THE MAGNETOM

FLASH

newsletter for SIEMENS MAGNETOM users • vol. 2 no. 2/1994

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- Apps Resources

From the Editor

The Siemens FLASH newsletter continues to broaden its scope to meet your professional needs. Anticipating the certification examinations facing MRI technologists within in the next two years, this issue of the FLASH provides a list of resources which includes pamphlets, videos, applications guides, and phone contacts with other users. Also included in this issue are several feature articles focusing upon clinical imaging of the heart and coronary arteries. Announced within this issue are upcoming meetings and seminars, new products, and software upgrades for Siemens' users. As usual there is a section for applications tips and protocols from Siemens' Applications Specialists or from you, our users. And finally, no issue would be complete without questions and comments from you, the readers.

If your MRI supervisor has not received all three previous issues of the FLASH and shared them among all your technical staff, contact me for additional back issues. Since this is your newsletter, you must continue to contribute articles, announcements, interesting cases, questions, comments, etc.

The MAGNETOM FLASH

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Announcing Magnetom Open and Vision

MR Division
Siemens Medical Systems, Inc.

Magnetom OPEN

The new Magnetom OPEN system from Siemens received 510(k) clearance by the FDA in March 1994. The revolutionary open design of the system should prove especially inviting to claustrophobic patients, larger patients, older anxious patients, and children who need comforting during the exam by family or friends. With MR-compatible patient monitoring or life support equipment, even critically ill patients should be able to undergo an MRI exam with the OPEN system. Due to the new open magnet architecture and the new circularly polarized flex coils, excellent kinematic studies of knees, elbows, and shoulders should be possible.

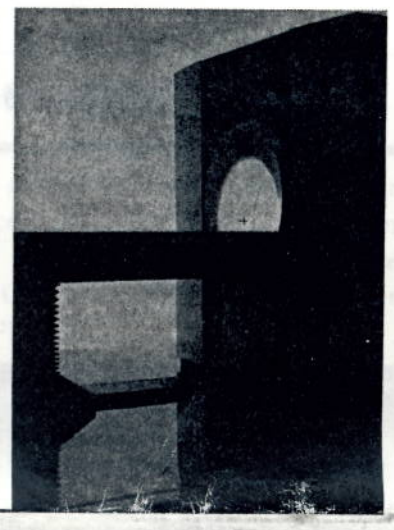
Operating at 0.2 Tesla, the new system uses an open C-shaped magnet with flat, actively-shielded gradients (10 mT/m), circularly polarized coil technology, and the same computer platform as the Magnetom

IMPACT and Magnetom VISION. The OPEN achieves excellent image quality by utilizing advanced techniques such as MR Angiography, Turbo Spin Echo, TurboFLASH, integrated 3D post-processing, and integrated cardiac motion studies. As a member of the Siemens family of Magnetom systems, which includes the well-proven 1.0 Tesla Magnetom IMPACT and the new 1.5 Tesla Magnetom VISION, the 0.2 Tesla Magnetom OPEN can easily adapt to new imaging techniques and evaluation programs as they are developed.

Magnetom VISION

The new Magnetom VISION system from Siemens received 510(k) clearance by the FDA in January, 1994. There are more than 10 VISION systems operating in the U.S. This new system has the highest gradient strength (25 mT/m) on the market today designed for current and future clinical applications, along with the fastest computer system for higher efficiency, and the widest bore for increased patient comfort. The system is designed to fit many needs from high throughput clinically oriented sites to state-of-the-art research facilities.

The VISION is a continuation of Siemens Path to the Future. If You own a 1.5 Tesla system, contact your Siemens sales representative today to discuss how you can upgrade to the VISION.



Applications Support

Siemens Medical Systems, Inc.

The Siemens MRI Applications Group has recently increased its customer support in two important ways. As of March 1994, two Applications Specialists are assigned for support of the Toll-Free Applications Hotline during its normal business hours of M-F 9am-6pm. Prior to March 94, only one Applications Specialist was available for this support. We encourage you to use this valuable resource to help you with questions you may have or to assist you during the daily routine. The number is (800)333-3137. Please let Siemens know if you have any problems with the support line or if you have any suggestions for improvements.

ASRT certification credits are now available to registered technologists who attend the following programs:

1. Essentials of MRI - up to 37 category A (ASRT) continuing education credits may be earned by those who attend this week-long course, located in New Brunswick, NJ.
2. Hands-on Training - up to 27 category A (ASRT) continuing education credits may be earned by those who attend this week-long course, located at various installed Siemens MRI sites across the U.S.
3. On-site applications training - up to 34 category A (ASRT) continuing education credits may be earned by those who attend this week-long course and follow the ASRT-approved agenda during the turnover.

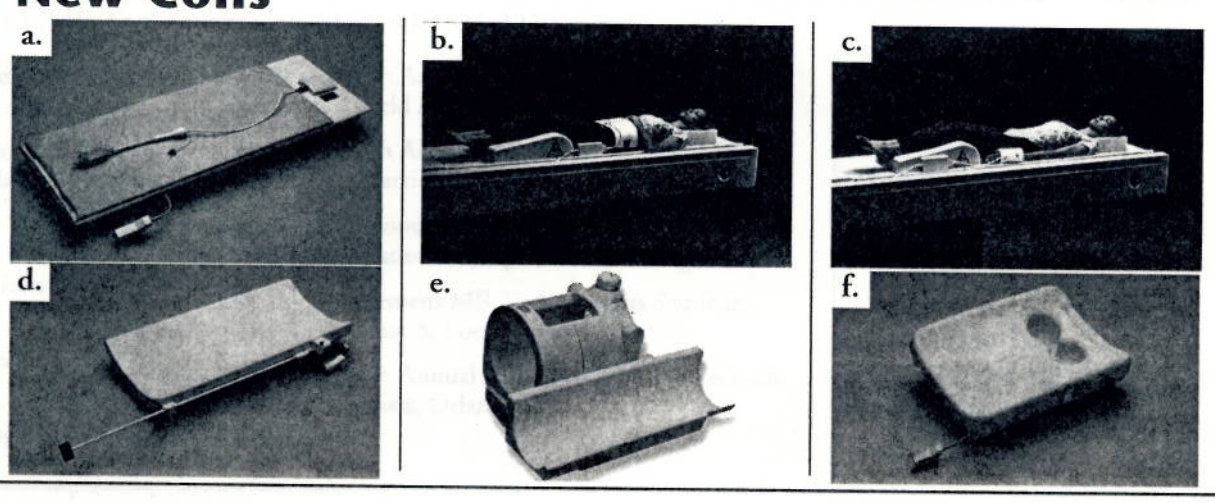
Upgrades

Siemens Medical Systems, Inc.

System upgrades and new coils are options which may be purchased. Software upgrades are free-of-charge for systems under service warranty or service contract, or may be purchased for systems not under service warranty or service contract. Contact your Siemens representative for details.

SYSTEM UPGRADES	AVAILABILITY
MAG42 GBS2 1.0 T > IMPACT	NOW
MAG63 GBS2 1.5 T > IMPACT	NOW
42SP 1.0T > IMPACT	NOW
MAG63 GBS2 1.5T > VISION	OCT 1994
63SP 1.5T > VISION	OCT 1994
SOFTWARE UPGRADES	**AVAILABILITY**
A2.5 (42SP, 63SP) > A2.7	NOW
A1.5 (IMPACT) > A2.1	NOW

New Coils



a. Prostate Coil
b. Large Flex Coil*
c. Small Flex Coil*
d. CP Spine Coil
e. CP Knee Coil
f. Bilateral Breast Coil

*Available for order now, delivery 4th quarter '94

Service Marketing

The Siemens *UPTIME* Service Center began operation servicing the northeastern region of the country in June 1993. The dispatchers and technical experts who staff the Cary, NC, Center have been challenged to improve the efficiency and effectiveness with which Siemens responds to and resolves service calls. One way this works is by asking the customer a series of initial questions that may resolve the problem without dispatching an engineer. The purpose of the *UPTIME* Center is two-fold. One focus is to improve customer satisfaction through increased system uptime, and the other focus is improved support for the Siemens engineer. Currently, there is a pooling and rotating of engineers from headquarters and the field to serve as Technical Support Engineers (TSE) at the *UPTIME* Center.

Customer calls are automatically routed to the Center via a toll-free phone number, and a service call is opened by the dispatchers. Once the incident number has been assigned, the customer's problem is matched to the best TSE for that problem.

About one half of all MR related service calls can now be fixed over the phone by employing a wide range of sophisticated tools such as remote diagnostics and expert systems. Siemens also expects a significant improvement in its first-time fix rates. Combined with the improved capabilities of the *UPTIME* Service Center and the improved logistics system, Siemens expects a 30 % increase in the first time resolution of calls in which parts are involved. However, if the TSE can not clear the problem over the phone, the service call is quickly escalated according to a well-planned protocol. The goal at this step is to get a well-informed Field Service Engineer (FSE) to the customer site as soon as possible with the appropriate tools and parts.

Many Siemens FSEs now use cellular phones. Our customer response time is expected to improve by allowing immediate communication between the *UPTIME* Center and the FSE. Meanwhile, the FSE will be on the way to the customer while being informed of the situation. A long-range goal is the use of intelligent cellular information devices which will provide FSEs with direct access to Siemens databases for improved call dispatching, parts requests, troubleshooting aids, and call closing.

There are dynamic changes taking place in the Siemens Spare Parts & Logistics Department. The FSE no longer has to order spare parts through the parts manager in his local district. Instead, he may dial directly into a menu at the *UPTIME* Center to place an order or check on a previous order, or to get technical clarification, if necessary. Several depots located strategically across the U.S. will stock commonly used parts. This will allow such parts to be expedited directly to the customer's site within, often, only four hours after the order is placed. Also, FSEs will maintain a stock of low-cost, high-usage parts in their own vehicle at all times. The goal is to eventually have each FSEs vehicle stock reflect his individual installed base of customer systems.

The managers of the Siemens *UPTIME* Service Center and the Spare Parts & Logistics Department are sworn anew to the goal of improved customer satisfaction through faster resolution of service calls and improved system uptime.

Optical Archive Disks

We have all heard that the LM 510 WORM (Write-Once-Read- Many) disks from Laser Magnetics are no longer being manufactured and are in short supply. You may still buy these disks from Siemens at $135 each through the Spare Parts Department, or directly from Rorke Data (800)328-8147. Alternatively, you may choose one of the following solutions:

SP/4000

Use the DEC 502A WORM disks from Pioneer. These disks are still non-reusable.

