SIEMENS

Vol. 4 No. 1 1996

The MAGNETOM Flash

Newsletter for Siemens MAGNETOM Users

IN THIS ISSUE...

From the Editor

We have received very few articles, interesting cases, or applications tips from you, our users, over the past several months. Your special technique or unique insight into a particular issue may be big news to other Siemens users. Contact us by mail, voicemail, or fax to submit your contributions, to request previous issues, or to add your name to the mailing (no home addresses, please).

This issue contains an extensive discussion of MRI prescan adjustments required for optimal image quality. A better understanding of these procedures will allow you to evaluate the performance of your MAGNETOM system as you image on a day-to-day basis. As always, this issue contains announcements about upcoming educational seminars and meetings held throughout the world. Several useful applications tips are offered, including hints on opthalmic MRA, radial knee reconstructions from 3D data sets, artifacts common with sickle cell anemia patients, and a high resolution IAC protocol for visualizing the tiny structures of the inner ear. We continue the column called "Ask The Experts" in which acknowledged experts will answer questions that you, our users, commonly ask. You will also find announcements of several major upgrades announced at the RSNA 1995 for each of the MAGNETOM systems. These include the Turbo Gradients for the Impact Expert system, the Power Gradients and the MR Guided Procedures Kit for the Open system, and the Gradient Overdrive, Flow Quantification, and Proton Spectroscopy Packages for the Vision system. And finally, an MRI word puzzle is offered for recreational relief.

Gary McNeal, M.S.
Editor, MAGNETOM Flash Newsletter

THE MAGNETOM Flash

Published by:
MR Applications
Siemens Medical Systems, Inc.
186 Wood Avenue South
Iselin, NJ 08830

Editor and Correspondence:
Gary R. McNeal. M.S.
1108 Bradley Drive
Franklin, TN 37069
(800)753-6336,ext2112.
Fax (615) 591-7094

Technical Editor:
Helmuth Schultze-Haakh, Ph.D.

ASK THE EXPERTS: SELECTING THE BEST VOPT?

Ralph E. Lee, M.A., R.T., (R, MR), MRI Research Associate
UCLA, VA Campus, San Francisco, CA

In the previous issue of this newsletter, I contrasted the use of Phase Contrast Angiography (PCA) versus Time-of-Flight (TOF) Angiography for imaging the Intracranial Vessels (ICV). In this issue, I will discuss how to use a series of rapidly acquired 2D PCA scans to help you choose the Optimal Velocity Range (Vopt) for a high resolution 3D PCA scan.

Unlike TOF, the PCA technique requires that the user select, in advance, the velocity of blood flow that the technique will optimally visualize. So, PCA protocols that are appropriate for slowly flowing vessels, such as veins, will likely fail to image rapidly flowing vessels, such as arteries, and vise versa. Although 3D PCA scans tend to take as long (or longer) to acquire as 3D TOF scans, 2D PCA scans tend to be very quick. Consequently, it is recommended that you should acquire a series of rapid 2D PCA "scout" scans of the area as part of a "set-up procedure" for a subsequent 3D PCA scan.

Let's review the concept of Vopt, as described in the previous issue of this newsletter. A sequence designed with Vopt of 45 cm/sec assigns the maximum pixel brightness (white) to blood flowing at 45 cm/sec and assigns the minimum pixel brightness (black) to blood not flowing at all (zero velocity). Blood flowing at velocities less than Vopt will be assigned pixel intensities somewhere between black and white. In this example, 15 cm/sec velocity will be only one-third of maximum brightness and 30 cm/sec velocity will be only two-thirds of maximum brightness. Thus, the sequence is optimized to best visualize blood flowing at (or just below) the selected Vopt.

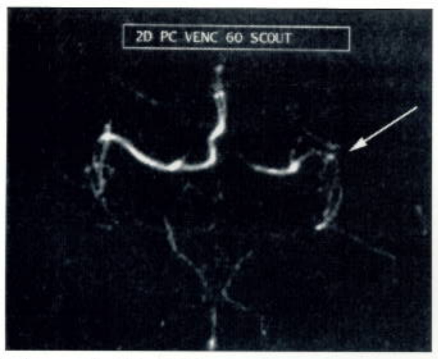

Figure 1: 2D PCA axial "scout" image with a Vopt of 60 cm/sec. Notice that the distal vessels of the left Middle Cerebral Artery (arrow) are not well visualized, suggesting that the flow velocity in this region is much slower than normally expected.

Therefore, for best results, the user should have some advance idea of the actual blood flow velocity in the vessels of interest. Although a typical Vopt for the ICV is about 45 to 60 cm/sec, we don't really know in advance if this is best for any particular patient. So, a quick series of 2D PCA "scout" scans can provide this information. A "setup procedure" for a high resolution 3D PCA scan of the ICV might go as follows. Using 2 Acquisitions (ACQ), acquire an axial 2D PCA scan with Vopt of 20 cm/sec through the ICV. Then, repeat the scan at the same location with three more 2D PCA sequences using Vopt's of 30, 45, and 60 cm/sec. This entire process should take 5 minutes or less. As each 2D PCA scan is completed, it is automatically reconstructed and processed. There is no need to take additional time to create a Maximum Intensity Projection (MIP) of the images. Review the magnitude image from each of these four scans in a 4:1 display mode to select the best Vopt for your subsequent 3D PCA scan. Choose a Vopt which best visualizes the vessels of interest.

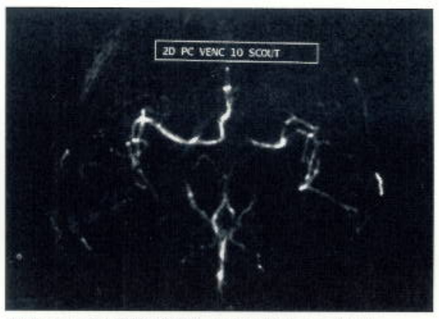

Figure 2: 2D PCA axial "scout" image with a Vopt of 10 cm/sec. Notice that the vessels of interest are much better visualized, confirming that the flow velocity in this region is much slower than normally expected.

This "scout" method is not only effective for optimizing the 3D PCA technique, but it can also prove extremely effective for evaluating complex vascular pathology. For example, in the case of a cerebral AVM, we are faced with a variety of blood flow velocities, both arterial and venous, within the same complex structure. The multiple Vopt 2D PCA method (except, using 4 to 6 ACQ and lasting about 1.5 to 2 min each) can provide images of rapidly flowing arterial blood and slowly flowing venous blood in an AVM. Such a series can evaluate a vessel with normal flow velocity that is proximal to a stenosis, or a high velocity flow jet at the stenosis, or low velocity flow beyond a severe or critical stenosis. If the "phase images" are acquired, in addition to the "magnitude images", these 2D PCA scans can help identify retrograde flow in cases of complete occlusion of the ICV.

For MAGNETOM users who do not have access to PCA sequences, a combined approach utilizing both 3D TOF and 2D TOF sequences can be used to evaluate areas of complex flow such as AVMs.

