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The MAGNETOM Flash

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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. Please support your users' newsletter. Your special technique or unique insight into a particular issue may be big news to other Siemens users. If you are within the United States, contact me by mail or fax to submit your contributions, or to request previous issues, or to add your name to the mailing list (please, no home addresses). If you are outside the United States, contact Dagmar Thompsik-Schröpfer in Erlangen, Germany. Both our addresses and fax numbers are listed below.

This issue contains an extensive technical discussion of MRI safety issues. A better understanding of these precautions will ensure safe operating conditions for your patients, your colleagues, and yourself. A clinical article by a Siemens user discusses prostate cancer staging with the endorectal coil. As always, this issue contains announcements of upcoming educational seminars and meetings. Several useful applications tips are discussed, including hints on FatSat and Water Saturation, hints on MAPshim, hints on the MagicView workstation, hints on RecFOV, hints on Measurement History, and a new acronym for determining slice locations.

All articles represent the techniques and opinions of the authors and may not represent specific recommendations or endorsements from Siemens Medical Systems, Inc. Authors sometimes describe results from their own sequences and protocols. Contact them directly for further information about their techniques and opinions.

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

THE MAGNETOM Flash

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APPLICATIONS TIP:

BODY SCOUT WITH SHIM INLINE

For **MAGNETOM Vision** and **Impact Expert** systems: A software error may occur when using any surface coil and, simultaneously, acquiring BODY SCOUT images with SHIM INLINE selected. Initially, it may seem as though all is well - the BODY COIL shim file is automatically loaded, the inline MAPshim procedure is performed, and the BODY SCOUT is measured with optimal shim values for the body coil (this is correct). However, immediately after this measurement, the STANDARD shim file is automatically reloaded, thereby setting the shim parameters back to their default values (this is an error). When this error occurs, any subsequent FatSat images may be inhomogeneous due to non-optimal shim values for that patient. Even if SHIM INLINE is again selected during any subsequent FatSat scans (either the surface coil or the body coil) the system does not repeat the MAPshim procedure because it believes that the parameters are still optimized for the patient. It does not recognize that the STANDARD default shim values now apply.

This software error will be resolved in a future software update. However, a reliable method to avoid this situation when using a surface coil is to either not acquire BODY SCOUT images at all, or acquire them only as the first planning study of your patient exam and do not use SHIM INLINE when acquiring them. It would then be ok to use SHIM INLINE on subsequent scans with the surface coil, and the correct shim file would be used for MAPshim. Courtesy of Atsu Manabe, Ph.D., Siemens Research & Development, Erlangen, Germany.

APPLICATIONS TIP:

MEASUREMENT HISTORY FUNCTION

For **MAGNETOM Vision** and **Impact Expert** systems: If you run a routine protocol (e.g. T1 sagittal) and then use the HISTORY function with SLICE/SAT PARAMETERS to setup a FatSat or MT protocol (e.g. T2 sagittal with FatSat or MT), the second scan will not be run with FatSat or MT as you expected. This is not a software error. Since FatSat and MT are both SAT pulses, just like spatial Presat bands, the HISTORY function turns off the FatSat or MT as it sets up a history of all the SLICE parameters and all the SAT parameters from the previous scan (e.g. T1 sagittal without FatSat or MT). So, prior to running the second scan, you must again turn on FatSat or MT.

If you had not gone back into PROTOCOL/CHANGE and seen that FatSat or MT was turned off before starting the second scan, you would have wondered why it did not work. The take home message is that the HISTORY function may change more than you think, so always go back into the PROTOCOL/CHANGE menu and check the parameters before starting the measurement. Also, label your saved protocols so that the name indicates whether you want to use FATSAT or MT. Courtesy of Jay Rocker, M.S., R.T., Siemens MR Applications Specialist, Minneapolis, MN.

APPLICATIONS TIP:

DETERMINING SLICE LOCATIONS

For **all MAGNETOM** systems: Some users and referring physicians have difficulty determining the slice locations, in spite of the text acronym which is printed on every image (+ F A L means Positive, Feet, Anterior, Left). A more easily remembered acronym (**P A I L** means Positive, Anterior, Inferior, Left) may help you more easily determine the slice locations. If you are doing an exam with an off-center FOV, such as a shoulder or knee exam, then all the sagittal images are going to have either positive or negative Slice Positions (noted SP+ or SP- on the image text). According to the **P A I L** acronym, sagittal images with the most positive slice positions are farthest toward the patient's left side and the most negative slice positions are farthest toward the patient's right side. For coronal images, positive slice positions are toward the patient's anterior and negative slice positions are toward the posterior. For axial images, positive slice positions are toward the patient's inferior and negative slice positions are toward the superior. Courtesy of Scott Mayo, B.A., R.T., Siemens MR Applications Specialist, Detroit, MI.

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 (phone 908-321-3270, or fax 908-321-3219).

Apr 27 - May 3	ISMRM, MAGNETOM Users Meeting, New York Hilton and Towers, New York City, NY
Jun 9-13	19th International Congress of Radiology, SINOMED '96, China World Trade Center Beijing, China
Jun 23-28	MRI Orthopedic Workshop, MRI Education Foundation, Inc, Vienna, Austria
Jun 26-29	10th International Symposium and Exhibition, Computer Assisted Radiology, Paris, France
Jul 21-26	11th National Symposium, Caesar's Palace, Las Vegas, NV
Sep 4-8	8th Annual Meeting, Advances in Mid and Low Field MRI, Buena Vista Palace Lake Buena Vista, FL
Sep 12-15	13th International Meeting, European Society of Magnetic Resonance in Medicine and Biology, Prague, Czech Republic
Sep 18-20	8th International Meeting, Society for Minimally Invasive Therapy, Milan, Italy
Oct 24-27	National Symposium, Economics of Diagnostic Imaging, Sheraton Hotel, Washington, DC
Nov 27-29	MRI Orthopedic Workshop, MRI Education Foundation, Inc, Chicago, IL

APPLICATIONS TIP:

FATSAT AND WATER SATURATION

This discussion may help you improve the reproducibility of your FatSat or Water Saturation techniques on the **MAGNETOM Vision** and **Impact Expert** systems. FatSat is often used in orthopedic, neuro, and body examinations, whereas Water Saturation is often used in breast examinations. A problem can arise sometimes when there is considerably more fat than water in the examined anatomy. The center frequency can adjust to the fat peak rather than the water peak if the former is much larger than the latter. This problem can be compounded if MAPshim doesn't converge optimally, causing the fat & water peaks to be indistinct.

