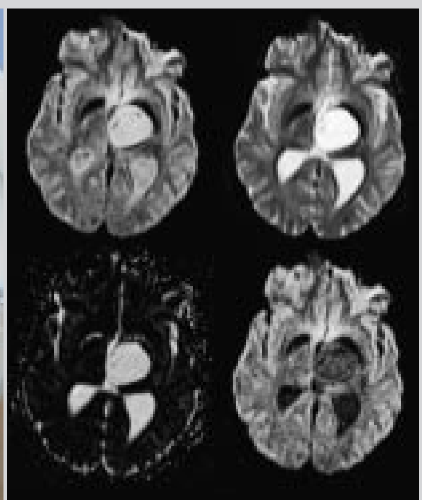
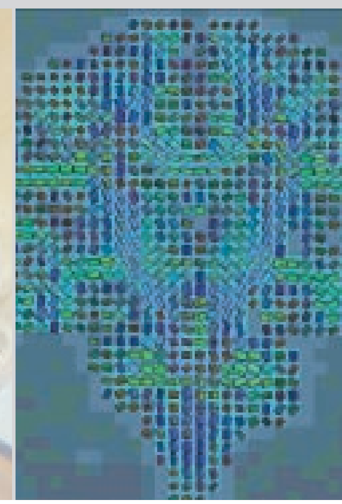
Innovative Applications



MAGNETOM Maestro Class

Diffusion Weighted MRI of the Brain

SIEMENS

medical

Diffusion Weighted MRI of the Brain

Introduction

Stroke disease is among the most prevalent diseases in the world. It affects approximately 750,000 new patients per year in the US. Approximately 4 million people survive an initial stroke and live with a reduced quality of life. The annual costs in the alone exceed US $30 billion.

Early and accurate diagnosis of stroke is the key to implementing successful therapy regimes and achieving improved quality of life for survivors. If a stroke is caused by a blood clot and is diagnosed within 3 hours of onset, anticlotting drugs such as tissue plasminogen activator (TPA) can be successfully utilized. Diffusion-weighted MR imaging (DWI), e.g. in combination with perfusion-weighted MR imaging, is a highly sensitive imaging method enabling early detection of cerebral ischemia (within 6 hours of onset). It may be used to assist physicians in determining the severity of the stroke and predicting recovery. ADC maps (Apparent Diffusion Coefficient) permit improved estimation of the age of stroke lesions, enabling a better characterization of events.

Diffusion Weighted Imaging

The rate of water diffusion (based on Brownian motion of water molecules) in all tissues is a direct function of its physiological state, and impacted by many diseases. For example, following strokes and tumors, the rate of water diffusion is altered as compared to healthy tissue. DWI makes it to visualize and measure these rates of diffusion quite often showing significant abnormalities when conventional anatomical MR and CT images do not.

The basic Stejskal and Tanner diffusion sequence is shown in Figure 1.

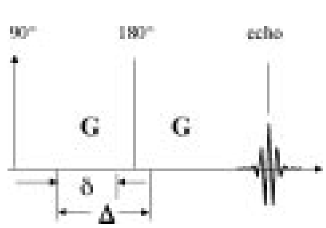


Figure 1: Stejskal and Tanner diffusion weighting scheme. The echoes can be read out using many different imaging schemes. All Siemens diffusion sequences use EPI for speed and decreased motion effects.

If the spins move, e.g. in physiologicalyl healthy cell formations, then the complete echo formation does not occur, and the signal from these spins is "dark". If the spins being imaged do not move in the period encompassing the two opposing gradient pulses (G), the net "dephasing effect" of the gradient pulses cancels out, leading to complete echo formation, and a "bright" image.

In acute stroke, the swelling that accompanies the disruption of blood flow to the tissues and the subsequent cascade of biochemical disruptions causes a marked decrease in the extracellular space, thus limiting diffusion. A DWI of a recent stroke shows the stroke region as bright, while the normal tissues appear dark. The degree of signal attenuation in a DWI approximately follows the simple equation: $^{\exp(-b D)}$, where D is the diffusion constant of the water in the tissue being imaged. The parameter "b" is dependent on the design of the pulse sequence and is proportional to the square of both the strength and the duration of the gradient pulses. High quality diffusion imaging requires a critical combination of gradient requirements: high gradient amplitudes with high slew rates and exceptionally high duty cycles as offered by Siemens Maestro Class MR systems.