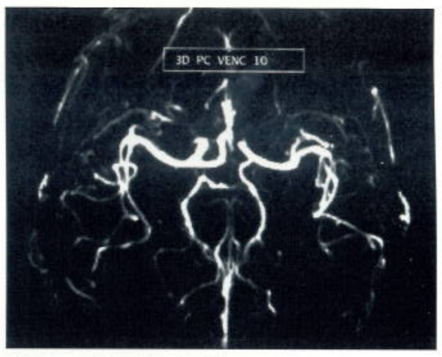

Figure 3: 3D PCA axial MIP image with a Vopt of 10 cm/sec. Notice that the vessels of interest are well visualized with a Vopt of 10 cm/sec. This 10 min scan would have been of no diagnostic value if the user had not run the 2D PCA "scout" scans beforehand.

Announcement: Seminars and Meetings

For additional information on any of these meetings, or to include a meeting announcement in our next issue of the FLASH, please contact Michele McDonald, MR Applications Group, at (908) 321-3270 or fax (908) 321-3219.

Feb 10-17, 1996	11th Annual Snowmass 1996: MR & CT of the Head and Spine, Snowmass, CO
Mar 8-11, 1996	MRI Conference for Technologists, Doubletree Hotel at Park West, Dallas, TX
Mar 9-16, 1996	6th Annual Snowmass 1996: MRI in Clinical Practice, Snowmass Conference Center, CO
Mar 21, 1996	ARRT Registry Exam for MRI (Application Deadline Jan 1, 1996)
Apr 11-13, 1996	Siemens Spring MR Technologist Seminar, Omni Inner Harbor Hotel, Baltimore, MD
Apr 27 - May 3, 1996	SMR, MAGNETOM Users Meeting, New York Hilton and Towers, New York City, NY
Jun 23-28, 1996	MRI Orthopedic Workshop, Vienna, Austria
Jul 21-26, 1996	11th Annual MRI 1996: National Symposium, Caesars Palace, Las Vegas, NV
Sep 4-8, 1996	8th Annual Advances in Mid & Low Field MRI, Buena Vista Palace, Lake Buena Vista, FL
Oct 24-27, 1996	Economics of Diagnostic Imaging 1996: National Symposium, Sheraton Washington, DC

INTERESTING CASE:
SKIN MARKER MIMICS COMPLEX LESION

Jim Gerber, R.T., MR technologist
Maine Magnetic Imaging, Portland, ME

An MR orthopedic examination was performed to evaluate a possible soft-tissue mass. A liquid-filled bead was taped to the outside of the skin to mark the suspected area. The pre-gadolinium transverse T1-weighted FatSat scan demonstrated a somewhat homogeneous soft-tissue mass, directly beneath the liquid-filled skin marker. However, the post-gadolinium transverse T1-weighted FatSat scan demonstrated a more heterogeneous soft-tissue mass, which lead to a very confusing interpretation. If the bright signal within the mass represented the contrast-enhanced lesion, what was the dark signal within the bright signal, directly beneath the skin marker ? After removing the skin marker, the post-gadolinium transverse T1-weighted FatSat scan was repeated, and this demonstrated that the unknown dark area had disappeared. The entire volume of tissue was contrast-enhanced. We concluded that the compression of the marker being taped to the skin caused enough vascular occlusion directly beneath the marker to stop the contrast from reaching the central volume of the lesion. When the compression was released, the flow resumed and the central portion of the lesion also became enhanced. So, when using skin markers over a lesion, beware of vascular compression which can confuse the diagnosis.

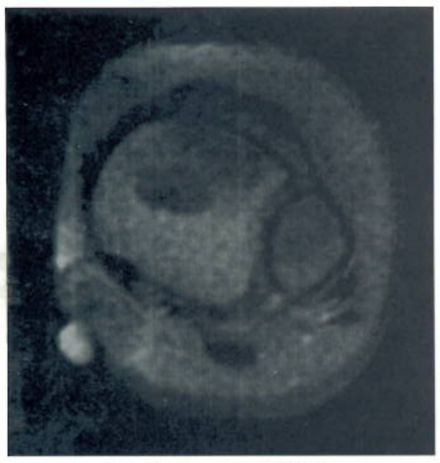

Figure 1: The pre-gadolinium transverse T1-weighted FatSat scan demonstrated a somewhat homogeneous soft-tissue mass, directly beneath the liquid-filled skin marker.

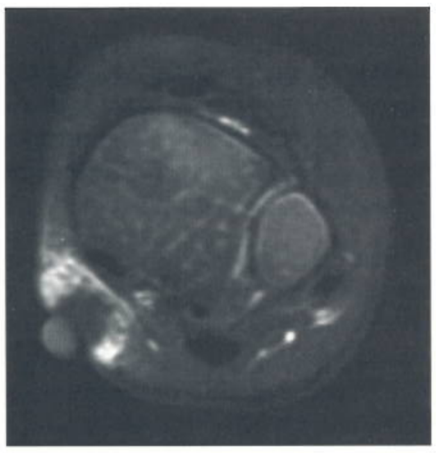

Figure 2: The post-gadolinium transverse T1-weighted FatSat scan demonstrated a more heterogeneous soft-tissue mass, which lead to a very confusing interpretation.

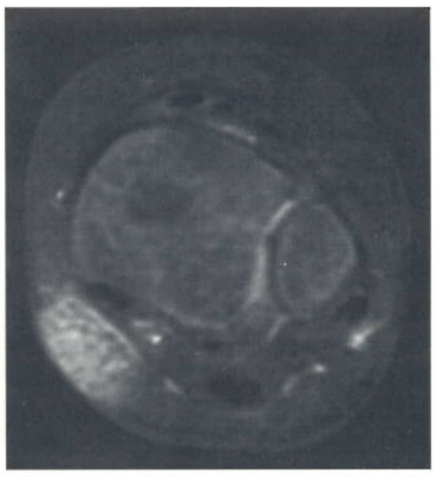

Figure 3: After removing the skin marker, the post-gadolinium transverse T1-weighted FatSat scan was repeated, and this demonstrated that the unknown dark area had disappeared.

APPLICATIONS TIP:
PEDIATRIC SICKLE CELL PATIENTS

Beware of a common artifact which may occur when doing MR Angiography (MRA) of the intracranial arteries of pediatric patients with sickle cell and other anemias. It often happens that there is a signal loss in the region of the carotid siphons which leads to speculation that there may be a thrombus or intimal hyperplasia. It is believed that this signal loss is most likely caused by abnormally high turbulence due to abnormally low blood viscosity from the anemia.