OR

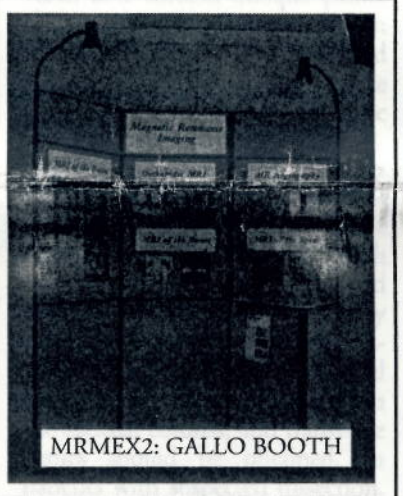
Use the DEC 702 REWRITEABLE disks from Pioneer. Since these disks are reusable, this may provide an economically sound solution. There are, however, several things to remember. You must first initialize each disk with VMS before using it, rather than just popping it into the drive and archiving on it with NUMARIS. Also, archiving on these disks must be done with the NUMARIS command FILE/ COPY/ STORE/ MOPTO rather than the NUMARIS command PATIENT/ ARCHIVE. And finally, the service engineer must permanently configure the disk drive as a MOPTO device rather than as the ARCHIVE device.

IMPACT

In the future, Siemens will be offering an upgrade from the Laser Magnetics LD 510 disk drives to the Pioneer rewriteable disk drives capable of supporting the DEC 502 WORM disks. Remember that these disks are still non-reusable.

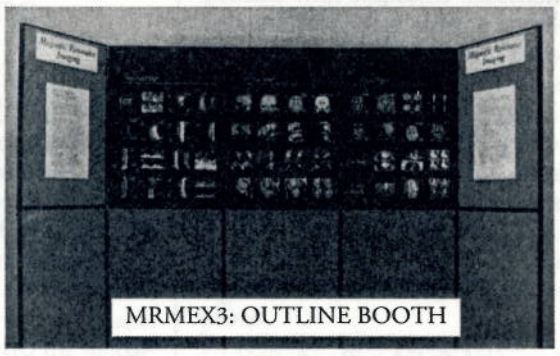
Exhibit Booths Available

Do you need help with an open house? Siemens will loan you a professional exhibit booth for displaying images and text panels. You can choose from three different designs to best meet your needs. The DESKTOP and GALLO booths come with setup instructions, mounted clinical images, text panels, and body-specific headers. The 5-PANEL OUTLINE booth comes with setup instructions, but no clinical images or text panels. Although there is no rental charge, the customer site is responsible for shipping charges. This offer is available only to Siemens Magnetom users having an open house. It is not available for trade shows. For further information, call 908-225-5382. Please reference the MRM number.



MRMEX2: GALLO BOOTH

MRMEX1: DESKTOP BOOTH



MRMEX3: OUTLINE BOOTH

A2.1 Software Drawing Winner

The winner of the A2.1 Software Drawing is Richard Svoma, MRI Manager, Northwestern Medical Imaging, Bemidji, MN. His name was randomly selected from those who responded by May 1, 1994, to the Siemens Questionnaire about the new A2.1 software being installed on Magnetom IMPACT systems. He will be awarded an all-expenses paid trip to the next MR Technologists Seminar. Thanks, Richard, and bon-voyage.

Marketing Support

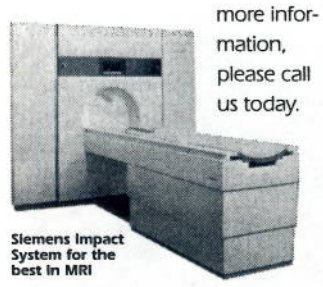
Do you need a professional advertisement to run in your community which announces your Siemens Magnetom IMPACT system? Call 1-800-334-4066, reference MRM800. Look for our VISION and OPEN ads in the next issue of The MAGNETOM FLASH.

JUST LIKE OUR PATIENTS ALL MRIs ARE NOT ALIKE.

That's why we have the Siemens Impact – a superior MRI system that provides your doctor with the clearest images for the most precise diagnosis. The extreme reliability of Impact ensures less chance for error and a more accurate method of getting the picture right the very first time – making it easier for you. This greatly reduces the need for a second scan and extra medical costs.

Our patient-friendly environment puts you at ease, and expert technicians are with you at all times to make sure you're comfortable. Plus, with the Impact noise-cancellation feature, you can relax and enjoy your favorite music throughout your examination.

If you, or someone you know, are referred for an MRI or want more information, please call us today.



Siemens Impact System for the best in MRI

Seminars and Announcements

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

June 17,18	Cape Fear MRI Conference, Wilmington, NC
Jul 24-29	National Neuroradiology and Musculoskeletal Radiology Review Course 1994 Comprehensive Tutorial, Laguna Niguel, CA
Jul 26	Magnetom Western Users Meeting, Laguna Niguel, CA
Aug 06-12	Society Magnetic Resonance, San Francisco, CA
Aug	Siemens Users Meeting, San Francisco, CA, Date TBA
Sep 29 - Oct. 2	6th Annual Advances in Mid & Low Field MRI, Disney World, FL
Oct 13-16	8th Annual Bill Bradley & David Stark Practical MRI, Disney World, FL
Oct 28-31	Economics of Diagnostic Imaging 1994 National Symposium, Washington, DC
Oct	Siemens MR Technologists Seminar, Date & Location TBA
NOV 16-19	5th Annual Advanced MRI for Technologists, Orlando, FL

MRI Essentials for Technologists

Hyatt Regency New Brunswick, NJ

Jun 20-24

Aug 01-05

Sep 12-16

Oct 24-28

For registration information concerning MRI Essentials for Technologists, please call:

1-800-589-5685.

Error Correction

Ralph Lee, research technologist at the VA Hospital in San Francisco, offers private consulting services to anyone needing help with MR Angiography. The last issue of this newsletter incorrectly listed his phone numbers. Mr. Lee's correct phone number is 415)221-4810 (extension 3805) and his correct fax number is 415)750-6938.

CLINICAL FOCUS: CONGENITAL HEART DISEASE

Richard B. Jaffe, M.D. and Shari L. Combe, B.S., RT(R)
Pediatric Medical Imaging Department , Primary Childrens Medical Center, Salt Lake City, UT

INTRODUCTION

While published articles over the past decade have beautifully illustrated the utility of MRI in defining intracardiac anatomy, referrals for MRI studies from cardiologists remain limited because precordial and transesophageal 2D and color-flow doppler echocardiography provide excellent anatomic and hemodynamic information about almost all intracardiac lesions. Today, MRI in the evaluation of chronic heart disease (CHD) is largely limited to imaging of extracardiac anatomy and a few intracardiac lesions.

High-quality ECG-gated MRI depends on contrast between rapidly flowing blood, which provides little or no signal, and stationary cardiac structures and vessel walls. The major advantages of MRI are the ease with which large fields of view are obtained and the ability to image planes at any angle. This article focuses on practical aspects of MRI in CHD and great vessel disease in infants, children, and adolescents.

TECHNICAL: CONTRAINDICATIONS AND PATIENT PREPARATION

Patients with ferromagnetic foreign bodies in or around the orbit, intracranial metallic aneurysm clips, and epicardial or intracardiac pacemakers must be excluded from MRI studies. Patients with prosthetic valves, sternal wires, or small metallic hemostatic clips in the thorax or abdomen can be imaged safely.

Obtaining good images of the heart and great vessels requires sedation in infants and children to avoid motion artifacts. Sleep deprivation is a helpful adjunct when used prior to sedation and in older children who are not sedated. We sleep deprive all patients under 12 years of age and those older patients who are hyperactive, mentally retarded, or emotionally unstable. Infants and children under the age of 6 years are routinely sedated with chloral hydrate (80 mg/kg po). Supplemental sedation, if needed, utilizes rectal Nembutal (1-2 mg/kg). Small and large children are sedated with titrated sodium pentobarbital (Nembutal, IV, 6 mg/kg). Older children and adolescents are sedated with a mixture of midazolam (Versed, 0.1 mg/kg) and nalbuphine (Nubain, 0.1 mg/kg).

Since ECG-gated images are dependent on a high-quality ECG tracing for accurate gating, proper lead placement is critical. The optimal position of the ECG electrodes is on the patient's back, in order to limit electrode motion from patient respiration. A small amount of alcohol is utilized to cleanse the patient's skin before placing the electrodes. The leads are placed in a vertical configuration with the first lead on the right mid scapula, the second lead 7-8 cm inferiorly from the first lead, and the third lead 7-8 cm inferiorly from the second lead. The ECG tracing is checked and, if not optimal, one lead at a time is moved medially or laterally while continuously observing the ECG tracing for improvement. An abdominal compression band can limit unnecessary abdominal motion during respiration. Presaturation bands placed anterior, superior, and inferior to the imaging plane improve image quality.

TECHNICAL: IMAGING PROTOCOL

T1-weighted spin-echo imaging parameters for our Siemens 63SP/4000 are: TR=(RR-150 msec.), TE=30 msec., thickness=3 to 5 mm. for infants and small children, 5 to 10 mm. for large children, matrix=192x256, acq.=3 to 4, gap=100%, and fill. To evaluate blood flow, turbulence, and valvular regurgitation, gated-cine MRI protocols are: TR=50 msec., TE=12 msec., thickness=4 to 5 mm. for infants, 5 to 10 mm. for small and large children, matrix=192x256, acq.=3, gap= minimum 200% for 2 slices, flip angle=30°, num. phases=(RR-150 msec.)/50msec. FOV=200 mm. for infants, 280 mm. for small children, 400 mm. for large children. The CP head coil is used for infants and small children, the body coil is used for large children.

CLINICAL: AORTIC ANOMALIES

The entire thoracic aorta, brachiocephalic vessels and their relationship to the thoracic airway are well-visualized in patients of any age. Management decisions regarding abnormalities of the aorta can be made without further diagnostic study in many of these patients. The large fields of view obtainable in any plane make MRI the modality of choice for the aorta and brachiocephalic vessels. These patients represent the largest source of referral in our practice. Vascular rings and related anomalies (Figure 1) and their relationship to the tracheobronchial tree are exceptionally well-depicted on spin-echo images in the transverse and coronal planes, and occasionally in the sagittal plane. After a localizing sequence in the sagittal plane, interleaved transverse images are obtained at 3-5 mm intervals, followed by 3-5 mm interval interleaved coronal images. Patients with coarctation are imaged best in the transverse, sagittal, and left anterior oblique (sagittal oblique) planes (Figure 2) to visualize the dilated ascending aorta (secondary to an associated bicuspid aortic valve), transverse arch, coarctation, and post-stenotic descending aorta. MRI is an excellent modality to serially follow the results and recognize associated complications and development of recoarctation following operation or balloon dilatation (Figure 3). In these patients the coronal plane also is imaged after sagittal and transverse images have been obtained. Cine MRI in the sagittal oblique (LAO) plane is useful for identifying areas of turbulence and associated valvular aortic regurgitation.

