI SAFETY

- 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 cause potential injury to patients or hospital staff.
- MRI departments are divided into Zones for Safety



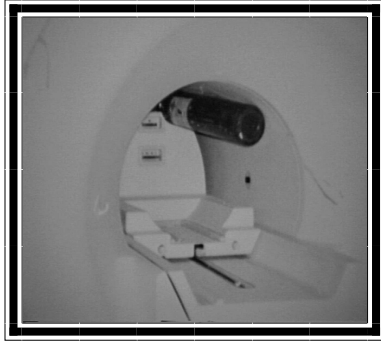
29

## MRI SAFETY



30

## O2 Tank, "Missile"

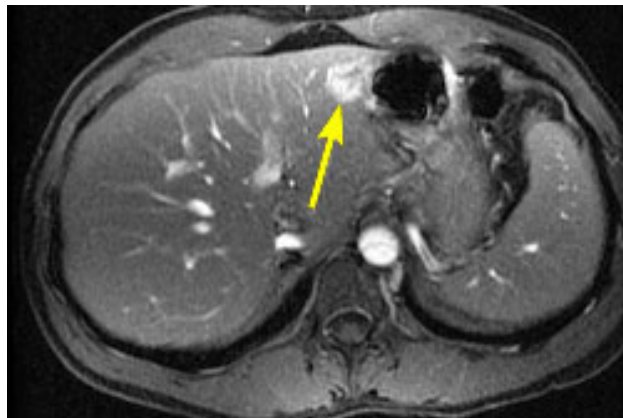


An Oxygen tank can become an Airborne torpedo in an MRI



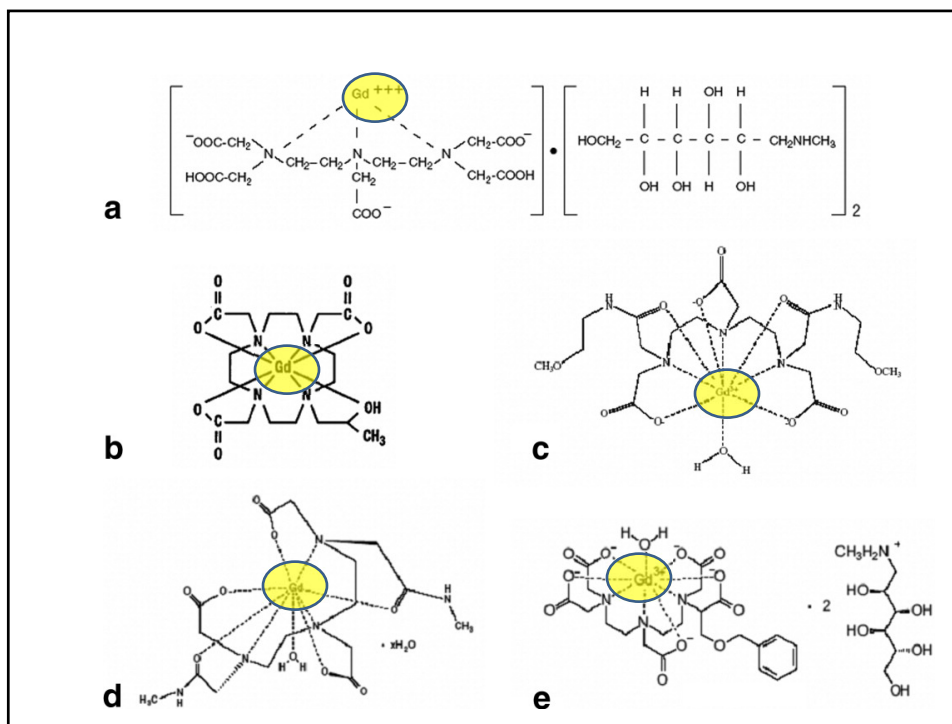
31

## Value of MR Contrast Media



32





33

Extracellular Gd-CM	Type	Thermodynamic stability constant	Conditional Stability	Amount of excess chelate (mg ml <sup>-1</sup> )	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

34

## Nephrogenic systemic Fibrosis



Patient with very poor renal function received multiple linear Gd injections for MRI.