In some of these cases, the patients get transfusions of normal whole blood. When this happens the viscosity tends to increase toward normal. MRA done after such a transfusion may help rule out thrombus. Also, MRA sequences with shorter TE's tend to reduce the flow void effects due to flow turbulence. Finally, black blood MRA techniques may be useful. Blood flowing through the carotid siphons tends to be black when you use a spin echo sequence with a long TE (25-35 msec), thin slices (2-4 mm), no flow compensation or active flow dephasing, and a transverse presaturation band positioned just inferior to the carotid siphons. Any stationary thrombus tends to show up in the vessel as a high intensity signal. Courtesy of William G. Bradley, MD, Long Beach Memorial Hospital.

APPLICATIONS TIP: MRA OF OPTHALMIC ARTERIES

When using 3D Time-of-Flight (TOF) angiographic techniques to image the Circle-of-Willis and the Vertebral-Basilar junction, TONE UP pulses are commonly employed to improve the visualization of smaller intracranial vessels. This works well for most of the small intracranial arteries flowing toward the crown of the head, toward the frontal lobe, or toward the posterior portions of the brain. However, this typically does not work well for the opthalmic arteries which flow in an anterio-inferior direction from the central circulation. The TONE UP pulse is designed to enhance signal flowing in the upward direction, but actually degrades signal flowing in the downward direction. Thus, in order to better visualize the opthalmic arteries, position the 3D TOF TONE UP slab with a forward tilt (figure 3) rather than a backward tilt (figure 1) such that the TONE pulse is directed more along the direction of opthalmic flow rather than against it. Courtesy of Abraham Padua, MR Application Specialist in Tampa, FL.

Figure 1. Typical oblique positioning of 3D TONE UP slab for Circle-of-Willis exam.

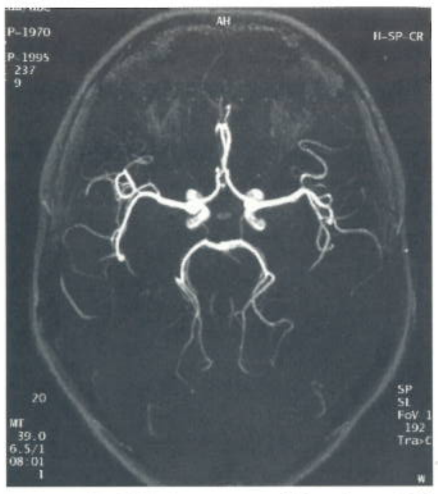

Figure 2. MIP image resulting from 3D slab positioned tilted backward as in figure 1. Opthalmic arteries are not visualized due to signal saturation from TONE UP working against the flow.

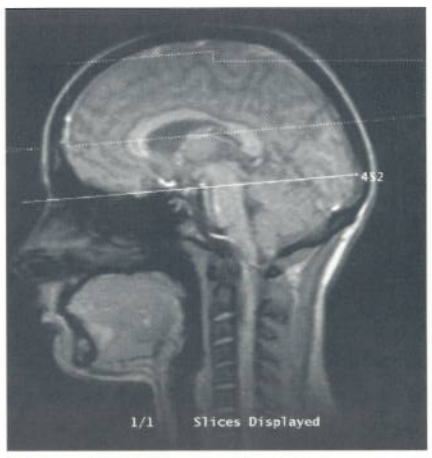

Figure 3. Recommended oblique positioning of 3D TONE UP slab for Circle-of-Willis exam which will allow opthalmic arteries to also be visualized.

Figure 4. MIP image resulting from 3D slab positioned tilted forward as in figure 3. Opthalmic arteries are visualized due to TONE UP working with the flow.

APPLICATIONS TIP:
HIGH RESOLUTION IAC EXAMINATION

The 3D DESS sequences provides an excellent technique for high resolution examinations of the Internal Auditory Canal (IAC). This sequence is available on all MAGNETOM Vision, and Impact Expert systems. The recommended protocol provides a bright-fluid contrast with contiguous 0.75 mm thick slices. These images are then MIP processed, rotated, and magnified to present the optimal view of the tiny structures within the IAC. The recommended protocol is: Sequence DESS3D_6B195, TR 19 ms, TE 6 ms, Flip 40 deg, FOV 200 mm, RecFOV 6/8, Matrix 192x256, Slab Thickness 48 mm, Partitions 64, Acquisitions 1, Orientation Transverse, Phase/Readout Directions Swapped, Raw Data Filter, Scan Time 3:55 min. Courtesy of Gary McNeal, MR Applications Specialist in Iselin, NJ.

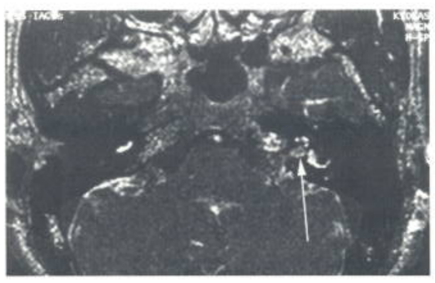

Figure 1: One of four contiguous 0.75 mm slices through a 6 mm acoustic neuroma (arrow).

Figure 2: MIP view of only the few slices containing the neuroma and the tiny structures within the IAC. MIP images may be rotated, cropped, and magnified for optimal viewing direction and background suppression.

RSNA 1995: PRODUCT UPGRADE ANNOUNCEMENTS

Dean Kaufman, M.S., Vision Product Manager
Anne Deery, B.S., Impact Product Manager
Sandra Schaffer, R.T., Open Product Manager

MAGNETOM IMPACT EXPERT UPGRADE: INTRODUCING 20 mT/m TURBO GRADIENTS

Siemens Medical Systems, Inc. is now pursuing the development of advanced gradient operation on its MAGNETOM IMPACT 1 Tesla Magnetic Resonance Imaging System - 20mT/m in all three axes. Such gradient developments will enable smaller Fields Of View (FOVs) down to 2cm, and allow 1024 matrix imaging. The Turbo Gradients will also empower new imaging techniques such as Diffusion and Functional MRI. The system can handle echo train lengths up to 240 for high resolution Cholangiographic studies. Siemens introduced the gradient upgrade and its potential applications as works-in-progress at the 1995 RSNA.

Flow quantification is now commercially available for the MAGNETOM Impact and Impact Expert.

There are over 1,000 MAGNETOM IMPACTs installed worldwide. The system's actively-shielded magnet and compact components allow the system to be installed and operational in just four weeks in an area as small as 410-square-feet.

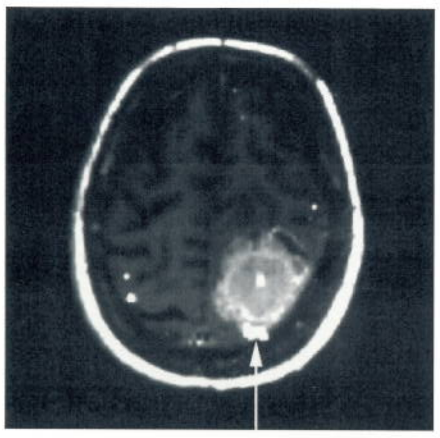

Figure 1: Works-In-Progress. A functional MRI study shows displacement of the motor cortex (arrow), courtesy University of Muenster.

