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MAGNETOM Flash

An Applications Reference for Siemens Magnetom Users

MR Technologists Seminar 1997

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The Siemens MR Technologists Seminar was held May 1-3, 1997, in sunny San Diego, CA, at the Hyatt Islandia Hotel on Mission Bay. Not only did we have a beautiful view, but we enjoyed a fun filled and information packed three days. Attendants earned 12 Category A Continuing Education Credits from the American Society of Radiological Technologists (ASRT).

Joining us this year were two international MR technologists, Danny C.W. Leung from Hong Kong Adventist Hospital and Yolanda Jauregui from Hospital De Galdacano, Bizkaia, North Spain. In fact, this is the second year in a row for Yolanda (thanks)!

The educational program was opened by Mike Coles, R.T., R(MR), from Siemens MR Applications Group in San Francisco, CA, who presented a great review of neuro anatomy and pathology.

Mary Ellen Bentham, R.T., R(MR), from Shands Hospital in Gainesville, FL, shared a lot of good ideas about making the MR experience as comfortable as possible for her patients, thereby reducing the number of patients that cancel the exam due to claustrophobia. She made some noteworthy points regarding patient throughput, especially to ensure that the scan protocols are prepared before the patient is on the table.

Ann Fulcher, M.D., from Medical College of Virginia in Richmond, VA, presented a very informative discussion of abdominal imaging. She featured the new technique MR Cholangiopancreatography (MRCP) which is beginning to compete favorably with the more conventional technique Endoscopic Retrograde Cholangiopancreatography (ERCP). Dr. Fulcher believes that she can get more information from an MRCP than an ERCP, and it is certainly much more comfortable for the patient. Some of the advantages of MRCP over ERCP include: no contrast, no intervention, no radiation, no sedation, and very short scan times.

Kostaki G. Bis, M.D., from Beaumont Hospital in Royal Oak, MI, brought us up-to-date on what is happening in the world of cardiac MR. He believes there are many good applications for cardiac MR, including congenital heart disease, tumors, thrombi, pericardial disease, valvular disease, myocardial disease, coronary angiography, and aortic dissection. Dr. Bis is optimistic that cardiac MR will soon be a one-stop shop for cardiovascular disease.

Susan Ascher, M.D., from Georgetown University in Washington, DC, reviewed the latest concepts in breast MR for both implants and breast lesion detection. It was really interesting to note that surgeons do not always use the same kind of implant material for both breasts. Dr. Ascher stressed the need for an accurate history and a dedicated breast coil. She also feels that, in certain cases, breast MR can be a useful tool for evaluating breast parenchyma.

Nouha Salibi, Ph.D, from Siemens MR Applications Group in St. Louis, MO, and Kevin Johnson, R.T., R(MR), from Abbott Northwestern Hospital in Minneapolis, MN, and Bill Leon, R.T., R(MR), from HealthSouth Doctors Hospital in Coral Gables, FL, presented reviews of the basics of flow quantifications, single voxel spectroscopy (SVS), and chemical shift imaging (CSI). Their excellent presentations made these difficult subjects seem very understandable. Their reviews of numerous clinical examples included cases in which the radiation treatment of brain tumors was followed by spectroscopic evaluations pre- and post-treatment. They believe these techniques are at the cusp of becoming part of the clinical MR routine.

Paul Sohlden, R.T., R(MR), from MRI Scan Center in Ft. Lauderdale, FL, shared with us his insightful views on open bore low field MRI with the MAGNETOM Open system.

Steve Eilenberg, M.D., from Tri-City Medical Center in Oceanside, CA, gave a clinical presentation on his optimized approach to orthopedic MRI with the MAGNETOM Vision system.

Alan DiGiovanne, R.T., R(MR), from Siemens MR Applications Group in Philadelphia, PA, talked about the theory and clinical applications of echo planar imaging (EPI) with the Gradient Overdrive option on the MAGNETOM Vision system.

The educational program was completed by Michele Kessler, Manager of the Siemens MR Applications Group in Iselin, NJ, who shared with us the future directions for Siemens' MR products and applications support.

Of course this year's meeting was not all work with no play. Friday evening we had an energetic volleyball game on the beach, followed by a barbecue dinner and dancing. It was amazing how much energy some people could burn after a hard day at the "office" (hey, you know who you are)!

Next year's meeting will be somewhere in the Eastern U.S., again in the Spring. If you have any comments or suggested topics for that meeting, please call us at the MR Applications Helpline (Phone 800-333-3137).

Figure 1. International MR technologists included Danny C.W. Leung from Hong Kong Adventist Hospital and Yolanda Jauregui from Hospital De Galdacano, Bizkaia, North Spain.

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Upcoming Meetings And Seminars 1997

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Oct 11: 1997 SMRT Fall Regional Educational Seminars, Dallas, TX, USA, Phone 510-841-1899

Oct 18: 1997 SMRT Fall Regional Educational Seminars, Springfield, IL, USA, Phone 510-841-1899

Nov 1: 1997 SMRT Fall Regional Educational Seminars, Portland, ME, USA, Phone 510-841-1899

Oct 7-11: Introductory Course & IX International Workshop on MR Angiography: New Horizons in MRA and CTA, Valencia, Spain
Phone 011-34-6-352-2727, http://www.mrangio97.com

Oct 16-19: 9th Annual Advances in Mid & Low Field MRI, Orlando, FL, USA
Phone 800-338-5901, http://www.edusymp.com/serv0297.htm

Oct 17-18: 2nd Interventional MRI Symposium, Duesseldorf, Germany
Phone 011-49-211-811-7752/8767, http://www.mr.uni-duesseldorf.de

Oct 27-29: ISMRM Fast MRI Workshop: Methodological Perspectives & Advances in Cardiac, Neuro, Angiography, & Abdominal Imaging, Monterey, CA, USA
Phone 510-841-1899, http://www.mri.jhu.edu/ismrm_mirror/fastmri/

Oct 27-31: MRI/CT Update: Body & Neuro Imaging, Harvard Medical School, Boston, MA, USA
Phone 617-432-1525, http://www.feltco.com/hmscme/data/71048.htm

Nov 17-21: MR Imaging Concepts & Applications, Siemens Training Center, Cary, NC, USA
Phone 800-813-4531

Nov 30-Dec 4: Radiological Society of North America (RSNA), Chicago, IL, USA
Phone 320-571-7850, http://www.rsna.org/

Apr 18-24, 1998: ISMRM Annual Meeting, Sydney, Australia
Phone 510-841-1899, http://www.ismrm.org/

Clinical Principles of Diffusion Imaging

YURI WEDMID, PHD, HIGH FIELD PRODUCT MANAGER
SIEMENS MEDICAL SYSTEMS, ISELIN, NJ, USA
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Siemens is pleased to announce the Diffusion Imaging Package, now available with software upgrade B31B for ALL MAGNETOM VISION SYSTEMS (with/without Gradient Overdrive). This new MR OPTION is considered by many experts to be the best tool currently available for early assessment of acute stroke. Siemens is the first in the MR industry to make this important clinical application commercially available. Every competitor in the MR industry talks about Diffusion Imaging, but only Siemens "Walks The Talk". Recently, we interviewed several leading experts who have been involved with our development efforts over the past several years to determine their views on the clinical efficacy of Diffusion Imaging.