Before attempting a FatSat or Water Saturation technique, always check to see that both MAPshim and ADJUST/FREQUENCY were optimized. Take a look at the frequency spectrum. This allows you to make any needed corrections before running the FatSat or Water Saturation sequences. Unfortunately, when checking the frequency spectrum, there is no vertical line drawn at the center frequency in the graphical display, so you may want to use a ruler to determine which peak is at the center of the displayed window. The water peak is always displayed on the left and the fat peak on the right. Typically, the water peak is larger than the fat peak, but not always.

To optimize the adjustments for FatSat or Water Saturation techniques:

1. Setup the desired protocol, position the slices and presat bands, click on FatSat.
2. Click on ADJUSTMENTS: INLINE and SHIM: INLINE.
3. Click on LOAD to adjust everything automatically and load the sequence.
4. Click on ADJUSTMENTS: OFFLINE and SHIM: OFFLINE.
5. Click on ADJUST/FREQUENCY/START to look at the frequency spectrum.
6. If necessary, manually change the center frequency in megaHertz (see below).
7. Click on APPLY, then EXIT the menu (do not START again).
8. Click on ADJUST/TRANSMITTER/START to adjust the transmitter again.
9. Click on ADJUST/RECEIVER/START to adjust the receiver again.
10. Click on MEASURE to load the sequence again and start it.

Under various conditions it may be necessary to manually change the center frequency (see step 6 above) to shift the suppression pulse to the desired peak:

a) If the center frequency did adjust to the water peak and you desire a FatSat technique, it is not necessary to change the center frequency because the suppression pulse is automatically shifted down to the fat peak. Click on FatSat to get a FatSat pulse.

b) If the center frequency did adjust to the water peak and you desire a Water Saturation technique, it is necessary to increase the center frequency to shift the suppression pulse to the water peak (add .000220 megaHertz @ 1.5 T, or add .000140 megaHertz @ 1.0 T). Click on FatSat to get a Water Saturation pulse.

c) If the center frequency did adjust to the fat peak and you desire a FatSat technique, it is necessary to increase the center frequency to shift the suppression pulse to the fat peak (add .000220 megaHertz @ 1.5 T, or add .000140 megaHertz @ 1.0 T). Click on FatSat to get a FatSat pulse.

d) If the center frequency did adjust to the fat peak and you desire a Water Saturation technique, it is necessary to increase the center frequency to shift the suppression pulse to the water peak (add .000440 megaHertz @ 1.5 T, or add .000280 megaHertz @ 1.0 T). Click on FatSat to get a Water Saturation pulse.

Courtesy of Sheila Bero, R.T., Siemens MR Applications Specialist, Cary, NC.

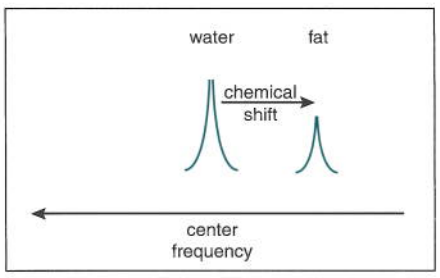

Figure 1. Typical case: MAPshim converged optimally, so fat and water peaks are distinct and shifted. Frequency adjusted to water peak because it was considerably larger than fat peak. Fat peak is chemically shifted down from water peak (220 Hz @ 1.5 T, or 140 Hz @ 1.0 T).

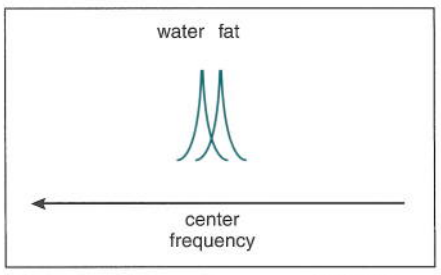

Figure 2. Alternative case: MAPshim did not converge optimally, so fat and water peaks are not distinct and shifted. Frequency adjusted somewhere between the fat and water peaks. This may occur when imaging ankles, necks, breasts, or shoulders because MAPshim may have difficulty with anatomy which is non-symmetrically shaped or positioned far off-center.

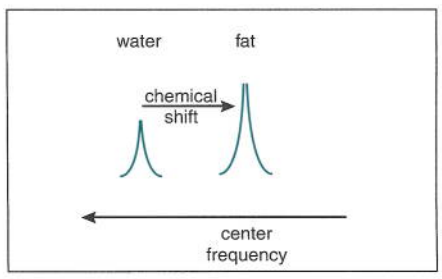

Figure 3. Alternative case: MAPshim converged optimally, so fat and water peaks are distinct and shifted. But, frequency adjusted to fat peak because it was much larger than water peak. This may occur when imaging knees, spines, breasts, or other anatomy which contains a large proportion of fat.

APPLICATIONS TIP:

OPTIMIZING RECFOV

For the **MAGNETOM SP** system: When using RecFOV we sometimes choose to be safe rather than sorry, so we estimate a RecFOV which is larger than we really need in order to avoid wrap-around artifacts. But there is a way to check the size of the actual RecFOV on a scout image before you run the sequence. This enables us to use a tighter RecFOV without worry of wrap-around artifacts and, thus, reduce the phase encoding matrix to shorten the scan time (sometimes by a minute or more) without sacrificing resolution. Courtesy of Greg Thomas, R.T. and Mary Bell, R.T., MRI Technologists, Memorial MR Center, Ormond Beach, FL.

RECFOV PROCEDURE

1. Acquire and display a scout image in the same plane as you intend to acquire the RecFOV protocol (both must be exactly the same plane of orientation). This scout should have a slightly larger FOV than the images to be acquired with RecFOV.

2. After setting up the desired RecFOV protocol in the SEQUENCE/CHANGE menu, go into the SLICE/SAT menu to display the square box representing the FOV in the same plane as the scout image (see Figure 1). Remember, a square box will be displayed whether you have initiated RecFOV or not.

3. Go back into the SEQUENCE/CHANGE menu and reduce the FOV by the appropriate factor for your desired RecFOV (see Table 1).