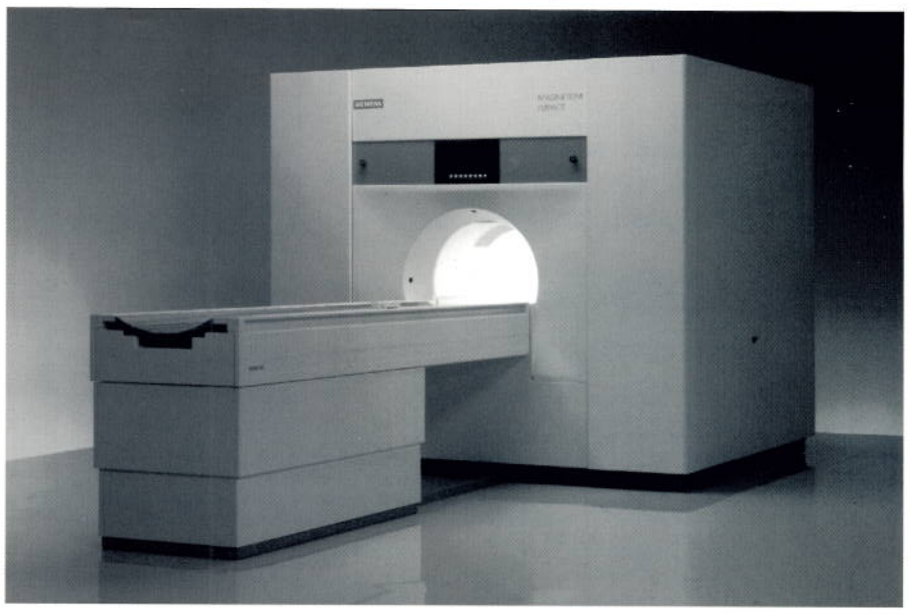

Figure 2: Over 1000 MAGNETOM Impact systems installed worldwide.

MAGNETOM VISION UPGRADES: GRADIENT OVERDRIVE, FLOW QUANTIFICATION, AND PROTON SPECTROSCOPY UPGRADES ARE NOW COMMERCIALLY AVAILABLE

More than 200 MAGNETOM Vision systems have been installed worldwide since its introduction two years ago. Three new features for the MAGNETOM Vision are now commercially available: the Gradient Overdrive Upgrade, Flow Quantification Package and Proton Spectroscopy Package.

The Gradient Overdrive upgrade installs in 2 days, and extends the Vision's inherent functionality without replacing the existing gradient components. Brain and body applications will benefit from the ability to acquire 20 T2 weighted images in 2 seconds with the single shot Echo Planar technique. The Gradient Overdrive upgrade will also improve many non-EPI techniques: smaller FOVs, quicker acquisition times and reduction of motion artifacts due to cardiac or respiratory motion.

The Flow Quantification package features interactive ROI (region-of-interest) definition and graphical display of flow profiles for ease of use with RACE and Phase Contrast based techniques. The Proton Spectroscopy package offers SVS (Single Voxel Spectroscopy) and CSI (Chemical Shift Imaging) exams. The open windows interface offers ease of use, fast set up times and fully automated post-processing. SVS adds 6-10 minutes to an exam.

Siemens R&D is also pursuing emerging body applications. At RSNA '95 several new Works-In-Progress techniques were introduced: MR Cholangiography using Single Shot TSE, 3D Body MRA with 2 msec TE and acquisition times under 1 minute for 512 resolution, ultrashort breath-hold TIR and TSE for cardiac imaging.

Figure 1: Works-In-Progress. 3D MRA, TE 2 msec, 512 resolution in 41 seconds, courtesy Diagnostic Radiology Grosshadern.

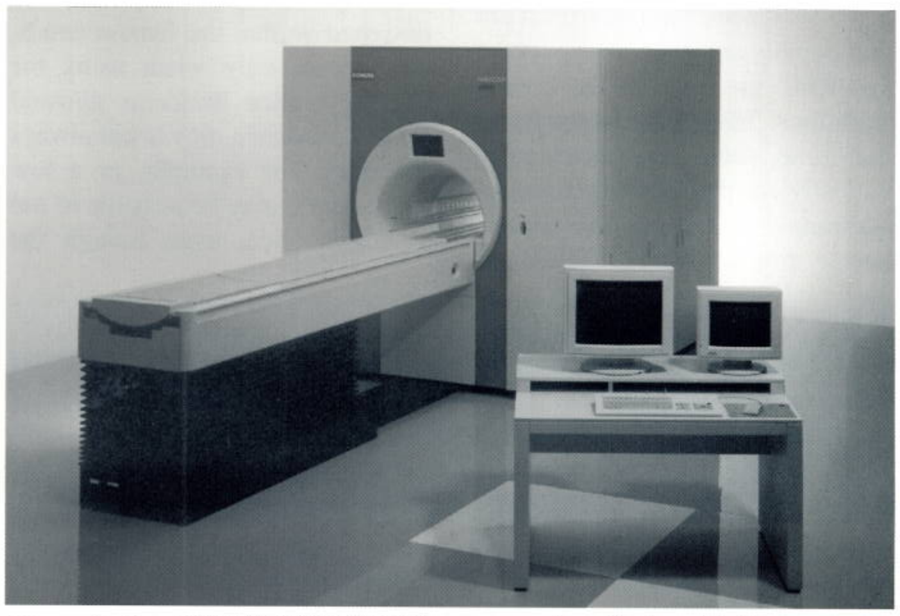

Figure 2: Over 200 MAGNETOM Vision systems installed worldwide.

MOBILE MAGNETOM IMPACT: SUPPORTING THE OLYMPICS

Siemens Medical Systems, Inc., will provide a mobile magnetic resonance imaging system and two ultrasound imaging systems for use by the medical staff during the Summer Olympic Games in Atlanta, GA. The systems include a Mobile MAGNETOM Impact, the world's best-selling mobile MRI system. The Mobile Impact is the first high-field MRI system capable of being transported over U.S. roadways while "ramped" at full field strength. The Mobile Impact offers a wide range of image contrast to non-invasively assess damage to athletes.

Siemens will also provide its SONOLINE Elegra ultrasound imaging system. The new SONOLINE Elegra is a premium, all-digital ultrasound imaging system with advanced image acquisition and processing capabilities and a unique, user-defined, easy-to-learn user interface.

"We are pleased to be able to support the Olympics by providing the use of our advanced MRI and ultrasound systems during the Summer Games," said Robert V. Dumke, President and CEO, Siemens Medical Systems, Inc. "If needed, the Olympic athletes will be able to receive the best possible diagnostic imaging."

