Dynamic Chiropractic



# Introduction to Magnetic Resonance Imaging

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Learning Magnetic Resonance Imaging (MRI) is a lot like learning a foreign language. When learning a foreign language, one needs to learn to work with new nouns and verbs. With MRI, one needs to learn a new Gray scale and new relationships between soft tissues. For instance on CT, cortical bone is always white, while on MRI it is always black. To complicate matters, where CT is absolute, MRI often provides relative relationships. CSF is always black on CT but with MRI can be gray or white depending upon the pulse sequence chosen. With CT scanning, Hounsfield units represent a constant value and the Hounsfield unit number (HU#) always translates to a certain shade on a Gray scale.

This is not the case with MRI. Soft tissues have variable appearances based on the pulse sequences chosen. If you are looking for absolutes in MR imaging, you will be disappointed. When looking at a scan, always consider the relative relationships for a given TR (reception time), and TE (echo time) in spin echo imaging, and a given TR, TE, and TI (time of inversion) in inversion recovery imaging. One needs to understand TR, TE, and flip angle relationships when performing imaging in the pulse sequence family known as field echo or gradient echo imaging.

A point of confusion is the different families of pulse sequences with MRI. As an analogy, one can think of different dialects when trying to learn a foreign language. If you were attempting to learn Chinese, it would be important to know whether you are learning Mandarin or Cantonese or one of the other many dialects found in China. Similarly, there are different families of pulse sequences within the umbrella of MRI. There is nothing analogous to this with plain film radiology or CT scanning. With CT, there are different ways of looking at tissues. One can use soft tissue windows or bone windows, but this is not analogous to the differential relationships that can be created by altering the pulse sequences with MRI.

First, we will summarize the pulse sequence families and then take a more detailed look at each.

The families of pulse sequences in MRI include:

I. Spin Echo and Its Brother "Fast Spin Echo" -- The radio frequency pulse train is 90 degrees-180 degrees-180 degrees. This $90^{o}$-$180^{o}$-$180^{o}$ train may be repeated several times through the same information slice. The time between successive trains is called the TR value or repetition time. Within a given $90^{o}$-$180^{o}$-$180^{o}$ train the time between the 90 degree pulse and the time one listens for the signal after the administration of the first 180 degree pulse is known as the first TE value or the first echo. The time between the 90 degree RF pulse and the time one listens after the administration of the second 180 degree pulse is known as the second echo or second TE value.

II. Gradient Echo Imaging -- Also known as field echo imaging, low angle imaging, and partial flip imaging, it has a fast cousin referred to as echo planar imaging, which is not yet clinically available. Contrast relationships are controlled not only by TR and TE, but by an additional factor called the flip

angle. With spin echo imaging, one starts with a 90 degree pulse and then follows with 180 degree pulses for refocusing of the signal. With gradient echo imaging, one usually starts with a flip angle less than 90 degrees (flip angle is important in determining contrast relationships) and signal is refocused not by using 180 degree pulses as in spin echo imaging, but by altering the magnetic fields in the bore of the imager. This is achieved by reversing whichever side of the magnet is of higher magnetic field strength, and whichever is lower (gradient reversal).

III. Inversion Recovery -- The radio frequency pulse sequence for inversion recovery imaging is 180 degrees-90 degrees-180 degrees. In inversion recovery, the time between successive $180^{o}$-$90^{o}$-$180^{o}$ trains is called the TR value. The time between the middle 90 degree RF pulse and the second 180 degree pulse is called the TE time or echo time. With inversion recovery, we introduce a new time value called the TI value or time of inversion. This is the time between the first 180 degree pulse and the middle 90 degree pulse. Contrast is in part controlled by altering this TI value. If one uses a very short TI value, one can suppress the fat signal intensity. This can be quite useful when looking at bone marrow for infection or tumor. Short TI inversion recovery imaging is quite popular and is referred to as STIR imaging. Currently, investigators are experimenting with long TR, long TE, and long TI inversion recovery as a way of improving contrast within the soft tissues of the brain and spinal cord (i.e., improved visualization of multiple sclerosis plaques).

