Other Diagnostic Modalities

Nuclear Medicine, Ultrasound and MRI

MRT Program

Nuclear Medicine (NM)

- Use of radionuclides (tracers)
- Injected, inhaled, or taken orally
- Gamma or scintillation camera
- Single-photon emission computed tomography (SPECT): 3D images of anatomy
- Fusion technology: CT and SPECT



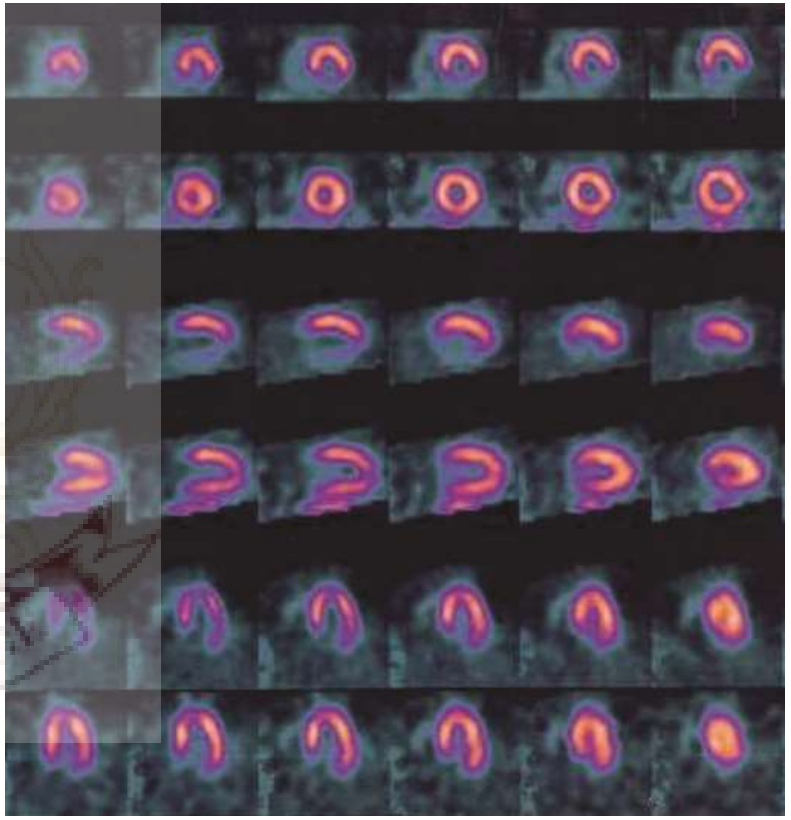
- Fusin Imaging System (CT and SPECT)

© MRT Program, Anderson College

Nuclear Medicine

- Clinical applications
  - Bone scintigraphy: study of skeletal system
  - Genitourinary studies: anatomic and functional studies of kidneys
  - Brain scan: to evaluate for stroke, Alzheimer's disease, and Parkinson's disease

- Clinical applications (cont'd)
  - Gastrointestinal studies: gastric emptying, hepatobiliary studies, liver and spleen studies
  - Cardiac studies: myocardial perfusion—stress/rest cardiac imaging
  - Lung studies: ventilation/perfusion studies



- Bontrager

Nuclear Medicine

- Clinical applications (cont'd)
  - Thyroid uptake study: sodium iodide (^{123}I) taken orally (evaluates for hyperthyroid and hypothyroid)
  - Thyroid uptake measurement



- Bontrager

Nuclear Medicine Team

- Nuclear medicine technologist
  - Handling, assessment, and administration of radionuclides
- Nuclear medicine physician
  - Interpretation of nuclear medicine procedures
- Radiation safety officer (RSO)
  - Reviews imaging protocols and dosimetry records
- Health physicist
  - Calibration and maintenance of equipment

Nuclear Medicine Terminology

- Biologic half-life
- Cyclotron
- Decay
- Half-life
- Isotope
- Scintillation
- Technetium 99m

Positron Emission Tomography

- PET Imaging System



- Bontrager

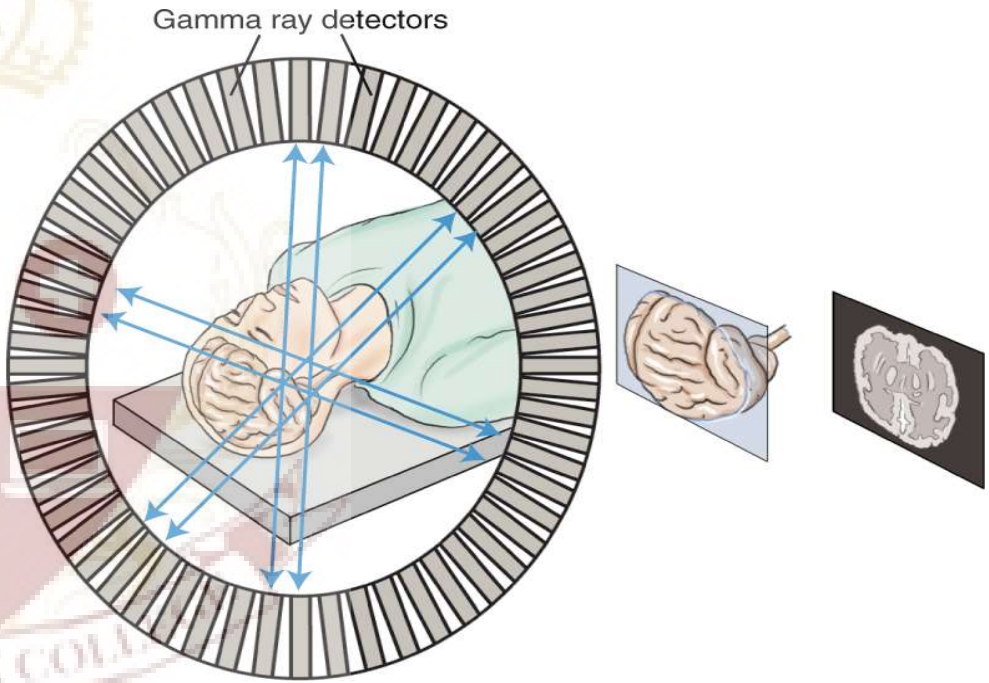
Positron Emission Tomography

Three-dimensional, tomographic imaging technique that demonstrates biomechanical functioning of body organs and tissues

- Detects abnormal function
- Detects diseases in early stages
- Measures responses to treatment

Positron Emission Tomography

- Positron emission process
  - Tracers administered to patient
  - Radiation emitted by tissue
  - Positron emitted from nucleus, combines with electron
  - Undergoes annihilation
  - Produces two 511-keV photons emitted 180° from each other