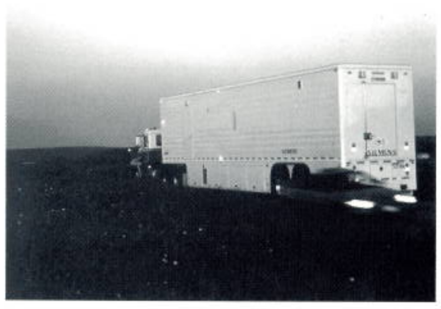

Figure 1: Mobile MAGNETOM Impact system to be used at the 1996 Summer Olympic Games in Atlanta, GA.

MAGNETOM OPEN UPGRADES:
INTRODUCING 15 mT/m POWER GRADIENTS AND MR GUIDED PROCEDURES KIT

As open MRI imaging evolves from a "niche market" to mainstream use, the ability to perform new applications becomes more important for maintaining a competitive advantage. The best way to protect this investment is to maintain the system at state-of-the-art performance through hardware and software upgrades. At this year's RSNA, Siemens introduced two new features for the MAGNETOM Open: the Power Gradients Upgrade and the MR Guided Procedures Kit.

The Power Gradients boosts the gradient system to 15mT/m, enabling smaller Fields Of View (FOVs) and a 1 msec rise time to 15 mT/m. The Power Gradients option is Works-In-Progress and not commercially available in the US.

The MR Guided Procedures Kit includes a local monitor with mouse and stand, footswitch, 35cm flexible body coil, bore light, chair, upper pole shoe drape, automatic image display ('autodisplay'), and fast imaging (2 images / second) protocols. The MR Guided Procedures Kit is pending FDA review. The In-Room monitor has been given a whole new vertical look (Fig. 2). The monitor may be tilted and the stand adjusted in the vertical direction. The In-Room monitor allows the operator to start scans or review clinical images while standing next to the magnet and patient.

B21B software for the Open offers streamlined scanning and will enhance throughput by increasing productivity and patient comfort. This software features Measurement Queue, Measurement History, Integrated MT (Magnetization Transfer) and FatSat Pulses, Integrated MAP Shim, Pixel Size and S/N indicators, Integrated Phase Oversampling, Integrated 3D Partition Oversampling, Integrated RecFOV, Dual Scout Localizer, Flexible 3D Partitions, and Erasable Optical Disk.

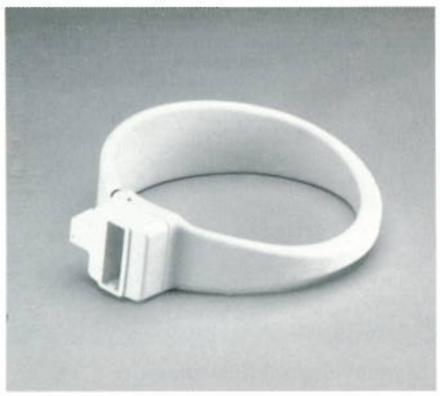

Figure 1: The new 21 cm and 16 cm Shaped Coils are now commercially available.

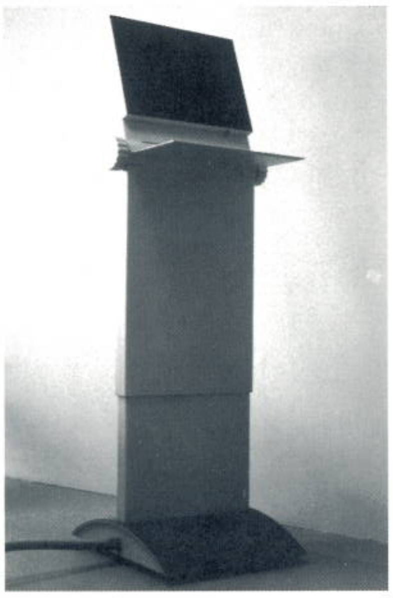

Figure 2: The in-room monitor may be tilted and the stand may be adjusted vertically.

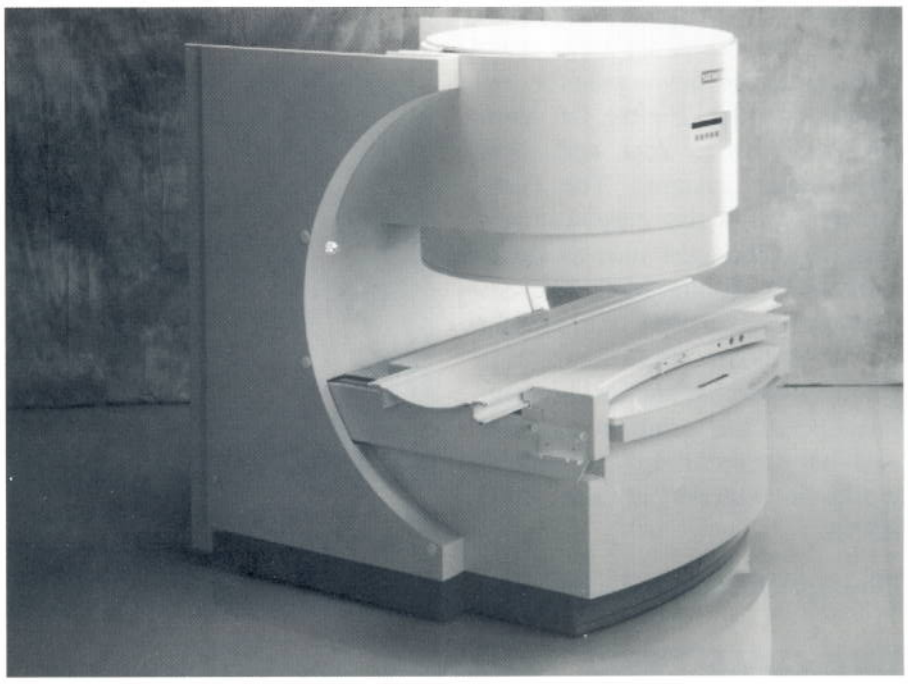

Figure 3: Over 120 MAGNETOM Open systems sold worldwide.

APPLICATIONS TIP:
MISADJUSTED RECEIVER GAIN

Under certain conditions, scans have been done on MAGNETOM Vision and Impact Expert systems with a misadjusted receiver gain, thus resulting in ADC voltage clipping and undiagnostic images. This is because some sequences running on the Vision and Impact Expert are intentionally designed to bypass the ADJ/REC pre-scan under certain conditions. To reduce the total prescan time, these sequences automatically set the receiver to a predetermined gain if the slice is less than a pre-determined thickness (usually near the minimum allowable thickness). This would be particularly useful in time-sequential techniques where the ADJ/REC pre-scan could be a significant portion of the actual total scan time.

Although most pulse sequences are designed so that the bypass condition occurs only when using the minimum slice thickness allowed by that sequence, this is not always the case. For example, in a few sequences it may be possible to use a 2 mm slice, even though the ADJ/REC is bypassed at a threshold of 3 mm or less. In nearly all cases, the receiver gain is set to 90 dB if the used thickness is at or below the threshold thickness. ADC voltage clipping could occur if the signal being received during the scan is so large that a 90 dB amplification yields a voltage exceeding the ADC limit.