In patients with cystic medial necrosis, MRI in the sagittal, transverse, and coronal oblique planes clearly depict the thoracic aorta in its entirety. It is the preferred modality for following these patients for serial changes in aortic size and for development of associated complications, such as dissection. Cine MRI also is useful in evaluating the severity of aortic regurgitation. Patients with supravalvular aortic stenosis and associated peripheral pulmonary artery stenosis can be imaged accurately in the sagittal and coronal planes. After surgery, imaging in the sagittal, coronal, and transverse planes should be obtained. In patients with suspected dissection, spin-echo imaging should be followed by cine-MRI to better evaluate abnormalities of flow in the true and false lumen. Other abnormalities involving the descending thoracic aorta, such as pseudocoarctation, mycotic aneurysms and postoperative conduits, are well visualized in the sagittal, coronal and transverse planes.

CLINICAL: PULMONARY ARTERIES AND PULMONARY VEINS

Although the central pulmonary arteries and veins can be well visualized by echocardiography, they can not be seen with a high degree of confidence at the level of the pulmonary hila. These vessels can be imaged in multiple planes with MRI, and their relationship to the tracheobronchial tree well delineated. These patients constitute the second largest source of patient referral.

The pulmonary artery origin and central confluence are evaluated best in the transverse projection with 3-5 mm interleaved spin-echo images. Cine-MRI can be helpful in identifying pulmonary flow in small vessels, distinguishing them from adjacent bronchi. Aberrant origin of the left pulmonary artery from the right pulmonary artery (pulmonary sling) is well visualized in the transverse (Figure 4) and sagittal projections. Unilateral or bilateral absence of central pulmonary arteries, origin of systemic-pulmonary artery collaterals from the descending aorta, and areas of pulmonary artery stenosis can be recognized with confidence on high quality spin-echo imaging. Thin-section transverse-oblique images in the plane of the right and left pulmonary artery sometimes are helpful in identifying focal areas of stenosis. The central left pulmonary artery may also be seen in the sagittal plane and the right pulmonary artery in the coronal plane. Spin-echo images in the sagittal plane well- visualize the right ventricular outflow tract, pulmonary valve, and proximal main pulmonary artery.

Aneurysmal enlargement of the central pulmonary arteries and their relation to the tracheobronchial tree can be evaluated in all planes with 3-5 mm interval interleaved images. This type of aneurysmal enlargement is usually seen in patients with Tetralogy of Fallot and absent pulmonary valve. In other patients, aneurysmal dilatation of the pulmonary arteries usually secondary to pulmonary hypertension easily can be distinguished from hilar masses, such as bronchogenic cysts, tumors, or adenopathy.

Certain patients with partial or total anomalous pulmonary venous return may benefit from multiplanar MR imaging. As patients with complex cyanotic CHD related to asplenia invariably have anomalies in pulmonary venous return, MRI may permit evaluation of systemic and pulmonary venous return, and complex intracardiac anomalies in a single study. Patients with suspected focal pulmonary venous stenosis should be studied in both transverse and coronal planes with thin 3 mm interleaved images.

CLINICAL: COMPLEX HEART DISEASE

MRI is ideal for visualizing both extracardiac and intracardiac anomalies in patients with complex heart disease related to abnormalities in situs, and in those with asplenia or polysplenia syndrome. Scans in the coronal plane allow analysis of the tracheobronchial tree for symmetry, and determination of abdominal situs. Coronal and sagittal images are utilized to locate the inferior vena cava and aorta within the abdomen and to document azygos and hemiazygos continuation of the inferior vena cava. Atria, unilateral, or bilateral superior venae cavae and their relation to the coronary sinus are easily identified in coronal and transverse images.

CLINICAL: PERICARDIAC AND INTRACARDIAC MASSES

MRI can identify primary and secondary myocardial and pericardiac masses in the transverse and, occasionally, the coronal planes. Differentiating mediastinal masses from the heart and great vessels is facilitated by the contrast between flowing blood within the heart and great vessels. The fibrous pericardium is of low signal intensity and provides a cleavage plane between mediastinal tissue and cardiac structures. Pericardial tumor involvement may be visualized as focal thickening of the pericardium or disruption of the low-intensity pericardial line. Associated pericardial effusions are visualized as areas of decreased signal intensity on these T1-weighted spin-echo images. Pericardial effusions and vascular extension of tumor in either the inferior vena cava or superior vena cava can be recog-

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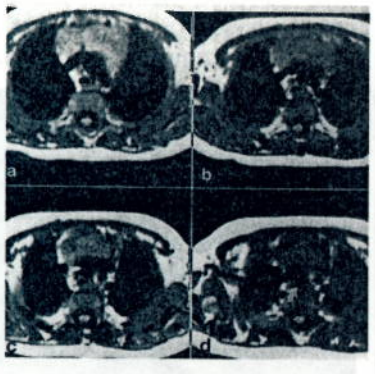

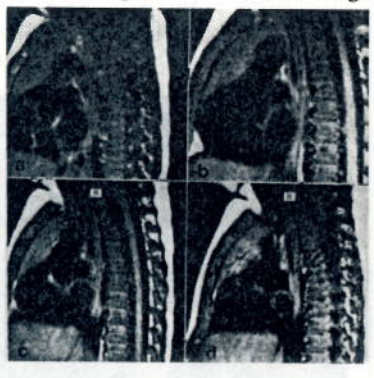

Four and one-half month old male with innominate artery compression syndrome. [1] Transverse and [2] sagittal 3 mm interleaved spin-echo images demonstrate significant tracheal compression by the innominate artery as it courses obliquely upward from its left aortic arch origin to the right mediastinum.

FIG [1] As the right innominate artery begins to pass anterior to the trachea there is mild tracheal compression.

FIG [2] As the right innominate artery (arrow) passes anterior to the trachea there is marked tracheal compression with near complete obliteration of the tracheal lumen.

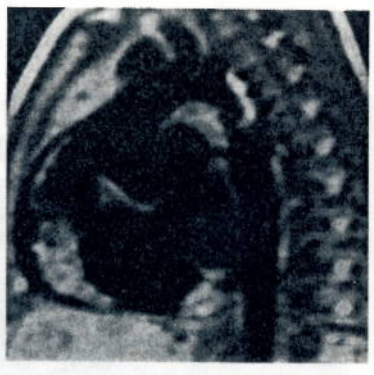

FIG [3] One year old girl with coarctation of the aorta. Sagittal oblique 3-mm spin-echo MRI (LAO equivalent) demonstrates the thoracic aorta in its entirety and depicts well the hypoplastic arch between the left carotid and left subclavian artery, aortic isthmus, and coarctation.

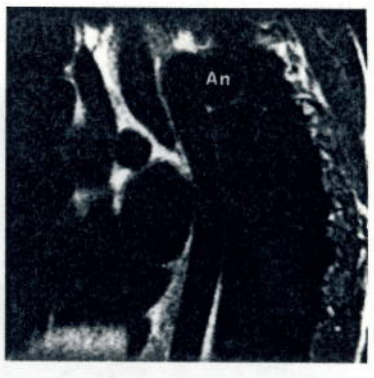

FIG [4] Twenty year old male, four years post balloon angioplasty for recoarctation. Three mm spin-echo image in the sagittal oblique (LAO equivalent) demonstrates an aneurysm (An) arising from the posterolateral wall of the proximal descending thoracic aorta.

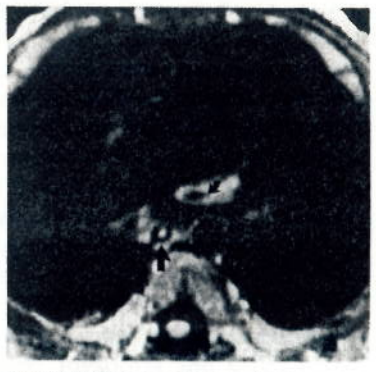

FIG [5] Three and one-half month old male with aberrant origin of the left pulmonary artery from the proximal right pulmonary artery (pulmonary artery sling). Three mm transverse spin-echo image at the level of the pulmonary arteries demonstrates aberrant origin of the left pulmonary artery from the proximal right pulmonary artery. The left pulmonary artery passes behind the trachea (curved arrow), and anterior to the esophagus (straight arrow) and descending aorta. The trachea is markedly narrowed secondary to complete cartilaginous tracheal rings and vascular compression. The adjacent 3 mm image demonstrated no narrowing of the left pulmonary artery as it passed anterior to the descending aorta.

CLINICAL FOCUS: MYOCARDIAL VIABILITY

Kostaki G. Bis, M.D. and Anil N. Shetty, Ph.D.
Diagnostic Radiology Department, William Beaumont Hospital, Royal Oak, MI

INTRODUCTION

Initially, spin-echo sequences were developed to image the anatomy of the heart and the great vessels in order to evaluate tumors and thrombi, congenital heart defects, pericardial and myocardial diseases and acquired thoracic abnormalities such as aneurysms and dissections. Later, gradient-echo cine sequences were developed to evaluate myocardial and valvular function, mass lesions, and thoracic aortic dissections. Recently, velocity encoded gradient-echo cine sequences have been developed for quantification of flow velocities and volumes in blood vessels such as the aorta and pulmonary artery, thus allowing for the quantification of intracardiac shunting and differential pulmonary arterial flow volumes. These are also helpful in measuring peak velocities and, thus, pressure gradients through areas of valvular or vascular stenoses. Magnetization prepared rapid acquisition gradient-echo (MPRAGE and TURBOFLASH) sequences are currently available for assessment of the first pass perfusion of gadolinium contrast agents through the myocardium. These compliment spin-echo and cine sequences for evaluating patients with ischemic heart disease. Finally, segmented gradient-echo sequences coupled with fat suppression are showing promise for noninvasive visualization of the coronary arteries. With the development of a multitude of sequences for evaluating the cardiovascular system, MRI has great potential as the single modality of choice for providing a noninvasive comprehensive examination.

TECHNICAL: SPIN-ECHO SEQUENCES

Conventional spin-echo sequences are the work horses for imaging the cardiovascular system because they visualize anatomy and pathoanatomy with high spatial resolution and they provide excellent soft tissue contrast between the myocardium or vessel wall and the underlying blood pool. T1-weighted images are obtained by gating to every R wave with a TR up to 800 msec (or 80% of the R-R interval) and with a short TE of 15-30 msec. T2-weighted images are obtained by gating to every second or every third R wave with a TR up to 1800-2500 msec, and with TEs of 22 and 60 msec. Both T1- and T2-weighted spin-echo techniques can be improved with fat saturation. Most commonly, T2-weighted fat saturated sequences and gadolinium enhanced T1-weighted fat saturated sequences are used in patients with myocardial infarction. T2-weighted sequences are frequently flow compensated to reduce pulsation artifacts.

The contrast to noise ratio may be improved (darker blood signal) by accentuating the flow void phenomenon. There are three ways to improve black blood imaging with spin-echo sequences. The first method is to use thinner slices and/or longer TE's to accentuate the washout effect. The second method is to apply a simple bipolar gradient along the direction of flow to dephase the signal of complex flowing spins while leaving unchanged the signal of stationary spins. The third method is to place presaturation bands adjacent to the imaged slices in order to better suppress the signal from blood flowing into the slices. A pair of parallel presaturation bands is used when imaging in the transverse plane, or oblique presaturation bands are placed over the atrial chambers when imaging horizontal long axis or vertical long axis planes. This causes presaturation of blood flowing into the ventricles from the atria, and is used only when the myocardium of the ventricular chambers is the imaging target, such as for patients with ischemic heart disease.