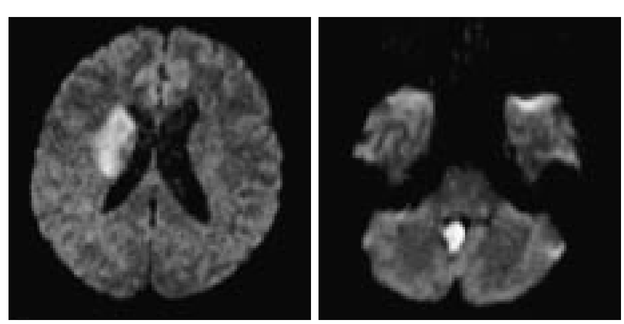


Figure 2: DWI of patients with strokes in the peri ventricular and low skull base regions, acquired on MAGNETOM® Symphony with Quantum gradients. The sequence has been optimized to achieve very short echo spacing, thus limiting susceptibility artifacts. This is achieved using a combination of sampling data on the gradient ramps, and double oblique diffusion gradient encoding, where the diffusion gradients are not applied separately along each axis, but rather obliquely on all 3 axis at the same time. This boosts the strength of the gradient by up to a factor of 1.7, thus allowing a given b value to be applied in less time, decreasing both the echo spacing and the TE.

ADC Map

As diffusion is not the only weighting of a DWI image, very bright objects in a T2 weighted image may appear bright in a DWI and still not be associated with stroke. This is called "T2 shine trough". One way around this problem is to acquire images with two or more b values, use the attenuation equation $^{\exp(-b D)}$, and calculate D at every point in the image. This is the ADC map and effectively removes T2 shine through.

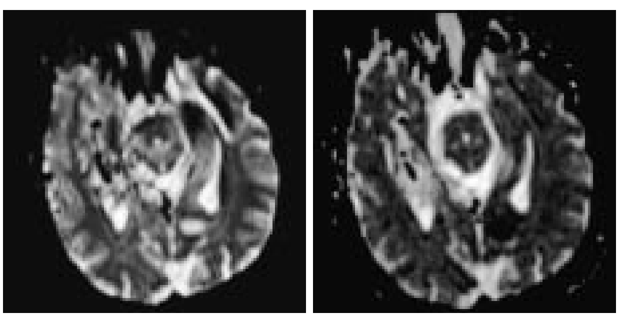


Figure 3:
The image on the left is a conventional diffusion image of a stroke acquired on MAGNETOM Sonata. The image on the right is an ADC map of the same patient. With Siemens Maestro Class systems, the diffusion images and the ADC map can be immediately viewed and evaluated, since they are generated in real-time mode during the acquisition with Inline Technology. This Inline processing capability has great advantages over conventional of post-processing approaches.

Stroke Diagnosis

The recommended protocol for MR stroke diagnotics involves acquisition of diffusion-weighted images and ADC maps, both of which should be acquired with multiple diffusion directions, i.e. isotropically. The b values are important, a trial value could be 1000 mm^2/s. To differentiate acute from sub-acute or chronic ischemia, the ADC map permits relative determination of the age of the lesions. DWI in combination with perfusion imaging (capillary blood flow) allows for definition of the tissue at risk (penumbra), i.e. reduced blood flow but still vital cell formations.

Tensor Imaging

It is overly simplistic to assume that diffusion is fully isotropic, i.e. the same in all directions. This becomes very clear when comparing DWI images with diffusion gradients applied in different directions. It is also clear when DWI are acquired with very high b values. In order to take better account of the anisotropic nature of the diffusion phenomenon, we need to introduce the diffusion tensor, D, the 6/12 independent components of which can be measured by 6/12 different image acquisitions with diffusion gradients applied in 6/12 different orientations. From this data we can calculate the three "principal" axis of diffusion ($\lambda_1, \lambda_2, \lambda_3$,) in each voxel of the image. This is called tensor imaging.

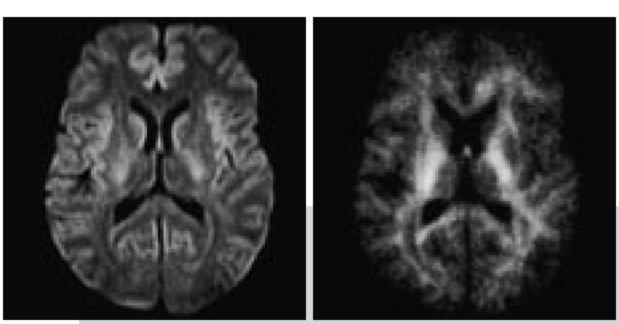


Figure 4:
The image on the left is a b=1000 mm^2/s DWI of a stroke, while the image on the right is b=4000 mm^2/s of the same lesion. Both were obtained on MAGNETOM Symphony with Quantum gradients.