AJR 188 Feb 2007

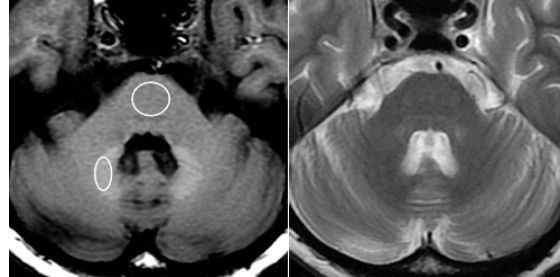
35

## 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.

36

# Residual Gadolinium!



Extracellular Gd-CM	Type	Thermodynamic stability constant	Conditional Stability	Amount of excess chelate (mg ml <sup>-1</sup> )	Kinetic stability (biocleavage half-life at pH 7.0)
Gadovetamide, 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
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Gadoterate, Gd-DOTA (Dotarem, Guerbet, France)	Ionic cyclic	25.8	18.8	None	>1 month

37

# Use of MRI

28 year old with hereditary cancer syndrome for evaluation of liver tumor

MRI

Renal Function?

T1,T2W

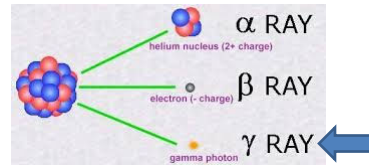
Diffusion

Gd  
DCE

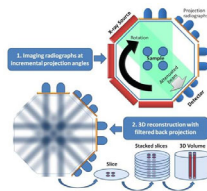
38

# Single Photon Emission Computed Tomography-SPECT

- Single Photon Emission



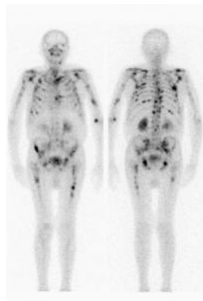
- Computed Tomography



39

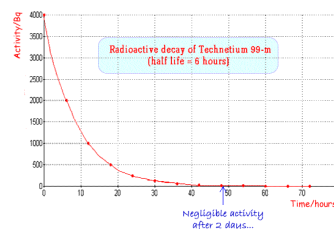
# SPECT Imaging

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



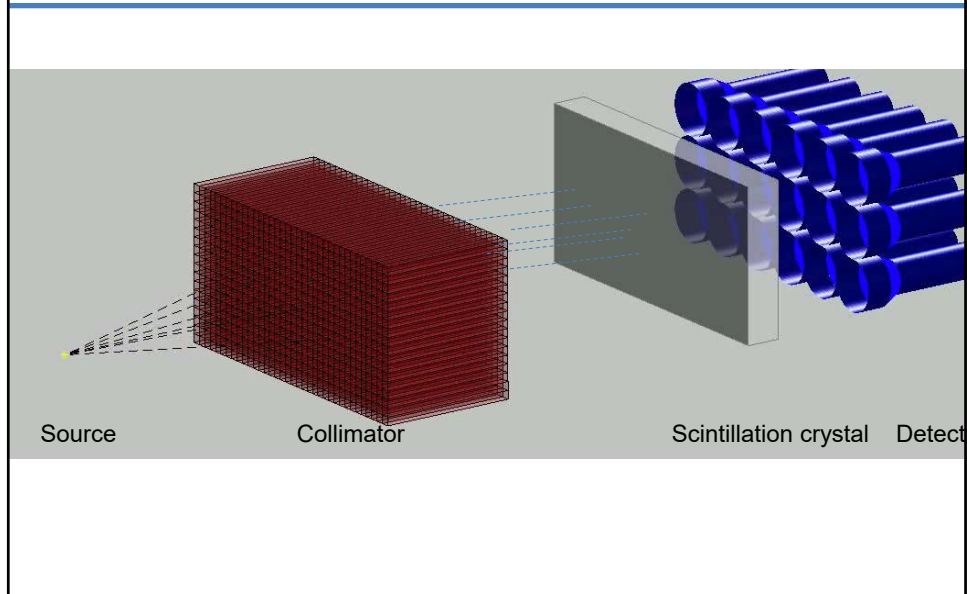
The bone scan:

<sup>99m</sup>Techetium-methyl diphosphonate



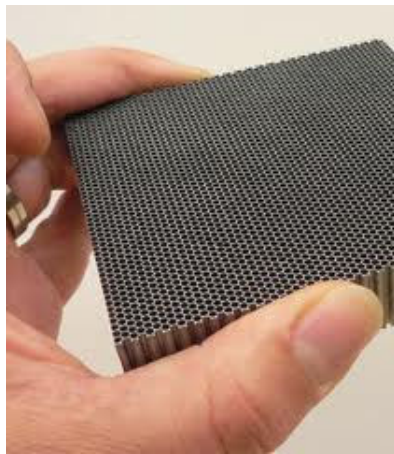
40

## SPECT detectors



41

## Collimation cont'd

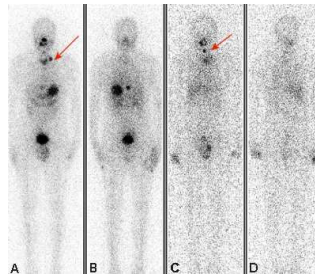


Collimation reduces the sensitivity and resolution of SPECT by rejecting the majority of events