TECHNICAL: CINE SEQUENCES

Physiologic variations and blood flow dynamics can be studied using bright blood techniques in which low flip angle gradient-echo pulse sequences are commonly employed. Acquiring these gradient-echo pulse sequences in a cine mode allows one to assess physiologic variations throughout the cardiac cycle. Gradient-echo pulse sequences are flow compensated along the readout and slice-encoding directions to improve flow-related enhancement. They are used with TEs as short as 7 msec or as high as 12 msec. The shorter TE of 7 msec is used to minimize the effects of signal loss in areas of turbulent flow. They are routinely used for imaging the aorta for dissection and the heart for myocardial function and tumors. The longer TE of 12 msec is used to allow more spin dephasing (signal loss) in areas of turbulent flow due to valvular or vascular stenosis or intracardiac shunting. Thus, depending on the clinical situation and the indication for scanning, it is important to appropriately choose the TE for cine examinations. Conventional cine sequences can be coupled with magnetization transfer contrast (MTC) pulses to further reduce the myocardial signal and, thus, improve the contrast between the myocardium and the blood pool.

TECHNICAL: SEGMENTED CINE SEQUENCES

In a standard cardiac cine pulse sequence, only one phase- encoding line (Fourier line) is acquired per heartbeat. An image matrix of 192x256 would, thus, require 192 heartbeats to acquire. This not only prolongs the scan time, but also allows for excessive artifacts due to respiratory and involuntary patient motion. However, k-space can be subdivided into several segments consisting of several Fourier lines each. When an entire segment is acquired per heartbeat, the total acquisition time may be significantly reduced, even down to a reasonable breathhold period. A set of segmented k-space TURBOFLASH sequences with flow compensation along the readout and slice-select directions have been developed for this type of imaging. Depending upon the patient's heartrate, from 8 to 12 cardiac phases can be imaged within a single breathhold period. Typically, 9 cardiac phases are imaged (with 7 Fourier lines per segment) in a 12-14 second breathhold period. These sequences are routinely used for assessing the aorta in the transverse plane for the presence of aortic dissection and for assessing the left ventricle in the short axis plane for global and regional myocardial function.

TECHNICAL: FLOW QUANTIFICATION SEQUENCES

The principle of the flow quantification technique is based upon the phase shift acquired by spins moving along a magnetic field gradient. When one varies the strength of the magnetic field in one direction using a unipolar gradient, stationary and moving spins acquire a phase shift in their magnetization. If a second gradient with equal magnitude but opposed direction is applied, there is cancellation of the phase shift of stationary spins. However, moving spins acquire a net phase shift during this bipolar gradient which is proportional to the flow velocity. Typically, two data sets are acquired with bipolar gradient pulses of equal strength but opposite direction. A phase image is obtained by subtraction between these two data sets. Since pixel intensity is directly proportional to velocity in this subtracted phase image, the flow velocity through a blood vessel is easily evaluated by measuring the mean signal intensity over the cross-sectional area of the vessel. The volume of blood flow through a vessel is easily evaluated by multiplying the cross-sectional area of that vessel times the mean flow velocity within that vessel. Such velocity-encoded cine sequences must be prescribed perpendicular to the direction of flow and, typically, 16 phases are acquired per cardiac cycle in which both magnitude and phase images are obtained.

TECHNICAL: MYOCARDIAL TAGGING SEQUENCES

Cine MRI with spatial modulation of magnetization (SPAMM) employs the use of thin presaturation bands placed in a grid of horizontal and vertical lines superimposed over the MR image. These myocardial tags are placed onto the imaging slice immediately prior to cardiac systole. The displacement and distortion of these tags follows the displacement and distortion of the actual myocardium over the cardiac cycle. This is followed over time with a cine MR acquisition utilizing a segmented k-space gradient-echo sequence employing 9 to 10 cardiac phases per cardiac cycle and either a 7 or 9 mm tag spacing. These sequences highlight underlying wall motion abnormalities and are frequently used in patients with ischemic heart disease.

TECHNICAL: MYOCARDIAL PERFUSION SEQUENCES

For direct visualization of myocardial perfusion, a TURBOFLASH sequence with a very short TE is used. This is a 2D magnetization prepared rapid acquisition gradient-echo (MPRAGE) sequence which uses a preparatory 180° RF pulse to establish the image contrast. An appropriate inversion time (TI) may be chosen to establish contrast in which the signal intensity is low for both the myocardium as well as the blood pool. Then, after a bolus injection of gadolinium contrast, the myocardium enhances in well-perfused areas but fails to enhance as well in ischemic areas. Typically, one image is obtained in a selected plane for each cardiac cycle. After the sequence is loaded with 60 measurements, imaging is performed with the pre-scan adjustments off-line. After 10 heart beats (10 images), the patient is instructed to hold his breath for as long as tolerated. At that time, gadolinium contrast is injected as a bolus over 5 seconds (0.1 mmol/kg ionic contrast dose) or over 10 seconds (0.2 mmol/kg nonionic contrast dose).

TECHNICAL: CORONARY MR ANGIOGRAPHY SEQUENCES

For MRI of the coronary arteries, we use segmented k-space gradient-echo pulse sequences with fat saturation and flow compensation along the readout and slice-encoding directions. These sequences acquire either 7, 9, or 11 Fourier lines per segment per heartbeat, and are acquired within a single breathhold. The sequence with the fewest lines per segment (7) has the shortest acquisition period, thus making it the least sensitive to cardiac motion. However, the disadvantage of acquiring fewer lines per segment per heartbeat is that more heartbeats are required to acquire k-space and, thus, a longer breathhold period is required. For example, using 7 lines per segment one can acquire 140 lines (140x256 matrix) in 20 heartbeats. For a heart R-R interval of 1000 msecs, it will require 20 seconds, which is a reasonable breathhold period. As a rule of thumb, for higher patient heart rates (lower R-R intervals) we use a sequence with fewer lines per segment. As the R-R interval increases with slower heartrates, use a sequence with more lines per segment. As lower bandwidth sequences are developed, SNR will be improved and patients may be imaged in the supine position with the body coil. In the meantime, patients are typically imaged in a prone position on the spine surface coil.

CLINICAL: TUMORS AND THROMBI

Cardiac tumors (Figure 2) and thrombi are more readily evaluated with MRI than with other modalities. MRI is not only accurate for the diagnosis of tumors and thrombi, but it remains as the only modality for differentiation of the two. Bland thrombi and myxomas are typically of lower signal intensity than skeletal muscle on cine sequences, however, other neoplasms are of equal or higher signal intensity. Furthermore, myxomas and other neo-

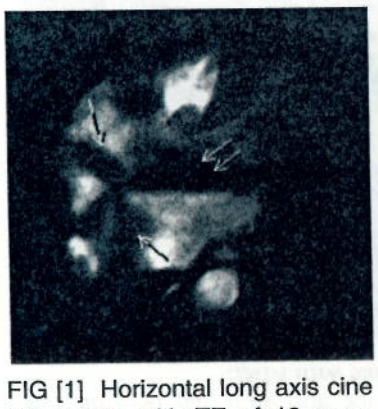

FIG [1] Horizontal long axis cine MR image with TE of 12 msec tends to accentuate the signal void due to ASD (single arrows). Flow void is noted in the right and left atrial chambers from the turbulent bi-directionality of the shunt. Signal void from mitral insufficiency is accentuated (double arrows).

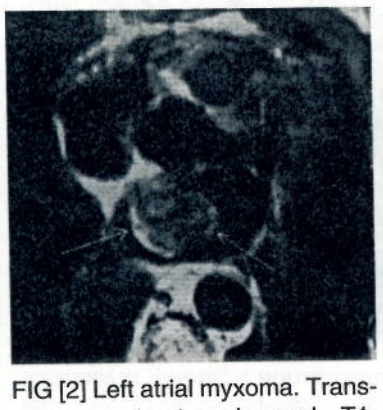

FIG [2] Left atrial myxoma. Transverse contrast enhanced T1-weighted image shows enhancement indicating the presence of a tumor and, thus, a left atrial myxoma. Since the mass enhances, the diagnosis of thrombus is excluded.

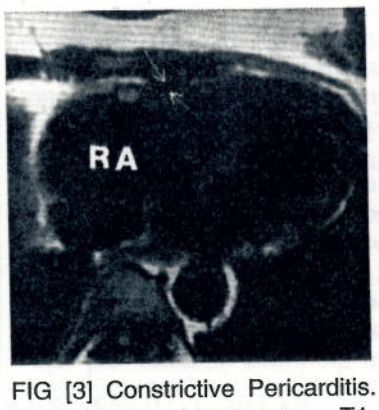

FIG [3] Constrictive Pericarditis. Contiguous transverse T1-weighted image of the heart shows a focal area of pericardial thickening (arrows) overlying the right ventricle and atrioventricular groove. The right atrium (RA) is enlarged.

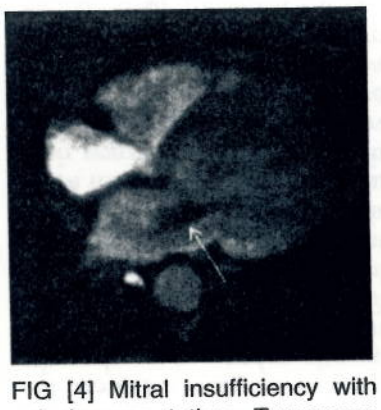

FIG [4] Mitral insufficiency with valvular vegetation. Transverse cine MR image with TE of 7 msec reveals a regurgitant jet due to mitral insufficiency within the left atrium (arrows).

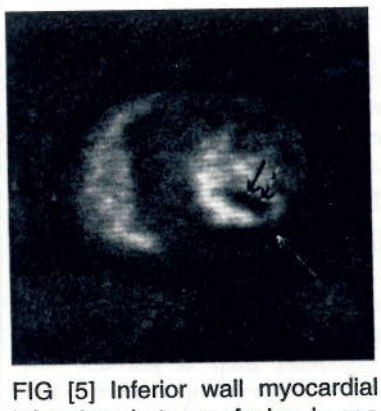

FIG [5] Inferior wall myocardial infarction. Later perfusion image reveals low signal intensity to the inferior sub-endocardium (single arrows) indicating lack of perfusion to this region of infarction. Notice that the posterior-inferior papillary muscles (double arrows) also show lack of perfusion due to infarction.

plasms usually enhance after contrast administration and bland thrombi invariably lack enhancement. MR has been established as the most accurate modality for assessing the extent of both intra- and paracardiac tumors. Finally, MR frequently narrows the differential diagnosis and can give a specific diagnosis of various fatty neoplasms such as lipomas and lipomatous hypertrophy of the interatrial septum.