William G. Bradley, MD, PhD

PROFESSOR OF RADIOLOGY,
UNIVERSITY OF CALIFORNIA
IRVINE

LONG BEACH MEMORIAL
MEDICAL CENTER,
LONG BEACH, CA, USA

Siemens: What is the major message to the medical community regarding Diffusion Imaging?

Dr. Bradley: For the first time we have a way of confirming a diagnosis of stroke in time to treat it with the appropriate therapy. We should get the word out that if your patient has symptoms of stroke, get him to the hospital immediately. If your patient gets a Diffusion Imaging scan early enough, we have a better idea of what is going on. We will be able to look at the actual physiology and have a sense of whether or not the patient would benefit from a thrombolytic agent or if he might be at greater risk of hemorrhage from such an agent. With this new technology we are better able to confirm the diagnosis of early stroke within the first 24 hours, as compared to traditional MR techniques.

Siemens: What is a stroke?

Dr. Bradley: The definition of a stroke is an "acute neurologic event". There are two types of strokes: ischemic and hemorrhagic. About 85% of strokes are ischemic infarcts, which means "no blood". What usually happens is that one of the arteries supplying the brain becomes blocked by a blood clot. If the clot was formed right there, typically due to arteriosclerosis, it is called a thrombosis. Or, as more commonly happens, if the clot was formed elsewhere and becomes lodged at the stroke site, it's called an embolus. Such "embolic infarcts" have a greater chance of secondary bleeding than "thrombotic infarcts".The other type of stroke is frank hemorrhage from a ruptured aneurysm or bleeding from a vascular malformation or from a tumor. We do not know until we start imaging the patient whether he has an infarct or a bleed.

Michael Brant-Zawadski, MD

CLINICAL PROFESSOR OF
RADIOLOGY,
STANFORD UNIVERSITY
MEDICAL CENTER

HOAG MEMORIAL HOSPITAL,
NEWPORT BEACH, CA, USA

Siemens: What images would you use to illustrate the benefits of Diffusion Imaging in the early detection of stroke?

Dr. Brant-Zawadski: I would show the comparison between Diffusion Imaging and more conventional MR techniques, to prove the greater sensitivity of Diffusion Imaging. I would also show MR Angiography (MRA) to demonstrate the blockage of the vessels. The overall beauty of MR is that you not only see the insult in the brain tissue itself, but you also see the cause for it in the blood vessels.

Siemens: What volume of stroke patients do you see at your institution?

Dr. Brant-Zawadski: We see about 150 stroke patients per year, or about 3 per week. We have a major stroke program with advanced imaging as well as clinical research therapeutic programs for treating acute stroke, including intravenous thrombolitic therapy and neuro-protective agent therapy.

David M. Lefkowitz, MD

ASSOCIATE PROFESSOR OF
RADIOLOGY
AND NEUROLOGY,
CREIGHTON UNIVERSITY

ST. JOSEPH HOSPITAL,
OMAHA, NE, USA

Siemens: How does Diffusion Imaging change the way you diagnose and treat stroke patients?

Dr. Lefkowitz: We have been using Diffusion Imaging for almost 2 years now and have scanned over 600 patients. It has really become our routine and preferred means of making the diagnosis of ischemic stroke. It has been apparent for quite some time that Diffusion Imaging is much more sensitive to stroke when it is still hyperacute, ie., within about the first 6 hours. Beyond that 6 hour window, even though you can make the diagnosis with standard MR or CT, it is generally too late to apply any of the acute stroke treatments that are becoming available commercially or on an investigational basis. Within the first 24 hours we find Diffusion Imaging to be extremely valuable simply because it more reliably separates the acute from the chronic ischemic changes. This is not an idle consideration because the pattern of acute ischemia, as has long been recognized from experience with CT and routine MRI,often reveals to us something about the mechanism of the stroke – whether it is an embolic stroke or something related to slow-flow globally, such as heart failure.

Siemens: What role does Diffusion Imaging play in diagnosing complicated clinical cases?

Dr. Lefkowitz: Elderly patients, who are at higher risk for stroke, often have fairly complicated features on their standard MR brain images. It would be impossible with any other imaging modality to pick out a very subtle lacunar infarct against a background that could be extremely complex. We have even been able to make a diagnosis of acute stroke in a person who has had prior brain surgery for a tumor followed by radiation treatment. We were still able to see the small lacunar infarct that explained an acute hemiparesis. This has not been possible without Diffusion Imaging. The more complicated the clinical background and the baseline imaging evaluation, the better Diffusion Imaging performs in comparison to other modalities. If you have a clean baseline scan, then there are certain circumstances where a CT scan or conventional MR scan might compete. But even under those circumstances, the accuracy of Diffusion Imaging within the first 24 hours far exceeds that of other imaging tools.

Steven J. Warach, MD,

ASSOCIATE PROFESSOR OF
RADIOLOGY
AND NEUROLOGY,
HARVARD MEDICAL SCHOOL

BETH ISRAEL DEACONESS
MEDICAL CENTER,
BOSTON, MA, USA

Siemens: What role is being played by Diffusion Imaging in discovering new therapies for stroke?

Dr. Warach: Diffusion Imaging is playing an important role. We are in the middle of a large multi-center clinical trial that is using Diffusion Imaging to determine whether a drug not only makes a patient better but actually reduces the amount of brain damage. Only with Diffusion Imaging can we detect and localize the brain damage before we give the patient the medicine. There are several other clinical trials that are being planned and will start over the next year using Diffusion Imaging. I believe that many drug companies will require that a patient receive Diffusion Imaging to be eligible for a new experimental therapy.

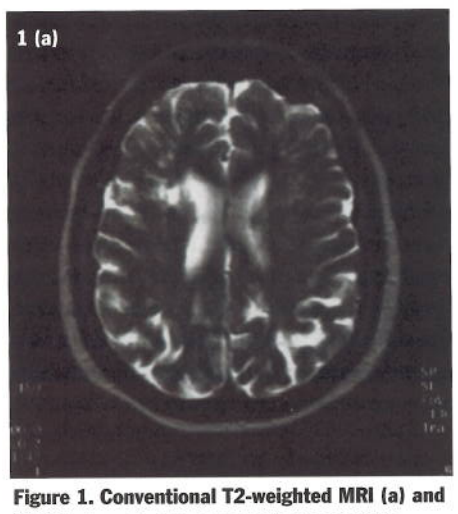
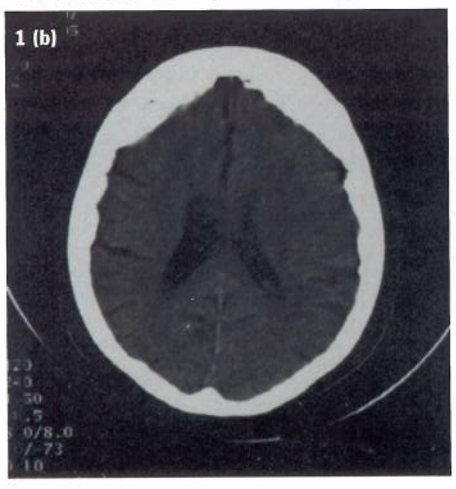


Figure 1. Conventional T2-weighted MRI (a) and CT (b) of acute stroke patient are negative.



