

Introduction to Basic Principles of Imaging

Nancy N. Byl, PhD, PT

Professor and Chair

Department of Physical Therapy and
Rehabilitation Science

Winter 2004

Nuclear Imaging

- Radionuclide Bone Scan: diagnostic use of radioactive isotopes. This scan is a nuclear imaging test of the skeletal system
- Radiopharmaceuticals that are tissue specific to bone are injected intravenously
- Patient paced under scintillation camera detects the distribution of radioactivity in body
- Picks up pathology in bone

Magnetic Resonance Imaging (MR)

- MR (or MRI) best for learning more about soft tissue
- No ionizing radiation
- Patient placed in a scanner containing magnetic fields
- MR's are based on the magnetic properties of hydrogen nuclei (tiny magnets spinning in random direction with neighboring atoms until influenced by externally applied magnetic fields)
- Patient placed in a scanner containing magnetic fields
- Produces information via action of tissue with radiofrequencies in the magnetic field

Principles of MR

- Hydrogen atoms have an unpaired proton and exhibit a spin
- Spin results in a small magnetic moment; thus hydrogen protons will react to external magnetic fields
- Any nucleus with an unpaired proton or neutron (hydrogen 1, phosphorus 31, sodium 23) has a magnetic moment and could be used for MRI
- Hydrogen is the most abundant element in the body
- Spins of hydrogen atoms are oriented in a random fashion

Principles of MR

- Nuclei spin around parallel axes at frequencies specific to this tissue type
- Radiowaves pulsed to patient at this frequency and are absorbed by the nuclei; transfer of energy induces resonance among the nuclei
- Different tissues resonate at different frequencies
- In the magnetic fields, random atomic nuclei align themselves with the fields
- When an outside source of strong magnetic energy is applied, the atoms lie parallel to the direction of the external magnet

MR

- Radiowaves from a secondary coil are then directed at nuclei from different angles
- Nuclei absorb this energy and slip 180° from their previous positions
- Energy released is measured electronically and analyzed by computer algorithms to create two dimensional images depicting a thin slice of tissue

Terms

- T1 Relaxation: longitudinal relaxation time or spin-lattice relaxation time
- Tissue specific time constant
- Time required for 63% of the deflected nuclei to realign with external magnetic field and return to equilibrium state after termination of a 90° pulse

Terms

- T2 Relaxation: transverse relaxation time or spin spin relaxation time
- Is tissue specific time constant describing rate at which nuclei lose their phase coherence after being tipped from equilibrium
- Immediately after an RF pulse, deflected nuclei are in phase with each other and emitted signal maximal
- With T2 relaxation, phase coherence decreases and signal becomes weaker
- Different tissues have different signal intensities on the T1 and T2 weighted images

T1 T2 Weighted Images

- | T1 | T2 |
|-------------------------------------|---------------------------|
| • Bright High Signal | • Bright High Signal |
| – Fat | – CSF, water |
| – Marrow | |
| – Brain, white matter | – Intervertebral disk |
| – Liver, pancreas | – Brain gray matter |
| – Brain, gray matter | – Spleen |
| – Kidney | |
| – Spleen | – Brain white matter |
| | – Liver |
| – Cerebrospinal fluid | – Fat |
| – Water; lung | – Iron in basal ganglia |
| – Bone, cortical, flowing blood air | – Bone, air flowing blood |
| – Dark Signal | Dark Signal |

Terms: Pulse Sequences

- Pulse sequence : precisely defined pattern of RF pulses and listening intervals used to generate MRI
- Consists of 90° pulse followed by pause after which a 180° pulse is applied
- After an additional pause, receiver coil set to listen to signal (echo) emitted from tissues; then repeated
- Time period for tissue to emit signal is called time to echo (TE) Time between pair of 90° RF pulses: time of repetition (TR)
- Different tissues have different signal intensities depending upon what values of TR and TE are selected

Pulse Sequences

- Spin echo sequence can be T1-weighted or T2 weighted
 - T1 weighted have TE less than or equal to 40 msec and TR less than or equal to 800 msec
 - T2 weighted have TE greater than or equal to 80 msec and TR greater than or equal to 1500 msec
 - Proton density weighted images are generated with TR long (minimizing T1 effects) and TE short (minimizing T2 effects)
- Main determinant of signal intensity in spin echo sequences is proton density

Terms: Fat Suppression

- Process of minimizing the contribution from fat containing tissues to signal of an MRI image
- When used with T2 weighted images, water becomes conspicuous
- Suppression is done with: chemical saturation or inversion recovery
 - frequency selective chemical saturation (selective RF pulse that deflects only fat hydrogens used before the main pulse sequence)
 - minimizes fat and leaves other tissues to respond to RF signal
 - usually used with fast spin-echo T2 weighted sequences to increase the visibility of edema or fluid.
 - Can also be used with T1 weighted images after administration of contrast (fat bright on T1 weighted now becomes dark)
 - inversion recovery (takes a long time but also suppresses fat signal)

Terms



- Contrast agents
 - Based on gadolinium chelates
 - Transition element that has paramagnetic activity
 - Unpaired electrons in outer shells and creates own small local magnetic
 - Shorten the T1 and T2 relaxation times of hydrogen nuclei (leads to brighter signal on T1 images)
 - Results in MR arthrogram