- Bontrager

Positron Emission Tomography

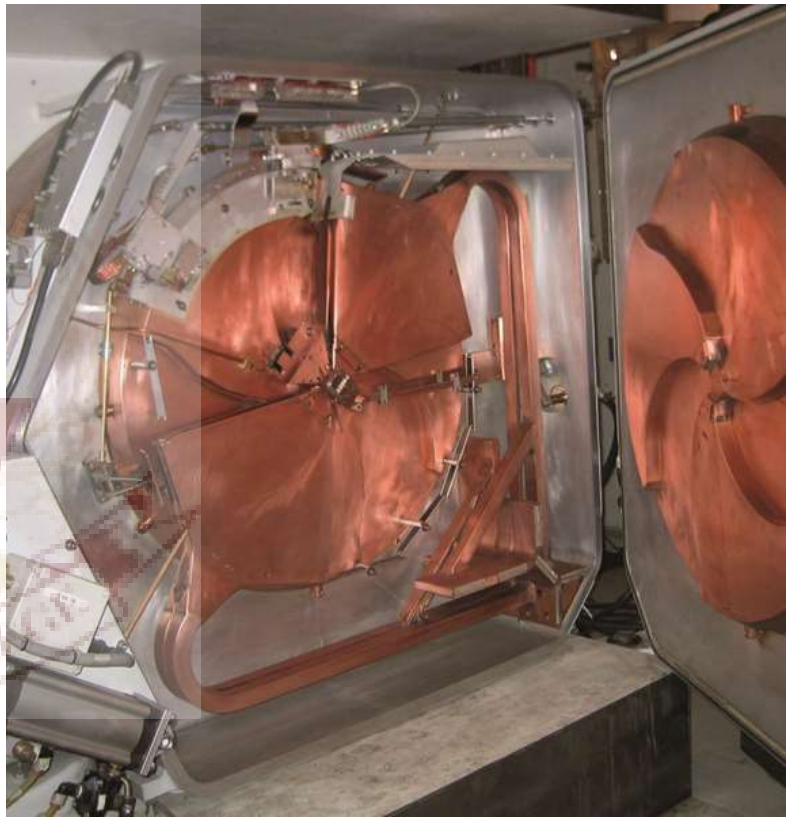
- Common positron-emitting elements
  - Oxygen
  - Nitrogen
  - Carbon
  - Fluorine

Positron Emission Tomography

Radionuclide compounds	Measures
^{18}F-FDG	Glucose metabolism
^{15}O-water	Blood flow/perfusion
^{13}N-ammonia	Blood flow/perfusion
^{11}C-methionine	Amino acid metabolism

Positron Emission Tomography

- Cyclotron
  - Accelerates subatomic particles
  - Directs particles to nonradioactive target, producing radionuclide
  - Tracers have very short half-life—120 sec to 110 mi



Positron Emission Tomography

- Clinical applications
  - Oncology: assess and stage possible tumors
    - FDG used to measure glucose metabolism
    - Tumors demonstrate increased sugar (FDG) uptake
    - Image demonstrates metastatic disease (excluding brain and bladder)
    - Coronal view, Whole body PET scan



- Bontrager

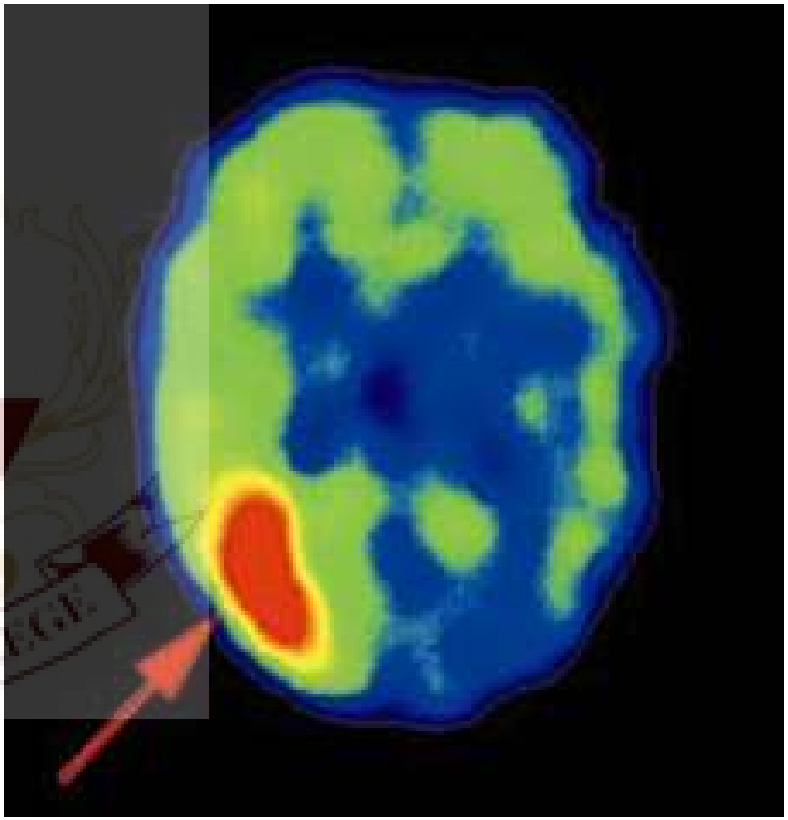
Positron Emission Tomography

- Clinical applications (cont'd)
  - Cardiology: evaluate for coronary artery disease
-) ^{13}N-ammonia, given to evaluate heart perfusion (sufficient blood flow to heart tissue



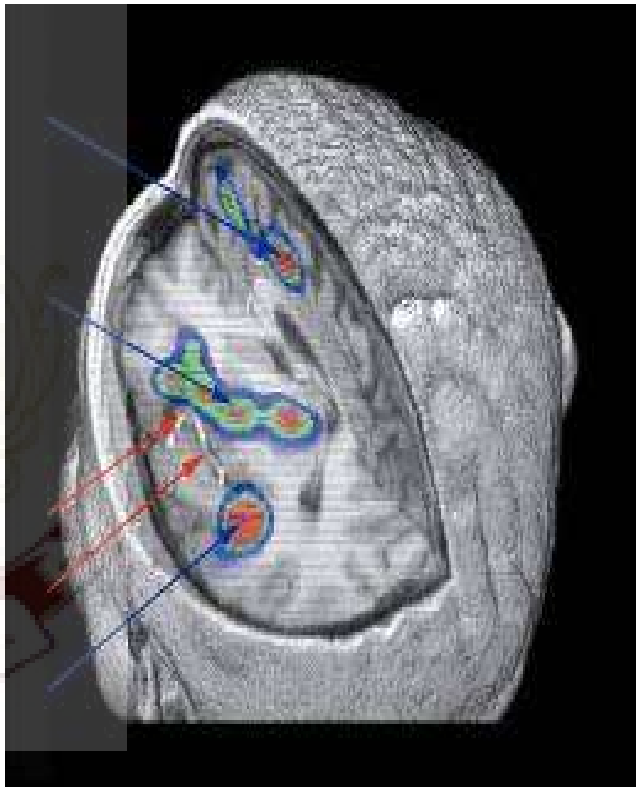
Positron Emission Tomography

- Clinical applications (cont'd)
  - Neurology
    - Epilepsy: ^{18}F-FDG given to localize seizure site
- Arrow indicated increased glucose uptake (indicative of active seizure focus)