Generally, the most probable cause for ADC voltage clipping is eddy currents. However, this is highly improbable because the MAGNETOM Vision and Impact Expert systems have shielded gradients. If ADC voltage clipping occurs on either of these two systems, thus yielding undiagnostic images, you should determine if the scan was done with the ADJ/REC pre-scan bypassed. Unfortunately, there is nothing in the image label or in the image header that will indicate that the ADJ/REC was bypassed, so you will need to reproduce the exact scan conditions and sequence parameters and simply watch and listen to determine if the ADJ/REC is performed or bypassed. If it is performed, then begin looking for another cause for the ADC voltage clipping. But if it is bypassed, you have two options to avoid this problem in the future - either perform a manual ADJ/REC whenever using this protocol, or use a thicker slice which does not cause the bypass to occur. Courtesy of John Kirsch, Ph.D., Siemens *Uptime* Service Center in Cary, NC.

WORD FIND (Words May Be Backwards)

B	U	F	M	R	O	L	N	W	X	O	P	C	R	A	P	J
T	A	I	O	E	Y	H	H	L	L	S	I	U	E	N	E	T
T	G	C	P	Z	Q	G	C	Y	Z	T	I	M	L	M	C	J
F	K	X	E	I	F	W	T	E	A	P	Q	E	P	S	P	Y
O	G	S	N	L	N	J	L	C	N	I	R	T	M	A	E	F
U	S	E	C	A	G	O	F	O	R	I	O	E	A	E	C	A
R	W	A	E	C	C	N	I	M	W	M	P	C	S	O	N	T
I	E	Z	J	O	A	S	A	T	K	C	Q	S	R	A	U	S
E	K	N	T	L	S	G	R	P	I	U	P	A	E	F	T	I
R	A	O	S	E	N	E	W	R	I	T	Q	U	V	C	N	A
W	R	E	C	E	C	U	Z	S	E	L	E	N	O	O	D	T
P	T	E	T	F	D	N	I	L	G	M	F	P	I	N	M	A
U	R	O	O	M	A	T	R	I	X	E	I	S	E	T	A	S
P	M	V	G	L	I	O	C	T	N	E	I	D	A	R	G	T
E	M	I	T	O	H	C	E	M	H	V	Q	H	A	A	N	A
G	B	A	N	D	W	I	D	T	H	N	A	X	W	S	E	F
T	C	A	F	I	T	R	A	L	A	N	G	I	S	T	T	J

WORD LIST

ACQUISITION	FOURIER	OVERSAMPLE	SEQUENCE
ARTIFACT	IMPACT	PRECESSION	SIEMENS
BANDWIDTH	LOCALIZER	PRESAT	SIGNAL
CONTRAST	MAGNET	PROTOCOL	SPINECHO
ECHOTIME	MAGNETOM	PULSE	TESLA
FATSAT	MATRIX	RECFOV	VISION
FLIPANGLE	OPEN	REPITITION	

ERROR CORRECTIONS

In the previous issue, Vol 3, Num 3, the author of the technical article on Phase Contrast MR Angiography was erroneously credited with B.S. and R.T. degrees. Actually, Jay Rocker has an M.S. degree and is ARRT registered and certified in MR. Also in the previous issue, the coauthors of the case history of Pheochromocytoma were erroneously omitted. The technologists at Boca Raton Community Hospital are Chris Notebaert, R.T., Mark Aroyo, R.T., and Jan Ortlieb, R.T.

APPLICATIONS TIP:
RADIAL 3D KNEE

When using the MPR feature to do a radial knee reconstruction from a sagittally acquired 3D dataset, the reconstructed knee images might be displayed lying on their side rather than vertically. To avoid this, follow these simple instructions. Select MPR, select LOAD STUDY, select ROTATED, select the transverse image for the working segment, select DEFINE AXIS, select the transverse image AGAIN, position the dot which represents the axis on a meniscus of the knee, select DEFINE START, select 360, etc... The key element in this method is to TWICE select the transverse image, and not select OBLIQUE first. Courtesy of Susan Straughn, MR Applications Specialist in Pittsburgh, PA.

TECHNICAL ARTICLE: MR PRESCAN ADJUSTMENTS

John Kirsch, Ph.D., Advanced Physics and Service Support
Siemens *Uptime* Service Center, Cary, NC

Introduction

Maintaining good image quality is paramount in every clinical practice. Superior images with excellent edge definition, tissue contrast, and low noise levels translate into maximum diagnostic utility that increases reader confidence and offers a greater accuracy of interpretation. It is commonly known that the imaging parameters that make up the clinical protocols (such as TR, TE, thickness, and matrix) can profoundly affect the overall image quality of the examination. However, less is typically known about the hardware adjustments that ensure all of the components operate at peak performance for each study of each patient. Failing to do the proper prescan adjustments prior to the actual scan is like driving a race car without giving it a proper engine tune-up prior to the big race.

This article describes each of the prescan adjustments that must be done prior to scanning and their influences on image quality. Under normal circumstances, all of these should be done to attain the highest level of system performance. However, it will also be shown that some of these procedures need only to be performed once, at the beginning, when the patient is first placed in the magnet; these are not necessary prior to each scan. For your convenience, all prescan adjustments may be saved in your protocols to be done automatically (Inline) when you start the first measurement.

Coil Tuning

Tuning coils that transmit the RF and receive the MR signal is crucial for overall image quality. It is the very first adjustment procedure, and needs only to be done once at the beginning of the examination after the patient is moved into the center of the magnet. Some coils are specifically designed to be both a transmitter as well as a receiver (e.g., body coil, head coil, and extremity coil), while others are used only to pick up the MR signal (e.g. spine coil, neck coil, breast coil). In the latter case, a separate coil (typically the body coil) is used for the RF transmission, in which case both coils must be properly tuned.

Technically speaking, the purpose for tuning is to adjust the internal electronic components (capacitors) of the coil in order to maximize the forward power and minimize the reflected power. This can be directly compared to adjusting a venetian window blind. With the blind completely closed, no sunlight enters the room. This means that the forward power of the sunlight is zero and all of the sunlight is reflected. As the blind is adjusted, sunlight will begin to enter into the room. Finally, when the blind is adjusted to exactly the correct angle, all the sunlight will pass through the window, resulting in maximum forward power and minimum reflected power. This is analogous to an optimally tuned coil.

The reason why tuning the coils is essential for image quality is because any reflected power decreases the basic efficiency of the coil performance (figure 1). A poorly tuned RF transmission coil will mean that it will take more RF power to generate the necessary RF pulse flip angles in the body. This is because some of it will be reflected back instead of being transmitted. Although this in itself will not necessarily affect image quality, it can potentially damage the coil and increase the wear and tear on the RF hardware, thus shortening its lifespan.

On the other hand, a poorly tuned RF receiver coil can have a significant influence on image quality. Under most conditions, an MR signal coming from the body is very weak. Therefore, it is worth all the effort to try to receive as much of it as possible for producing the image. If a receiver is not properly tuned, then some of the MR signal will become reflected and never get received for processing. A well tuned coil will have maximum forward power and will therefore maximize the MR signal reception, thus leading to optimal image quality.