42

## SPECT agents for cancer

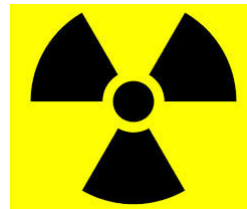
- $^{99m}\text{Tc}$  MDP Bone Scan
- $^{99m}\text{Tc}$  Pertechnetate (thyroid, salivary gland)
- $^{201}\text{Tl}$  Chloride (parathyroid)
- $^{111}\text{In}$  oxine (WBC labelling)
- $^{131}\text{I}$  Iodine (thyroid)



43

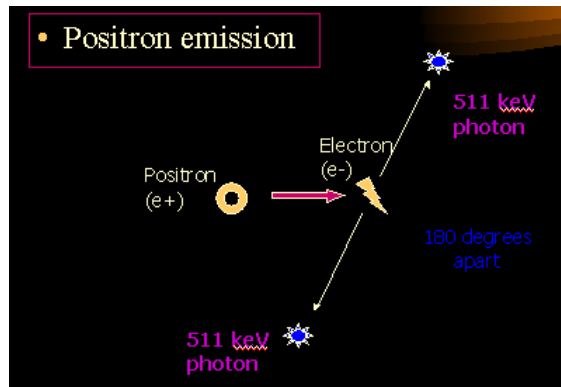