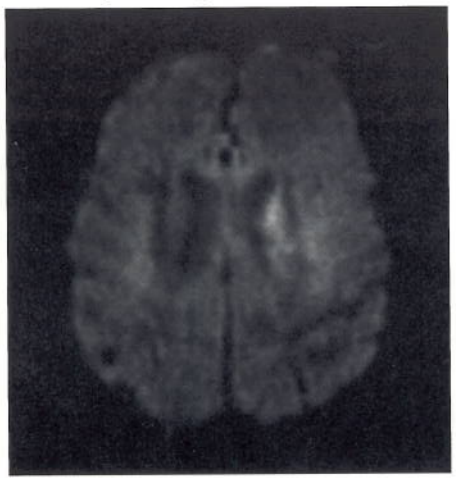


Figure 2. Diffusion Image of acute stroke patient shows the positive "light bulb" sign.

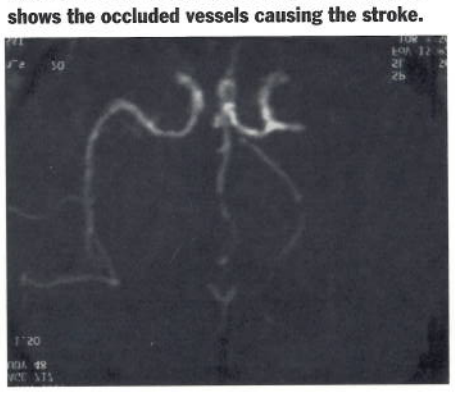


Figure 3. MR Angiogram of acute stroke patient shows the occluded vessels causing the stroke.

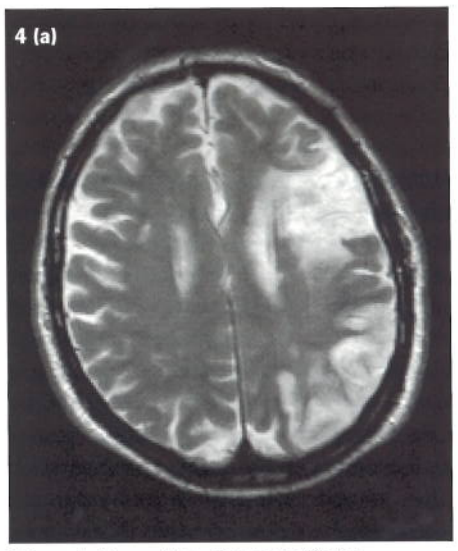
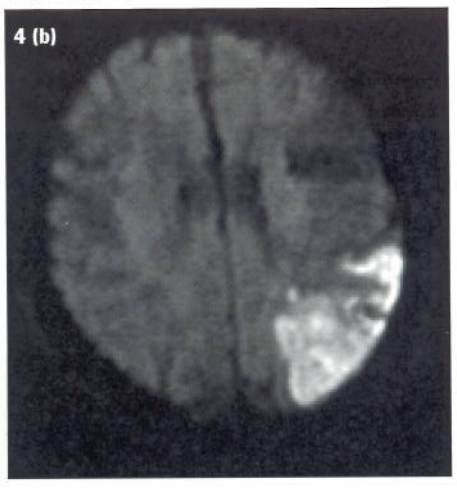


Figure 4. Comparison of a conventional T2-weighted MRI (a) with a Diffusion Image (b) demonstrates the keen ability of Diffusion Imaging to differentiate between acute stroke (bright signal) and chronic stroke (dark signal).



Technical Principles of Diffusion Imaging

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Introduction

Diffusion-weighted MR imaging is a technique for imaging the diffusive mobility of water or other proton-containing molecules. The technique has been shown to be potentially very useful in a number of clinical applications, including acute cerebral infarction. But it has only been with the development of high performance gradient hardware and very rapid imaging techniques that diffusion-weighted imaging has become a practical tool in the clinical setting.

The diffusion of a proton spin in the presence of a magnetic field gradient has long been known to reduce the available MR signal from that spin. Figure 1 shows that as water molecules move randomly through a magnetic field gradient, the degree of phase shift will be different for each molecule. The result of the summation of the signals from molecules with different phases within an imaging voxel is a net loss in signal from that voxel. Magnetic resonance imaging pulse sequences can be designed to take advantage of this behavior. The resulting images have tissue image intensities that depend partially upon the diffusion properties of the water in the tissues

The diffusion properties of materials are usually expressed in terms of the diffusion coefficient, D. It is a measure of the distance a water molecule will move by random diffusion processes in a given amount of time. D is frequently expressed in units of mm^2/s, and the D value for free water at room temperature is approximately 2.0×10^{-3} mm^2/s. D values for brain tissues are approximately in the range 0.5 to 1.0×10^{-3} mm^2/s.

The degree of diffusion sensitivity of an MRI pulse sequence is usually expressed in terms of the diffusion-sensitivity b value. The MR image intensity of a substance with diffusion coefficient D, imaged using a pulse sequence with diffusion-sensitivity b, is

$$I = I_0 \exp(-b\,D) \exp(-TE/T2) \qquad (1)$$

The image intensity therefore varies exponentially with the negative product of b and D. Tissues or materials with higher D values will have lower intensities in diffusion-weighted images. Areas of decreased diffusion coefficient (for example, as is observed in acute cerebral infarcts) appear as areas of higher image intensity. The exponential behavior depending on TE and T2 is included in equation (1) since most pulse sequences with diffusion-weighting will also have significant T2-weighting. I0 is the image intensity if there is no diffusion or T2 weighting. Clinically useful b values of 1000 s/mm^2 or more are readily attained on the MAGNETOM Vision.

Diffusion effects occur in all MRI acquisitions that use imaging gradients. The effect, however, is usually negligible compared to other sources of contrast such as T1 and T2. It is conceptually a very simple matter to modify a conventional pulse sequence so that diffusion effects will dominate the image contrast. The placement of two identical large gradient lobes on each side of the 180 degree refocusing RF pulse in a conventional spin-echo pulse sequence can add a considerable amount of diffusion-weighting to the resulting images. The diffusion sensitivity value b for this scheme can be calculated from

$$b = g^2 g_d^2 L^2 (S - L/3) \times 10^{-15} \quad \text{(in units s/mm2)} \qquad (2)$$

where g = 268000 Radians/seconds/mT, g_d is the strength of the diffusion gradient in mT/m, L is the length of each of the two gradient pulses in milliseconds, and S is the center-to-center spacing of the two gradient pulses in milliseconds. The implementation of this scheme with conventional spin-echo pulse sequences has a serious drawback; the sequence is also very sensitive to all other sources of motion. This problem can be avoided, however, by adding diffusion-weighting to a very fast imaging technique such as Echo Planar Imaging (EPI).