When is it necessary to tune the coil? The state of the tuning is very much influenced by the physical environment immediately surrounding the coil, such as when it is near a patient's body. Each time a patient is placed in a coil, the tuning of the coil will be different from when it was used previously on a different person. Therefore, in order to ensure that the coil is properly tuned, it should be performed as the very first prescan adjustment for each new patient. Once this has been done, however, it is no longer necessary to again adjust it for the rest of the examination, provided that the patient does not move.

In the early days of MR, coils needed to be tuned manually by the technologist. This tedious procedure took time and decreased patient throughput. Now, all of the coils are automatically tuned by the system as soon as the patient's position is accepted. Some coils have even been specially designed with "fixed" tuning, so that no tuning is required per patient.

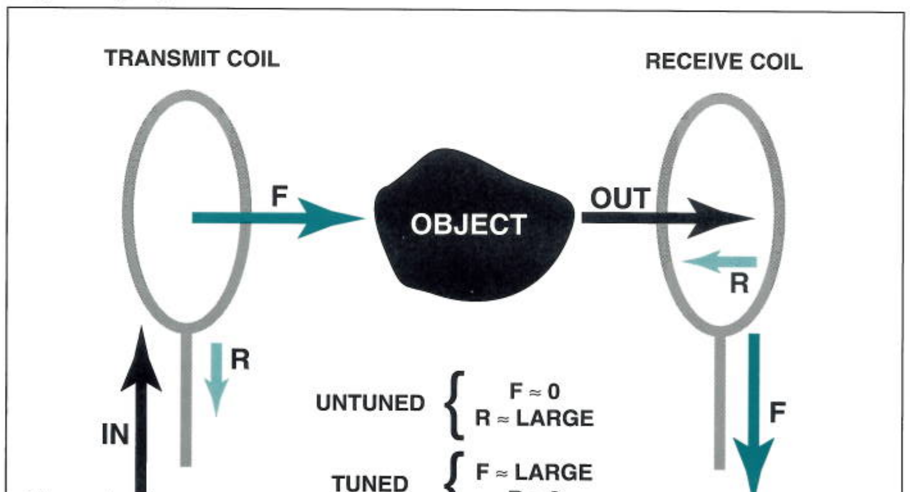

Figure 1

Shim Adjustment (MAP Shim)

The next prescan adjustment that is necessary for optimal image quality is to achieve the highest level of static magnetic field homogeneity. The static field not only magnetizes the body's hydrogen nuclei, but it also acts as a reference for subsequent RF excitation and spatial encoding. If this reference magnetic field level is not the same everywhere in the body, then the regions of spatial or spectral excitation and encoding will not be correct. Depending on the sensitivity to the field homogeneity of a particular application (i.e., FatSat), it may or may not be absolutely necessary to perform a shim procedure on each patient. However, if shimming has been done once at the beginning of the patient exam, it no longer is required for the rest of the examination.

Shimming the main magnetic field can be likened to physically shimming a window. When a window gets installed, it might be slightly tilted. By using a level, it can be straightened by placing small slivers of wood in strategic places around its framework. In MR, there are basically two types of magnetic shimming - passive and active. During the installation of an MR system, the magnet is passively shimmed by using small thin strips of metal that are strategically placed around the bore. It is termed "passive" because the metal will slightly change the main field to make it more homogeneous simply by its presence. Active shimming sometimes uses an actual shim coil (and also will use the gradient coil) that resides inside the bore. Shim coils have electrical currents running through them at all times to generate the slight changes in the main magnetic field required for optimal homogeneity; hence the term "active". Usually, passive shimming is a coarse adjustment of the main field that yields as good an overall homogeneity as possible. Then, active shimming is used to finely tune the homogeneity.

Although the human body is not a highly magnetic object, it nevertheless can distort the main magnetic field. This will, in a sense, ruin the homogeneity achieved during the installation and tuneup of the system by the service engineer. Depending on the area of the body to be imaged, it may distort the field linearly in space (called "first order" field distortions) or in a more spatially contorted manner (called "higher order" field distortions). The first order distortions are normally shimmed by sending a constant electrical current through the gradient coils used for spatial encoding of the MR signal. The higher order distortions are normally shimmed by sending a constant current through separate shim coils, but these are not always necessary and are not present in all MR systems (i.e., MAGNETOM Impact). In nearly all applications, the good homogeneity initially attained prior to the presence of the patient will be again attained after a first order shim adjustment.

There are many different methods for performing a shimming procedure. However, most of them are manually performed, very tedious, and usually only done by experienced individuals working in spectroscopy (where field homogeneity is of utmost importance). Although shimming was necessary for certain techniques (i.e., FatSat), it was rarely done for routine techniques. Now, Siemens scientists have developed a fully automated procedure called MAP Shim that can achieve excellent shim results in a matter of seconds. For most general applications, adequate homogeneity still exists even without shimming on each individual patient. Therefore, MAP Shim is currently available as an option in the Protocol/Change setup menu. If it is not selected, the procedure will be bypassed during the prescan adjustments. Since FatSat is a technique which is particularly sensitive to subtle magnetic field inhomogeneities, it is essential that MAP Shim be performed prior to doing a FatSat scan. The MAP Shim procedure only needs to be done once during the first prescan adjustment, as long as the patient does not move. Many users consider it well worth the few extra seconds to do a MAP Shim during the prescan adjustments of the first scout scan, to assure the best image quality for every scan thereafter, regardless of the application.

Frequency Adjustment (ADJ/FRE)

Coil tuning and shimming constitute the initial environment of the system, setup in order to achieve optimal results from all subsequent MR experiments. Once these two have been adjusted to the presence of a patient, several additional procedures are required.

The purpose of doing a frequency adjustment is to assure that the RF transmission frequency matches the Larmor frequency of the hydrogen nuclei so that the resonance condition is optimally satisfied. As long as the patient has not moved and the shimming has not changed, this only needs to be done once during the first prescan adjustment. As we just discussed, the presence of a patient will slightly change the main magnetic field. Shimming

(continued on page 6)

(continued from page 5)

will slightly compensate the main field and assure that the adjusted field then becomes as homogeneous as possible over the region of interest. The resultant field will therefore vary slightly from patient to patient. In addition, slightly different chemical components in the body (from region to region, or patient to patient) will also slightly change the Larmor frequency. The combined effect means that every time a new patient is placed in the bore, a frequency adjustment should be done to find the exact Larmor frequency for that patient and shim condition.