## SPECT Advantages/Disadvantages

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

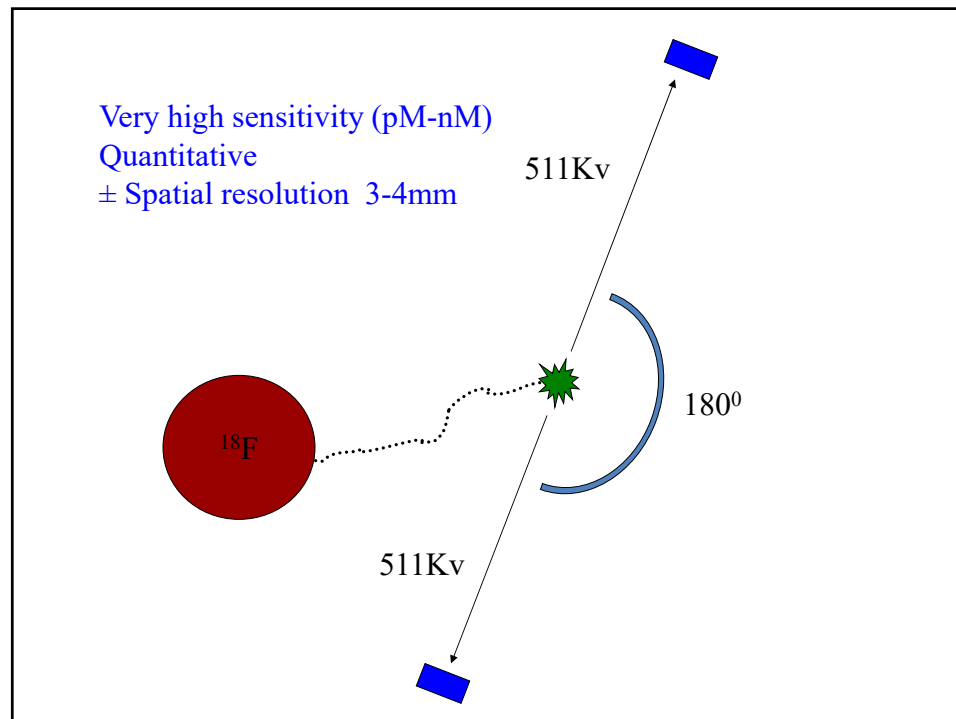


44

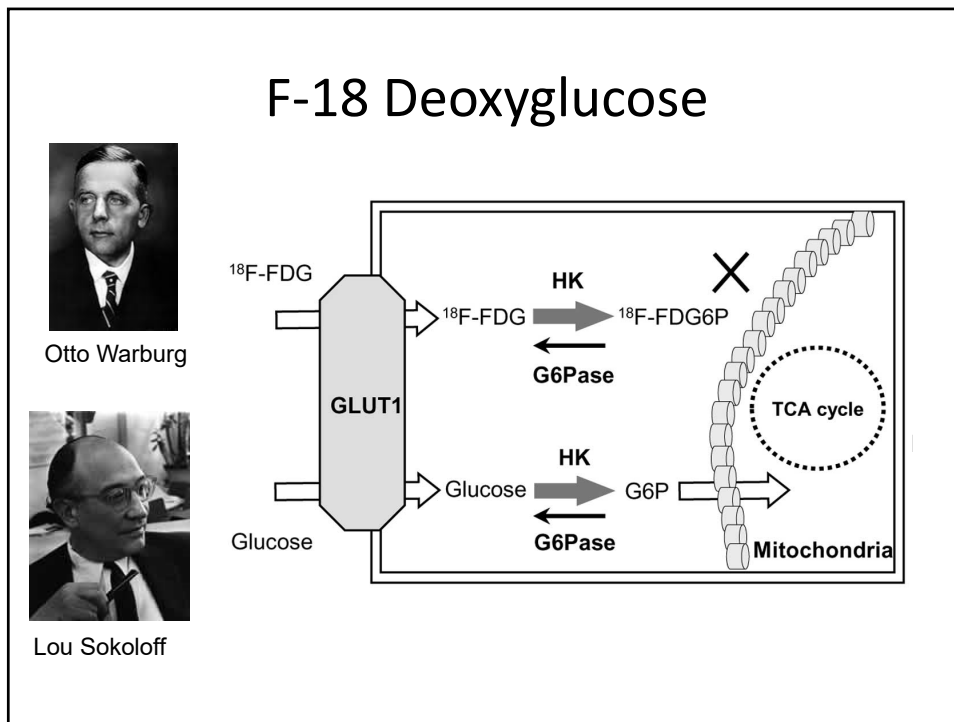
## Positron Emission Tomography



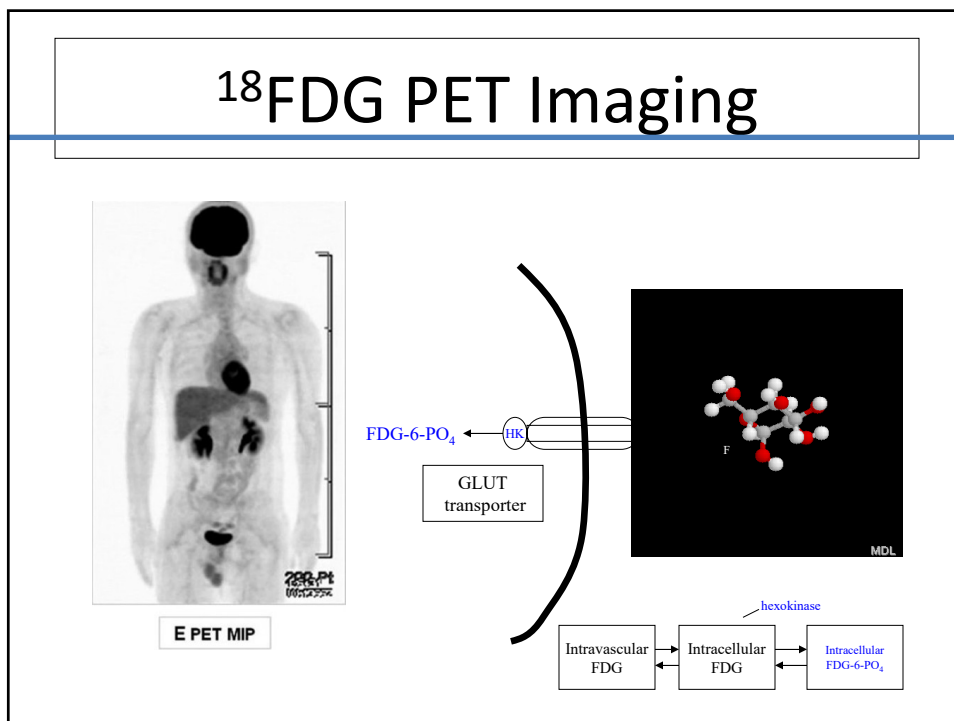
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46