CLINICAL: PERICARDIAL DISEASE

The findings of constrictive physiology following cardiac catheterization are frequently nonspecific and the differential diagnosis of constrictive pericarditis vs. restrictive cardiomyopathy is frequently raised. Abnormally thickened pericardium (Figure 3) can be diagnosed with MRI in patients with constrictive pericarditis. Additionally, MRI is useful in the diagnosis and differentiation of pericardial tumors and cysts.

CLINICAL: VALVULAR DISEASE

Cine MRI consistently displays the signal void in areas of turbulent flow related to either valvular stenosis or insufficiency (Figures 1, 4). The amount of signal loss is dependent on the degree of turbulent flow and on the echo time that is chosen. Following diagnosis of valvular stenosis or insufficiency, velocity encoded cine MRI can be performed for measurement of peak velocities through areas of stenosis. Using a modified Bernoulli equation, the pressure gradient can be calculated from these peak velocities. The effective right and left ventricular stroke volumes can also be calculated by measuring flow volumes in the pulmonary artery and aorta, respectively. This technique allows one to calculate regurgitant fractions in patients with single valve insufficiency. Alternatively, retrograde flow in the aorta can be assessed for measurement of aortic insufficiency.

CLINICAL: MYOCARDIAL DISEASE

There are a number of myocardial disorders that have been evaluated with MRI and applications are rapidly expanding. In patients with hypertrophic cardiomyopathy, the location and extent of disease is identified, as is left ventricular mass. Utilizing contiguous sections through the left ventricle, the endocardial and epicardial surfaces can be outlined for measurement of myocardial areas on individual slices which are then used to calculate ventricular mass. With inflammatory processes such as sarcoidosis, myocarditis, and contusions there is prolongation of the T2 relaxation time of the myocardium and this is imaged with T2-weighted sequences as areas of high signal intensity. Due to the expanded extracellular fluid space, these involved areas frequently enhance more than the surrounding normal myocardium following IV injection of contrast in T1-weighted imaging. Arrhythmogenic right ventricular dysplasia is currently imaged with either ultrafast CT or MRI. With MRI, there is either full thickness right ventricular wall replacement by fat or presence of small islands of fat within the right ventricular myocardium. In addition, these patients frequently have findings described as endocardial scalloping or right ventricular functioning aneurysms. Finally, a significant amount of research is underway to develop MRI techniques for ischemic heart disease. In the evaluation of patients with ischemic heart disease, one needs to assess global and regional myocardial function and this is performed with conventional cine or breathhold cine sequences. This may be followed by tissue characterization with T2-weighted or contrast enhanced T1-weighted images to denote the presence of myocardial damage due to infarction. Cine sequences with myocardial tagging (SPAMM) further delineate areas of wall motion abnormality (Figure 6). Tissue viability can be further assessed with myocardial perfusion imaging using gadolinium contrast. Myocardial infarction or scar will lack first pass perfusion, whereas viable tissue will have preserved or decreased perfusion (Figure 5). Complications of myocardial infarction such as true and false aneurysms and underlying thrombi are also routinely assessed.

CLINICAL: CORONARY ANGIOGRAPHY

Multiple institutions are currently active in developing MR coronary angiography techniques. Preliminary results are promising for depicting the proximal and, sometimes, distal anatomy and pathology. With phase modulation techniques, coronary blood flow velocities can be assessed during rest and under adenosine stress. This will allow for a physiologic quantification of the degree of coronary stenosis (Figure 7). Currently, coronary imaging and flow mapping require further development for improvement of signal-to-noise ratio (SNR) and spatial resolution since there are frequent pitfalls such as partial volume averaging as a vessel courses in and out of the section plane. Lower bandwidth sequences may allow the use of the CP body coil rather than the spine surface coil for coronary imaging.

FUTURE DIRECTIONS

In the future, conventional spin-echo pulse sequences may be replaced by turbo-spin-echo or turbo-gradient-spin-echo sequences, and conventional cine sequences may be replaced by segmented cine sequences. TURBOFLASH sequences which visualize first pass myocardial perfusion within only a single slice may be replaced in the future with echoplanar MR perfusion exams which could allow for whole heart perfusion studies. Phase modulation sequences, which provide information regarding flow velocities and volumes, may be replaced with faster breathhold sequences such as interleaved echoplanar acquisitions. Current assessment of regional myocardial function with cine MRI, as well as with myocardial tagging, may likely be replaced in the future with myocardial phase modulation techniques giving information of myocardial velocities in three dimensions. Coronary angiography with single slice breathhold fat saturation sequences may be replaced with breathhold echoplanar or spiral MR acquisitions of the entire coronary arterial bed. Finally, the possibility of obtaining information regarding myocardial metabolism through phosphorous and proton nuclear magnetic resonance spectroscopy may become a clinical reality. Due to the development of faster pulse sequences, higher gradient performance and improved coils, a comprehensive cardiovascular examination with a one stop shop may become feasible with MRI.

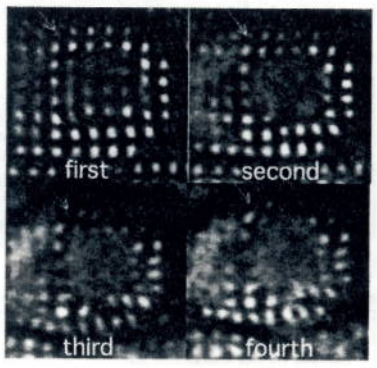

FIG [6] Hibernating myocardium. Serial short axis cine MR images with myocardial tagging using the SPAMM sequence show marked decrease of distortion of the myocardial tags in the anteroseptal wall (arrows). The remainder of the myocardial segments show inward or radial displacement, as well as distortion of the myocardial tags.

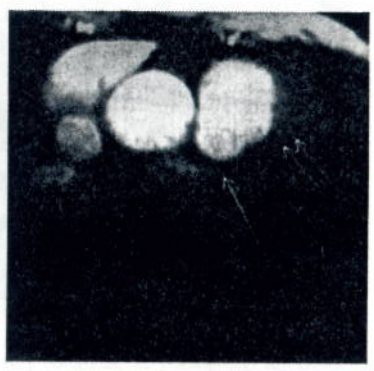

FIG [7] Critical LAD stenosis prior to angioplasty. Transverse MR coronary angiogram obtained in the prone position over a surface coil shows abrupt cutoff of the LAD (single arrows) with minimal patchy signal distally in the LAD (double arrows).

MR IMAGING PROTOCOLS FOR MAGNETOM 63SP

INDICATION	VIEW	TR/TE/FLP	MATRIX	FOV	THK/GAP	ACQ
aortic dissection	tra T1	RR/30	192x256	360	8/0.2	2
	sag obl T1	RR/30	192x256	390	5/0.2	2
	tra cine bh	RR/6/30	126x256	350	9/-1.0	1
	post-gd tra tfl bh	5/2/12	80x128	340	10/0.2	1
coarctation, arch anomaly, rings	sag obl T1	RR/30	192x256	360	4/0.2	3
	tra T1	RR/30	192x256	340	4/0.2	3
	cor T1	RR/30	192x256	360	4/0.2	4
	sag cine	RR/7/30	192x256	360	5/0.2	2
constrictive pericarditis	tra T1	RR/30	192x256	350	7/0.2	3
	2 level tra cine	RR/7/40	192x256	340	8/0.2	2
	tra flow quant	RR/6/20	192x256	350	6/none	1
coronary	bh tra seg-15	RR/8	240x256	350	5/none	1
	bh sag obl seg-11	RR/8.5	176x256	320	4/none	1
rv-dysplasia	tra T1	RR/30	192x256	350	5/0.2	2
	fs tra T1	RR/18	192x256	350	5/0.2	2
	3 level tra cine	RR/7/30	192x256	350	8/0.2	2
tumor, thrombus	tra T1	RR/30	192x256	350	7/0.2	2
	fs tra T1	RR/18	192x256	350	7/0.2	2
	tra cine	RR/7/30	192x256	340	8/0.2	2
	post-gd tra T1	RR/18	192x256	350	7/0.2	2
myocardial viability	cine bh short axis	RR/6	126x256	350	7/-1.0	1
	spamm short axis	RR/10/20	126x256	340	8/none	3
	spamm long axis	RR/10/20	126x256	340	8/none	3
	fs short axis T2	3RR/22,60	144x256	340	8/0.2	2
	tfl perfusion TI=100	6.2/3/12	80x128	380	10/none	1
	post-gd fs short axis T1	RR/30	192x256	350	8/0.22	1

Congenital Heart Disease

...continued from page 3

nized in any imaging plane.

While most intracardiac masses can be recognized on echocardiography, those lesions involving myocardial walls are best evaluated by MRI with its large field of view. Multiple imaging planes, including true long- and short-axis images of the ventricles are suggested. Cine-MRI is helpful in showing tumor motion between atria and ventricles and associated valvular regurgitation.

CLINICAL: POSTOPERATIVE EVALUATION

Surgical correction of complex congenital heart disease is often accomplished by creating geometrically complex structures, or by creating pathways within the mediastinum that are difficult to interrogate by ultrasound. Multiplanar spin-echo imaging is particularly useful to evaluate patients with many systemic-pulmonary artery shunts, right atrial- or right ventricular-pulmonary artery conduits, atrial baffles (Mustard or Senning procedure), pulmonary artery bands, and all operations involving the aorta.

Serial evaluation of the central pulmonary arteries following systemic-pulmonary artery shunts (usually Glenn, classic or modified Blalock-Taussig, or gortex central shunts) is ideally performed in the transverse and coronal projections. A flow void in both shunt and pulmonary artery implies patency (Figure 5). Cine-MRI (Figure 6) can confirm flow but may also demonstrate turbulent flow within the shunt or pulmonary artery.

In patients with right atrial-pulmonary artery, or right ventricular-pulmonary artery conduits, areas of stenosis and/or compression by the sternum are well recognized in the transverse projection. Right ventricular-pulmonary artery conduits may require imaging in transverse, coronal, sagittal, and oblique projections to visualize the conduit in its entirety. A metallic artifact from prosthetic valves may be seen, but it is generally small and does not interfere with interpretation. Multiple imaging planes may be required to visualize ascending-descending aortic conduits placed to bypass severe arch obstruction, or left ventricular apical-descending aortic conduits.

In patients not able to undergo arterial switch for transposition, atrial baffles may be placed (Mustard or Senning procedures). Development of systemic venous limb or pulmonary venous limb obstruction can be recognized by multiplanar spin-echo imaging. Patients with obstruction in the systemic venous limb of the atrial baffle (IVC of SVC) are best studied in the coronal plane. The transverse and sagittal planes are preferred for studying patients with suspected obstruction in a pulmonary venous limb. Patients with SVC obstruction will demonstrate narrowing along the superior aspect of the systemic venous limb of the atrial baffle. Dilatation of the superior vena cava and azygos vein will be noted. Patients with IVC obstruction will show narrowing along the inferior aspect of the systemic venous limb of the atrial baffle. The IVC may be dilated, and collateral flow through a dilated azygos of hemiazygos system also may be seen, particularly in the coronal plane.