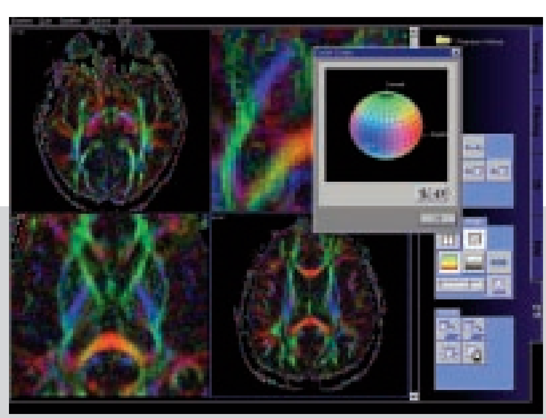


Figure 5:
The syngo MR Diffusion Tensor Imaging Task Card (works in progress). Color representation of diffusion information in 3D gives additional information on Morphology and Pathology and on how white matter and cells are affected by certain diseases and can be used as a basis for fiber tracking in the brain.

Maestro Class Inline Technology

Inline Technology, uniquely introduced in the MAGNETOM family, is defined as the fully automated way of image processing for real-time data acquisition, including multiple parametric calculations. The Inline Technology of *syngo* MR also simplifies operations for diffusion imaging, ADC maps, and neuro perfusion. This new, automated feature provides the reviewing physician the benefit of instantly viewing the calculated results directly while scanning. This significantly enhances the diagnostic process with accelerated speed and more reliable diagnosis.

Figure 6 shows the *syngo* MR Diffusion Inline card. Just a few mouse clicks are necessary to get to the results. Up to 16 b values with a maximum b value of 10,000 mm^2/s may be selected.

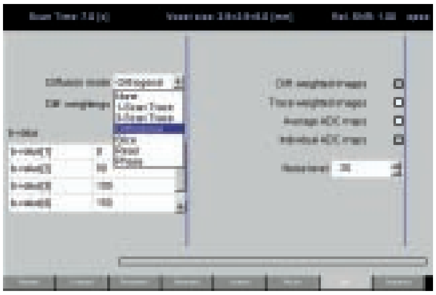
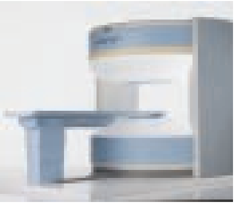


Figure 6:
syngo MR Diffusion Inline card

Figure 7 shows the *syngo* MR examination task card. The task card allows the selection of automatic ADC calculation with one single mouse click.

Figure 7:
syngo MR examination task card

MAGNETOM Family

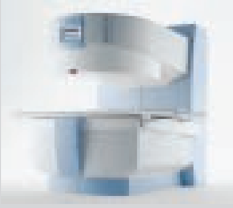


MAGNETOM Rhapsody
Open Class

MAGNETOM Symphony
Maestro Class

MAGNETOM Allegra
UHF Class

All products of the MAGNETOM Family allow diffusion weighted imaging



MAGNETOM Concerto
Open Class

MAGNETOM Harmony
Maestro Class

MAGNETOM Sonata
Maestro Class

MAGNETOM Trio
UHF Class

0.2 | 1.0 | 1.5 | 3.0 | Tesla

Due to increased SNR and higher resolution the products of the Ultra High-Field Class are especially suitable for diffusion weighted imaging.

Integrated Parallel Acquisition Techniques (iPAT)

Parallel acquisition techniques have been significantly improved by Siemens. iPAT together with highest gradient performance, stands for ultra high-speed acquisition in MR.

Siemens has implemented two types of algorithms. mSENSE, an improved version of SENSE, is an image based algorithm, whereas GRAPPA, an improved version of Auto-SMASH, is a k-space based algorithm. This increases flexibility for certain applications, e.g. ultra fast EPI. iPAT is fully compatible with the Integrated Panoramic Array (IPA) coil concept and allows PAT factors up to 4.

iPAT now incorporates a new feature – auto calibration. Conventionally, the coil sensitivity profile is measured in a separate pre-scan, adding approx. 1 minute to each image acquisition. With auto-calibration, this measurement is integrated into the image acquisition, thereby adding only 1 second or less to the overall process.

Clinical benefits are ultra high-speed acquisition, higher resolutions, and reduced image artifacts.

CAUTION

Laser Radiation
do not stare into beam

PEAK POWER <3mW
WAVE LENGTH 540-700nm
CLASS II LASER PRODUCT

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