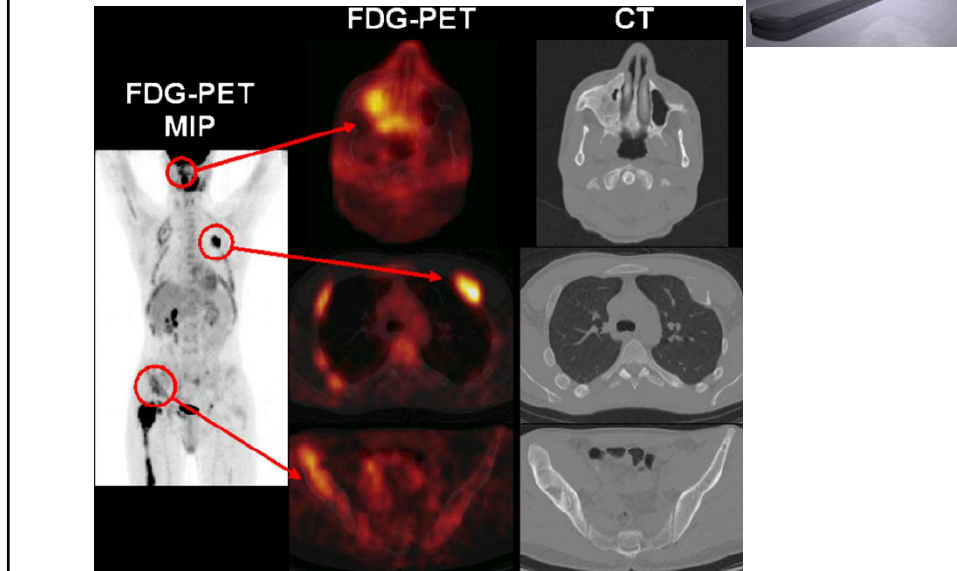
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48

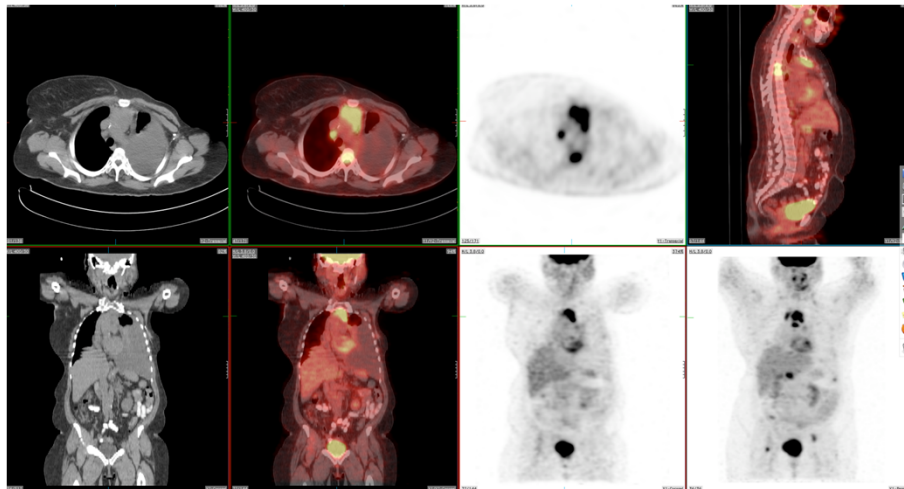


## PET-CT scanners



49

## Mediastinal and spine metastases (breast)



Metastatic Breast Cancer

50

## New PET agents

- DOTATATE “Net Spot” for Neuroendocrine
  - Lutathera (Lu-177-DOTATATE for therapy)
- PSMA “Pylarify” for prostate cancer
  - Pluvicta (Lu-177 PSMA for therapy)
- FES for breast cancer (estrogen receptor)
- IND agents:
  - FAPi - Fibroblast imaging
  - Plerixifor CXCR4 imaging
  - Axumin Multiple Myeloma

51

## PET:Advantages and Disadvantages

- Highly sensitive and specific
- Metabolic information
- Better spatial resolution than SPECT
- Combined with CT
- \_\_\_\_\_
- Expense
- Regulatory
- Short half life

52

## Using PET/CT

57 year old woman with Non Hodgkins Lymphoma for re-evaluation

NPO 4 hours  
Limited activity

Check BS  
1 hour  
incubation

Lips to hips  
Scan PET&CT

Hydration to  
avoid bladder  
exposure

53

## General Guidelines

- Overall “workhorse” for oncology: CT
  - If radiation is an issue: MRI
  - Most with IV contrast except if contraindicated
- Specialty cancers: brain, liver, prostate: MRI
- Problem solving (e.g cyst vs. solid): US
- Bone mets: bone scan
- Metabolic activity: PET
- Whole body staging: PET

54



## Tumor Imaging:

<http://mip.nci.nih.gov>  
pchoyke@nih.gov