4. Go back into the SLICE/SAT menu to visually check the size of the reduced FOV and use the SEPARATE menu to enter any offcenter shifts needed to position the reduced FOV. When juggling the size and location of the reduced FOV, remember that the acquired FOV will be reduced only along the phase direction since the frequency direction is never affected by RecFOV (see Figure 2). Pay careful attention to whether or not the phase and frequency directions are SWAPPED. Remember, visually ignore the reduced size of the FOV along the frequency direction.

5. You may have to repeat steps 3 and 4 a couple times to determine just how small you can push the RecFOV without cropping off the image or getting wrap-around. Once you have determined the optimal RecFOv factor, you can reduce the phase encoding matrix accordingly (see Table 2) and return to your original desired FOV in the SEQUENCE/CHANGE menu.

PITFALLS

1. Don't forget to return to your original desired FOV before initiating RecFOV and starting the measurement.

2. Occasionally, the sequence will not allow you to reduce the FOV as small as suggested by Table 1, so you will have to "guesstimate" from the minimum FOV allowed by the sequence.

3. Extreme offcenter shifts in which the displayed box tries to overlap the edge of the scout will prevent the box from being displayed at all. Go back and re-run the scout with a larger FOV.

4. Beware of using RecFOV too tightly on anatomy which is angled.

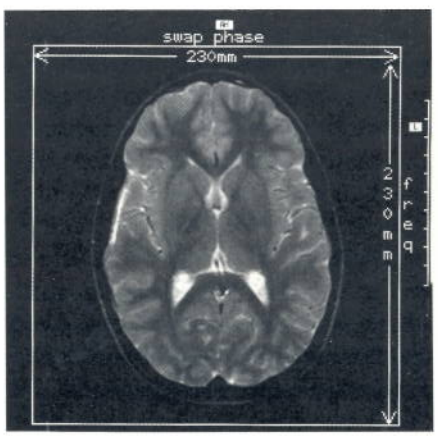

Figure 1. Square box representing the desired FOV on the scout image.

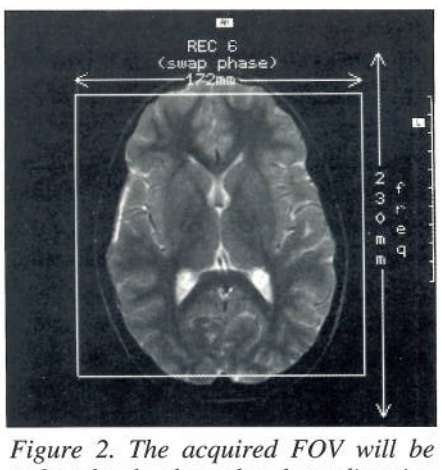

Figure 2. The acquired FOV will be reduced only along the phase direction since the frequency direction is never affected by RecFOV.

RECFOV	REDUCTION FACTOR	EXAMPLE REDUCED FOV
4/8	0.500	500 mm X 0.500 = 250 mm
5/8	0.625	500 mm X 0.625 = 313 mm
6/8	0.750	500 mm X 0.750 = 375 mm
7/8	0.875	500 mm X 0.875 = 438 mm

Table 1

DESIRED RESOLUTION	256	224	192	180
RECFOV	PHASE ENCODING MATRIX TO USE			
4/8	128	112	96	90
5/8	160	140	120	112
6/8	192	168	144	135
7/8	224	196	168	157

Table 2

TECHNICAL ARTICLE: MRI SAFETY

Judith Behrens, R.T., MR Applications Specialist
Siemens Medical Systems, Greensboro, NC

Introduction

This article addresses some important safety issues that should be considered when working in, or in close proximity to, a magnetic resonance imaging (MRI) department. This article is not intended to supersede any warnings or vendor specific recommendations but, rather, it is intended to be used as an adjunct to such. The international standard for MR safety has been officially adopted (IEC-601-2-33 - Particular Requirements for the Safety of Magnetic Resonance Equipment for Medical Diagnosis). Some of the safety levels differ from those currently accepted by the FDA (i.e., the average acoustic noise levels are limited to 99dB). The FDA has not officially adopted the IEC guidelines, but is moving toward adopting the levels specified.

It is important that all personnel who work around the MR environment be trained in MR safety. This includes technologists, physicians, nurses, secretaries, janitorial and maintenance workers. Good safety practices include a thorough knowledge of the MR environment, complete and consistent patient screening, clearly outlined and understood emergency procedures, and a working understanding of MR safety terminology.

Let's begin by explaining the three types of "fields" employed within an MR system, each of which poses its own set of potential hazards. Every MR system includes a static magnetic field (the magnet), some time-varying magnetic fields (the gradients), and some time-varying electromagnetic fields (the RF).

Static Magnetic Field - The Magnet

The main safety issues regarding the static magnetic field include the potential for biological effects, the potential for attraction of ferromagnetic objects, and the potential for a quench of the cryogens. Although many studies have been done regarding biological effects of static magnetic fields, there is no conclusive evidence to date that static magnetic fields up to 2 Tesla can cause lasting harmful biological effects. The FDA has established that static magnetic field levels below 2 Tesla are below a level of concern.

A 1.0 Tesla magnet has a field that is roughly 20,000 times stronger than the earth's magnetic field. Ferromagnetic objects brought within near proximity to the static magnetic field can become projectiles which could cause harm to someone standing between the object and the magnet. The force of attraction between a magnet and a ferromagnetic object is determined by the magnetic field strength (actually, the fringe field), the magnetic susceptibility of the object, it's mass, its distance from the magnet, and its orientation to the field. This force of attraction is exponentially proportional to the inverse of the distance (D) between the magnet and the object, but linearly proportional to the mass (M) of the object. For example, if the distance is decreased by a factor of four, the attractive force on the object is increased by a factor of sixteen. The heavier a ferrous object is, the stronger the attraction.