Diffusion-weighted Single-shot Echo Planar Imaging

Siemens is pleased to announce the Diffusion Imaging Package, now available with software upgrade B31B for the MAGNETOM Vision system. Diffusion sensitivity is added to the basic spin-echo type EPI pulse sequence by applying a large magnetic field gradient pulse before the 180 degree refocusing RF pulse and an identical gradient pulse after the 180 degree RF pulse, as shown in Figure 2. The use of the single-shot EPI technique allows the acquisition of a single diffusion-weighted image in approximately 200 ms. This short acquisition time reduces or eliminates image artifacts due to sources such as patient motion or due to physiological processes such as CSF pulsatility. The effective echo time (TE) of the pulse sequences, which determines the degree of T2-weighting in the images, ranges between 103 and 123 ms for the various available pulse sequences.

Also included in the optional Diffusion Imaging Package are diffusion-weighted EPI pulse sequences that acquire multiple images at each slice position with the diffusion-sensitizing gradient applied in three different directions: along the slice-select, read-out, and phase-encoding directions. In tissues with an inherent structure that results in different diffusion properties in different directions, the contrast in these three images will be different. For example, white matter nerve tracts will appear darker in diffusion-weighted images when the diffusion gradient is aligned with the tracts (the easiest direction for diffusion to occur) than when the diffusion gradient is applied perpendicular to the nerve tracts (Figure 3). These pulse sequences also generate an EPI image with negligible diffusion-weighting at each slice position, but that has the same T2-weighting as the diffusion-weighted images. This provides a comparison image for helping to differentiate diffusion effects from T2 effects in the diffusion-weighted images.

Artifacts in Diffusion-weighted EPI Images

The most serious drawback of the EPI-based diffusion-weighted pulse sequences is a consequence of using the EPI technique. Echo planar imaging is very sensitive to magnetic field inhomogeneities, and images are distorted wherever susceptibility effects cause field inhomogeneities. In the head, distortions are particularly noticeable at the air-tissue interfaces of the sinus cavities and at the base of the brain. In addition to distortions, magnetic susceptibility changes at boundaries can also result in hyperintense signal from those regions. These artifacts are usually recognizable, but in some situations might obscure pathology.

EPI-based diffusion-weighted imaging is also sensitive to the effects of eddy currents. The very large diffusion gradients (20 mT/m or more gradient strength for 30 milliseconds or longer) are capable of generating much larger eddy currents than are typically generated in conventional image acquisitions. EPI is also unusually sensitive to the presence of eddy currents because of the technique's inherently low bandwidth in the phase encode direction. Diffusion-weighted images can be shifted and distorted in the phase encode direction to varying degrees depending upon the direction of the diffusion gradient and the effectiveness of eddy current compensation. Another problem that the eddy currents can cause is incomplete suppression of the signal from fat. When fat is not properly suppressed in a diffusion-weighted EPI acquisition, the fat image will appear quite bright and will be displaced with respect to the water image by about one-quarter of the field of view.

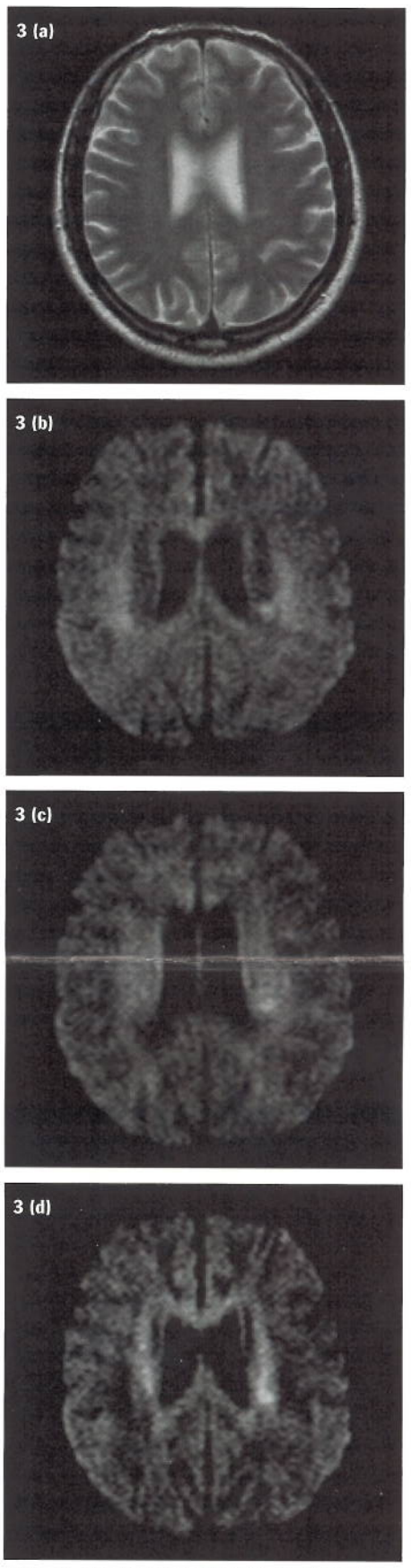

Figure 3. (a) Negative T2-weighted MRI imaged at <24 hours after onset of symptoms (exact time unknown) was also negative on CT. Positive diffusion-weighted images of same patient are encoded in three separate directions to demonstrate the importance of viewing all three images to distinguish lesions from anisotropy of brain tissues: (b) slice-select, (c) readout, (d) phase-encoding directions.

Further Reading

1. *Le Bihan D, et al. Diffusion MR Imaging: Clinical Applications. AJR 1992; 159:591-599.*
2. *Warach S, et al. Acute Human Stroke Studied by Whole Brain Echo Planar Diffusion-Weighted Magnetic Resonance Imaging. Ann. Neurol. 1995; 37:231,241.*

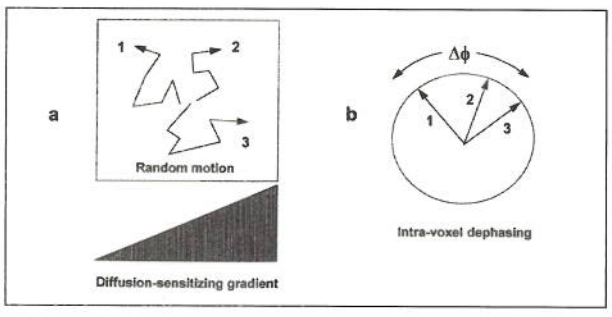

Figure 1. (a) Random motion of spins within a voxel due to diffusion. (b) The resulting intra-voxel dephasing that causes signal loss.

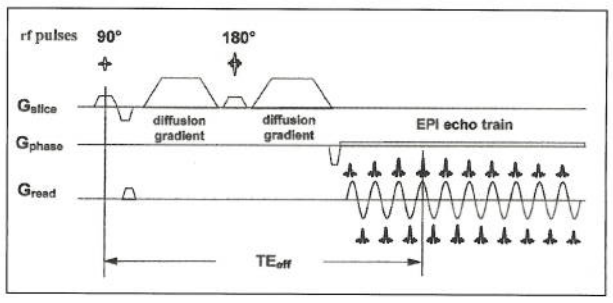

Figure 2. Diffusion-weighted single-shot EPI pulse sequence with diffusion sensitivity in the slice-select direction.

Comprehensive Cardiac Imaging Package

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SIEMENS MEDICAL ENGINEERING, ERLANGEN, GERMANY
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Introduction

Siemens is pleased to announce the Comprehensive Cardiac Imaging Package for the MAGNETOM Family (now available with software upgrade B31B for the MAGNETOM Vision/ Plus, Impact Expert/Plus, as well as the new Symphony and Harmony systems). Developed together with clinical sites worldwide, this advanced cardiac package offers a number of general classes of measurements which allow you to acquire both anatomical and functional cardiac information in a one-stop exam.