Patients with pulmonary artery bands are imaged best in the transverse and transverse-oblique projections with 3 mm interleaved images. Distal pulmonary artery band migration may produce proximal right or left pulmonary artery stenosis.

Multiplanar spin-echo imaging may be the only imaging modality necessary to evaluate patients following aortic operation for supravalvular aortic stenosis, dissection, aortic conduits, systemic-pulmonary shunts, or coarctation.

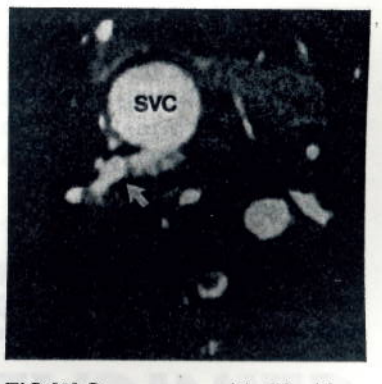

FIG [6] Seven year old girl with pulmonary atresia, and patent Glenn shunt. Transverse cine-MRI demonstrates a patent Glenn anastomosis between the superior vena cava (SVC) and right pulmonary artery (arrow).

CLINICAL FOCUS: Coronary MR Angiography

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INTRODUCTION

Magnetic Resonance Angiography (MRA) of the coronary arteries has recently become possible due to the development of a new group of ultrafast imaging sequences. Coronary arteries are small tortuous vessels subjected to significant physiological motion (respiration and cardiac contractions). The two key features which allow coronary artery imaging are the clever scheme for segmentally acquiring the data to minimize cardiac motion artifacts and the use of patient breathholding to minimize respiratory motion artifacts. MRI is noninvasive, does not require any contrast agents or ionizing radiation, and thus offers the potential of becoming a very important cardiac screening tool.

TECHNICAL: VARIOUS METHODS

Several different methods for performing MRA of the coronary arteries have been described, including two dimensional (2D) methods, three dimensional (3D) methods , and projectional methods . All methods require consistent cardiac triggering and only allow visualization of the proximal portions of the coronary arterial tree. No method is yet capable of consistently visualizing the distal coronary arteries. With the 2D technique, a series of 2D images are acquired to follow the course of the proximal coronary tree. The 2D technique requires a significant amount of physician time and interaction because the selection of the appropriate imaging planes can be quite difficult. In order to be successful, the 2D technique requires a consistent patient breathholding pattern. Since cooperative patient breathholding is essential for the success of the 2D technique, it can be difficult to use this technique in the pediatric population or in the geriatric population because of their typical inability to consistently follow breathholding commands.

Other techniques, such as 3D and projectional, require less physician interaction. With the 3D technique, a single 3D slab is acquired to cover the proximal coronary tree. In order to be successful, the 3D technique requires a consistent patient breathing pattern and monitoring of the breathing.

Although still preliminary, the projectional techniques appear to be very promising because they may be easier to use. A single projection of flow in the coronary arteries is obtained by imaging a volume of interest which contains the vessel in question within a single breathhold. This technique was originally developed at Stanford University and then modified at Beth Israel Hospital in Boston .

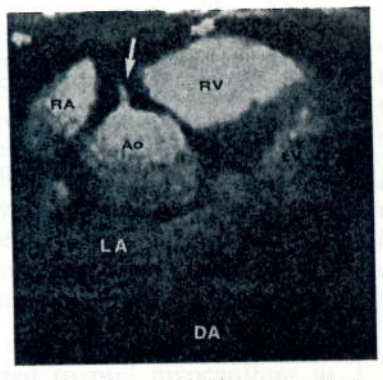


FIG [1] Transaxial image across the aortic root shows the origin of the right coronary artery (arrow). The other anatomical structures shown are left ventricle (LV), right ventricle (RV), right atrium (RA), left atrium (LA), aortic root (Ao), superior vena cava (S), and descending thoracic aorta (DA).

TECHNICAL: CARDIAC GATING

One of the prerequisites for implementation of these techniques is consistent cardiac gating. With experience, cardiac gating is easy to perform. However, at centers where cardiac gating is not routinely done, this may require some practice. We recommend placement of the three electrodes on the left upper back of the patient, with relatively large spacing between the electrodes. With some of the newer fiber-optic based patient monitoring equipment, such as from In-Vivo Technologies, the electrodes should be placed very closely around the left heart apex region (left side of the patients chest, under the left nipple). Your local Siemens applications specialist can help beginners develop some familiarity with cardiac gating.

TECHNICAL: PATIENT POSITIONING AND SURFACE COILS

During preliminary work with the Siemens 2-D MRA technique, all patients were placed in the prone position with the base of the heart located over the center of the elliptical spine surface coil. This is used to increase the signal-to-noise ratio significantly above that of the CP body coil. However, a new phased array CP body coil which Siemens is currently developing should allow the patient to be imaged in a supine position with superior signal-to noise capabilities. Furthermore, the Magnetom VISION system, with its echoplanar capability, should eliminate the need to image the patient in a prone position on the spine surface coil.

TECHNICAL: SIEMENS 2D CORONARY MRA TECHNIQUE

The following is a step-by-step guide for using the Siemens 2D MR coronary angiography technique. These technical factors are valid for current SP, IMPACT, and VISION systems.

1. Coil - Install the elliptical spine coil as the RF receiver coil. The CP body coil is used as the RF transmitter coil.

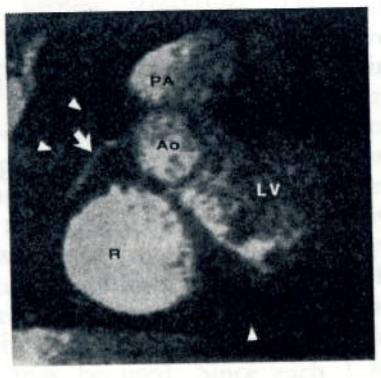
2. Patient Setup - Attach the cardiac gating leads on the patient's back (upper left) or chest (mid left). For the SP and the IMPACT systems, position the patient head-first, prone with the center of his sternum place directly over the center of the elliptical spine coil. For the VISION system, position the patient head-first, supine with the center of his sternum located at isocenter, and use the CP body coil. When the phased array coil becomes available, the patient may be positioned head-first, supine on all systems.

3. Patient Instructions - Instruct the patient to hold his breath during a non-forced, normal end-expiration for the duration of each scan.

4. Protocol - The imaging technique employs an ultrafast gradient-echo (GRE) sequence with incremented flip angle series and k-space segmentation (segmented TurboFLASH), such that nine phase-encoding steps are acquired in rapid succession, thus constituting one segment. Sixteen interleaved segments (16 heartbeats) are required in order to complete a 144 x 254 matrix during a single breathhold period. A spectrally selective fat saturation pulse is applied before each segment to suppress the signal from surrounding epi-cardial fat, and thus enhance the signal from coronary blood flow. The sequence is electrocardiographically (ECG) gated to allow the acquisition of each segment in early to mid diastole (trigger delay = 350 to 600 msec, depending upon the heart rate). A repetition time of TR = 13 msec and an echo time of TE= 8 msec are used, with an effective temporal resolution of 157 msec per segment. Slice thickness is 5 mm with a field of view (FOV) of 230 to 300 mm. The sequence is named TFL9_9 on the SP system and is named TFL9_9 on the IMPACT system. The minimum TR=157 msec available for this sequence represents the minimum time period to acquire nine phase encoding steps (9 lines of k-space, or 1 segment of k-space) and one fat saturation pulse.

5. Variations of protocol - If the patient has trouble holding his breath for the required duration of 16 heartbeats, we lower the matrix size to 126 x 254 to scan over only 14 heartbeats. We also adjust the trigger delay (TD) depending upon the patient's heart rate. If the RR interval is 1000 msec (slow heart rate) we select TD = 500 to 600 msec. If the heart rate is faster, we lower TD to 350 msec or less. If the ECG signal is very noisy and cardiac triggering is suboptimal, we increase the sequence TR from 157 to 200 msec or more to prevent the scanner from double triggering during a single heart beat.

6. Image slice selection - Beginning at the level of the aortic sinus, transverse images are obtained along the aortic root over a coverage of from 20 to 30 mm, with an overlap of 2 to 3 mm between slices. Subsequently, single and double oblique images are obtained in planes positioned in the right atrio-ventricular and inter-ventricular grooves to visualize the right coronary artery (RCA) and the left anterior descending (LAD) coronary artery. No systematic attempt is made to visualize the circumflex coronary artery, as it is located too far posteriorly in the chest wall to be well-visualized with a surface coil. Total imaging time ranges from 45 to 90 minutes per patient.



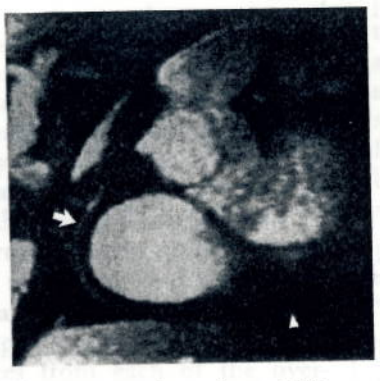


FIG [2] Anatomy of pericardial sac and coronary artery. Images in double oblique planes along the right atrio-ventricular groove demonstrate the right coronary artery (arrow) and the pericardial sac (arrowheads). [2A)] The origin of the RCA. [2B] The middle and distal RCA. The other anatomical structures shown are left ventricle (LV), aortic root (Ao), right atrio-ventricular groove (R), pulmonary artery (PA), and pericardial sac (arrowheads).

Note, there are some tricks to make the imaging plane selection relatively easy. One can first localize the aortic root, and then take some sequential transverse images throughout the lowest portion of the aortic root. This usually allows visualization of the left main coronary artery, the proximal left anterior descending and circumflex coronary arteries and, on the lowest cuts, the origin of the right coronary artery. Using this approach, one can then interactively try to find the right atrial-ventricular groove. However, a quicker method is to use a transverse image at the level of the left ventricle (short-axis view) to prescribe a sagittal oblique slice through the middle of the left ventricle (long-axis view). From this, one can then easily acquire images along the atrial-ventricular grooves.