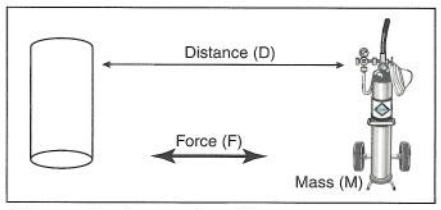

Figure 1. Attractive Force
$F \alpha M * (1/D)^2$

Besides the hazard of projectiles, the static magnetic field can cause ferromagnetic objects within the patient (such as angio clips, prostheses, etc.) to move or torque, thus possibly causing harm. Electrically, magnetically, or mechanically activated implants can become dysfunctional due to the static magnetic field. If these devices are life-supporting, harm could result. For example a ferromagnetic aneurysm clip might try to align itself with the magnetic field flux lines, and this would cause the clip to move or torque, thus tearing the vessel it is attached to. Or, the static magnetic field could change the function of a pacemaker by activating the switch and changing the pacemaker from a demand pacer to a fixed pacer. The closer a pacemaker is to the magnet, the more likely it is to become completely dysfunctional. All MRI manufacturers are required to identify a 5 gauss pacemaker exclusion zone to avoid the possibility of pacemaker dysfunction. All of the above discussions pertain to patients, operators, physicians, or anyone entering the MR suite.

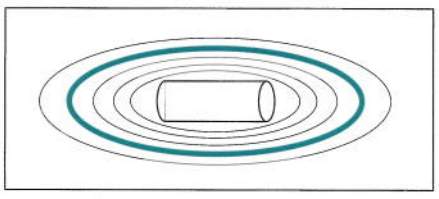

Figure 2. 5 gauss fringe field line surrounds magnet

With superconducting MR systems, another concern related to the static magnetic field is a quench of the cryogens. A quench, which is actually a sudden boil-off of the entire volume of cryogenic liquid, causes a sudden loss of the static magnetic field. It is not the loss of the field which poses the hazard, but rather the boiled-off gasses. Most superconducting MR systems have a duct system for venting the boiled-off gasses into the outside air. However, if that venting system should fail, the cryogen gasses could easily replace most of the oxygen in the magnet room. Since this poses a potential asphyxiation hazard to both the patient and to personnel, it is critical to have a well planned method to quickly remove the patient and personnel from the magnet room if a quench should occur.

Figure 3. Quench poses asphyxiation hazard

Additionally, since the cryogen gasses are odorless, tasteless, and colorless it is particularly important to keep an oxygen monitor in the magnet room at all times, and to periodically check it for proper functioning. If there is ever an accident in which the liquid or gaseous cryogen contacts human skin, specific steps should be taken to avoid frostbite and always consult a physician immediately. Such procedures should be established and made readily available to all personnel. Always store cryogen supplies in a restricted and well ventilated area.

Time Varying Magnetic Fields - The Gradients

In addition to the static magnetic field, every MR system uses time-varying magnetic fields to spatially encode the MR signal during a scan. These time-varying magnetic fields, called gradients, turn on and off very rapidly and with very high amplitudes. Such high frequency gradient switching is characteristic of fast imaging techniques, such as echo planar imaging (EPI). However, one potential biological hazard resulting from this is that a current will be induced in any conductive material lying within the rapidly changing magnetic field. In fact, the greater the rate of change of the magnetic field (dB/dt, slew rate) the larger will be the induced current. Note that the muscles, nerves, and blood vessels of the human body are all conductive materials. There is evidence which suggests that the very fast rates of magnetic field change (dB/dt) used in EPI techniques may cause peripheral nerve stimulation or the appearance of flashing lights known as magnetophosphenes. Though most commercially available systems cannot technically operate at levels that cause stimulation, some operate at levels that have the potential. Each manufacturer is required to include information in their system guides identifying the potential for stimulation, if it exist.

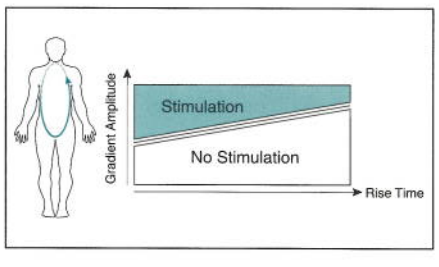

Figure 4. Large gradient amplitudes switched very quickly (large dB/dt) may cause nerve stimulation at periphery of body due to induced currents in nerves. This is most likely to occur with EPI techniques in which the large dB/dt is applied along the Y axis, thus causing currents to be induced as indicated by the green circle in this figure.

These problems are not an issue at dB/dt rates used in routine clinical MR today. However, especially with ultrafast imaging techniques, constant contact with the patient should be maintained to ensure that the patient does not feel any discomfort. Patients should be instructed not to clasp their hands or cross their feet during the exam since this may create a current loop which may lower the stimulation threshold. Special considerations should be given regarding the risk of scanning special patient groups such as children, pregnant women, epileptics, patients with metallic implants, cardiac arrhythmia, peripheral neuropathy, comatose patients, or patients who are unable to communicate. Additionally, since most metallic prostheses are excellent conductors, all large metallic prostheses should be individually evaluated for excessive heating due to gradient induced currents within the metal. Follow the manufacturer's guidelines or consult a reference on the specific prosthesis.

Another potential safety issue regarding the gradient switching is the resulting loud noise. The rapid alternations of currents within the gradient coils causes the coil assemblies to vibrate against their mountings, thus generating a loud resonant noise. The noise may sound like a banging in most cases or even a high pitched whistle with some EPI sequences. Routine clinical sequences generate acoustic noise levels of typically 65-95 dB, but when faster sequences are run the gradients tend to vibrate harder and the noise tends to get louder.

For clinical MRI systems, the FDA currently accepts acoustic noise levels established by the Occupational Safety and Health Administration (OSHA), which indicates that the average noise must remain below 105 dB and the peak acoustic noise must remain below 140 dB. With the advent of high speed gradient systems, it is more important than ever to ensure that the patient uses earplugs or some type of hearing protection system. If the procedure requires that you communicate with the patient during the examination, be sure to use a noise-damped intercom system.

Time Varying Electromagnetic Fields - The RF

An oscillating electromagnetic field which operates in the lower megahertz range is known as a Radio Frequency (RF) field. Pulses of RF energy are used in every MR system to generate the signal which is measured during each scan. Analogous to a microwave oven, these RF pulses generate heat within the patient's body and, if unregulated, can cause extensive localized heating (and even tissue damage in extreme cases). As it turns out, RF heating of tissues is greatest at the skin surface or periphery. The Specific Absorption Rate (SAR), a

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term used to estimate the amount of heat dose received by the patient, is expressed as Watts of power per kilogram of the patient's body weight. For the SAR to be correctly calculated, it is critical to enter the patient's correct weight and birthdate. Failure to do so will result in incorrect SAR values, possibly resulting in patient heating or burns.