Cardiac Morphology

A variety of pulse sequence types are now available with a magnetization preparation pulse that nulls the signal from flowing blood within the ventricles and great vessels. This dark-blood pulse, in combination with cardiac triggering and respiratory breath-hold, allows fully motion artifact-free morphological cardiac imaging.

High resolution T1-weighted Turbo Spin Echo (TSE) sequences with the dark-blood pulse provide strong contrast between the myocardium, the blood pool, and the surrounding soft tissues for optimal assessment of aneurysms, dissections, masses, and myocardial infarctions (Figure 1).

High resolution T2-weighted TSE sequences with the dark-blood pulse provide excellent lesion conspicuity and tissue characterization. TSE sequences minimize the scan time compared to conventional Spin Echo, thus allowing the acquisition of a single slice position within a comfortable breath-hold of typically less than 18 heart beats (Figure 2).

Turbo Short Tau Inversion Recovery (Turbo STIR) sequences with the dark-blood pulse provide fat suppressed T2 like images, thus making this technique particularly useful to detect edema and inflammation of myocardial tissue. The Turbo STIR sequence also acquires a single slice position in a comfortable breath-hold (Figure 2).

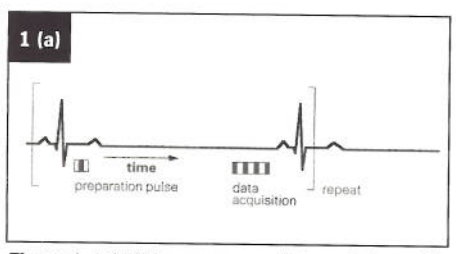
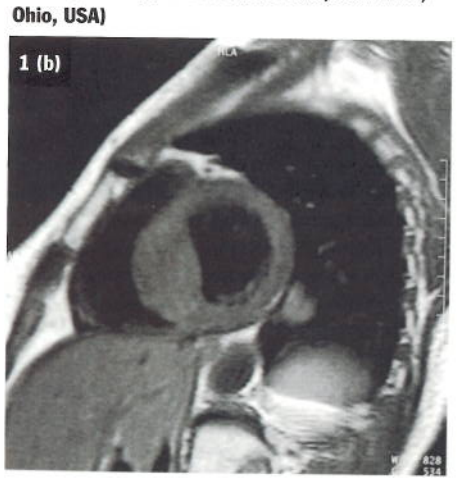


Figure 1. (a) TSE sequences which are triggered on every heart beat will produce static T1-weighted images of the heart in diastole. (b) T1-weighted TSE visualizes anatomy of the heart. (Courtesy of Cleveland Clinic, Cleveland, Ohio, USA)



Half Acquisition Single Shot Turbo Spin Echo (HASTE) sequences with the dark-blood pulse can acquire a single T2-weighted image in as short as 300 ms, which is fast enough to "freeze" respiratory and cardiac motion when acquired in diastole. Although this technique is useful when the patient cannot hold his breath, it provides less spatial resolution than the TSE techniques.

Cardiac Function

Comprehensive assessment of cardiac function must include both qualitative as well as quantitative information. The Siemens Comprehensive Cardiac Imaging Package provides both with a shared-echo segmented K-space technique that acquires a complete cine study at a single slice position with a temporal resolution of less than 50 ms, all in a breath-hold. Consecutive slice positions are acquired in consecutive breath-holds with this gradient echo technique which demonstrates bright blood signal due to inflow effects.

Qualitative assessment of heart function includes the cine display of valve motion, valvular stenosis, and regurgitation or coarctation which causes turbulent flow to be seen as signal void.

Quantitative assessment includes the quick and easy calculation of ejection fraction, stroke volume, systolic and diastolic volumes, cardiac output, and regional myocardial wall thickness by use of the new ARGUS cardiac evaluation package with auto-segmentation of myocardial and ventricular contours.

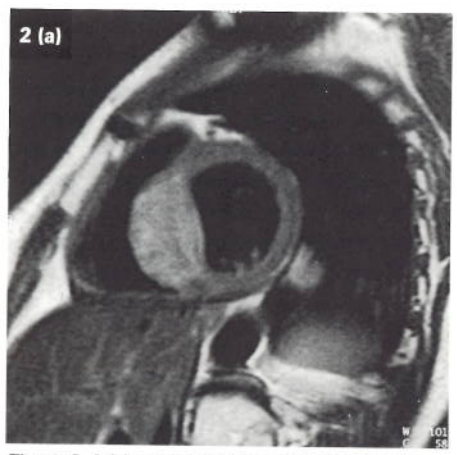
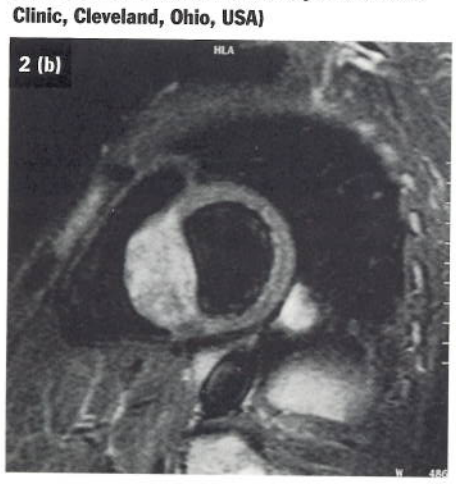


Figure 2. (a) For T2-weighting, the data acquisition will be triggered on every second or third R-wave to result in a longer TR. T2-weighted TSE visualizes metastatic tumor in ventricular septum. (b) Turbo STIR technique is helpful to show edema or inflammation. (Courtesy of Cleveland Clinic, Cleveland, Ohio, USA)



MR Angiography

Visualization of the complex flow patterns in the heart and throughout the cardiovascular system are provided by new cardiac triggered, breath-hold 2D and 3D Time-of-Flight (TOF) techniques for abdominal and thoracic MR Angiography (MRA) as well as a new 3D Navigator technique for proximal coronary MRA in cooperative patients. Vascular abnormalities such as aortic dissections and aneurysms can be non-invasively visualized, thus providing significant additional information to complement parenchymal exams.

Typically a 2D TOF technique is used to acquire single cross-sections of the vascular anatomy. However, when this technique is combined with cardiac triggering and respiratory breath-holding for proximal coronary artery imaging, both single and double oblique slices are acquired along the right atrioventricular and interventricular grooves to visualize the right coronary artery (RCA) and left anterior descending artery (LAD).

A new 3D Navigator technique, available only for the MAGNETOM Vision, allows visualization of the proximal coronary arteries in cooperative patients. This technique simultaneously acquires the imaging data with a 3D volume scan and detects the diaphragm position with a 1D navigator pulse incorporated into the same sequence. The diaphragm position is then used to retrospectively gate the imaging data, thereby significantly reducing respiratory motion artifacts. Multi-Planar-Reconstruction (MPR) can then be used to identify areas of interest (Figure 3).