CLINICAL: TYPICAL IMAGES

The origin of a right coronary artery is shown in Figure 1. This is a transverse image through the root of the aorta. Based upon this, one can then visualize the right coronary artery and the right atrial-ventricular groove, as in Figure 2. Unfortunately, most of these coronary arteries are very tortuous and can not be visualized in a single 2D plane. Often several planes are needed. For example, Figure 2A shows the proximal artery whereas Figure 2B shows the middle and more distal portions of the right coronary artery. This is another limitation of the 2D approach. Although 2D gives crisper images, with better spatial resolution than the 3D approach, it is limited by the fact that one needs several images to fully evaluate a single coronary artery. However, with practice and experience, this does not appear to be a problem. Similarly, Figures 3A, 3B, 4A, 4B illustrate the quality of the MR coronary angiogram in visualizing the left main and left anterior descending coronary arteries.

CLINICAL: UTILITY

The clinical utility of MR coronary angiography is still unproven at the present time. An initial report by Manning et al. showed a sensitivity of 90% in detecting hemodynamically significant coronary artery lesions. Later reports were unable to reproduce these results when using blind readings of the MR images. Duerinckx et al., in a double blind prospective study of 20 patients, found a sensitivity of 72% in detecting hemodynamically significant lesions in the left anterior descending artery. Similarly, Pennell et al. found a sensitivity of 65% in a group of 17 patients when using blind assessment of the MR images.

Despite these potential pitfalls, 2D MR coronary angiography is a very promising technique to evaluate coronary arterial and venous structures. At this point, caution is needed when interpreting these angiograms. Some of the images show both arteries and veins. Multiple partial voluming or partial imaging artifacts can either simulate disease of create the impression of lack of disease. The best approach is to obtain multiple images of each vessel possible in two different perpendicular planes before ruling in or ruling out the presence of pathology.

MR coronary angiography techniques are improving and may become the premier screening tool for proximal coronary artery disease. The technology and pulse sequences are constantly evolving, as this is a very active area of research. Specifically, research is proceeding with newer 3D techniques and the projectional technique. The automated monitoring of the regularity of breathholding for 3D acquisitions will alleviate some of the problems from breathhold-to-breathhold variations in organ position within the imaging plane . The use of contrast agents may also enhance the image quality of coronary MRA.

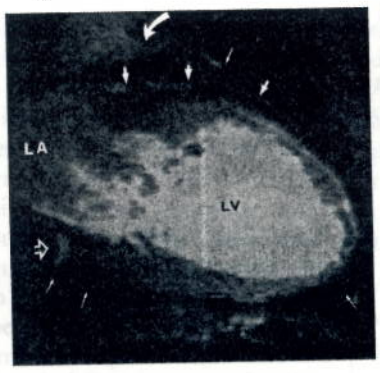
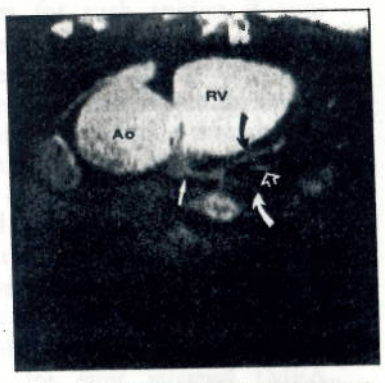


FIG [3] Coronary arteries in images obtained in double oblique planes along the superior inter-ventricular groove, corresponding to a vertical 2-chamber view of the left ventricle. The left anterior descending coronary artery is shown (arrows). The other anatomical structures shown are pericardial sac (thin arrows), left ventricle (LV), left atrium (LA), left atrial appendage (curved arrow), and coronary sinus (open arrow).



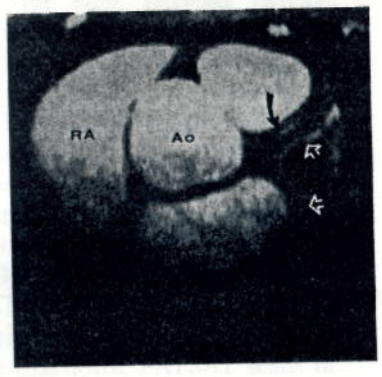


FIG [4] Superposition of artery and vein illustrated in transaxial and oblique transverse views of the proximal left coronary artery system. The left main coronary artery [4A white arrow] and the proximal LAD [4A,B black curved arrows] are demonstrated. A ramus intermedius branch is shown (curved white arrow). [4A] In the transverse plane, a vascular structure which appears to originate from the ramus branch is shown (open arrow). [4B] A slightly oblique transverse view demonstrates that the vascular structure in [4A] represents the great cardiac vein (open arrows).

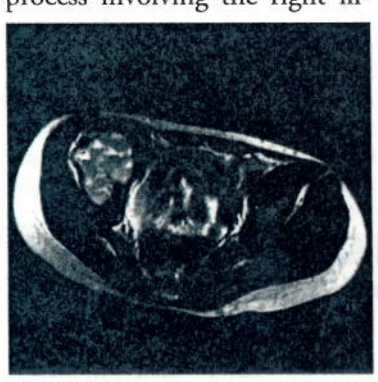
Interesting Case — Aneurysmal Bone Cyst

Siemens would like to thank Suzanne Gronemeyer, Ph.D., from the Diagnostic Imaging Department of St. Jude Childrens Research Hospital in Memphis, TN., for submitting this very interesting case.

A 10 year old boy with a 3 month history of right leg limp was referred with a presumptive diagnosis of Ewing sarcoma or osteosarcoma. Referred plain films revealed a large lytic process involving the right ilium and acetabulum. The lesion's well-margined contours suggested a slow process. Referred body CT showed a cortical break-through and a soft tissue mass, indicative of a progressive and aggressive process. From these studies, possible diagnoses included Ewing sarcoma, aneurysmal bone cyst, or Langerhans cell histiocytosis. The therapy for aneurysmal bone cyst (ABC) is wide local excision, but the malignancies Ewing sarcoma and osteosarcoma are treated with chemotherapy for 6-9 weeks and then surgery (or radiation for non-expendable bones, in the case of Ewing sarcoma).

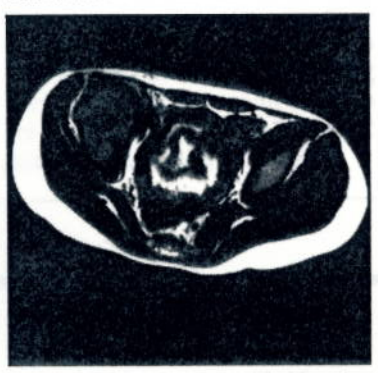
MRI exams on a Siemens Magnetom 63SP/4000 included T1 and TURBOSTIR coronal images, PD/T2 transverse images, pre- and post-contrast T1 transverse images, and post-contrast T1 FATSAT transverse images. Also, a dynamic uptake study was performed by rapid intravenous injection of gadolinium (Omniscan) after starting a sequence of 30 views of the same slice through the lesion with the sequence: FLASH2D_S_10B195.

The PD/T2 transverse images showed a multiple loculated lesion with fluid-fluid levels whose signal characteristics were consistent with hemorrhage. This appearance is most suggestive of aneurysmal bone cyst, although it is sometimes seen in telangiectatic osteosarcoma. At biopsy, the surgical appearance and frozen section were consistent with ABC, so the surgeon curetted out the lesion and packed it with bone chips. The lesion recurred, and the surgeon performed a much more extensive resection. The patient's most recent MRI shows minimal residual ABC tissue, and he is up and active.

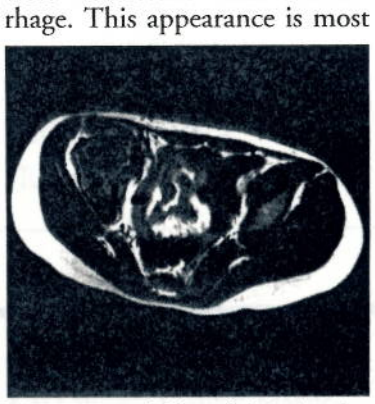


Transverse proton density-weighted spin-echo image.

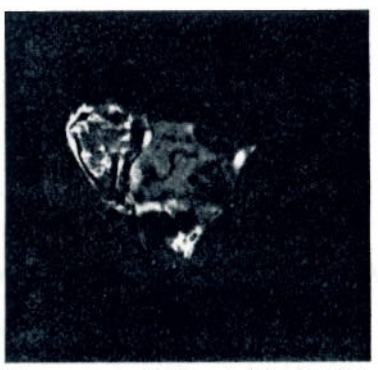
Transverse T2-weighted spin-echo image.



Transverse T1-weighted spin-echo image.



Transverse T1-weighted spin-echo image acquired after the administration of contrast.



Transverse T1-weighted FAT-SAT image acquired after the administration of contrast.

Applications Tips and Protocols

SLIDEMAKER

☞ IMPACT, SP, VISION

To make quick and easy 35 mm slides from your Magnetom, just use a 16:1 display screen format with a 6:1 camera format and cut up the tiny 35 mm images directly from the film. Use the square format (SUPERSLIDE) frame mounts for your slides. On the *VISION, IMPACT, P8, and* OPEN systems you can directly select a 16:1 display screen format, but on the 63SP and 42SP systems you must first create a special 16:1 display screen format and save it as follows:

1. Select the menus DISPLAY, SCREEN, MODE, DEFINE, 31.
2. Name the new display format SLIDES.
3. Use the potentiometers and trackball to create four small boxes (16:1 size) positioned in the 4 quadrants of the screen; only four small boxes may be created.
4. Thereafter, rather than directly selecting a 16:1 display format, use the menus DISPLAY, SCREEN, MODE, to select the SLIDES format.

MYOCARDIAL PERFUSION

☞ IMPACT, SP, VISION

For myocardial perfusion exams, the sequence TURBOFLASH_3B355 may be used with the IMPACT, SP, or VISION. This very fast sequence minimizes the single-shot data acquisition period (TR*#lines) in order to freeze physiological motion. This sequence is run once pre-gadolinium and then again in a dynamic series post-gado.

The protocol should be optimized to null myocardium in the pre-gadolinium image in order to best visualize non-enhanced (ischemic) areas in the post-gadolinium images. Optimal myocardial nulling occurs if the middle line of data is acquired exactly when the myocardium reaches the null point in its T1 recovery curve, about 500-700ms after the inversion pulse. Calculating that the middle line of data is acquired at TI+(TR*#lines/2), and assuming that myocardium nulls at 600ms after the inversion pulse, and assuming that you acquire a 128 line matrix with a fixed TR=7ms, it is necessary to use TI=150ms to cause the middle line to be acquired at the best null time: 600ms = 150ms + (7ms * 128/2). If the actual null time of myocardium is 100ms less than you assumed, it is necessary to decrease the TI by 100ms. Or, a longer null time will require a proportionately longer TI.

As several things may affect the optimal myocardial null time from patient-to-patient, it is recommended to experiment around with various TI values (50, 100, 150, 200, 250ms) prior to running the post-gadolinium dynamic series. Always use the same matrix (#lines) in each of these quick 1-slice experiments.

After selecting the best combination of TI and #lines, setup the dynamic perfusion exam with 30 slices (distance factor= -1.0 to ensure all slices at the same level) and place the slice at the level of interest (through the suspected ischemic section). The total scan time for the entire 30 slice exam is about 30-35 seconds if acquired without cardiac triggering. The temporal resolution for such a dynamic exam is about 1 second per view.