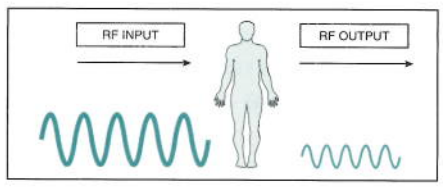

Figure 5. RF input may raise core body temperature or cause localized heating.

The FDA has established guidelines in the United States specifying allowable SAR limits for commercial MR systems. Two guidelines were specified, and each vendor can choose which guideline to follow. One guideline specifies that the SAR should be equal to or less than 0.4 Watts/kg averaged over the patient's whole body and equal to or less than 8.0 Watts/kg averaged over any one gram of tissue. The other guideline, which Siemens chose to comply with, specifies that the RF energy dose should not increase the patient's core body temperature more than 1 degree Celsius and localized temperatures should not exceed 38 degrees Celsius in the head, 39 degrees Celsius in the trunk, or 40 degrees Celsius in the extremities. Siemens limits its SAR values to 1.5 Watts/kg for the whole body RF exposure and 8.0 Watts/kg for localized RF exposure. For patients with normal thermoregulatory systems, the whole body SAR limit can be raised to 3.0 Watts/kg, but the localized SAR limit cannot be raised. Raising the SAR limit should only be done when you are sure that it is safe for your patient, and you should be particularly cautious. Watch and listen to your patient, and instruct him in the use of the "panic" button or squeeze bulb. If he complains of being too warm or experiencing any localized burning, stop the scan immediately and investigate his claims. Do not raise the whole body SAR limit for patients who are insensible or those incapable of communicating with you. It helps to have adequate air flow within the bore of the magnet and to keep the magnet room cool. When contemplating raising the SAR limits, also remove additional blankets to avoid unnecessary heating of the patient.

Numerous factors affect the calculated SAR value for a scan. The number and type of RF pulses used within the pulse sequence, the type of coil, patient positioning, and the static magnetic field strength are among the most pertinent factors affecting the calculated SAR. The more slices per TR, the higher the SAR. The more RF pulses per slice, the higher the SAR (Turbo Spin Echo > Spin Echo > Gradient Echo). Higher flip angles require more energy, and thus higher SAR, than lower flip angles. Saturation techniques such as Presat, FatSat, and MT require additional RF pulses which further increase the SAR.

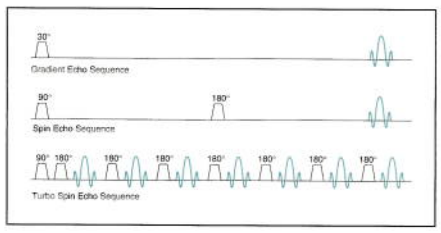

Figure 6. The more RF pulses per TR, the higher the SAR.

(Turbo Spin Echo > Spin Echo > Gradient Echo).

The larger the volume of the transmitter coil, the higher the SAR. Since the body coil, spine coil, and flex coils all use the large-volume body coil for a transmitter, they generally have higher SAR values than the small volume, transmit/receive head coil and extremity coil. Patients positioned near the isocenter and centered within the coil have lower SAR values than those positioned offcenter because the coil has a higher loading factor (less RF energy is reflected back by the coil during transmission, so energy is transferred into the patient more efficiently). Lower magnetic field strengths have lower SAR values than higher field strengths because less energy is required by each RF pulse to accomplish the desired flip angle.

Another potential biological hazard related to the RF field is due to the fact that ECG and other metallic leads can act like antennae. The induced currents in the leads and electrodes may cause them to get so hot that they can actually cause burns in adjacent tissues. Therefore, when using an ECG triggered MR technique, it is important to use only the Siemens recommended disposable electrodes and compatible leads. These carbon fiber wires are less likely to cause burns because carbon is more resistant to induced currents. Never loop ECG wires or other monitoring leads because looped wires act like MR coils and readily pick up induced currents. For further information about ECG leads, contact the Siemens Applications Hotline (800-333-3137).

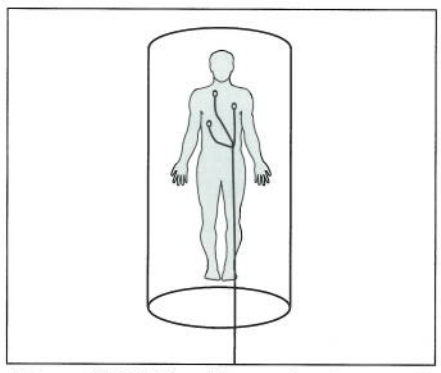

Figure 7. ECG cables and other monitoring wires should be as straight as possible within the magnet bore and should never form loops.

The ECG triggering feature on the Siemens MAGNETOM system is not intended for accurate ECG monitoring of critically ill patients. It is designed only for synchronizing the scan acquisition with the patient's heartbeat. For accurate ECG monitoring, there are MR compatible devices, electrodes, and cables available from various vendors. Electrodes that are used for routine ECG monitoring (e.g. inpatients on heart monitors) must be removed prior to the MR exam unless you are absolutely sure that they are MR compatible. If you are using the MR compatible patient monitoring system manufactured by InVivo, you should use only the MR compatible ECG leads manufactured by Siemens because patient burns have been reported with the InVivo ECG leads. Safety notices have been sent from InVivo and Siemens regarding this issue.

It has been reported that a patient received second degree burns to the underlying skin while undergoing an MR exam and wearing aluminized-backed transdermal patches. According to the latest information from Dr. Frank Shellock these types of products should be removed before an MR exam.

Coils

The coils are the antennae for the RF system. You should familiarize yourself with the published operating instructions for each coil; all the recommendations and warnings are included in the system guides. The Small FOV Coil has safety rubber bumpers that should be installed on the cable to prevent a patient from touching the cable and possibly getting burned. To avoid possible burns, the Flex Coils should never have their cables routed across the patient's head or near his eyes. The CP Array Coils have an electronics box that should always be securely strapped to the patient to avoid possible injury to the patient while the table is being rolled into or out of the magnet bore. You should always keep all cables and wires from contacting the patient's skin, separated by pads and cushions. All unused electrical and metallic materials and all unplugged surface coils should be removed from the magnet bore during scanning. Make it a practice to routinely check for broken or frayed wires or cables on ECG leads, pulse oximeter leads, and other monitoring equipment that is used on the patient during scanning. Ensure that the patient is not wearing clothes with metallic threads or inserts.