Positron Emission Tomography

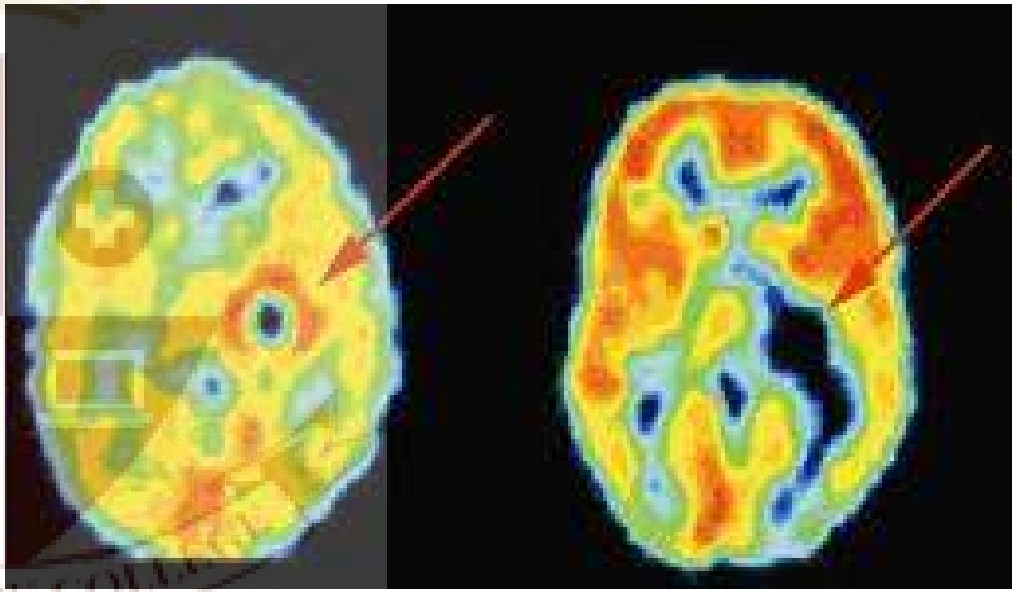
- Clinical applications (cont'd)
  - Neurology
    - Brain mapping:
      Localize areas of brain function, including language, memory, vision, and movement
    - Determine whether lesion will affect key areas of brain
    - Blue arrow indicates language region in brain
    - Red arrow demonstrates AVM (arteriovenous malformation)



- Bontrager

Positron Emission Tomography

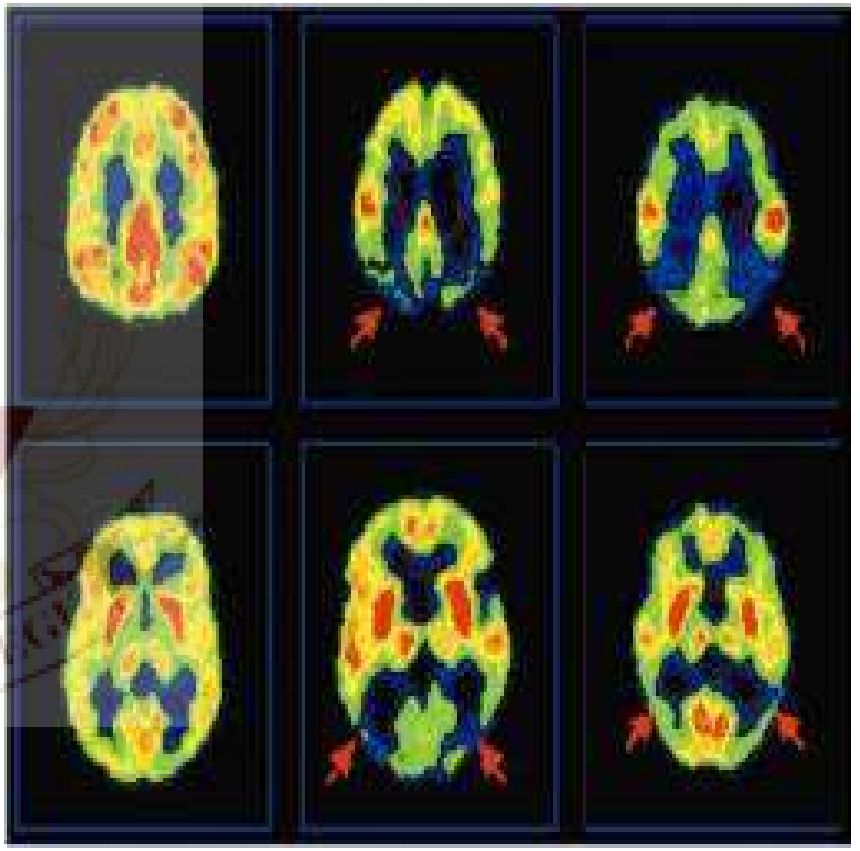
- Clinical applications (cont'd)
  - CNS tumor imaging
- ^{11}C-methionine assesses amino acid metabolism of tumor (left image)
- ^{18}F-FDG grades tumor to determine activity or glucose metabolism (right image)



- Bontrager

Positron Emission Tomography

- Clinical applications (cont'd)
  - Evaluation of dementia
    - ^{18}F-FDG given to measure glucose metabolism (activity) of brain
    - Left Column: normal activity
    - Middle Column: mild dementia
    - Right Column: severe dementia



- Bontrager

Sonography Ultrasound Imaging



Sonography

- High-frequency sound waves produce images of organs and structures in the body
  - 1-15 MHz (diagnostic ultrasound range)
  - Transmissible in liquids and solids
  - Poor transmission of sound through air or gas
- Abdomen study-liver with ascites



- Bontrager

Evolution of Sonography

- Sonar (1940s)—concept of ultrasound first used
- A-mode (early 1950s)—series of "blips" representing echoes
- Patient mode (B-mode) (late 1950s)—two-dimensional gray scale introduced
- Real-time imaging (1970s)—real-time assessment of the anatomy

Evolution of Sonography

- Doppler (1980s)—used to study vascular structure and behavior of flowing blood
- Digital systems (early 1990s)—convert ultrasound image to digital format to allow image manipulation, transmission, and storage on PACS



- Bontrager

- Transducer
  - Converts electrical energy to ultrasound energy
  - Acts as both transmitter and receiver
  - Gel applied to face of transducer/skin to reduce signal loss



- Bontrager

Sonography

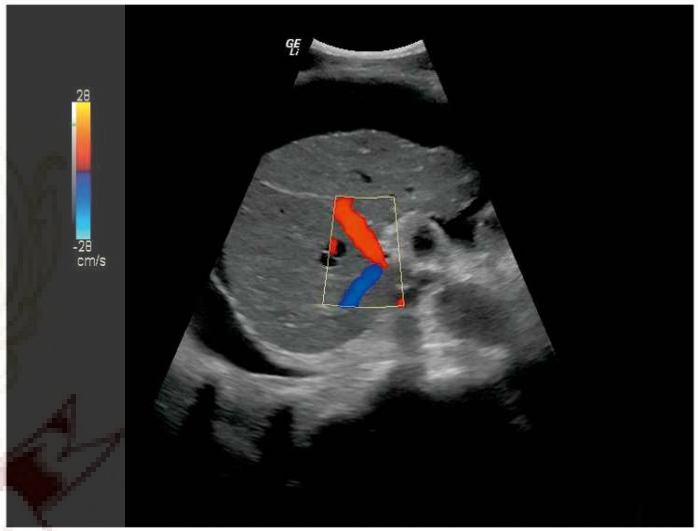
- Advantages
- Differentiation between solid vs. cystic structures
- Dynamic evaluation of joints
- Safe evaluation of fetus
- Limitations
- Bone-/air-filled structures