A new 3D breath-hold MRA technique can be used to acquire high-resolution volume data sets of most cardiovascular anatomy (except coronaries). Vascular contrast is created by the administration of a contrast agent (such as Gadolinium) which reduces the T1 relaxation time of the blood (Figure 4). See the article entitled "Optimized Breath-Hold 3D MRA" by Shetty, et al, in the MAGNETOM Flash, Vol 5, No. 2, June 1997.

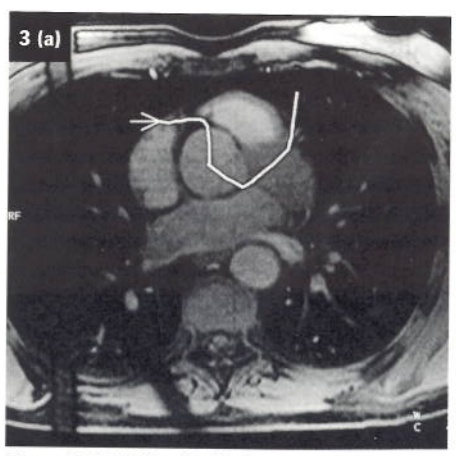


Figure 3. (a) Using the Navigator technique, a 3D data set of the heart is acquired in just 11 minutes. (b) Post processing along a curved cut (using MPR) visualizes the coronary arteries and allows appreciation of an RIVA stenosis. (Courtesy of University of Bern, Switzerland)

Flow Quantification

MR techniques which are sensitive to flow may be used to both visualize and quantify blood flow velocity; anatomical and flow information are provided simultaneously (Figure 5). Flow Quantification sequences are available in 1D (RACE), 2D , and 3D formats. The optimized velocity factor (VOPT), also known as the velocity encoding factor (VENC), ranges from 2 cm/sec (CSF flow) to 500 cm/sec (aortic coarctation). The quantitative flow analysis software provides a quick and easy quantification of flow velocities in the vessel of interest.

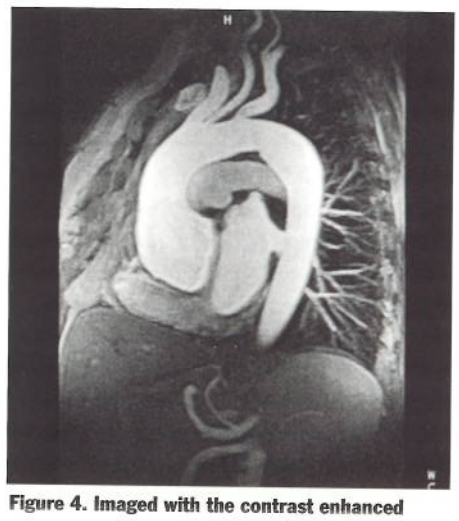


Figure 4. Imaged with the contrast enhanced 3D breath-hold MRA technique, this patient with Marfan Syndrome demonstrates a dilated aorta. (Courtesy of William Beaumont Hospital, Royal Oak, Michigan, USA)

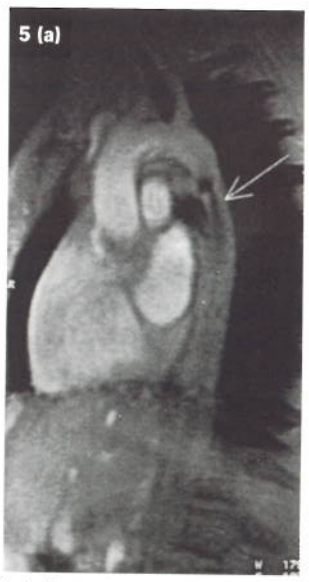
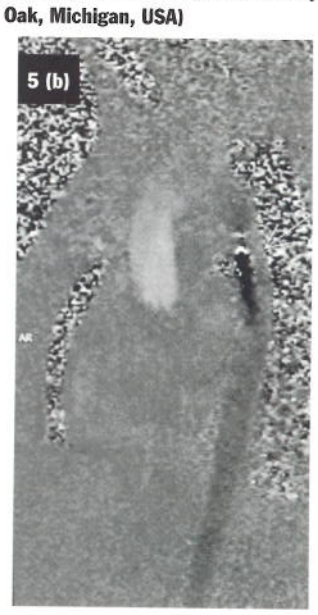


Figure 5. Patient with aortic coarctation. Gradient Echo cine images show region of signal void. (a) Magnitude image. (b) In-plane velocity encoded phase image visualizes turbulent blood flow. (Courtesy of William Beaumont Hospital, Royal Oak, Michigan, USA)



Hooks and Loops

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What is the least favorite exam you must perform on the Siemens MAGNETOM Open/Viva MRI system? We used to cringe when we had to image a thoracic spine. We experienced "hooks and loops" and we never knew just where they would show up. Invariably, the "loops" would cover part of the spine needed for counting vertebral bodies. The "hooks" would show up in the vertebral bodies in the middle of the image. We tried ECG triggering, no triggering, more presaturation bands, presaturation bands in an X configuration. All these tricks met with limited success.

We felt the quality of this exam was not up to our standards and kept working and asking questions to improve the thoracic spine exam. After all of the things failed that typically did work on the high field system, we decided to take another approach. We investigated some of the new features we recently acquired with the latest software update B31B. We made changes in presaturation bands, RecFOV, and phase oversampling.

We were impressed with our findings. We eliminated the "hooks and loops." The improvements in image quality were so marked that we have implemented the changes in other spine work that we do.

For the sagittal view (Figure 1):

1. Place an 80 mm thick coronal presaturation band just anterior to the spine. You don't need to presaturate the entire lung field and anterior chest wall. The decrease in number and thickness of the presaturation bands will make them more effective.
2. Swap the phase and readout directions such that phase-encoding is "superior/inferior". This throws aortic motion artifacts along a "superior/inferior" orientation to completely miss the spine.
3. Use RecFOV 7/8 with 75% matrix. This gives sharp image resolution with decreased acquisition time and, thus, less patient motion.
4. Use 100% phase oversampling and click on readout oversampling. This will both increase the signal-to-noise ratio (SNR) and prevent wrap (aliasing) artifacts.

For the transverse view (Figure 2):

1. Eliminate the presaturation band to give either more slices or a lower TR. We use a TR of 460 ms on Post-Gadolinium studies.
2. Swap the phase and readout directions such that phase-encoding is "left/right." This will move the motion artifacts created by the aorta into a "left/right" orientation which is completely out of the spine rather than an "anterior/posterior" orientation which goes through the spine.
3. Use RecFOV 6/8 with 75% matrix.
4. Use 80% phase oversampling and click on readout oversampling.

Try adjusting the number of Acquisitions (averages) to maintain approximately the same SNR you had before making these changes. These changes have cleaned up the "hooks and loops" artifacts that we had experienced with the large 45 cm flex coil and when using large fields of view with the body coils.