If you acquire without cardiac triggering, the heart may move in and out of the desired plane as the heart beats, possibly missing the suspected infarct. Thus, to ensure that the same slice position is scanned in each of the 30 slices, cardiac triggering may be used. Since each slice takes just over 1 second to acquire but the patient's R-R period is typically less than 1 second, it is necessary to setup the triggering with zero trigger delay and number of pulses = 1. This will cause the trigger to be fired on every second heartbeat, rather than on every heartbeat, because each slice is scanned through slightly more than one R-R period. The total scan time for the entire 30 slice exam is about 50-60 seconds if acquired with cardiac triggering. The temporal resolution for the dynamic exam is about 2 seconds per view. Although this is poorer temporal resolution than for the non-triggered exam , you are more likely to hit the same slice position of interest for every view.

MULTISLAB MRA

☞ IMPACT, SP, VISION

Sometimes when doing MULTISLAB MRA, one may encounter the message "Reduced ROI Box" while trying to load images into the MIP post-processing program of the SP system. This situation may occur if there is even a very small residual overlap between the remaining slices (after throwing away slices from the overlapped region). This situation can be avoided by ensuring that the remaining slices either have a small residual gap instead of an overlap or are exactly contiguous.

A convenient way to ensure that the slices are exactly contiguous is to scan with 32 mm thick 3D slabs, 32 partitions each, shifted exactly 20 mm apart, and then throw away 12 slices from the overlapped region when loading images into the MIP program (throw away 6 slices from each of the overlapped slabs). Or, another way to ensure that the slices are exactly contiguous is to scan with 64 mm thick 3D slabs, 64 partitions each, shifted exactly 40 mm apart, and then throw away 24 slices from the overlapped region (throw away 12 slices from each of the overlapped slabs).

A convenient way to ensure a small gap between remaining slices is to scan with 26 mm thick 3D slabs, 32 partitions each, shifted exactly 18 mm apart, and then throw away 10 slices from the overlapped region when loading images into the MIP program (throw away 5 slices from each edge of each slab). Or, another way to ensure a small gap between remaining slices is to scan with 52 mm thick 3D slabs, 64 partitions each, shifted exactly 36 mm apart, and then throw away 20 slices from the overlapped region (throw away 10 slices from each edge of each slab). The first case results in a 0.125 mm gap between the remaining slices, and the second case results in a 0.250 mm gap. Both gaps are clinically insignificant but are quite effective in avoiding the "Reduced ROI Box" situation.

The merit of the "small gap" approach over the "contiguous" approach is higher resolution due to thinner slices, but the total coverage and signal/noise ratio may be slightly compromised. In either case, to ensure exactness, the slice positions of the 3D slabs should always be specified numerically in the protocol/change menu (mean-shift rounded off to zero decimal places) rather than graphically in the slice/position menu.

One last suggestion is that, when loading multiple 3D data sets into the MIP program, it is advised to load images in ascending anatomical order (ie., from negative to positive slice position). For example, even though you may have first acquired an inferior transverse slab and then acquired a more superior transverse slab, images from the superior slab should be loaded first because they are more negative in slice position.

IMPACT CAROTIDS

☞ IMPACT

Please note an MR Angiography protocol change for software version A2.1 on the Magnetom IMPACT. In the Siemens protocol list for HEADCOIL/ CAROTIDS/ FISP3D_TRANS, you should change the slice position of the presat band from a positive value (+) to a negative value (-) in order to change the position of the presat band from below to above the 3D imaging slab. This will ensure that you image the carotid arteries rather than the jugulars. Make sure to save this modified protocol.

FATSAT LUMBAR

☞ IMPACT, SP

Shimming in the spine for FAT-SAT can be difficult at times due to the geometry of the area of interest and the localized sensitivity of the surface coil. This suggests an improved procedure to shim for such studies if your Siemens scanner has a body/surface coil switch (hardware or software). Position the patient on the spine surface coil as though for a regular L-spine exam. However, for shimming, activate the body coil (scout) switch and shim as you would for a liver (except with a midline sagittal orientation). On the SP you may save these optimal shim values into a shim file for later retrieval (MEASUREMENT/ SHIM/ REMOTE/ SET-CURRENTS/ WRITE-FILE/ name:FAT-SAT_SPINE). On the IMPACT, however, it is not possible to save these optimal shim values into a shim file, so the shimming procedure (MEASUREMENT/ ADJUST/ GRADIENT-OFFSET) must be done for each patient. Then, prior to acquiring the diagnostic FATSAT scans of the lumbar spine, switch back to the spine surface coil.

Although this technique should work well most of the time, it is always a good idea to check the uniformity of the shim for each patient with a quick FATSAT scan (ie., 64x128 matrix and only 1 acquisition) before proceeding on with the longer diagnostic FATSAT scan (ie., 256x256 matrix and 4 acquisitions). The fat signal closest to the surface coil will probably still be rather bright, but the fat signal should be well suppressed in the vertebral bodies and further away from the coil.

Applications Tips and Protocols

FAT/WATER IN/OUT PHASE

☞ IMPACT, SP, VISION

For any gradient echo sequence, fat and water oscillate in and out of phase with each other as a function of TE. This is often used for purposes of fat suppression or water suppression. The in/out of phase TE's are listed below as a function of field strength. Note that 3D Time-Of-Flight MR Angiography should be done with fat and water out of phase in order to ensure minimal background (fat) signal with maximal blood flow (water) signal. Also note that breathhold abdominal imaging is often requested with both in phase and out of phase scans for comparison. Always choose the lowest TE (in/out phase) which your MRI scanner can provide for the desired type of sequence (fisp, flash, turboflash, etc). In general, the stronger the gradient strength of the scanner, the lower the TE's available for the sequences.

TE's FOR FAT/WATER PHASES AT 1.0 TESLA

0.0 in	3.4 out	6.8 in	10.2 out	13.6 in
17.0 out	20.4... in...			

TE's FOR FAT/WATER PHASES AT 1.5 TESLA

0.0 in	2.3 out	4.5 in	6.8 out	9.0 in
11.3 out	13.5... in...			

DYNAMIC ABDOMEN MASS

☞ IMPACT

This protocol is used on a 1.0 Tesla Magnetom IMPACT at Northwestern University, Chicago, IL, for assessing abdominal masses. It employs a dynamic, gadolinium-enhanced acquisition with a FLASH2D sequence during suspended respiration.

First, a set of breathhold coronal slices is acquired as a localizer. Then, a set of breathhold transverse slices is acquired pre-contrast. Finally, gadolinium is injected at a dose of 0.1 mmol/kg over 20 sec and post-contrast scans are acquired at 15 sec, 45 sec, 2 min, 3 min, 5 min, & 10 min.

SEQUENCE:

FLASH2D_10RB195

TR: 100-150 ms (depending upon desired breathhold period)

TE: 10 ms

FLIP: 70 degrees

SLICES: 7-10 (depending upon TR)

THICKNESS: 5 mm (kidneys) or 10 mm (liver)

DISTANCE: 0.2-0.3

FOV: 350-400 mm

MATRIX: 128x256, o

ACQUISITIONS: 1

PRESATS: none

FATSAT STREAMLINED

☞ SP

For FATSAT imaging on the 42SP and 63SP systems, a command procedure called FSFIX1 may be used to help guide you through the steps for optimal FATSAT imaging. The command procedure may be assigned to a function key for quick access during routine imaging. Jim Mackey, a Technologist at The Methodist Hospital in Houston, developed FSFIX1 for use at his facility & may be reached by fax at (713)793-1548 for further information. Siemens is not responsible for the proper use or functioning of the FSFIX1 command procedure.

MRI Resources

Personal Resources

The previous issue of the FLASH listed several technologists you could contact for specific areas of expertise on the IMPACT and SP systems. Listed here are phone contacts for the GBS1 and GBS2 systems.

GBS1 software D1.3
Tony Perez, Kevin Sullivan
Dallas Diagnostic Center, Dallas, TX (214)827-5186

GBS2 software D1.3
Danielle Stocks, Bill Thornhill
Vanderbilt Medical Center,
Nashville TN (615)322-2394

GBS2 software D2.0
Scott Darnell, Carrie Nicholas
Southern Colorado MRI,
Pueblo, CO (719)542-3125

Videos

Call 1-800-334-4066. Reference MRM number. $10.oo charge for each copy.

- Understanding the MRI Exam, Adult - MRM 100 (English and Spanish)
- Understanding the MRI Exam, Child - MRM 101 (English and Spanish)

Fax the Siemens MRI Applications Department at (908)632-2813 for additional copies free-of-charge.

- Magnetom Cardiac Evaluation Package
- Clinical Spectroscopy on the Siemens Magnetom
- Implementing A2.7 Software on the Magnetom SP
- Principles of Basic MRI Physics
- Implementing A2.1 Software on the Magnetom IMPACT

Publications

PAMPHLETS

- 1994 MR Resource Guide, Society of MRI, Journal of MRI, Volume 3(S), Nov/Dec 1993, call Tom Shimala (RSNA) at (708)571-7819 for additional copies at about $15 each.
- 1994 Fast MR Imaging Primer, Editor R. Edelman, Siemens Publication # MG/5000-406-121PH13M1/94, 1994, call your local Siemens sales representative for additional copies free-of-charge.

SIEMENS APPLICATIONS UPDATES

Fax the Siemens MRI Applications Department at (908)632-2813 for these copies free of charge.

- Bilateral Breast MRI, Magnetom SP & IMPACT, 1993.
- 3D Surface Display, Magnetom SP, 1993.
- Cardiovascular, Magnetom SP & IMPACT, 1993.
- Single Voxel Proton Spectroscopy, Magnetom SP,1993.
- Command Procedures, Magnetom SP, 1993.
- Segmented Cardiac Cine, Magnetom SP & IMPACT,1994.
- Coronary Arteries, Magnetom SP & IMPACT, 1994.
- Spatial Resolution vs SNR, Magnetom SP & IMPACT, 1994.

SIEMENS MAGNETOM APPLICATIONS MANUALS

* Applications Guide, Magnetom SP, Software A2.7, 1994, Siemens Publication # C2-020.208.04.03.02, call your local Siemens sales representative for additional copies at about $90 each.

- Applications Guide, Magnetom IMPACT, Software A2.1, Part 1: Techniques, 1994, Siemens Publication # M2-035.208.17.01.02, call your local Siemens sales representative for additional copies at about $45 each.

* Applications Guide, Magnetom IMPACT, Software A2.1, Part 2: Protocols, 1994, Siemens Publication # M2-035.208.18.01.02, call your local Siemens sales representative for additional copies at about $45 each.

THE MAGNETOM
FLASH
newsletter for SIEMENS MAGNETOM users • vol. 2 no. 2/1994
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