Sonography Imaging Team

- Sonographer
  - Performs ultrasound study and provides initial interpretation
- Sonologist
  - Interprets ultrasound study and provides diagnosis

Sonography

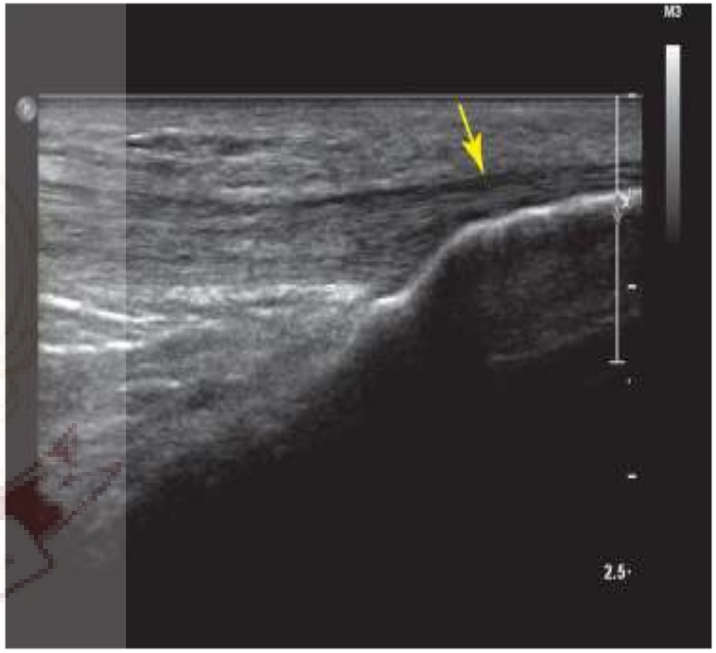
- Clinical applications
  - Liver and gallbladder—excellent for examining gallbladder
  - General abdomen studies of the spleen, pancreas, and kidneys



- Bontrager

Sonography

- Clinical applications
  - ➢ Musculoskeletal ultrasound—a noninvasive, functional assessment of synovial joints
    - Shoulder
    - Hip
    - Knee
    - Ankle
    - Achilles tendon (yellow arrow)



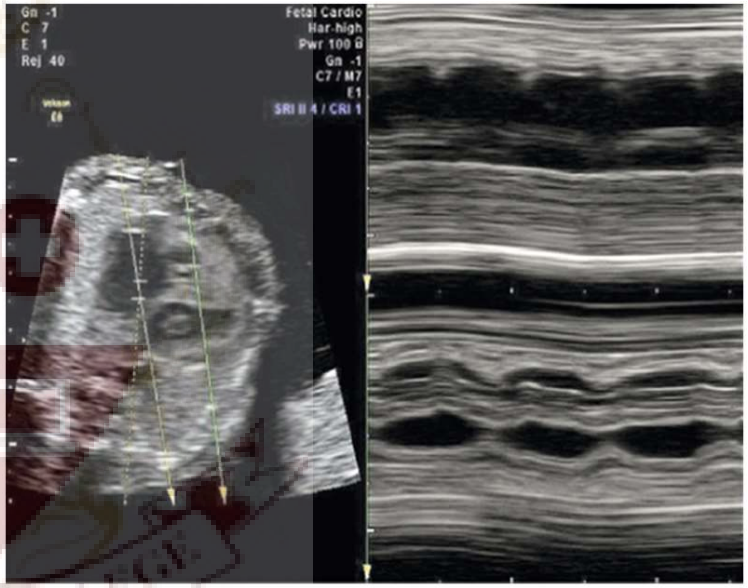
- Bontrager

Sonography

- Clinical applications (cont'd)

➢Heart

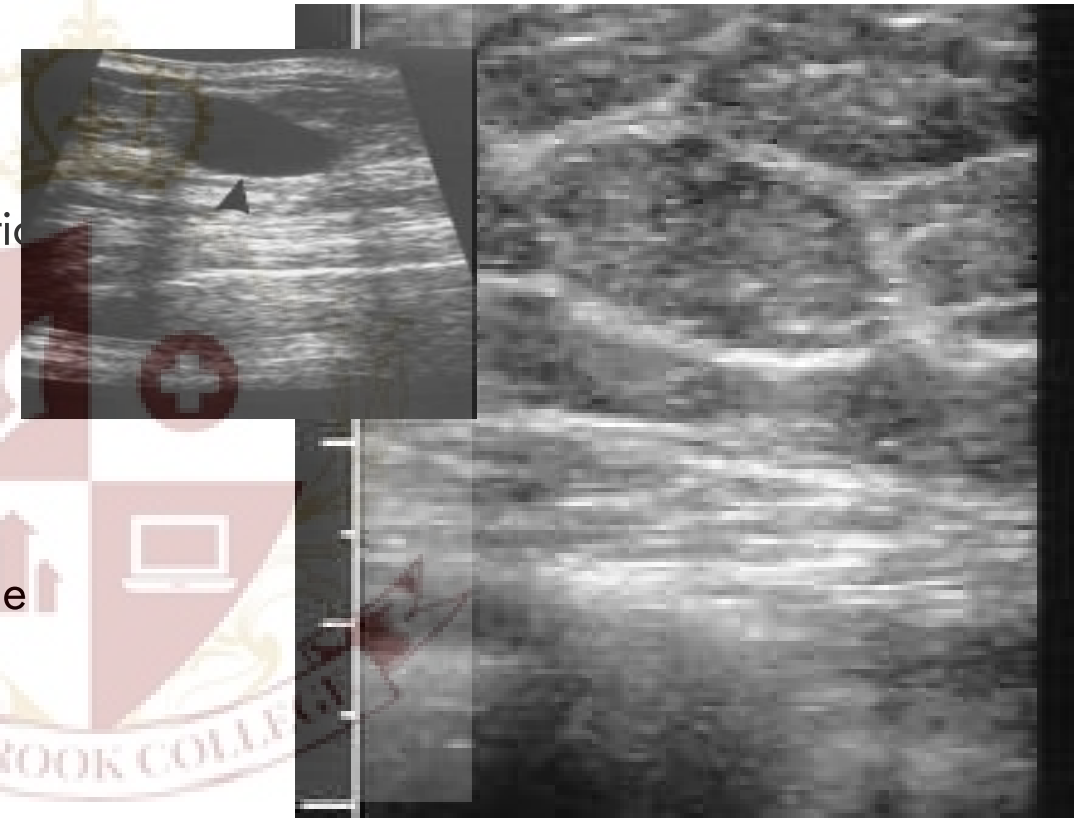
  – Echocardiography
  – Pericardial effusion
  – Diagnose septal defects
  – Diagnose heart valve defects



Courtesy GE Healthcare.