The frequency adjustment procedure is a simple one. Since the Larmor frequency is initially unknown, an arbitrary flip angle RF pulse is transmitted nonselectively so that it excites the entire volume of interest. The frequency bandwidth of transmission is wide enough to make sure that wherever the Larmor frequency is located in the frequency spectrum, the hydrogen nuclei will become excited. After the excitation, the free induction decay (FID) signal is detected. As long as there is some signal, the frequency of it can be determined. Once this is known, as long as the patient does not move or the shim environment has not changed, the frequency adjustment no longer needs to be performed for the rest of the examination. Remember, if the patient moves or you re-shim, the frequency adjustment must be repeated.

In principle, if the frequency is not correctly adjusted, it will mean that the RF transmission frequency will not match the Larmor frequency of the patient's protons. This will reduce the efficiency of the RF in flipping the magnetization of their spins. In reality, the main effect on image quality will be that incorrect slice locations will be excited, and objects in the image will be shifted along the frequency encoding direction. Nevertheless, some applications that rely on a very exact detection of the Larmor frequency (i.e., FatSat) will be completely compromised if a frequency adjustment is not performed.

Transmitter Adjustment (ADJ/TRA)

The purpose of a transmitter adjustment is to determine the level of RF transmission voltage (or power) necessary to produce a given RF flip angle in the body. Since there is a known mathematical relationship between all RF flip angles and waveforms that are used, this calibration only needs to be done once at the beginning of the examination. All subsequent RF pulsing is then mathematically scaled based on the transmitter adjustment result. RF flip angles are directly proportional to the applied transmission voltage and its duration. However, it will also depend on the type of coil being used for transmission, the tuned state of the transmitting coil, and the region of the body being imaged. Therefore, in order to achieve a particular flip angle, the voltage will not be known unless some type of calibration to the specific coil and patient is done.

There are several ways to do a transmitter adjustment. The most direct way is by trying a certain voltage and seeing what comes back as an MR signal. Since it is known that a 90 pulse will yield maximum signal and a 180 pulse will yield minimum signal, stepping through different transmission voltages will achieve a successful calibration. However, it can take some time to go through all the iterations until a maximum or minimum condition is found. The current method that Siemens employs is a more precise measurement that, in theory, does not have to be repeated. According to theory, if a stimulated echo is generated along with a spin echo by using three successive RF pulses, there is only one unique combination of flip angles that yields a particular ratio of the two signals. Therefore, after one measurement with a known RF voltage, the signal ratio can be determined and the flip angle can be calculated. All other flip angles can then be calculated based on this result.

If the transmitter adjustment is not calculated correctly (done once at the beginning of the patient examination), then the wrong voltages will be used for the RF pulses, thus leading to incorrect flip angles. This can significantly reduce the image quality and even result in incorrect tissue contrast.

Receiver Adjustment (ADJ/REC)

All the previously described prescan adjustments need to be done only once per patient, prior to the first scan. The total time to execute those prescans is typically less than a couple of minutes. The only prescan adjustment that needs to be done for each study is the receiver adjustment. This is done not only to normalize the signal output so that the image intensities are within a nominal range, but is also done to ensure that the received MR signal amplitude does not exceed the limit of the analog-to-digital converter (ADC).

Depending on protocol parameters, the MR signal amplitude can vary significantly from study to study. Although some effects can be anticipated (i.e., doubling the slice thickness doubles the received signal), others will depend on the anatomy being imaged (i.e., various T1 and T2 values) and the pulse sequence being used (i.e., gradient echo versus spin echo). Therefore, there is no certainty of what the signal amplitude will be unless an initial "test" measurement is done. This constitutes the receiver adjustment prescan procedure which must be done before each scan.

Through the course of an entire scan, it is known that when the acquisition crosses through zero phase encoding it will produce the largest signal in the rawdata before reconstruction. Therefore, a receiver adjustment is simply the measurement of a few lines of the pulse sequence at or near the middle phase encoding step (zero gradient amplitude). The amplitudes of these signals are evaluated and the amplification gain is adjusted such that the signal for the actual scan will be both normalized and below the maximum limit of the ADC.

Image quality can vary significantly if the receiver gain is not properly adjusted. If the gain is too low, then the signal is insufficiently amplified, thus leading to very low image intensity. This can potentially result in subtle losses in detail and make windowing difficult for filming purposes. If the gain is too high, the signal will be amplified to a level greater than what the ADC can handle. This will lead to erroneous digitization of the signal, producing an undiagnostic image.

Inline Mode versus Offline Mode

The MAGNETOM software offers the technologist the ability to run adjustments in either Inline Mode or Offline Mode. Inline mode means that the system automatically executes the required prescan adjustments in the required order, and keeps track of which were done. Offline Mode instructs the system to bypass all adjustments, leaving it up to the technologist to make sure they are performed manually in the required order. If Offline Mode is selected and the user fails to run the required prescan adjustments, the system will acquire scans with whatever values for shim, frequency, transmitter, and receiver that were obtained from the previous patient. Coil tuning is the only adjustment that will always be carried out regardless of the mode.

For clinical purposes, there is normally little reason to do a scan in Offline Mode. However, in some situations it can greatly facilitate the protocol, such as is in breath-hold studies. Here, each sequential slice is acquired one-at-a-time during successive breath-holds. If the system is in Inline Mode, the receiver adjustment is done for each new slice position during the Sequence/Load step. This can add significantly to the total prescan time if a large number of breath-holds is to be done. In Offline Mode, however, the receiver adjustment (ADJ/REC) can be done manually prior to only the first slice and saved in the measurement buffer for subsequent slices. Then, the user simply repeats the Sequence/Load and Sequence/Start commands after incrementing the slice position between slices.

Summary

A well-performing system will only generate optimum image quality if correct prescan adjustment procedures are followed (Table 1). As soon as a patient enters the bore of a magnet, his body affects how the MR hardware will operate. Tuning will maximize the efficiency of the coils. Shimming will yield a homogeneous static magnetic field. Frequency adjustment will determine the exact Larmor frequency of the patient's protons. Transmitter adjustment will calibrate the RF system to yield correct flip angles. And receiver adjustment will normalize the signal output and image intensity. Making sure that these prescans are performed correctly will ensure the best diagnostic quality scans on the system.

PRESCAN ADJUSTMENT PROCEDURE	PURPOSE	IMAGE QUALITY
(1) COIL TUNING	·Maximize forward power ·Minimize reflected power ·Maximize coil efficiency ·Increases SNR	·Minimizes required RF transmission
(2) SHIM ADJUSTMENT	·Maximize field homogeneity in region of interest	·Maximizes SNR ·Maximizes image uniformity ·Yields homogenous fat suppression
(3) FREQUENCY ADJUSTMENT	·Determine Larmor frequency	·Accurate slice excitation ·Accurate image mapping ·Maximizes fat suppression
(4) TRANSMITTER ADJUSTMENT	·Calibrate transmitter voltage	·Ensures correct RF flip angles ·Maximizes SNR ·Yields accurate tissue contrast
(5) RECEIVER ADJUSTMENT	·Normalize image intensity ·Maximize signal amplification without exceeding ADC limits	·Ensures adequate image intensity ·Avoids image artifacts associated with saturated ADC