In MR imaging, the faster we can scan, the more patients we can complete in a day. Over the years, imaging techniques have evolved, allowing us to scan faster and faster. Gradient Echo (GE) techniques were developed first, substituting a partial flip angle for the first 90° RF pulse and then using gradients instead of a 180° pulse to refocus spins. It is faster to turn a gradient on and off than to execute a 180° RF in a TR period, which is how a Gradient Echo sequence saves time.

The next development was Fast Spin Echo (FSE), allowing us to use multiple 180° RF pulses within each TR period. Each 180° pulse produces an echo, which fills a different line of K-space. This allows us to fill K-space in fewer TR periods, thus making the scan time much shorter. The newest of the “fast” techniques is Echo-Planar Imaging.

Echo-Planar Imaging

Hitachi AIRIS II systems are now capable of Echo-Planar Imaging (EPI) techniques. EPI is a purchasable option with Version 4.2 Software. It is the fastest imaging technique currently available and combines elements of both GE and FSE sequences. This combination of techniques allows us to scan very quickly while maintaining image quality.

EPI is a Spin Echo technique; therefore, 90° and 180° RF pulses are executed within each TR period. After the 180° RF pulse, multiple, rapid oscillations of the frequency gradient form numerous echoes. Every echo is encoded differently by the phase encode gradient, which oscillates in conjunction with the frequency gradient. This places each echo in a different line of K-space, filling K-space very quickly—so quickly in fact, that K-space is filled in as little as two TR periods. Remember the faster we fill K-space, the shorter the scan time will be.

While multiple echo formation is the cornerstone of EPI sequences, shot number is also an important parameter. A shot number is the number of RF excitations (or TRs) that are necessary to fill K-space for one slice. Shot
number equals the Phase Encoding steps divided by the Echo Factor. For example, if we choose 192 phase encoding steps and a shot number of 4, our echo factor will be 48. Therefore, it will take four TR periods to fill K-space. The smaller the shot number, the faster the scan time.

Clinical applications of EPI include rapid screening exams on highly anxious patients, pediatric cases and Diffusion-Weighted Imaging that is based on the EPI pulse sequence.

**Diffusion-Weighted Imaging**

Building on an EPI pulse sequence, Diffusion-Weighted Imaging (DWI) is capable of detecting ischemic changes in tissue shortly after an episode. For this reason, DWI techniques are a very powerful imaging tool.

The microscopic motion of water molecules (diffusion) occurs in normal brain tissue. When an ischemic attack occurs, the cells within the damaged brain tissue absorb the water molecules from the extra-cellular spaces, causing swelling. The water molecules become trapped within the swollen cells; therefore, diffusion in the damaged tissue is greatly decreased.

In order to detect this decreased level of diffusion, Motion Probing Gradients (MPGs) are applied to a SE-EPI pulse sequence. One is applied before, and one after, the 180° RF pulse. MPGs can also be applied to different gradients or combination of gradients in order to visualize molecules diffusing in different directions, since diffusion occurs randomly in many directions.

The degree of motion a DWI scan is sensitive to is determined by its “b-factor.” The higher the b-factor, the more sensitive it is to smaller degrees of motion. The characteristics of the motion probing gradients determine the b-factor. A change in the amplitude, duration or interval of these MPGs will change the b-factor.

The MPG’s ability to detect motion, or the lack thereof, also presents a problem. DWI sequences are very susceptible to patient motion due to these gradients. To compensate for this increased sensitivity to motion, the patient’s head needs to be fully immobilized, and this is accomplished with the use of the supplied head restraint device. Along with restraining the head, it is also necessary to use peripheral gating to diminish artifacts from flow and cardiac motion. In addition, a navigator echo is acquired at the beginning of the pulse sequence. The navigator echo is an extra echo acquired whose phase can be compared to a later echo. By doing this, phases introduced to an image that are not related to diffusion, patient motion for example, can be eliminated.

The resultant Diffusion-Weighted image is one that may not be very pleasing to the eye. Keep in mind that a Diffusion-Weighted image is used to image molecular motion. With DWI, signal to noise is no longer the key; it is contrast to noise that is the goal.
Clinically, DWI is useful in detecting stroke and for imaging lack of diffusion in other parts of the anatomy. It will also be helpful in differentiating active versus chronic MS plaques and for diagnosing cyst versus tumor.