- Bontrager

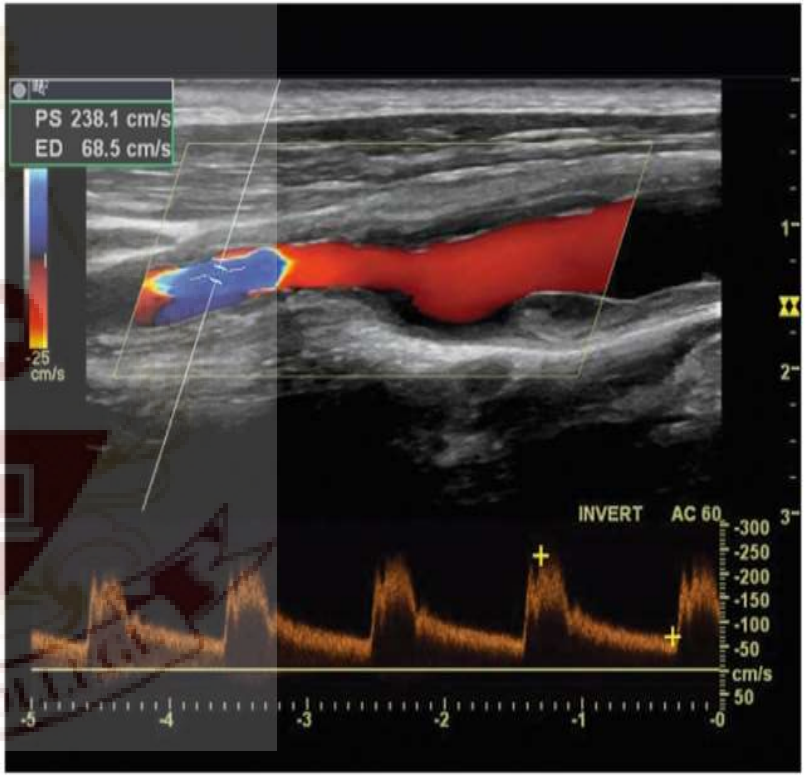
- Clinical applications (cont'd)
  - Breast—differentiate between cystic vs. solid mass
  - Eye—detect retinal detachment, vitreous hemorrhage, or foreign bodies
  - Upper image cyst in breast tissue lower image is normal breast tissue



- Bontrager

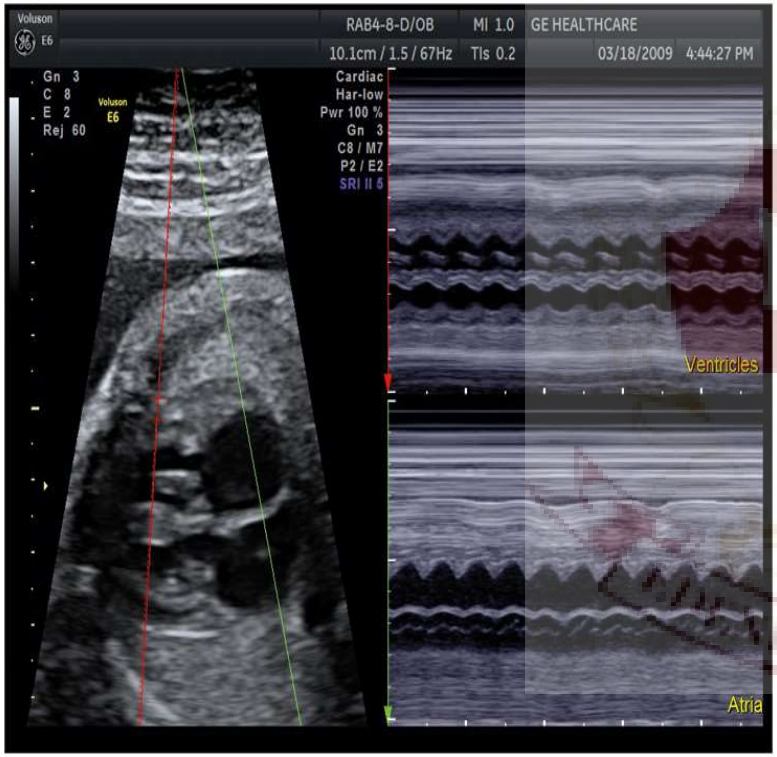
Sonography

- Clinical applications (cont'd)
  - Vascular structures—strictures, restricted blood flow, or plaque formation
  - Deep vein thrombosis
  - Color-flow Doppler (color indicates direction of blood flow)



