Dynamic Chiropractic

Introduction to Magnetic Resonance Imaging, Part II

Murray A. Solomon, MD

Dr. Solomon is a neuroradiologist who lectures at Palmer West and has recently been appointed to the continuing medical education staff of Palmer, Davenport. He is medical director of an MRI facility, and co-medical director of another.

Subfamilies of the Spin Echo Family

T1 Weighted Image

Intermediate signal on T1 weighted images is seen with gray matter, white matter, and muscle.

Proton Density Image

The proton density image can be thought of as an image that is halfway between the T1 weighted and the T2 weighted image. Synonyms for the proton density image include spin density, balanced image, and mixed image. Unfortunately, there is no uniformity in the terms used in magnetic resonance imaging.

Fat is relatively bright on proton density images but is not as bright as it is on the standard short TR, short TE, T1 weighted image.

On the proton density image, there is good discrimination between the gray matter and the white matter with the gray matter being higher in signal intensity than the white matter. Pure cerebrospinal fluid is gray on the proton density image, but complex proteinaceous fluids may be of very high signal intensity on the proton density image. If one has T1 weighted images and T2 weighted images, why one would need a proton density image? The reason is that on T2 weighted images, one often cannot separate lesions from the CSF signal intensity since they are both white. On a proton density image, CSF is gray, lesions are often white or gray-white, allowing for clear discrimination from the cerebrospinal fluid (ventricles, cisterns, and sulci). On a T2 weighted image, one might not be able to separate a white multiple sclerosis plaque from white CSF if the lesion is in the periventricular white matter. There is higher signal to noise on the proton density image than on the T2 weighted image and good gray matter/white matter discrimination. Proton density images are therefore very useful for examining gray matter/white matter relationships and abnormalities of these relationships such as ectopic gray matter, progressive multifocal leukoencephalopathy, multiple sclerosis, and the leukodystrophies (inborn errors of metabolism).

T2 Weighted Image

A T2 weighted image is produced by using long TR and long TE pulse trains. The longer the TR and/or the longer the TE, the more T2 weighted the image is. The penalty for lengthening the TR is time and

the penalty for lengthening the TE is noisier images (reduced signal to noise). In the real world, one actually obtains T2 weighted images in part by lengthening the TR and in part by lengthening the TE. With newer pulse sequences (fast spin echo imaging) it will be possible to obtain T2 weighted images with very long TR, short TE images with short exam times, therefore mitigating the need to balance the TR and the TE to obtain heavily T2 weighted images.

On a mildly T2 weighted image, fat is gray and on a heavily T2 weighted image, fat is dark or even black. It is therefore important when looking at a T2 weighted image to understand whether it is a mildly T2 weighted image, a moderately T2 weighted image, or a heavily TE weighted image. There is excellent gray matter/white matter discrimination on a heavily T2 weighted image, but the signal to noise is so low that the images may be difficult to interpret, appearing fuzzy and indistinct. Again, the fast spin echo sequences will change this, allowing one to use TR values of four to six thousand milliseconds without substantially increasing exam time.

Free water and complex collections of fluid are both bright on T2 weighted images. Cerebrospinal fluid, simple cysts and proteinaceous cysts will be bright on the long TR, long TE, spin echo image. The long TR, long TE, T2 weighted image reflects increased water content. Increased free water (either intracellular or extracellular free water) will yield increased signal intensity on T2 weighted images. Lesions that are of very high signal intensity on the T2 weighted image include:

1. Tumor
2. Infarction
3. Abscess
4. Infection
5. Demyelinating disease (multiple sclerosis)
6. Certain forms of hemorrhage (exceptions would include deoxyhemoglobin and hemosiderin).

Pathology is usually the most striking on T2 weighted images. This is because the lesions are very bright. However, as noted previously, there may be difficulty discriminating a lesion from an adjacent CSF space. For this reason, it is popular to obtain both the proton density and a T2 weighted image at the same time. There is no timed penalty for obtaining the proton density and T2 weighted images at the same time.

Gradient Echo Imaging: (Field echo imaging, low flip angle imaging)

Historically, it was promised that fast gradient echo imaging would replace spin echo imaging. This has not occurred in the brain or spinal cord because of lower sensitivity for small lesions such as multiple sclerosis plaques, small areas of infarction, small foci of metastatic disease, and small foci of vasculitis. As we have noted, gradient echo image contrast is controlled by altering the radio frequency flip angle (Ernst angle), the TR, and the TE. By changing these parameters, it is possible to make the gradient echo images resemble T1 weighted images, the proton density images on T2 weighted images, as desired. This is quite confusing. Clear discrimination is made in the spin echo family, whether looking at a T1 weighted image, a proton density image, or a T2 weighted image. In the gradient echo image, the distinctions may not be quite as clear or may not be as clearly noted. However, where fluid is white (such as white CSF or white joint fluid) this is a T2 "like" or as it is referred to, a "T2*" gradient echo image. For "rapid myelographic" or "rapid arthrographic" magnetic resonance imaging, it is quite popular today to use T2* or T2 "like" gradient echo imaging.

Using gradient echo imaging, one can obtain white fluid in much less time than one could with long

TR, long TE, spin echo imaging. It is important to be aware of the fact that gradient echo imaging is very sensitive to motion and must be flow compensated. An artifactual result of this flow compensation is that flowing blood is extremely bright on T2 weighted images whether its velocity is high or not (on images without flow compensation vessels with high velocity are dark and vessels with low velocity are bright).

Another benefit or problem with gradient echo imaging, depending on how one looks at it, is increased sensitivity to metal and iron. This can be quite useful if one is looking for subtle hemosiderin deposits from a previous hemorrhage, but can be quite annoying if one is getting profound metallic artifact from a previously placed surgical pin or foreign body. Gradient echo imaging can be used to advantage to find hemosiderin, multiple cavernous hemangiomas that may have bled, and to confirm whether a previous infarct was hemorrhagic. A severe disadvantage may result from the artifact from metallic clips, surgical wiring, and interbody fusions in the spine. Within the fusion mass there may be microscopic bits of metal from drill bits that can severely degrade the image necessitating another radiologic study.

Gradient echo imaging works well with a technique known as 3D volume imaging. Historically, MR slices were obtained a single slice at a time (multislice imaging). It is now possible to obtain a solid block or cube of information and then slice that data in any plane or along any obliquity desired. From a single 10 minute data set it is now possible to obtain sagittal, coronal, axial, and oblique imaging if one has a sophisticated computer work station. Gradient echo imaging works very well in combination with the above described three-dimensional imaging. One can obtain one millimeter slices from a 3D data set, and one can have white joint fluid or white CSF if the gradient echo technique was a T2* gradient echo technique.

Recently, T1 weighted or T1 "like" gradient echo 3D imaging has been popular for showing morphologic changes such as mass effect or midline shift in the brain. The T1 weighted 3D volume gradient echo images can also be used with gadolinium, the only approved intravenous contrast material for MRI. With a combination of techniques, one can obtain one or two millimeter coronal slices through the pituitary gland to look for pituitary adenomas, or axial one or two millimeter slices through the VII and VIII cranial nerve bundle for acoustic neuroma and axial and coronal one or two millimeter slices through the optic nerve for tumor.

Murray Solomon, MD
Redwood City, California

JULY 1993