Precautions and Safety Training

Make sure you are familiar with your MR equipment and all the manufacturer's recommendations and precautions. All vendors are required to provide documentation which highlights areas of warning, caution, or notice. Such information is provided in the system guide and as defined, Warning means that failure to follow instructions or precautions could result in harm. Caution means that failure to follow instructions or precautions could result in damage to the equipment. Notice means that the information is to help you obtain optimum performance from your equipment and implies no hazard to users or equipment.

WARNING

Hazardous for persons with electromagnetically activated implants

CAUTION

If the Table STOP button fails to respond, immediately activate the Emergency Shutdown button.

NOTICE

The patient must be told to inform the operator via the squeeze bulb if he/she senses anything abnormal.

Figure 8. FDA requires manufacturer's documentation of potential hazards, precautions, and recommendations.

MR safety issues need to be stressed repetitively in a continuing education program. You should be prepared with a well understood action plan for any possible emergency such as fire, quench, or patient emergency. These plans should be carefully devised, written up, reviewed on a periodic basis, and practiced periodically to ensure that everyone understands their responsibility. For example, in case of an electrical fire, do the local fire department personnel know what precautions need to be taken for themselves as well as for the MR system? Do all your technologists know all the emergency buttons and when to use each (Electrical Stop, versus Quench)? Under what emergency conditions should you intentionally quench the magnet? What would you do if the patient has a medical emergency? Do you have an assigned emergency area outside of the magnet room where you can take a patient so that the emergency team can use the necessary equipment? Is the crash cart equipment functional and is it MR compatible? Are all emergency phone numbers in a clearly visible place? Do you and your schedulers understand proper patient screening and patient preparation techniques?

Referring physicians should be educated regarding which patients can be safely scanned within the MR environment. Transport personnel should be educated regarding the use of non-ferrous equipment such as stretchers, wheelchairs, oxygen tanks, infusion pumps, etc. EMT personnel should be trained to identify ferrous equipment on themselves and the patient before entering the magnet room. Nurses should be taught to properly screen themselves and their patients, and they should be aware of non-compatible monitoring equipment. Code teams should be able to identify the resuscitation area in case of an emergency. The Fire Department should be educated regarding the MR environment and they may need to obtain non-ferrous fire fighting equipment. Auxiliary personnel, such as maintenance and housekeeping, should be educated regarding MR safety. All of these personnel need to be screened for anything that they may be wearing or may bring into the magnet room. There should be an ongoing review of safety procedures on a regular basis with all of the above personnel. Siemens recently distributed a Magnet Safety video to its MR customers for

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use in their safety orientations for their hospital or clinic personnel. For additional copies of this video, contact the MR Applications Hotline at (800)333-3137.

Figure 9. Continuing safety training, good emergency planning, and rigorous patient screening are your best insurance against MRI safety disasters.

Patient Screening

A well designed patient screening questionnaire might include questions regarding the patient's history, pregnancy, foreign bodies in the patient (metallic or not), implants which are magnetically, electrically, or mechanically activated. All patients should be changed into a gown or scrub suit to completely eliminate any possibility of scanning pins, pencils, paper clips, etc. in their clothes. Furthermore, many types of street clothes are made of material which can cause static discharges during the examination which typically degrade the image quality. Several types of makeup can degrade the image quality. Be particularly wary of tattooed eyeliner which can not only degrade image quality but may actually burn the patient if it contains metallic pigments. Many wigs, toupees, and hairweaves (particularly black) include iron particles to enhance the color.

When screening patients for an MR exam, it is important to understand the different types of implants, which are generally classified into 4 groups. *Absolute contraindication* means that the patient absolutely should not be scanned. This includes cardiac pacemakers, automatic internal defibrillators, implanted infusion pumps, implanted insulin pumps, bone growth stimulators, non-removable neurological stimulators, cochlear implants, metal in the eyes, shrapnel in vital locations, and tattooed eyeliners or lipsticks. *Relative contraindication* means that some of these devices may and some may not be scanned. This includes aneurysm clips, penile prostheses, cardiac valve prostheses, middle ear prostheses, and shrapnel or foreign bodies in non-vital locations. *Safe* means that the device may be scanned without any problems. This typically includes orthopedic prostheses, pins, rods, plates, surgical clips (2-3 months post surgery), dental fillings, orthodontics, braces, root canal work, intrauterine devices, and contraceptive diaphragms. *Controversial* means that there is no general consensus on the safety of the device. This includes such things as Gianturco embolization coils, inferior vena cava filters, and endovascular stents. Dr. Frank Shellock, who has done a great deal of research regarding the MR compatibility of various implants, cautions that his list cannot be taken as the final word. It is prudent to assume that no list of supposedly "MR compatible" devices is absolutely correct. Paraphrasing Dr. Shellock from his latest pocket guide on MR procedures, "... a manufacturer may change the composition of the implant, material, device or object without going back to the FDA for new approval as long as the function of the device remains the same ..." Of course the final decision, when there is a question of safety, is the responsibility of the physician.

Contrast Agents

For certain MR procedures, a patient may require the injection of a contrast agent. These are currently available for brain and spine applications, and select areas of the whole body. Indications for use, recommended dose levels, warnings, and contraindications are identified on the product inserts. Contrast agents should only be administered under the direction of a physician. Be particularly watchful with patients having sickle cell anemia, patients having renal or hepatic problems, and patients who are pregnant or breast feeding. Always refer to the manufacturers' labeling prior to use of any injectable.

Pregnancy

The safety of magnetic resonance imaging environments for fetuses has not yet been established nor is there any specific FDA regulation regarding this issue. The only recommendation which the FDA offers is stated in the Federal Register (3/ 9/ 88), "Special concerns arise when scanning fetuses who are particularly susceptible to thermal overload and require careful monitoring for signs of cardiocirculatory and respiratory distress." For all MR scanners, the FDA requires labeling that "Addresses the risk of scanning fetuses (for whom data establishing the safety of the device are lacking)."

The safety of magnetic resonance imaging environments for pregnant patients or pregnant personnel has not yet been established nor is there any specific FDA regulation regarding this issue. MR scanning of pregnant women should be performed only when the sole alternative choice would be an imaging modality exposing the fetus to ionizing radiation.