- Bontrager

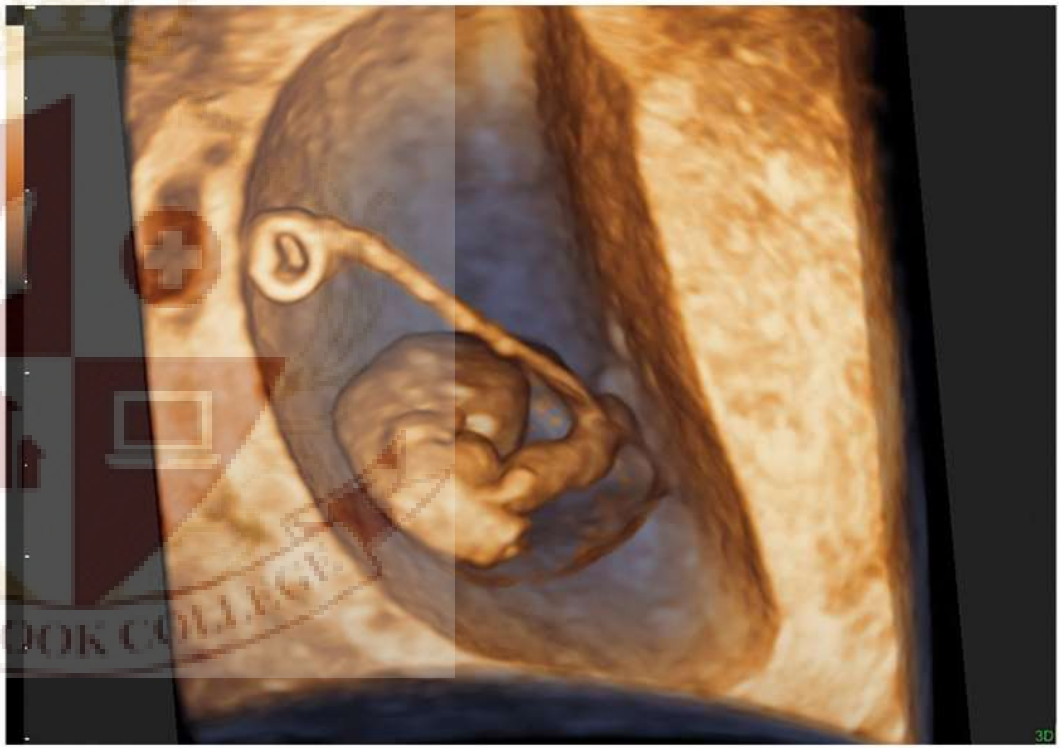
Sonography Case Studies



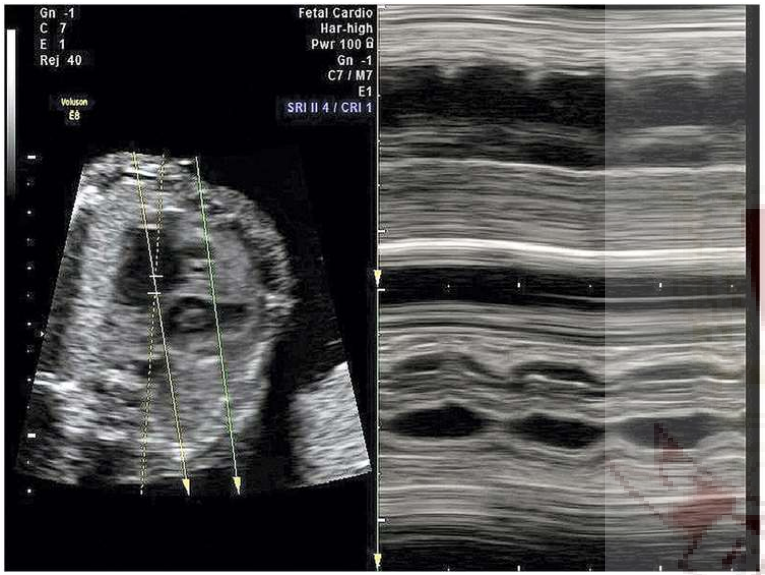


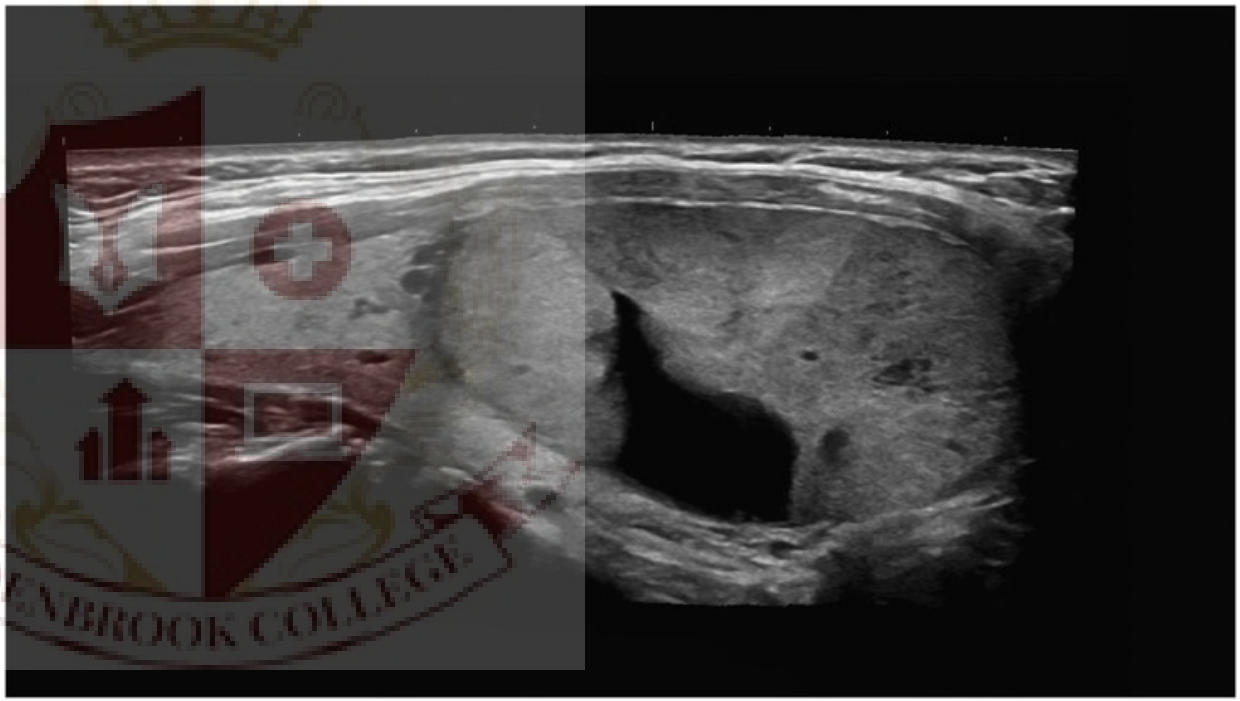
Sonography Case Studies





Sonography Case Studies





Sonography – Key Terminology

- Reflection
- Through transmission
- Transducer
- Wave
- Acoustic shadow
- Echo
- Echogenic
- FAST scan
- Hypoechoic

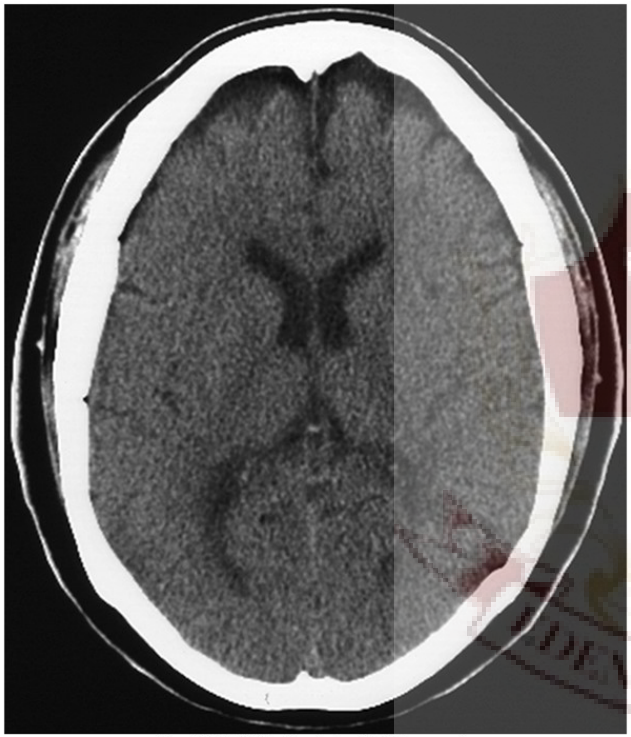
Magnetic Resonance Imaging



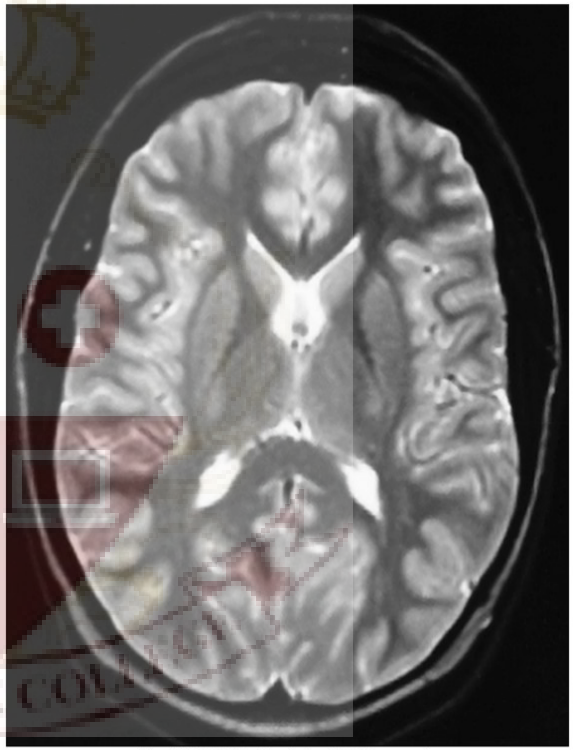
Magnetic Resonance Imaging

- Non-invasive examination technique that provides anatomic and physiologic information
- Totally different physical principals than CT/conventional radiography
- The use of magnetic fields and radio waves to obtain a mathematically reconstructed image

