Basics of Magnetic Resonance Imaging

John VanMeter, Ph.D.
Center for Functional and Molecular Imaging
Department of Neurology
Georgetown University Medical Center

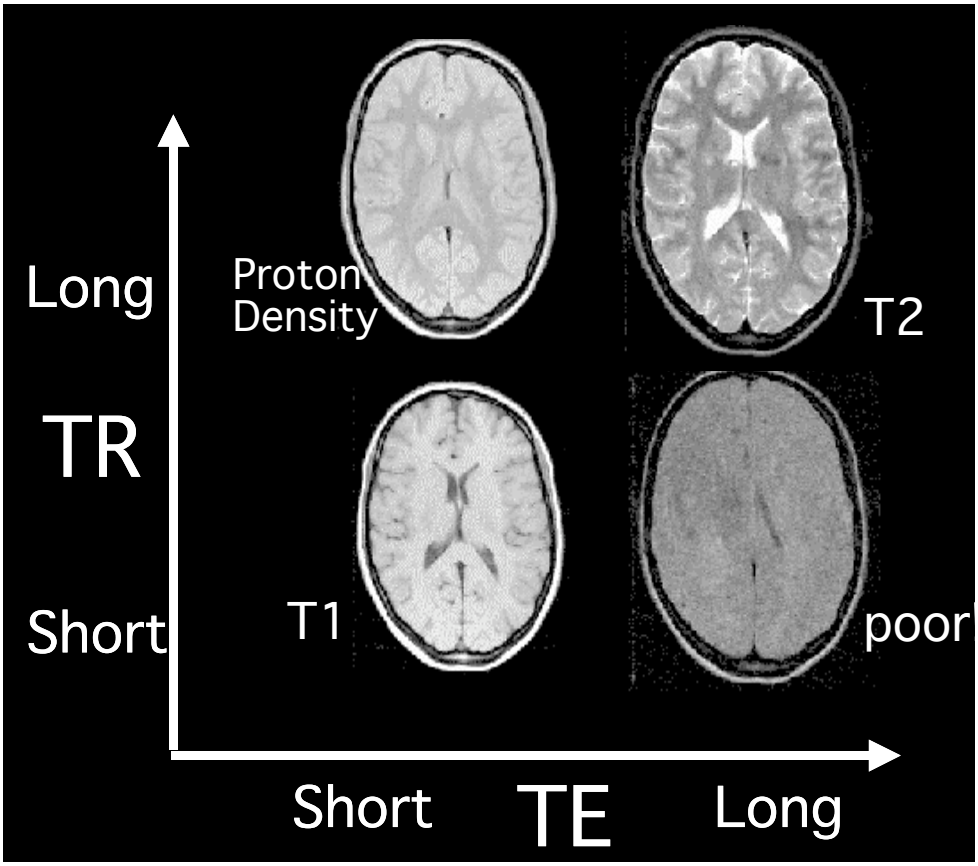
1. Unlike CT and PET, MRI does not use ionizing radiation. In addition, it has a higher spatial resolution than both modalities. Another major advantage of MRI is its ability to image tissues.

2. The magnetic field in an MRI scanner is generated by surrounding a coil of wire with super cooling fluids (liquid helium and liquid nitrogen) lowering the temperature to about 10^{o}K. Electrical current in the coil moves very fast creating an extremely large magnetic field.

3. Medical MRI takes advantage of the high prevalence of hydrogen in the body and the magnetic properties of the proton in a hydrogen atom. Hydrogen atoms induce a small magnetic field due to the spin of this atom's proton.

4. **The MRI Measurement** consists of the following:
    a. Alignment of the protons in the body with the large magnetic field of the MRI scanner. After a few seconds in the scanner the protons in the patient are aligned with the magnetic field.
    b. A radio frequency (RF) pulse is used to tip the protons out of alignment with the scanner's magnetic field.
    c. Once out of alignment the magnetic moment of the hydrogen protons can be measured as they rotate past measurement coils (loops of wire) inducing an electrical current.
    d. The protons are pulled back into alignment with the main magnetic field decreasing the measurable signal. The rate at which this occurs determines the T1 properties of a tissue. If the protons in a tissue return to alignment faster than all other tissues then this tissue will be brightest on a T1-weighted scan.
    e. While rotating the protons gradually become out of phase with one another decreasing the measurable signal. The rate at which this dephasing occurs determines the T2 properties of a tissue. If the protons in a tissue remain in phase with one another longer than all other tissues then this tissue will be brightest on a T2-weighted scan.
    f. A proton density (PD) scan minimizes both T1 and T2 contrast to produce an image in which brightness is determined by the number of protons in a voxel.

5. **Two controls determine tissue contrast**: TR (repetition time) and TE (echo time) of the scan.
    a. Repetition time is the time between successive RF pulses. A long repetition time allows the protons in all of the tissues to relax back into alignment with the main magnetic field. A short repetition time will result in the protons from some tissues not having fully relaxed back into alignment before the next measurement is made decreasing the signal from this tissue.
    b. Echo time is the time at which the electrical signal induced by the spinning protons is measured. A long echo time results in reduced signal in tissues like white matter and gray matter since the protons are more likely to become out of phase. Protons in a fluid will remain in phase for a longer time since they are not constrained by structures such as axons and neurons. A short echo time reduces the amount of dephasing that can occur in tissue like white matter and gray matter.
    c. The relationship between TR and TE and tissue contrast are shown in the figure below.



6. **MRI Safety**
    a. Several deadly MRI related accidents have occurred.
    b. The most dangerous part of an MRI scanner is its powerful magnetic field. The magnetic field in an MRI scanner is stronger than those used industrially to move cars. This magnetic field will cause objects made of ferromagnetic materials to be pulled into the scanner. It will also pull on ferromagnetic objects implanted in the body.
    c. The following metals are ferromagnetic and are **not MRI compatible**:
        i. Iron
        ii. Nickel
        iii. Cobalt

        Objects made of these materials should not be taken into the MRI scanner room.
    d. Patients should be screened for the following:
        i. Pacemakers
        ii. Surgical clips
        iii. Implants made of a ferromagnetic metal

Never send anyone for an MRI without screening them first!

Never go into the MRI scanner room without screening yourself and the ojbects you are taking with you first!