CLINICAL ARTICLE: PROSTATE MR IMAGING WITH THE ENDORECTAL COIL

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Introduction

The combination of endorectal coil MR imaging for local spread and body coil MR imaging for advanced disease makes MR imaging the premier imaging modality for the preoperative staging of prostate carcinoma. Differentiation between stage B (tumor limited to the gland) and stage C (tumor into or beyond the prostatic capsule, bladder neck or seminal vesicles) is best evaluated by the endorectal coil. An endorectal surface coil (Medrad, Pittsburgh) has been developed to obtain high-resolution MR images of the prostate. The ability to differentiate histologically distinct regions of the normal prostate is important, since clinically important prostatic diseases typically arise in different prostatic zones (benign prostatic hyperplasia in the transitional zone and carcinoma in the peripheral zone). The endorectal probe consists of a surface coil mounted on the inner surface of a balloon. The balloon is concave to ensure tight seating against the prostate. The coil is used on all patients being evaluated for prostatic carcinoma. We also use the coil for follow-up of prostatectomy patients if their PSA increases. Compared to the body coil, the endorectal coil provides increased resolution for MR imaging of the prostate gland and capsule, thus yielding improved sensitivity and specificity for staging prostate cancer (.65 sensitivity and .69 specificity for the body coil (References 1-7); .87 sensitivity and .85 specificity for the endorectal coil (References 1, 8-10).

Technique

Initially a rectal exam is performed with surgilube and a few ccs of lidocaine gel. The tip of the endorectal coil is then coated with surgilube and inserted with the patient in the lateral position. The balloon is inflated with 100-125 ccs of air, enabling the concave anterior surface of the balloon to seat over the posterior contour of the prostate. It is important not to torque the coil as it is inserted, so that the coil is well centered on the gland. Axial and sagittal localizing images show proper positioning of the coil. Axial Spin Echo T1-weighted images and axial, sagittal and coronal Turbo Spin Echo T2-weighted images are obtained with a 14-16 cm field-of-view and a 4 mm section thickness. Motion artifacts may be exaggerated by the large signal gradient at the tissue and air filled balloon interface. Thus, intramuscular injection of 1 mg of glucagon is used to reduce bowel induced artifact. In addition, frequency encoding in the anterior-posterior direction decreases balloon motion artifact. After the high resolution images, axial Spin Echo T1-weighted images are obtained with the body coil to evaluate for aortic and iliac adenopathy (Reference 11).

Anatomy

The prostate gland is similar to an inverted triangle with its inferior apex adjacent to the urogenital diaphragm and its superior base adjacent to the bladder base. The prostate has four well defined zones. The periurethral zone is a thin area around the urethra containing periurethral glands. The transitional zone marks the transition between the periurethral zone and the central zone. The peripheral zone surrounds the central zone and is the location of most prostate cancers; it contains more glandular cells that are less densely packed than the rest of the gland. Low signal is seen throughout the normal gland on T1-weighted images. On T2-weighted images, the normal peripheral zone forms a high signal postero-lateral rim and the central gland has a slightly lower signal intensity (Reference 12). The seminal vesicles are found on the postero-superior base of the prostate. They have a low to intermediate signal on T1-weighted images and high signal on T2-weighted images. The neurovascular bundle can be identified with good endorectal images at the postero-lateral aspect of the gland. Resectability and prevention of impotency by assessing invasion of this area are important aspects of MR evaluation. The bundle is best seen on T1-weighted sequences where the low signal common penile artery and vein and sacral nerve plexus run in a high signal triangle of fat in the recto-prostatic angle (Figure 1).

Prostate Cancer

Surgical cure of adenocarcinoma of the prostate is possible in over 80% of cases when the disease is confined to the gland capsule. Prostate carcinoma most often originates in the peripheral zone. In McNeal's study of 104 patients, among the 88 cancers he found whose probable zone of origin could be identified, 68% arose in the peripheral zone, 24% arose in the transition zone, and 8% arose in the central zone (Reference 13). It is common to find multiple foci of prostate cancer. T2-weighted low signal intensity in the peripheral zone is the most common appearance of tumor (Figure 2). On T1-weighted images, prostate cancer can have low to isointense signal. Post biopsy hemorrhage can simulate prostate cancer. Hemorrhage may be seen as regions of decreased T2 signal with corresponding regions of elevated T1 signal (Figure 3). MRI is relatively non-specific for low signal tumor in the central gland since benign prostatic hyperplasia (BPH) can demonstrate variable signal intensities and is most often found here.

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Benign Prostatic Hyperplasia

The MR characteristics of BPH are variable but predictable, depending on the distribution and size of the glandular elements as well as the composition of the surrounding stroma. In BPH, the changes typically begin in the central portion of the gland (Figure 4). The areas of highest signal intensity correspond to dilated glandular elements (cystic ectasia), while the areas of lowest signal intensity correspond to collagen (scar) and fibromuscular stroma. Nodules of mixed glandular BPH and fibromuscular BPH are found to have signal intensities similar to those of well-differentiated nodules of prostatic adenocarcinoma (Reference 14).

Conclusion

MRI using the endorectal coil has an important role in evaluating the prostate. With its high resolution multiplanar images of the complex prostatic and periprostatic anatomy, it may be the best modality for staging prostate cancer.

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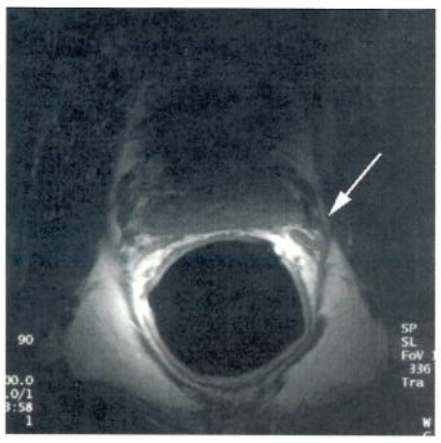

Figure 1. Spin Echo axial T1-weighted (TR 700, TE 17) endorectal coil image of prostate. The neurovascular bundle is clearly seen in the high signal periprostatic fat.