Comparison of MRI vs. CT



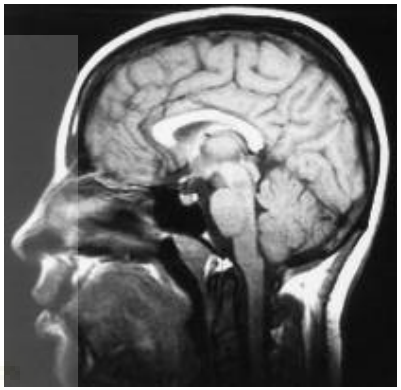
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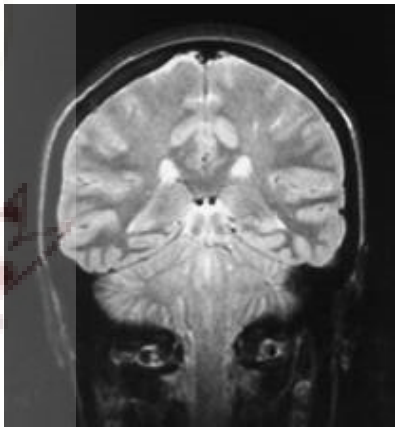


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Advantages of MRI

- Nonionizing energy source
- High-contrast resolution
- Imaging in multiple planes
- Ideal for brain and spinal cord studies

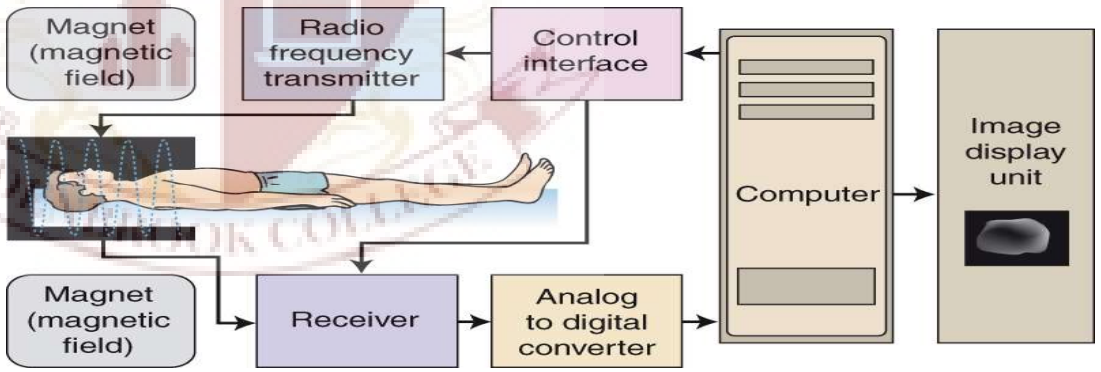




- Bontrager

Basic MRI Process

1. Nuclei receive and emit radio waves under influence of a strong magnetic field
3. Signal captured by receiver (coil)
4. Analog-to-digital (converter)
5. Image reconstructed (computer)
6. Image displayed

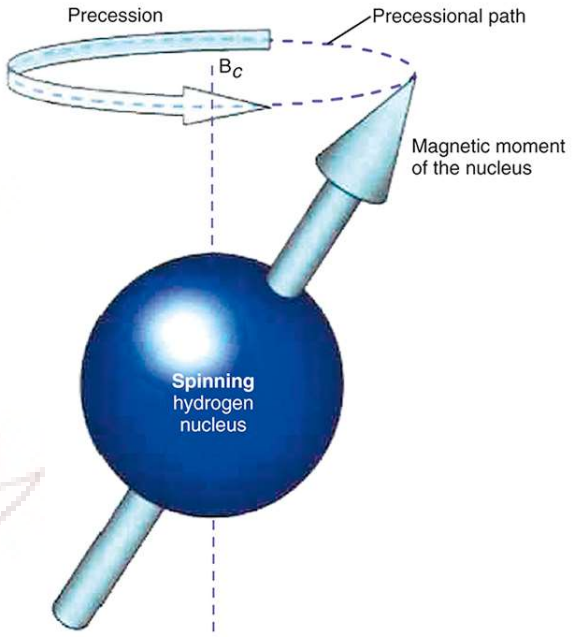


Suitable Nuclei for MRI

1. Odd numbers of protons and neutrons
2. Hydrogen abundant in the body (85% H_2O)

Precession

- A process where a spinning object is acted on by an outside force
- Not all protons align precisely with the external field but on an angle
- Causes them to rotate around the magnetic field and wobble



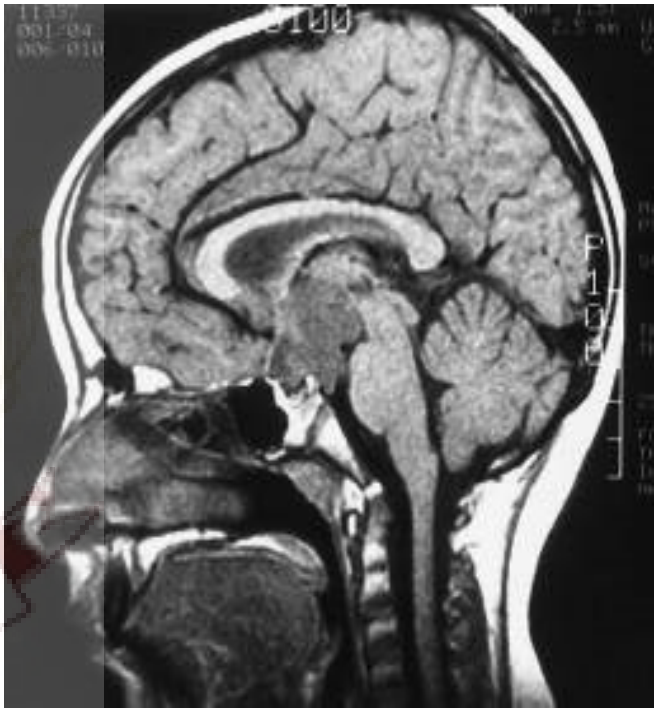
From Westbrook C: *MRI at a Glance*, ed 3, New Jersey, 2016, Wiley.

Relaxation

- Return to more random configuration
- Signal produced as nuclei relax
- The release of energy by the excited protons
- T1 relaxation – longitudinal or spin lattice
  - Time for MRI signal to decrease 63 % from max value
- T2 relaxation- tranverse or spin-spin
  - Time for MRI signal to decrease 37% from maximum value

Spin Density

- Spin density
  - Quantity of hydrogen nuclei present in tissue
- T_1 relaxation
- T_2 relaxation



- Bontrager

Magnetic Field Strengths

MRI
1.0-3.0 Tesla*
(10,000-30,000 Gauss)

Earth
0.0005 (Tesla)
(0.5 Gauss

(1 Tesla = 10,000 Gauss)





- Property of superconductivity (no resistance because of very low temperature)
- Cryogens required
  - Liquid nitrogen (–195.8°C)
- Liquid helium (–268.9°C) Up to 3.0 Tesla
- Flared, short-bore design (helps reduce claustrophobia)