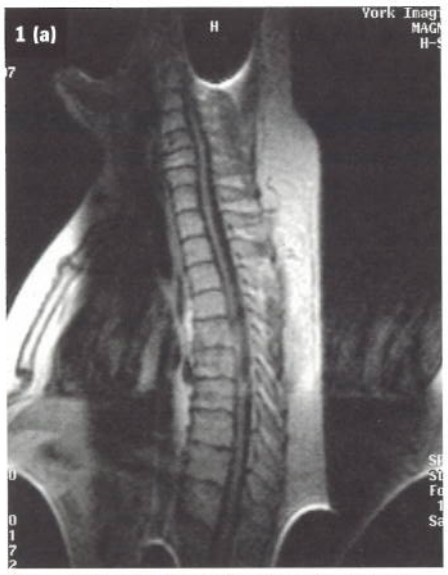
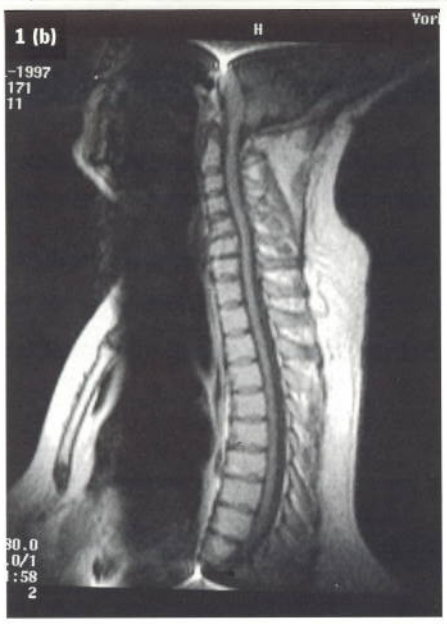


Figure 1. Sagittal thoracic spine with old technique (a) and with new technique (b).



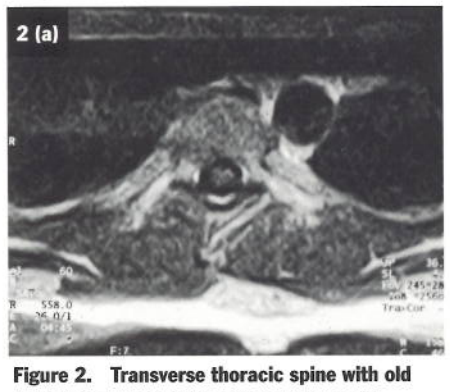
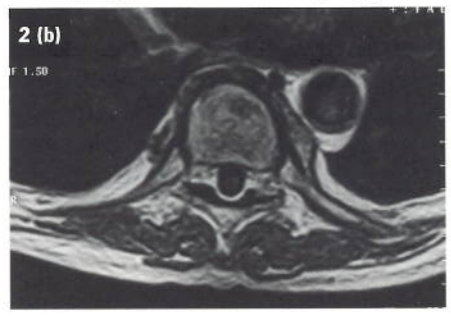


Figure 2. Transverse thoracic spine with old technique (a) and with new technique (b).



Clinical Protocols for 512 Imaging on the Magnetom Open/Viva

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	T1 Sagittal Lumbar	T2 Transverse Lumbar
Sequence	se_15b78.uhc	tse7_96b65.uhc
TR	460 ms	5000 ms
TE	15 ms	96 ms
Flip Angle	90 deg	180 deg
FOV	280 mm	360 mm
RecFOV	6/8	5/8
Matrix	192 x 512, o	168 x 512, o
Phase OS	0 %	42 %
Slices	11	25 (5 groups of 5)
Thickness	5 mm	5 mm
Acq	6	3
Dist Factor	0.25	0.20
Presat	1 anterior	1 anterior
Raw Filter	Weak	Weak
GOP Filter	15	15
Time	8:53 min	8:36 min

	T1 Sagittal Knee	T2* Coronal Knee	Isotropic 3D Knee
Sequence	se_26b39.uhc	fl2d_25b30.uhc	de3d_12b65.uhc
TR	912 ms	952 ms	41 ms
TE	26 ms	25 ms	12 ms
Flip Angle	90 deg	35 deg	40 deg
FOV	180 mm	260 mm	256 mm
RecFOV	6/8	5/8	5/8
Matrix	192 x 512, o	160 x 512, o	160 x 256, o
Phase OS	43 %	40 %	0 %
Slices	19	17	72 (22 % Part OS)
Thickness	4 mm	4 mm	72 mm Slab
Acq	2	2	1
Dist Factor	0.20	0.20	contiguous
Presat	none	none	none
Raw Filter	Weak	Weak	none
GOP Filter	15	15	15
Time	8:24 min	7:09 min	9:38 min

No Latex with MAGNETOM Systems

Latex is not used in the MAGNETOM MRI systems from Siemens, neither in the coils, coil cables, nor any cushions or any other patient positioning material.

The only exceptions are the 'MRinnervu' disposable endorectal coils from MEDRAD Inc., Pittsburgh, PA, USA, which contain a latex balloon at the coil's tip. This is mentioned as a warning hint in the 'MRinnervu Operating Instructions' by MEDRAD Inc.

TRAINING AND EDUCATIONAL MATERIALS

While supplies last, additional copies of these educational materials may be purchased from the MR Enhance Program (800-334-4066)

TITLE	FORMAT
Basic Principles of MRI	Video
MR Imaging Parameters	Video
Magnetic Zone (safety)	Video
Ultrafast MR Imaging	Video
MAGNETOM CP Coils	Video
NUMARIS Vision B31 Software	Video
NUMARIS Impact B31 Software	Video
NUMARIS Expert B31 Software	Video
Understanding the MRI Adventure (kids, adults, english, spanish)	Video
Understanding the Open MRI Exam	Video
MAGNETOM Flash Newsletter (back issues)	Brochure
Spectroscopy Primer	Brochure
Fast Imaging Primer	Brochure
Advanced MR Cardio Guide for MAGNETOM	Brochure
The MRI Exam (english, spanish)	Brochure
The Open MRI Exam	Brochure

Maxwell Field Error

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Introduction

The Maxwell Field Error is a little known physics phenomenon that has been scarcely described in the MR scientific literature. Although it can occur on any MR system regardless of the manufacturer, the Maxwell Field Error is likely to affect systems operating at gradient capabilities of 15 mT/m or greater, and is less likely to affect systems operating at 10 mT/m or less. Since all current MAGNETOM systems have the potential to operate at 15 mT/m or greater, this physics phenomenon could potentially affect any MAGNETOM system.

What Is the Appearance of the Error?

The Maxwell Field Error has been observed primarily in "Turbo" sequences (e.g., TSE, TIRM, TGSE, etc). Two image quality problems can occur, depending upon the particular pulse sequence and parameters. On some TSE techniques with a long TE, the slices nearest isocenter can have good Signal-to-Noise Ratio (SNR), but on the same acquisition slices far from isocenter can have significantly reduced SNR with a speckled, grainy appearance. Alternatively, on some TSE techniques with a short TE, the slices nearest isocenter can have good resolution, but on the same acquisition slices far from isocenter can have significantly reduced resolution with blurry edge definition.

When Does the Error Occur?

The Maxwell Field Error is more likely to exhibit itself as image quality problems when:

1. Small FOV is used.
2. Large slice shift is used.
3. Gradient Motion Rephasing (GMR) is used.
4. Large matrix is used.

When many or all of these conditions are met, as is typical when imaging transverse lumbar or thoracic spines, image quality problems may be significant. The severity of these image quality problems depends upon the particular pulse sequence and parameters used by the technologist, but will be worse on slices far from isocenter. In fact, a fundamental characteristic of this error is that slices closest to isocenter (within about 80 mm) will appear normal while slices farthest from isocenter will be affected.