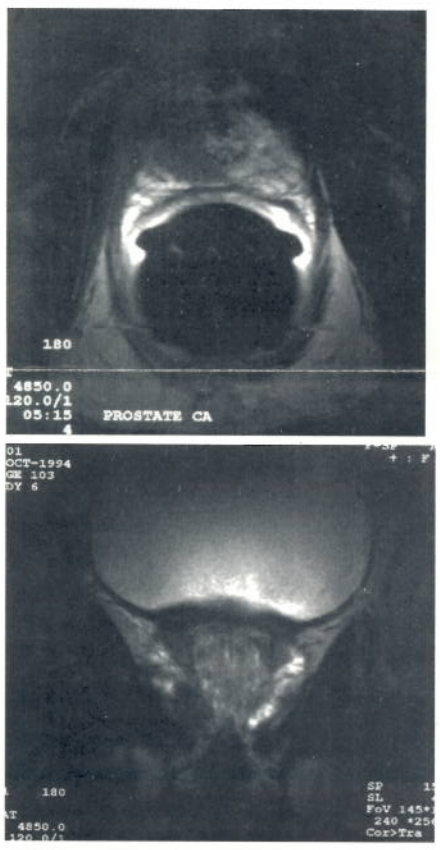

Figure 2. A. Turbo Spin Echo axial T2-weighted (TR 4850, TE 120) endorectal coil image. The low signal nodule in the brighter peripheral zone is typical of prostate cancer.

B. Turbo Spin Echo coronal T2-weighted (TR 4850, TE 120) endorectal coil image. The tumor involves the apex of the gland.

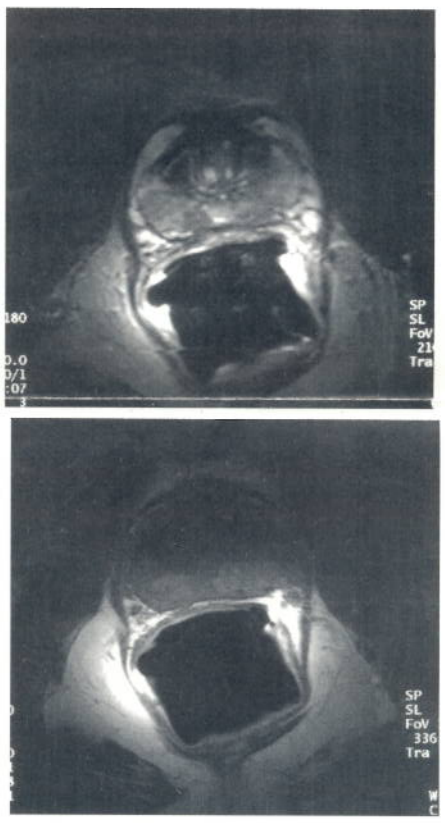

Figure 3. A. Turbo Spin Echo axial T2-weighted (TR 7150, TE 112) endorectal coil image after biopsy. Low signal in the peripheral zone simulates prostate cancer.

B. Spin Echo axial T1-weighted (TR 700, TE 17) endorectal coil image after biopsy. High signal in this same area represents methemoglobin from biopsy.

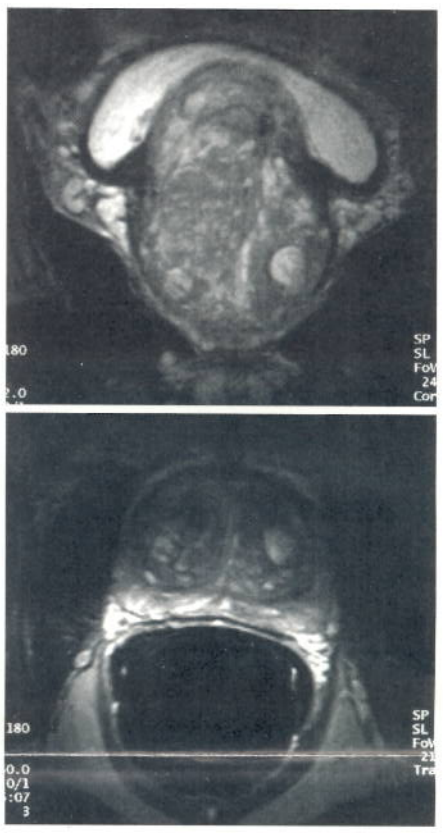

Figure 4. A. Coronal and B. axial Turbo Spin Echo T2-weighted (TR 7102, TE 112) endorectal coil images of patient with BPH. The brighter peripheral zone is compressed by BPH in the central portion of the gland.

Error Correction

In Volume 4 Number 1 of the Flash newsletter in an article entitled Applications Tips: High Resolution IAC Examination, the images were provided by Kyobashi Hospital of Tokyo, Japan by Mr. Katano, Chief Technician.

APPLICATIONS TIP:

MAGNETOM IMAGES COPIED TO MAGICVIEW

For **MAGNETOM Vision** and **Impact Expert** systems: If STUDY/DISPLAY images or COPY/SEGMENT images are copied from a MAGNETOM system to a MagicView workstation for remote review by a radiologist, an image numbering discrepancy will occur. This is because the STUDY/DISPLAY or COPY/SEGMENT functions assign the next available image number to each of these 'created' images, and then they are appended to the end of the STUDY from which they came. Thus, that study will most likely contain a discontinuous range of image numbers (e.g. 11, 12, ... 19, 137 : where 137 was the next available image number). However, the MagicView uses a different numbering scheme. It simply assigns the image numbers in the order as they are copied to it. Therefore, these 'created' images from STUDY/DISPLAY or COPY/SEGMENT are assigned a different number on the MagicView than on the MAGNETOM.

This is very confusing for the radiologists when communicating with the technologists. There are two solutions, one involving the radiologists and the other involving the technologists. Radiologists at the MagicView can simply 'cut and paste' those 'created' images to the end of the slice groupings. Or, technologists at the MAGNETOM can do STUDY/DISPLAY or COPY/SEGMENT functions only after all images have been acquired, at the end of the patient exam. Or, technologists at the MAGNETOM can continue doing STUDY/DISPLAY or COPY/SEGMENT throughout the exam, then write down all those 'created' image numbers, then at the end of the exam create a new study named "Created Images" which contains all these, then delete the original 'created' images from all the other studies throughout the exam. This results in all the measured images being consecutive and all the 'created' images being consecutive. This is easy to verify on the MAGNETOM by reviewing the STUDY/LIST prior to copying images to the MagicView. Courtesy of Jay Rocker, M.S., R.T., Siemens MR Applications Specialist, Minneapolis, MN.