Summary

Summary of MRI Process and System Components

Step	Component	Result
1. Apply static magnetic field	Magnet	Nuclei align and precess
2. Select slice by varying magnetic field	Gradient coil	Nuclei precess at the particular frequency
3. Apply RF pulses	RF sending coil	Nuclei in slice area are in phase at greater angle
4. Receive RF signal	RF receiving coil	Electrical signal received from nuclei and sent to computer
5. Convert signal to image	Computer	Reconstructed image is displayed

Relieving Patient Anxiety

- Music and relaxation techniques
- Move patient slowly into magnet
- Allow family member in room
- Good explanation of exam and communication with patient throughout



Absolute Contraindications

- Pacemakers
- Ferromagnetic aneurysm and surgical clips
- Metallic fragments in the eye
- Cochlear implants
- Starr-Edwards pre-6000 model prosthetic heart valve
- Internal drug infusion pumps (unless certified as MRI safe)
- Neurostimulators
- Bone growth stimulators

Safety Concerns

1. Potential hazard of projectiles
2. Electrical interference with implants
3. Torqueing of ferrometallic objects
4. Local heating of tissues and metallic objects
5. Electrical interference with normal functions of nerve cells and muscle fibers



Contrast Media

- Without contrast media (pathology appears gray)



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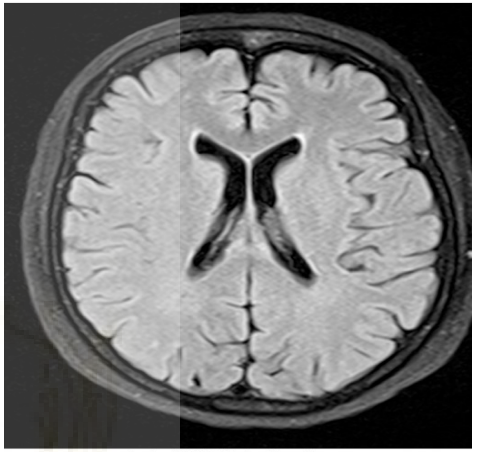
- With Gd-DTPA contrast media (pathology appears bright)



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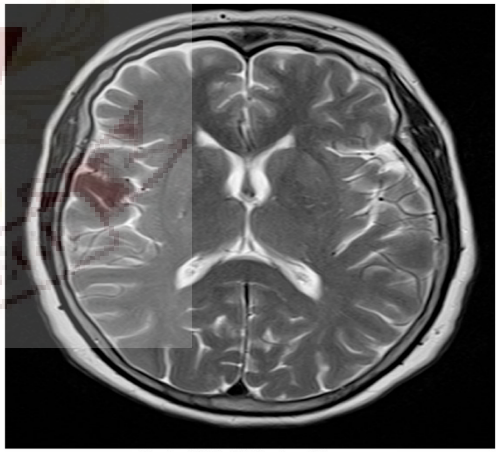
T1 and T2 Weighted Images

- T1 Weighted Image



Courtesy NEA Baptist, Jonesboro, Arkansas.

- T2 Weighted Image



Courtesy NEA Baptist, Jonesboro, Arkansas.

MRI

Appearance of T1- and T2-Weighted Tissues

Tissue	T1	T2
*Cortical bone	Dark	Dark
*Red bone marrow	Light gray	Dark gray
*Air	Dark	Dark
*Fat	Bright	Dark
*White brain matter	Light gray	Dark gray
*Gray brain matter	Dark gray	Light gray
*CSF/water	Dark	Bright
*Muscle	Dark gray	Dark gray
*Vessels	Dark	Dark

*Appearance similar for T1 and T2.

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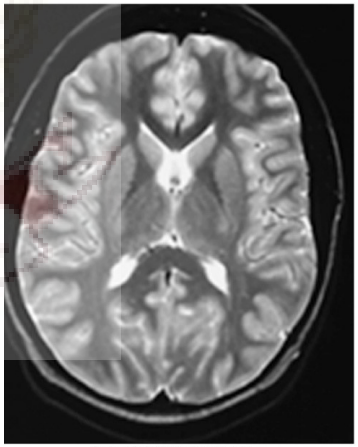
Brain Imaging

- Head coil
- T1/T2 sequences
- Gd-DTPA if indicated
- Patient supine, head first



Courtesy NEA Baptist, Jonesboro, Arkansas.


Courtesy NEA Baptist, Jonesboro, Arkansas.


Courtesy NEA Baptist, Jonesboro, Arkansas.

Spine Imaging

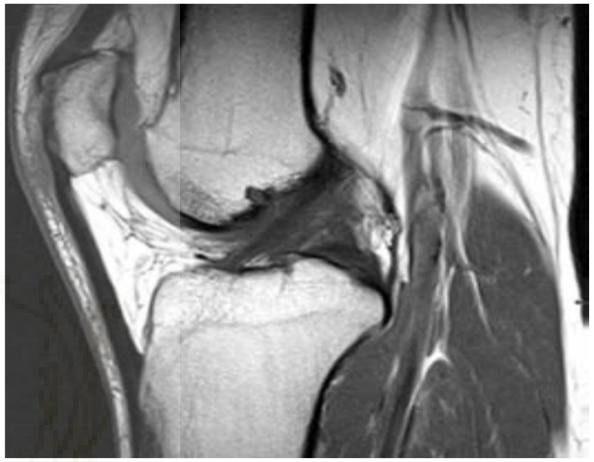
- Surface coil
- T1/T2 sequences
- Possible cardiac gating
- Gd-DTPA
- C-spine: patient supine, head first

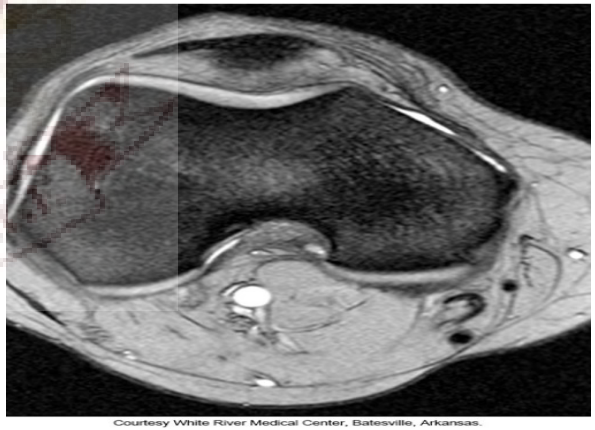


Courtesy White River Medical Center, Batesville, Arkansas.

Joint and Limb Imaging

- Surface or circumferential whole-volume coil
- T1/T2 sequences
- Supine or prone
- Head or feet first





Courtesy White River Medical Center, Batesville, Arkansas.

Abdomen and Pelvis Imaging

- Body coil
- T1/T2 sequences
- Cine as needed

- Respiratory gating
- Supine
- Feet first



Courtesy White River Medical Center, Batesville, Arkansas.

Functional MRI (fMRI)

- Evaluates both anatomic and functional aspects of brain
- Neural activity measured by blood oxygen level-dependent (BOLD) signal
- Evaluates brain centers responsible for language, vision, movement, hearing, and memory

MRI Terminology Review

- Artifacts
- Coil
- Cryogen
- Flip angle
- Free induction decay (FID)
- Gauss
- Gradient coil

MRI Terminology Review

- Precession
- Proton density
- Relaxation time
- Spin density
- T1
- T2
- TE
- TR