How to Avoid the Error?

1. Since the Maxwell Field Error is directly associated with high gradient amplitudes, the most straightforward method to avoid it is to use more relaxed pulse sequence parameters, such as larger FOV and smaller matrix size. For example, increasing the FOV by as little as 10-20% can significantly reduce the problem.
2. Positioning the patient such that the region of interest is closer to isocenter will help avoid this error. Shifting the patient so that a 60 mm slice shift may be used (instead of 80-100 mm) could possibly eliminate an image quality problem.
3. GMR pulse sequences tend to use large gradient pulses. If an application does not require motion compensation, do not use a GMR sequence. Or, when an application does require motion compensation, use GMR only in the direction of the motion. For example, using a sequence with GMR in only the readout direction, or in both the readout and slice select directions, is not optimal for transverse spine imaging because the blood flow and CSF pulsations occur in only the slice select direction. The large gradient pulses associated with GMR in the readout direction are not adding anything to the exam, and could potentially contribute to image quality problems associated with the Maxwell Field Error. Thus, in this case, using a sequence with GMR in only the slice select direction will provide the needed motion compensation while helping to avoid or minimize the error.

GMR nomenclature in the pulse sequence names follows these conventions:

1. Sequence names containing a single "r" (e.g., se_17rb130) have GMR in both the readout and slice select directions.
2. Sequence names containing "rs" (e.g., se_15rsb130) have GMR in only the slice select direction.
3. Sequence names containing "rr" (e.g., se_15rrb130) have GMR in only the readout (frequencey encoding) direction.

What Is the Physics Explanation?

As pointed out recently by physicist Dr. Peter Heubes with Siemens Medical Engineering in Erlangen Germany, there is a fundamental phenomenon on all MR systems that can exhibit significant image quality artifacts, particularly when large gradient amplitudes are used. A recent scientific paper describes how, according to the basic laws of electromagnetism, the application of a gradient field generates another much smaller field error (Maxwell Field Error) perpendicular to the main gradient field. This results in both amplitude and directional changes in the total gradient field. Furthermore, the extent of this field error will be approximately dependent upon several things:

1. G^2 – the field error is proportional to the square of the gradient amplitude. Thus, if the amplitude of the gradient pulse is doubled, the field error is quadrupled.
2. Z^2 – the field error is proportional to the square of the distance away from isocenter perpendicular to the applied gradient. Thus, if an X or Y gradient is pulsed, the field error will exhibit a dependence along the Z axis. Also, if the distance along Z is doubled, the field error is quadrupled.
3. $1/B_0$ – the field error is inversely proportional to the main magnetic field strength. Thus, if the main magnetic field strength is doubled, the field error is halved.

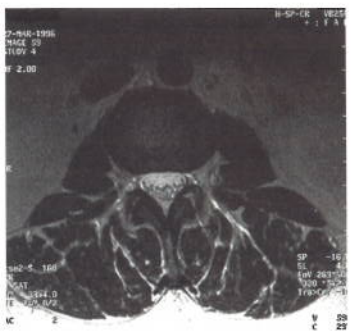

Figure 1 (a). On some TSE techniques with a long TE, the slices nearest isocenter can have good SNR.

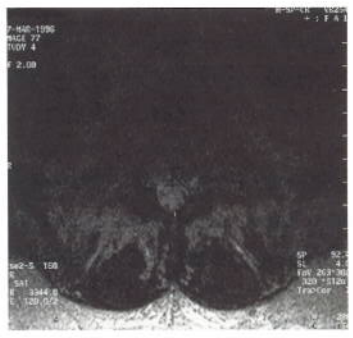

Figure 1 (b). On the same acquisition, the slices farthest away from isocenter can have significantly reduced SNR with a speckled grainy appearance.

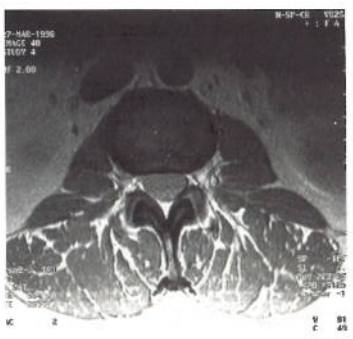

Figure 2 (a). On some TSE techniques with a short TE, the slices nearest isocenter can have good resolution.

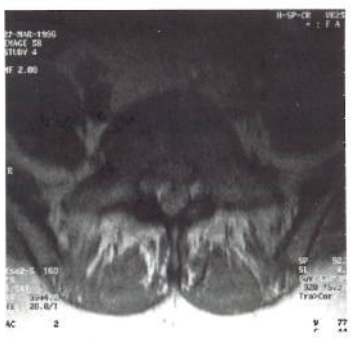

Figure 2 (b). On the same acquisition, the slices farthest away from isocenter can have significantly reduced resolution with blurry edge definition.

Applications Tips

MR technologists using a MAGNETOM that had just received the B31B software upgrade reported a peculiar problem. When using the Study Display function at their remote console during the filming of an exam, a message "Table Has Moved" would appear on the image that they were displaying slices on, even though the table had not been moved during the exam. Furthermore, when using the Study Display function at their main console, this message would not appear. Finally, it was discovered that the System Time on one console was Eastern Daylight Time (EDT) but on the other console was Eastern Standard Time (EST). When both consoles were set to the same System Time (US/Eastern for example which needs to be set by your Service Engineer) and rebooted, the problem was resolved.

Another group of MR technologists questioned whether the Study Display feature correctly displays the position of MIP'd images. As it turns out, the MIP platform points arrows in the directions that the MIP projections will be viewed by the observer. However, the Study Display platform displays lines which represent the image planes of the slice positions (a slice viewed on-edge is a line). These are two very different (but related) displays. The arrows displayed in the MIP platform point orthogonal to the slices represented in the Study Display platform. In this case, the two will be exactly perpendicular to each other for a given MIP view. In fact, if you think about it, Study Display probably should not even allow MIP's to be displayed because this is somewhat illogical. After all, a MIP is a projection (not a slice) and a projection has no single plane in space (only an angle). Thus, when trying to display a MIP projection, Study Display assumes the correct angle of the projection but simply assumes the central location of the projected slab of data. So, really, the only thing that can be relied upon in the Study Display of MIP images is their projection angles.

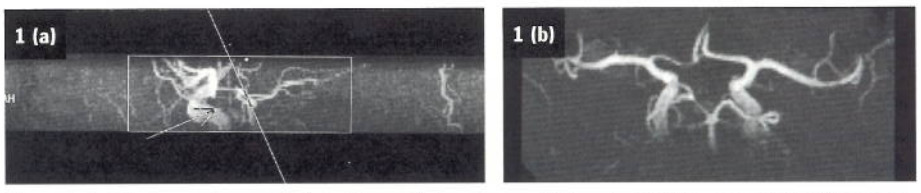

Figure 1. (a) Transversely acquired angiographic images are MIP projected into a coronal oblique view. The MIP platform shows an arrow pointing toward the coronal oblique view, but the Study Display platform displays a line representing the projection plane as it might be viewed on-edge. (b) The MIP projection is actually viewed as a coronal oblique (broadside, not on-edge).

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