IV. Diffusion Imaging -- This is an experimental technique designed to look at the motion of free water using very high magnetic gradients. You will hear people talk about the ADC, or apparent diffusion coefficients, which is a measure of how fast and in which direction water molecules are moving. Part of the movement is due to Brownian motion. Diffusion imaging will be very useful in the future for picking up very early changes in the brain parenchyma. Recent investigational work has shown that infarction of the brain or spinal cord can be detected within minutes, whereas historically it required hours before the findings were visible on standard MR imaging.

V. Perfusion Imaging -- This requires very fast scan times. one must be able to obtain an MRI image in one second or less. If one can obtain images in one second or less, an intravenous bolus of contrast material can be tracked through the brain or cord parenchyma. On most perfusion imaging studies, normal tissue turns dark as the contrast agent moves through that tissue (normally about 10 seconds after administration of the bolus of contrast). This is referred to as a susceptibility effect. Abnormal tissue that is not perfused will fail to show any change in contrast relationships as the contrast material passes through the vascular tree.

VI. Spectroscopy

VII. MR Angiography -- Modifications of current image pulse sequence families are used to produce MR angiography scans.

Let us now take a more detailed look at some of the MRI families.

A. Spin echo imaging. Within the spin echo family, one will find images referred to as T1 weighted images, proton density images and T2 weighted images. The following listing might be useful:

a. T1 weighted image (short TR, short TE) -- TR 600 milliseconds or less with a TE of 40 milliseconds or less.

b. Proton density image or spin density image as it is also known (long TR, short TE) -- The TR is usually 1,500 milliseconds or more with a TE value that is usually 40 milliseconds or less.

c. T2 weighted image (long TR, long TE) -- The TR value is usually 1,500 milliseconds or more with a TE of 60 milliseconds or more. These terms are relative. A T2 weighted image may be mildly T2 weighted or heavily T2 weighted depending on how long the TR and TE values are.

On spin echo images, there are substances that are black on all pulse sequences, whether one is considering a T1 weighted, proton density or a T2 weighted image. They are as follows:

> Air

> Cortical bone (marrow containing bone is bright on T1 weighted imaging)

> Calcification (tuberous sclerosis, cysticercosis, TORCH virus infections, dystrophic calcification and pediatric AIDS)

> Rapidly flowing blood (with a velocity exceeding 10 cm per second)

> Rapidly flowing CSF (with velocity exceeding 10 cm per second)

> Ligaments and tendons

> Dura

Relatively pure fluid such as cerebrospinal fluid or urine is black on T1 weighted images, gray on proton density images, and white on T2 weighted images. Fat and subacute blood in the form of methemoglobin tend to be brightest on the T1 weighted image with successively less relative signal intensity as one progresses to proton density and T2 weighted images.

There is one unusual set of signal intensities that one may see: gray signal on proton density images and black signal on T2 weighted images. This usually signifies that iron is present. Certain forms of hemorrhage such as deoxyhemoglobin and hemosiderin can present in this fashion. Iron may also be deposited in the basal ganglia with white matter disease such as multiple sclerosis and in leukodystrophies (inborn errors of metabolism). Subarachnoid hemorrhage may stain the pial surface of the brain producing this set of appearances (gray on the proton density image and black on the T2 weighted image) on the surface of the brain. This is referred to as superficial siderosis and is an unusual cause of hearing loss.

In review, the following relationships are important for interpreting MRI studies.

- Black on a T1 weighted image -- air, cortical bone and calcifications, rapidly flowing blood, rapidly flowing CSF, ligaments, tendons, and dura.

- White signal intensity on T1 weighted images -- fat, subacute hemorrhage (methemoglobin), some complex proteinaceous solutions (mucocele, colloid cyst, Rathke's cleft cyst, epidermoid cyst, cholesterol granuloma) and fine calcifications (hydration layer effect around calcium phosphate complexes).

- Gray signal intensity on T1 weighted images, lower signal intensity that normal white matter is seen with -- acute infarction, acute infection, primary brain tumor, and metastatic disease.

All of the above will be of high signal intensity on the T2 weighted image.

Look for Part II of this article in an upcoming California Forum.

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